Qeshm Free Zone Organization
(QFZO)

Japan International Cooperation Agency
(JICA)

THE PROJECT FOR COMMUNITY-BASED SUSTAINABLE DEVELOPMENT MASTER PLAN OF QESHM ISLAND TOWARD "ECO-ISLAND" IN THE ISLAMIC REPUBLIC OF IRAN

FINAL REPORT

Volume 5: Appendices

January 2019

RECS International Inc.
PADECO Co., Ltd.
Kokusai Kogyo Co., Ltd.

Currency Equivalents (as of November 30, 2015)
US$1.00=IRR 29,885
US$1.00=JPY 122.70
JPY 1=IRR 243.258
Source: OANDA.COM, http://www.oanda.com.

List of Appendixes

APPENDIX 1 BASELINE SURVEY A1-I
A1.1 Socio-economic Baseline Survey A1-1
A1.2 Environmental Baseline Survey A1-19
A1.3 Baseline Survey for Tourism A1-25

APPENDIX 2 DETAIL TECHNICAL ANALYSIS OF ECO-QESHM MASTER PLAN A2-I
A2.1 Discrepancies between Prevision and Realization of SWECO Master Plan on Qeshm Land Use and Population A2-1
A2.2 Date of Inland Ecosystem Management A2-10
A2.3 Environmental Carrying Capacity A2-25
A2.4 Estimate of Solid Waste Amount and Waste Stream for Solid Waste Management A2-33
A2.5 Trial Calculation to Install Photovoltaic System for Renewable Energy Development A2-50

APPENDIX 3 LANDFILL OPERATION GUIDELINES A3-I

APPENDIX 4 LANDFILL MONITORING MANUAL A4-I

APPENDIX 5 CAPACITY BUILDING A5-I
A5.1 Counterpart Training in Japan A5-1
A5.2 Environmental Technology Seminar A5-41

APPENDIX 6 PUBLIC RELATION AND PROMOTION ACTIVITIES A6-I
A6.1 Tourism Promotion Activities A6-1
A6.2 Investment Promotion Activities A6-22

APPENDIX 7 STAKEHOLDER CONSULTATION MEETING A7-1
A7.1 First Consultation Meeting A7-1
A7.2 Second Consultation Meeting A7-7

APPENDIX 8 OUTCOME AND EVALUATION OF PILOT PROJECTS A8-I
A8.1 Outcome of Pilot Project A8-3
A8.2 Evaluation of Pilot Projects A8-21

Abbreviations

AC	Air Conditioning
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
EIA	Environmental Impact Assessment
EUR	Euro
FAM tour	Familiarization tour
GDP	Gross Domestic Product
GGN	Global Geopark Network
GIS	Geographical Information System
GRDP	Gross Regional Domestic Product
ICHTO	Iran Cultural Heritage, Handcraft and Tourism Organization
IRR	Iranian Rial
IUCN	International Union for Conservation of Nature and Natural Resources
JICA	Japan International Cooperation Agency
JPT	JICA Project Team
KFZO	Kish Free Zone Organization
LNG	Liquified Natural Gas
NGO	Non-Governmental Organization
NPO	Non-Profitable Organization
OECD	Organisation for Economic Co-operation and Development
PV	Photovoltaics
QFZO	Qeshm Free Zone Organization
SNS	Social Networking Service
SS	Suspended Solids
Total-N	Total Nitrogen
Total-P	Total Phosphorus
TSS	Total Suspended Solids
UNESCO	United Nations Educational, Scientific and Cultural Organization
USD	United States Dollar
VFR	Visiting Friends and Relatives
WWTP	Wastewater Treatment Plant

Unit of Measurement

Area

m^2	square meter
km^2	square kilometer
ha	hectare (= 10,000 m^2)

Length

mm	millimeter
cm	centimeter
m	meter
km	kilometer

Weight

µg	micro gram
mg	milligram
kg	kilogram
t	ton (=1,000 kg)

Volume

l	liter
m^3	cubic meter (= 1,000 liter)

Time

sec, s	second
min	minute
h, hr	hour
d	day
y /yr	year

Energy

W	watt
kW	kilowatt
kWh	kilowatt-hour
MW	megawatt
GW	gigawatt
GWh	gigawatt-hour
cal	calorie
J	joules (=4.18 cal)
kj	kilo joules

Other

%	percent
Avg	average
degree	degree celsius
dB	decibel
mil.	million
p	person
ppm	parts per million

Comparison of Persian Year and Gregorian Calendar

Persian Year	Gregorian Calendar	Persian Year	Gregorian Calendar
1369	21 March 1990 – 20 March 1991	1393	21 March 2014 – 20 March 2015
1370	21 March 1991 – 20 March 1992	1394	21 March 2015 – 19 March 2016
1371	21 March 1992 – 20 March 1993	1395	20 March 2016 – 20 March 2017
1372	21 March 1993 – 20 March 1994	1396	21 March 2017 – 20 March 2018
1373	21 March 1994 – 20 March 1995	1397	21 March 2018 – 20 March 2019
1374	21 March 1995 – 19 March 1996	1398	21 March 2019 – 19 March 2020
1375	20 March 1996 – 20 March 1997	1399	20 March 2020 – 20 March 2021
1376	21 March 1997 – 20 March 1998	1400	21 March 2021 – 20 March 2022
1377	21 March 1998 – 20 March 1999	1401	21 March 2022 – 20 March 2023
1378	21 March 1999 – 19 March 2000	1402	21 March 2023 – 19 March 2024
1379	20 March 2000 – 20 March 2001	1403	20 March 2024 – 20 March 2025
1380	21 March 2001 – 20 March 2002	1404	21 March 2025 – 20 March 2026
1381	21 March 2002 – 20 March 2003	1405	21 March 2026 – 20 March 2027
1382	21 March 2003 – 19 March 2004	1406	21 March 2027 – 19 March 2028
1383	20 March 2004 – 20 March 2005	1407	20 March 2028 – 19 March 2029
1384	21 March 2005 – 20 March 2006	1408	20 March 2029 – 20 March 2030
1385	21 March 2006 – 20 March 2007	1409	21 March 2030 – 20 March 2031
1386	21 March 2007 – 19 March 2008	1410	21 March 2031 – 19 March 2032
1387	20 March 2008 – 20 March 2009	1411	20 March 2032 – 19 March 2033
1388	21 March 2009 – 20 March 2010	1412	20 March 2033 – 20 March 2034
1389	21 March 2010 – 20 March 2011	1413	21 March 2034 – 20 March 2035
1390	21 March 2011 – 19 March 2012	1414	21 March 2035 – 19 March 2036
1391	20 March 2012 – 20 March 2013	1415	20 March 2036 – 19 March 2037
1392	21 March 2013 – 20 March 2014		

APPENDIX 1 BASELINE SURVEY

Table of Contents

APPENDIX 1 BASELINE SURVEY A1-I
A1.1 Socio-economic Baseline Survey A1-1
A1.1.1 Historical background and the current situation in Qeshm Island A1-1
A1.1.2 General Information for Social Services A1-1
A1.1.3 Disaster risk and environmental problem A1-4
A1.1.4 Aggregate results of individual interview survey in each village A1-5
A1.1.5 Result of key informants survey A1-13
A1.2 Environmental Baseline Survey A1-19
A1.2.1 Introduction A1-19
A1.2.2 Monthly and annual atmospheric conditions A1-19
A1.2.3 Natural conditions and biological environment A1-19
A1.2.4 Legal system A1-20
A1.2.5 Topography, water Areas, wetlands and coastal areas A1-21
A1.2.6 River, hydrological conditions, and potential groundwater capacity A1-22
A1.2.7 Geology and soil A1-23
A1.2.8 Potential water sources A1-23
A1.2.9 Climate changes and their level A1-23
A1.2.10 Renewable energy A1-23
A1.2.11 Natural disasters and environmental pollutions A1-24
A1.2.12 Protection system for forests, environment and historical and cultural heritage A1-24
A1.2.13 Environmental assessments including strategic environmental assessment (SEA) A1-25
A1.3 Baseline Survey for Tourism A1-25
A1.3.1 Tourism interview survey A1-25
A1.3.2 Tourism Industry Survey A1-33

List of Tables

Table A1.1.1 Individual Interview Survey of Each Village A1-7
Table A1.1.2 Result of Key Informant Survey A1-14
Table A1.2.1 Animals on the Red List in Qeshm A1-20
Table A1.2.2 National Legislation related to Environment A1-21
Table A1.2.3 Status of Water Consumption of Hormozgan Province in 2008 by Source A1-23
Table A1.2.4 Comparison of Renewable Resources in Optimum Energy Extraction Conditions A1-24
Table A1.2.5 Cultural or Historical Sites Registered in the List of National Heritage A1-25
Table A1.3.1 Survey Details A1-25
Table A1.3.2 Gender by Season and Departing Point A1-26
Table A1.3.3 Generation by Season and Departing Point A1-26
Table A1.3.4 Purpose of Visit by Season x Departing Point A1-27
Table A1.3.5 Type of Travel by Season x Departing Point A1-28
Table A1.3.6 Average Length of Stay x Departing Point A1-29
Table A1.3.7 Places to Stay x Departing Point A1-29
Table A1.3.8 Expenses x Departing Point A1-30
Table A1.3.9 Satisfaction x Departing Point A1-31
Table A1.3.10 Business Category of Respondents A1-33
Table A1.3.11 Year of Establishment by Classification A1-34

Table A1.3.12 Number of Rooms and Beds by Classification A1-34
Table A1.3.13 Number of Resident Staff A1-34
Table A1.3.14 Present Situations of Apartment Hotels A1-35
Table A1.3.15 Present Situations of Travel Agencies A1-36
Table A1.3.16 List of Related Services A1-37
Table A1.3.17 Year of Establishment A1-37

List of Figures

Figure A1.1.1 Constraint for Village's Development and Main Livelihood A1-1
Figure A1.1.2 Quality and Quantity of Drinking Water in Qeshm A1-1
Figure A1.1.3 General Condition and Level of Sewerage Services in Qeshm A1-2
Figure A1.1.4 General Condition and Level of Solid Waste Management in Qeshm A1-2
Figure A1.1.5 General Condition and Level of Sanitation in Qeshm A1-2
Figure A1.1.7 Satisfaction Level of Road Accessibility and Road Condition in Qeshm A1-3
Figure A1.1.8 Satisfaction Level of Power Supply, Natural Gas and Communication Tools in Qeshm A1-3
Figure A1.1.9 Problem of Social Services and Priority Needs in Qeshm A1-4
Figure A1.1.10 Disaster risk and environmental problem in Qeshm A1-5
Figure A1.2.1 Yearly Rainfall and Koppen Map in Qeshm Island A1-19
Figure A1.3.1 Place of Residence x Departing Point A1-27
Figure A1.3.2 Places to Visit x Departing Point A1-28
Figure A1.3.3 Information Source x Departing Point A1-30
Figure A1.3.4 Travel Motivators x Departing Point A1-31
Figure A1.3.5 Satisfaction Level on Each Service of Airport Users A1-32
Figure A1.3.6 Satisfaction Level on Each Service of Zakeri Port Users A1-32
Figure A1.3.7 Satisfaction Level on Each Service of Laft Port Users A1-32
Figure A1.3.8 Guest Origin (Domestic) A1-34
Figure A1.3.9 Guest Origin (International) A1-34
Figure A1.3.10 Main Methods of Advertizement A1-34
Figure A1.3.11 Present Issues A1-34
Figure A1.3.12 Guest Origin (Domestic) A1-35
Figure A1.3.13 Guest Origin (International) A1-35
Figure A1.3.14 Main Methods of Advertizement A1-35
Figure A1.3.15 Present Issues A1-35
Figure A1.3.16 Channels of Ecotour A1-36
Figure A1.3.17 Ecotour Attractions A1-36
Figure A1.3.18 Main Methods of Advertizement A1-36
Figure A1.3.19 Present Issues A1-36
Figure A1.3.20 Guest Origin (Domestic) A1-37
Figure A1.3.21 Guest Origin (International) A1-37
Figure A1.3.22 Main Methods of Advertizement A1-37
Figure A1.3.23 Present Issues A1-37

A1.1 Socio-economic Baseline Survey

A1.1.1 Historical background and the current situation in Qeshm Island

In the old days, most of the villages in Qeshm Island had been developed by fishing, farming and animal husbandry because of the abundance of water, fertile soil, and marine resources. However, recent lack of water has caused barren soil, salt pollution, and the deterioration of farming and animal husbandry in most areas. Consequently, the results of the interview surveys are reflecting this issue. Most of the key informant interview surveys carried out in this baseline survey mentioned "lack of water" as a constraint for village development, and that most of these villages are depending on fishing as a main livelihood, as shown in the figure below. On the other hand, some villages in coastal areas and Hangom Island have started the development of mariculture and tourism, including dolphin watching, Hara mangrove tours by motor boats, egg-laying by green turtles, etc., aiming to improve the lack of water issues.

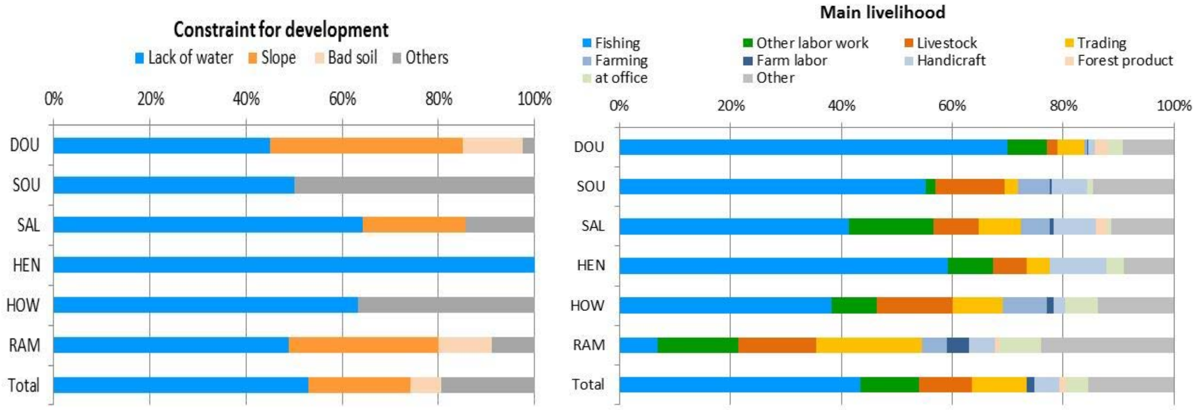


Figure A1.1.1 Constraint for Village's Development and Main Livelihood

A1.1.2 General Information for Social Services

(1) Drinking water

According to the interview survey for key informants, more than half of them answered "Poor" to the questions regarding water quality and water quantity, as the Figures below show. Low quality of drinking water causes infectious disease which relates to health service problems, such as lack of clinics and health centers. And a small quantity of drinking water also would lead to not only a decline in the agriculture and livestock industry but also a price increase in the supply.

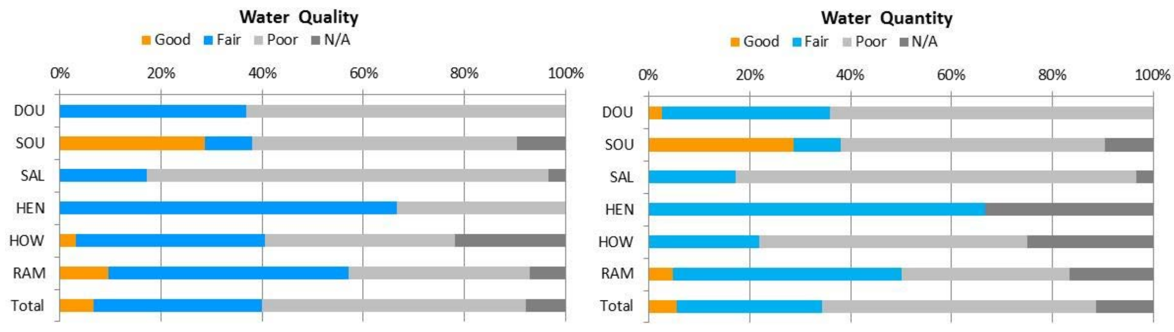


Figure A1.1.2 Quality and Quantity of Drinking Water in Qeshm

(2) Sewage

Most of the villages, in which sewerage facilities have already been installed adopting absorption wells, are accounted for 30% of all villages in Qeshm. However, only 10% of these villages answered

'Good' regarding the level of sewerage services in the key formant interviews, which signals that most of these villages are probably not satisfied with the wells. The figures below also show that more than 40% of the all villages in Qeshm do not have sewerage facilities.

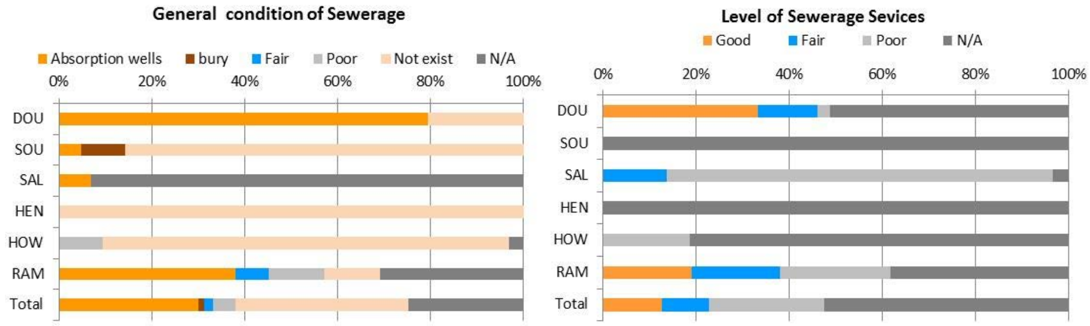


Figure A1.1.3 General Condition and Level of Sewerage Services in Qeshm

(3) Solid waste management

There are more remarkable differences regarding the relation between the general condition of solid waste management and the level of solid waste management than there is between the general condition of sewerage and the level of sewerage services, further details can be seen in each figure respectively. Only 10% of the villages in which some solid waste management services exist are satisfied with the current condition. However, since over 40% of the villages answered "N/A" in the key informant interviews, additional investigation will be needed.

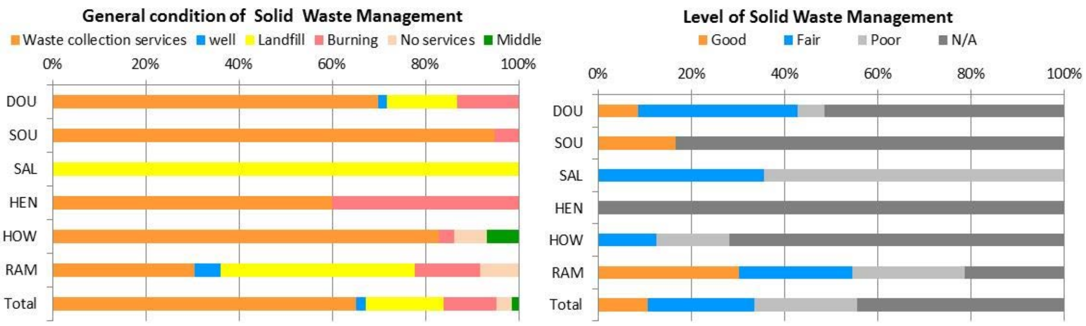


Figure A1.1.4 General Condition and Level of Solid Waste Management in Qeshm

(4) Sanitation

Most of the villages, in which sanitation facilities have already been installed adopting absorption wells, are accounted for 30% of all villages in Qeshm.

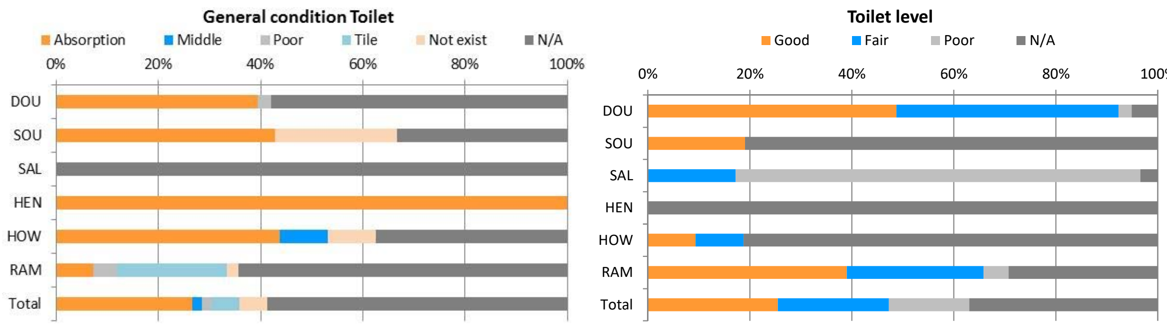


Figure A1.1.5 General Condition and Level of Sanitation in Qeshm

(5) Road

In total, 60% of the key informants answered "Good" or "Fair" in the question of the road accessibility and gave "paved road" as a one of the improved points in each village, which shows that the road accessibility and road conditions in Qeshm are being improved gradually. However, the proportion of "Good" regarding road conditions was much lower than the proportion of "Good" for road accessibility, which indicates that the quality of the pavement is quite poor.

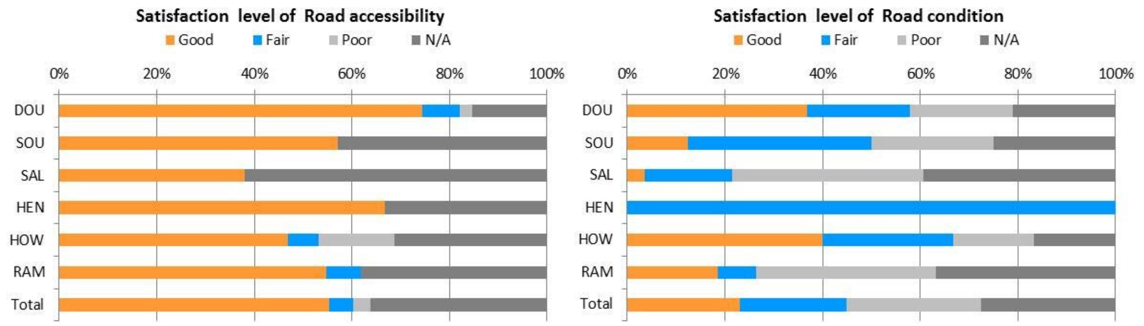


Figure A1.1.7 Satisfaction Level of Road Accessibility and Road Condition in Qeshm

(6) Others

In total, over 60% of the key informants answered "Good" or "Fair" to the question of satisfaction level of power supply, natural gas, and communication tools, which means these facilities have already been installed in most areas of Qeshm and they are more satisfied with these facilities compared to other sectors.

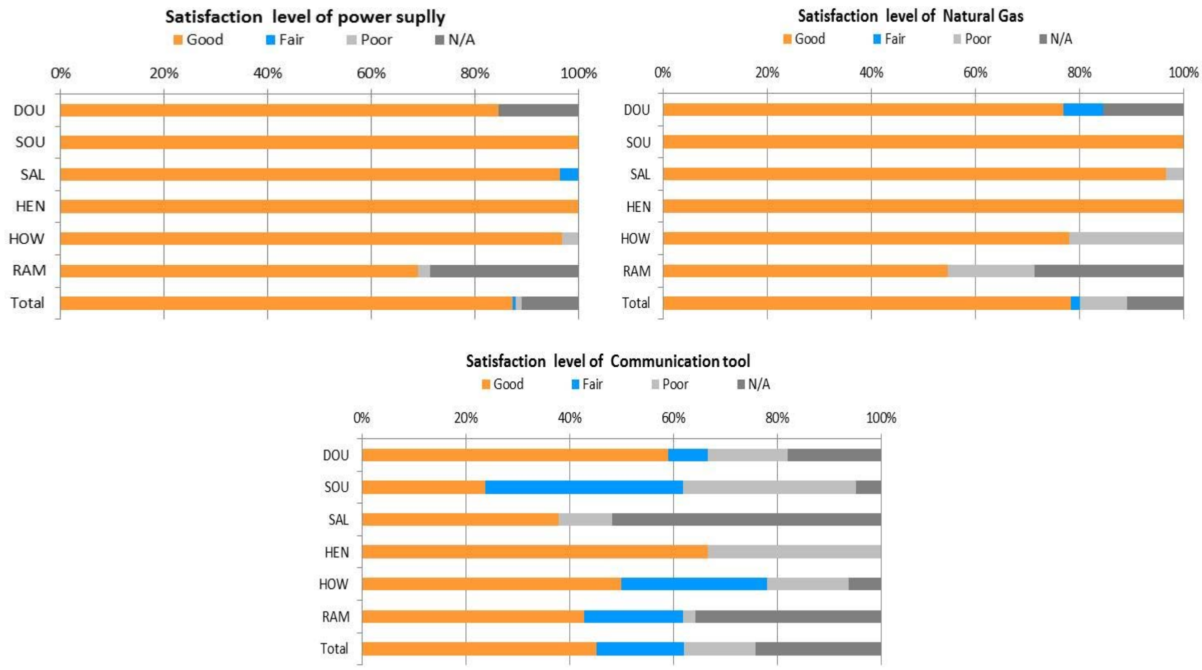


Figure A1.1.8 Satisfaction Level of Power Supply, Natural Gas and Communication Tools in Qeshm

(7) Problem and priority needs for social services

Water-related issues accounted for the largest percentage of responses to the question of social services' problem and priority needs, which means these issues have the first priority in all sectors. On the other hand, it was easy for the key informants to answer "Health", "Education", "Business Opportunity" and "Improving Livelihood" because they were given in the question as examples. That's why these answers also occupied from 10% to 15% respectively as priority needs. The main problems of each sector are as follows:

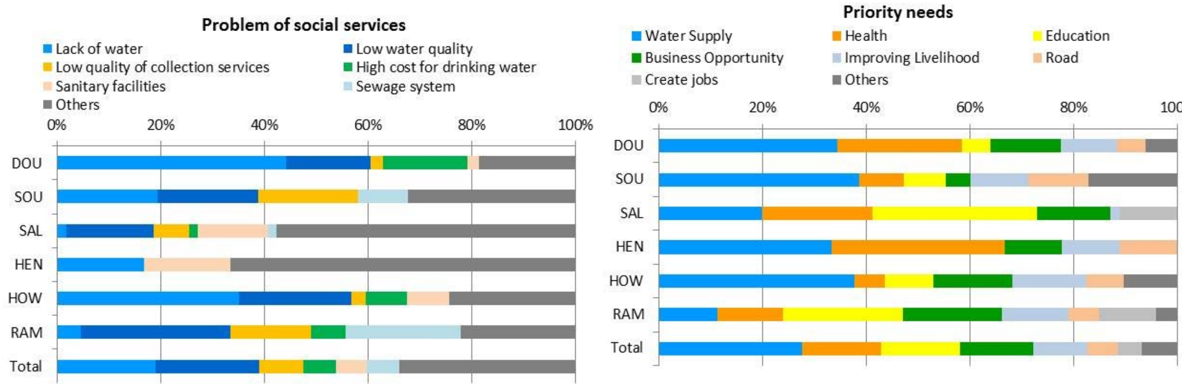


Figure A1.1.9 Problem of Social Services and Priority Needs in Qeshm

1) Health

Many key informants in all districts in Qeshm answered the lack of medical facilities, such as clinics and health centers, as a medical problem. Therefore, the villagers have to visit other areas in which there are clinics and medical centers, such as Doulab, Laft and Qeshm city, and the transportation cost becomes a heavy burden for them.

2) Education

The same type of problem exists as with the Health sector. In other words, it is the lack of educational facilities, such as high schools and guidance schools, compared to the number of students in Qeshm, which cause some kinds of problems for teachers, students and their parents. For example, the teachers cannot manage their classes in charge due to excess of students, as a result, the students have to go to a school at a different village and cannot receive an adequate education, and the parents have no choice but to let their children stop going to school due to high transportation costs, etc.

3) Business opportunity and livelihood

According to the interview survey, it is a severe situation for the younger generation to get jobs and receive sufficient salary for their livelihood with the exception of Laft, Shibderaz and Direstan which have potential resources in the tourism sector, such as Dolphin watching, Hara mangrove tours and laying eggs by sea turtles. Therefore, the young people have to migrate to other areas to get work.

A1.1.3 Disaster risk and environmental problem

Over 40% of the key informants answered "Earthquake" as a disaster risk and the risk occupied about 80% at Souza rural district (SOU) and Ramkon rural district (RAM), which seems to be a response to the earthquake in 2004 in which the seismic center was near these districts.

On the other hand, the problems of "Smell" and "Air pollution" stand out regarding environmental problems. Some key informants mentioned that the offensive odor was caused by discharged raw seafood and a cement factory. The factory also produced air pollution.

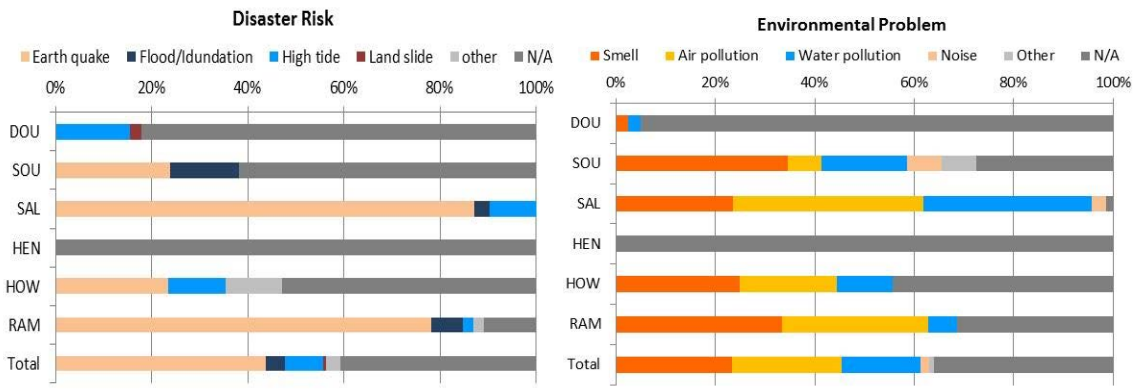


Figure A1.1.10 Disaster risk and environmental problem in Qeshm

A1.1.4 Aggregate results of individual interview survey in each village

Results of the individual interview survey of each village are shown in tables in the following pages.

Table A1.1.1 Individual Interview Survey of Each Village (1/6)

Village ID	Village Name	1. Number of samples collected	2. Information of household: 2.1 Number od members per household	2.2 Means of making money: 2.2.1 Number of bread earners per household	2.2.2 Main source of income (%): (1)Farming	(2)Livestock raising	(3)Fishing	(4)Hunting	(5)Trading	(6)Farm labor	(7)Other labor work	(8)Handicraft	(9)Collecting forest products	(10)Employed at office	(11)Other	Total	3. Type of Natural Resources used (% to the number of samples): (1)Groud water	(2)Tree, shurubs, mangrove and so on	(3)Wild animals	(4)Fishing	(5)Farming	(6)Reforestation	(7)Domesticated animals	(8)Other biological resources
DOU-01	Basaidu	11	3.4	1.4	0	0	21	7	0	0	0	0	14	57	0	100	64	18	0	18	0	0	0	0
DOU-02	Derakou	10	3.9	1.2	0	0	30	20	0	0	0	0	20	30	0	100	60	60	0	40	0	0	0	0
DOU-03	Doustakou	10	4.6	1.5	0	0	0	0	100	0	0	0	0	0	0	100	90	90	0	70	0	0	0	0
DOU-04	Kani	10	4.2	1.4	0	0	67	0	0	17	0	0	8	8	0	100	90	90	0	60	0	0	0	0
DOU-05	Konar Seiah	10	3.8	1.2	0	0	18	0	0	18	0	0	27	36	0	100	80	70	0	30	0	0	0	0
DOU-06	Gouri	10	4.2	1.6	0	0	14	0	0	29	0	0	14	43	0	100	50	60	0	50	0	0	0	0
DOU-07	Moradi	10	3.9	1.1	0	29	50	0	14	0	0	0	0	7	0	100	80	80	10	50	0	0	0	0
DOU-08	Tomgaz	9	3.4	1.7	0	0	33	0	0	0	0	0	0	67	0	100	89	67	0	67	0	0	0	0
DOU-09	Chahou West	10	4.6	1.2	0	8	25	0	0	0	0	0	17	50	0	100	90	30	0	20	0	0	0	0
DOU-10	Chahou East	11	5.0	1.4	6	13	6	6	0	13	6	0	13	38	0	100	100	55	0	45	18	0	0	0
DOU-11	Doulab	12	3.7	1.3	0	8	15	15	0	0	0	0	15	46	0	100	67	50	0	50	0	0	0	0
DOU-12	Sar Rig	11	4.6	1.6	0	6	19	13	0	6	6	0	13	38	0	100	91	45	0	36	0	0	0	0
DOU-13	Aysheh-Abad	9	3.8	1.3	0	0	27	0	0	9	0	0	9	55	0	100	67	89	0	44	0	0	0	0
Sub-total		**133**	**4.1**	**1.4**	**1**	**6**	**25**	**5**	**6**	**8**	**1**	**0**	**12**	**37**	**0**	**100**	**78**	**61**	**1**	**44**	**2**	**0**	**0**	**0**
HEN-01	Hengam	10	4.3	1.8	0	17	33	8	0	0	17	0	0	25	0	100	100	80	0	80	0	0	0	0
HEN-02	Old Hengam	0	No information collected																					
Sub-total		**10**	**4.3**	**1.8**	**0**	**17**	**33**	**8**	**0**	**0**	**17**	**0**	**0**	**25**	**0**	**100**	**100**	**80**	**0**	**80**	**0**	**0**	**0**	**0**
HOW-01	Ramchah	12	4.4	1.3	0	8	25	33	0	0	0	0	8	25	0	100	42	17	0	8	0	0	0	0
HOW-02	Tourgan	9	4.0	1.3	0	8	58	0	0	0	0	0	8	25	0	100	0	11	0	0	44	44	0	0
HOW-03	Kuvehee	12	4.3	1.1	0	0	18	0	0	9	0	0	9	64	0	100	17	0	0	0	0	0	0	0
HOW-04	Giahdan	12	4.5	0.9	0	8	8	0	0	8	0	0	15	62	0	100	17	0	0	0	0	0	0	0
HOW-05	Tonban	12	4.3	1.5	0	6	25	19	0	13	0	0	19	19	0	100	92	17	8	25	0	0	0	0
HOW-06	Kavarzin	11	3.8	1.1	0	9	0	9	0	0	0	0	36	45	0	100	73	9	0	0	0	0	0	0
HOW-07	Laft	11	4.9	1.1	0	0	8	0	0	31	0	0	0	62	0	100	9	0	0	9	0	0	0	0
HOW-08	Holor	12	4.9	1.0	0	0	17	0	0	25	0	0	8	50	0	100	0	0	0	0	0	0	0	0
HOW-09	Hamiri	10	4.3	1.0	14	29	0	0	0	29	7	0	0	21	0	100	50	40	0	0	0	0	0	0
HOW-10	Defari	19	3.7	1.1	0	16	0	26	0	21	5	0	5	26	0	100	21	0	0	0	0	0	0	0
HOW-11	Tola	12	4.3	1.0	0	8	8	0	0	8	0	0	17	58	0	100	0	0	0	0	8	0	0	0
HOW-12	Kabeli	0	No info collected because ther is no population living here.																					
Sub-total		**132**	**4.3**	**1.1**	**1**	**9**	**14**	**9**	**0**	**14**	**1**	**0**	**11**	**40**	**0**	**100**	**29**	**8**	**1**	**4**	**4**	**3**	**0**	**0**
RAM-01	Bangali	9	5.0	1.1	0	13	0	0	0	0	0	0	0	88	0	100	100	0	0	0	0	0	0	0
RAM-02	Jijan	10	4.9	1.1	0	0	0	8	0	17	0	0	25	50	0	100	20	100	0	50	0	0	0	0
RAM-03	Gorbehdan	10	5.5	1.1	8	23	8	0	0	15	0	8	15	23	0	100	100	40	20	20	0	0	0	0
RAM-04	Peyposht	11	5.1	1.0	0	0	29	7	0	14	0	0	14	36	0	100	73	82	0	55	0	0	0	0
RAM-05	Khaladin	11	5.2	1.0	14	14	14	7	7	14	0	0	7	21	0	100	36	91	0	36	0	0	0	0
RAM-06	Zainabi	11	5.0	1.1	0	8	8	15	0	0	0	0	31	38	0	100	0	100	0	36	0	0	0	0
RAM-07	Karavan	10	5.3	1.0	0	0	0	10	0	10	0	0	10	70	0	100	10	80	10	0	0	0	0	0
RAM-08	Kousheh	11	3.8	1.1	0	0	0	0	0	27	0	0	0	73	0	100	73	0	0	0	0	0	0	0
RAM-09	Kardova	9	5.2	1.1	0	33	7	7	7	20	0	7	0	20	0	100	44	100	0	0	0	0	0	0
RAM-10	Bagh Bala	9	6.7	1.6	0	11	0	0	0	56	22	0	0	11	0	100	89	0	0	0	0	0	0	0
RAM-11	Tomseneti	9	5.9	1.2	0	0	11	11	0	33	0	0	11	33	0	100	0	22	0	11	0	0	0	0
RAM-12	Tourian	11	4.8	1.1	0	0	8	0	0	0	0	0	25	67	0	100	55	0	0	9	0	0	0	0
RAM-13	Ramkan	24	4.7	1.1	0	0	0	0	0	20	0	0	24	56	0	100	0	4	0	0	0	0	0	0
Sub-total		**145**	**5.1**	**1.1**	**2**	**8**	**7**	**5**	**1**	**17**	**1**	**1**	**14**	**44**	**0**	**100**	**41**	**44**	**2**	**16**	**0**	**0**	**0**	**0**
SAL-01	Dehkhoda	10	5.7	1.1	0	0	9	0	0	0	9	0	18	64	0	100	70	40	0	10	0	0	0	0
SAL-02	Soheili	11	4.5	1.2	7	13	7	13	0	0	7	0	0	53	0	100	45	45	0	27	0	0	0	0
SAL-03	Haftrangou	10	5.7	1.2	0	31	15	0	0	8	0	0	0	46	0	100	100	100	0	70	0	0	0	0
SAL-04	Dourbani	10	5.4	1.0	6	19	38	13	0	6	0	13	0	6	0	100	100	80	0	80	0	0	0	0
SAL-05	Gomboron	10	4.6	1.1	0	8	50	0	0	0	0	0	17	25	0	100	70	40	0	50	0	0	0	0
SAL-06	Gouran	11	3.4	1.1	0	7	36	0	0	7	7	7	7	29	#####	#####	91	55	0	64	0	0	0	0
SAL-07	Melki	10	4.5	0.9	0	8	62	0	0	0	0	0	8	23	#####	#####	100	90	0	80	0	0	0	0
SAL-08	Tabl	12	4.9	1.3	0	0	31	19	0	25	0	6	13	6	0	100	58	58	0	67	0	0	0	0
SAL-09	Salakh	11	4.8	1.0	0	0	50	20	0	10	0	0	0	20	0	100	100	55	0	36	0	0	0	0
SAL-10	Naghasheh	7	3.7	1.3	0	0	54	0	0	8	0	0	8	31	0	100	86	0	0	14	0	0	0	0
Sub-total		**102**	**4.7**	**1.1**	**2**	**9**	**35**	**7**	**0**	**7**	**2**	**3**	**7**	**29**	**0**	**100**	**81**	**58**	**0**	**51**	**0**	**0**	**0**	**0**
SOU-01	Shibderaz	10	5.9	1.1	0	21	21	0	0	29	7	0	0	21	0	100	20	0	0	0	0	0	0	0
SOU-02	Messen	12	4.7	1.0	0	21	71	0	0	7	0	0	0	0	0	100	33	0	0	0	0	0	0	0
SOU-03	Borka Khalaf	10	5.4	1.0	0	31	38	0	0	8	0	0	0	23	0	100	50	0	0	0	0	0	0	0
SOU-04	Righoo	10	5.3	1.1	0	29	57	0	0	0	0	0	0	14	0	100	20	0	0	10	0	0	0	0
SOU-05	Zirang	11	4.5	1.3	0	8	0	8	0	15	0	0	15	54	0	100	36	27	0	0	0	0	0	0
SOU-06	Nakhl-E-Gol	9	5.7	1.0	0	42	33	0	0	8	0	8	0	8	0	100	89	0	0	0	0	0	0	0
SOU-07	Direstan	11	4.4	1.0	0	9	0	9	0	36	0	0	0	45	0	100	27	0	0	0	0	0	0	0
Sub-total		**73**	**5.1**	**1.1**	**0**	**23**	**33**	**2**	**0**	**14**	**1**	**1**	**2**	**23**	**0**	**100**	**38**	**4**	**0**	**1**	**0**	**0**	**0**	**0**
TOTAL		595	4.6	1.2	1	10	22	6	2	12	2	1	10	36	0	100	54	38	1	25	1	1	0	0

Source: JICA Project Team

Table A1.1.1 Individual Interview Survey of Each Village (2/6)

Village ID	Village Name	4. Property owned (% to the number of samples)								5. Source of Drinking Water (%)								6. Type of latrine (%)					7. Solid waste (%)						8. Access to power supply
		(1) House	(2) Barn	(3) Shop building	(4) Boat	(5) Car	(6) Motorcycle	(7) Computer	(8)Other	(1) Dug well	(2)Dug well with desalination	(3)Rain Water	(4)Tap water(desalinated and supplied)	(5)Tap water(Other)	(6)Water truck(desalinated water)	(7)Other	Total	(1) Absorbing well(pit latrine)	(2)Septic	(3)Sewer	(4)Other	Total	(1) Dump in the open field near our house	(2)Dump in our garden	(3)Collected by solid waste collection servise	(4)Segregate and sell valuable waste	(5)Other	Total	8.1 Accesibility to electricity(%)
DOU-01	Basaidu	64	0	18	0	73	36	0	0	0	0	15	0	5	55	25	100	100	0	0	0	100	0	0	100	0	0	100	100
DOU-02	Derakou	70	0	10	0	80	30	0	0	0	0	16	0	0	58	26	100	100	0	0	0	100	0	0	100	0	0	100	100
DOU-03	Doustakou	70	20	10	60	20	80	0	0	0	0	50	0	0	50	0	100	100	0	0	0	100	0	0	100	0	0	100	100
DOU-04	Kani	70	10	0	60	40	80	0	0	0	0	50	0	50	0	0	100	100	0	0	0	100	0	0	100	0	0	100	100
DOU-05	Konar Seiah	70	0	20	0	50	60	0	0	0	0	50	0	0	50	0	100	100	0	0	0	100	0	0	100	0	0	100	100
DOU-06	Gouri	80	0	20	10	60	80	0	0	0	0	50	0	0	50	0	100	100	0	0	0	100	0	0	100	0	0	100	100
DOU-07	Moradi	50	10	0	0	10	90	0	0	0	0	50	0	0	50	0	100	100	0	0	0	100	0	0	100	0	0	100	100
DOU-08	Tomgaz	100	0	22	33	22	67	0	0	0	0	50	0	0	50	0	100	100	0	0	0	100	0	0	100	0	0	100	100
DOU-09	Chahou West	80	0	20	0	50	90	0	0	0	6	28	0	17	50	0	100	100	0	0	0	100	0	0	100	0	0	100	100
DOU-10	Chahou East	82	18	18	18	36	55	0	0	8	13	42	0	13	25	0	100	100	0	0	0	100	0	0	100	0	0	100	100
DOU-11	Doulab	50	8	33	8	50	83	0	0	0	0	41	0	19	41	0	100	100	0	0	0	100	0	0	100	0	0	100	92
DOU-12	Sar Rig	82	0	27	9	73	91	0	9	4	0	33	0	33	29	0	100	100	0	0	0	100	0	0	100	0	0	100	100
DOU-13	Aysheh-Abad	89	0	11	11	44	78	0	0	2	0	41	0	20	37	0	100	100	0	0	0	100	0	0	100	0	0	100	100
Sub-total		**73**	**5**	**17**	**16**	**47**	**71**	**0**	**1**	**1**	**1**	**40**	**0**	**13**	**41**	**3**	**100**	**100**	**0**	**0**	**0**	**100**	**0**	**0**	**100**	**0**	**0**	**100**	**99**
HEN-01	Hengam	80	0	10	50	0	80	0	0	0	0	44	0	0	56	0	100	100	0	0	0	100	0	0	100	0	0	100	100
HEN-02	Old Hengam																												
Sub-total		**80**	**0**	**10**	**50**	**0**	**80**	**0**	**0**	**0**	**0**	**44.4**	**0**	**0**	**55.6**	**0**	**100**	**100**	**0**	**0**	**0**	**100**	**0**	**0**	**100**	**0**	**0**	**100**	**100**
HOW-01	Ramchah	75	0	25	42	50	67	0	0	0	0	50	0	0	50	0	100	100	0	0	0	100	0	0	100	0	0	100	100
HOW-02	Tourgan	0	11	0	0	11	-	0	-	11	0	0	0	0	89	0	100	100	0	0	0	100	40	0	50	0	10	100	100
HOW-03	Kuvehee	100	0	0	0	25	33	0	0	0	0	0	100	0	0	0	100	100	0	0	0	100	0	0	100	0	0	100	100
HOW-04	Giahdan	100	0	0	0	75	33	0	0	0	0	0	58	0	42	0	100	100	0	0	0	100	0	0	100	0	0	100	100
HOW-05	Tonban	83	8	25	33	50	67	0	0	0	0	43	0	4	52	0	100	100	0	0	0	100	0	0	100	0	0	100	100
HOW-06	Kavarzin	64	0	9	9	64	36	0	0	0	0	50	0	5	45	0	100	100	0	0	0	100	0	0	100	0	0	100	100
HOW-07	Laft	82	0	0	0	0	9	0	0	0	0	0	0	0	100	0	100	100	0	0	0	100	0	0	100	0	0	100	100
HOW-08	Holor	92	0	0	8	8	92	0	0	0	0	0	92	0	8	0	100	100	0	0	0	100	0	0	100	0	0	100	100
HOW-09	Hamiri	100	20	10	0	10	60	0	0	0	0	33	0	0	67	0	100	100	0	0	0	100	50	0	50	0	0	100	100
HOW-10	Defari	84	5	16	0	37	47	0	0	0	0	16	0	12	72	0	100	100	0	0	0	100	89	0	11	0	0	100	100
HOW-11	Tola	83	0	0	8	50	33	0	0	0	0	0	0	0	100	0	100	100	0	0	0	100	0	0	100	0	0	100	100
HOW-12	Kabeli																												
Sub-total		**80**	**4**	**8**	**9**	**36**	**33**	**0**	**0**	**1**	**0**	**24**	**17**	**3**	**56**	**0**	**100**	**100**	**0**	**0**	**0**	**100**	**21**	**0**	**78**	**0**	**1**	**100**	**100**
RAM-01	Bangali	89	11	0	0	0	67	0	0	0	0	100	0	0	0	0	100	100	0	0	0	100	100	0	0	0	0	100	100
RAM-02	Jijan	90	0	40	0	70	100	0	30	0	0	45	0	5	50	0	100	100	0	0	0	100	0	0	100	0	0	100	100
RAM-03	Gorbehdan	90	10	0	20	30	70	0	10	0	0	90	0	0	10	0	100	100	0	0	0	100	0	0	100	0	0	100	100
RAM-04	Peyposht	100	9	27	36	55	100	0	18	0	0	48	0	4	48	0	100	100	0	0	0	100	0	0	100	0	0	100	100
RAM-05	Khaladin	100	9	0	0	27	100	0	9	0	0	50	0	0	50	0	100	100	0	0	0	100	0	0	100	0	0	100	100
RAM-06	Zainabi	100	0	18	0	91	100	0	9	0	0	48	0	4	48	0	100	100	0	0	0	100	0	0	100	0	0	100	100
RAM-07	Karavan	100	20	20	0	60	90	0	20	0	0	36	0	18	45	0	100	100	0	0	0	100	0	0	100	0	0	100	100
RAM-08	Kousheh	64	0	9	0	18	91	0	0	0	8	0	8	0	85	0	100	100	0	0	0	100	0	0	100	0	0	100	100
RAM-09	Kardova	89	0	11	0	44	89	0	22	0	0	60	0	0	40	0	100	100	0	0	0	100	100	0	0	0	0	100	100
RAM-10	Bagh Bala	89	0	0	0	33	78	0	0	0	0	0	89	0	11	0	100	100	0	0	0	100	100	0	0	0	0	100	100
RAM-11	Tomseneti	78	11	33	11	44	100	0	33	0	0	40	0	0	60	0	100	100	0	0	0	100	0	0	100	0	0	100	100
RAM-12	Tourian	91	0	9	0	55	91	0	0	0	0	9	9	0	82	0	100	100	0	0	0	100	0	0	100	0	0	100	100
RAM-13	Ramkan	79	0	0	0	54	63	0	21	0	0	0	63	0	38	0	100	100	0	0	0	100	0	0	100	0	0	100	100
Sub-total		**88**	**5**	**12**	**5**	**46**	**86**	**0**	**14**	**0**	**0**	**39**	**12**	**3**	**46**	**0**	**100**	**100**	**0**	**0**	**0**	**100**	**19**	**0**	**81**	**0**	**0**	**100**	**100**
SAL-01	Dehkhoda	100	0	10	0	30	50	0	0	0	39	33	17	0	11	0	100	100	0	0	0	100	0	0	100	0	0	100	100
SAL-02	Soheili	91	0	27	9	55	64	0	0	0	0	33	0	10	52	5	100	100	0	0	0	100	0	0	100	0	0	100	100
SAL-03	Haftrangou	100	20	30	20	40	80	0	0	0	0	50	0	0	50	0	100	100	0	0	0	100	0	0	100	0	0	100	100
SAL-04	Dourbani	100	0	0	30	30	50	0	10	17	13	42	0	0	29	0	100	100	0	0	0	100	0	0	100	0	0	100	100
SAL-05	Gomboron	70	0	0	10	40	50	0	0	0	33	33	0	0	33	0	100	100	0	0	0	100	0	0	100	0	0	100	100
SAL-06	Gouran	73	0	0	18	27	73	0	0	18	0	39	0	11	32	0	100	100	0	0	0	100	0	0	100	0	0	100	100
SAL-07	Melki	100	10	0	50	30	50	0	0	9	0	41	0	5	45	0	100	100	0	0	0	100	0	0	100	0	0	100	100
SAL-08	Tabl	67	0	25	17	42	67	0	0	0	0	50	0	0	50	0	100	100	0	0	0	100	100	0	0	0	0	100	100
SAL-09	Salakh	82	0	18	9	36	55	0	0	0	33	33	0	0	33	0	100	100	0	0	0	100	0	0	100	0	0	100	100
SAL-10	Naghasheh	100	0	0	71	29	100	0	0	0	0	0	0	0	100	0	100	100	0	0	0	100	50	0	0	0	50	100	100
Sub-total		**87**	**3**	**12**	**22**	**36**	**63**	**0**	**1**	**5**	**14**	**38**	**1**	**3**	**39**	**0**	**100**	**100**	**0**	**0**	**0**	**100**	**11**	**0**	**83**	**0**	**6**	**100**	**100**
SOU-01	Shibderaz	100	0	0	40	30	40	0	0	0	0	0	0	0	100	0	100	100	0	0	0	100	0	0	100	0	0	100	100
SOU-02	Messen	58	0	0	25	50	58	0	0	0	0	0	92	0	8	0	100	100	0	0	0	100	0	0	100	0	0	100	100
SOU-03	Borka Khalaf	80	0	0	0	10	70	0	0	0	0	0	0	0	100	0	100	100	0	0	0	100	0	0	100	0	0	100	100
SOU-04	Righoo	60	0	0	10	20	90	0	0	0	0	0	0	0	100	0	100	100	0	0	0	100	0	0	100	0	0	100	100
SOU-05	Zirang	73	0	36	0	45	64	0	0	0	0	50	0	0	50	0	100	100	0	0	0	100	0	0	100	0	0	100	100
SOU-06	Nakhl-E-Gol	100	0	0	0	22	44	0	0	0	0	0	11	0	89	0	100	100	0	0	0	100	89	11	0	0	0	100	100
SOU-07	Direstan	91	0	0	9	18	73	0	0	0	0	0	91	0	9	0	100	100	0	0	0	100	0	0	100	0	0	100	100
Sub-total		79	0	5	12	29	63	0	0	**0**	**0**	**13**	**26**	**0**	**61**	**0**	**100**	**100**	**0**	**0**	**0**	**100**	**11**	**1**	**88**	**0**	**0**	**100**	**100**
TOTAL		82	4	11	13	39	66	0	4	2	4	34	8	6	46	1	100	100	0	0	0	100	12	0	86	0	1	100	100

Source: JICA Project Team

Table A1.1.1 Individual Interview Survey of Each Village (3/6)

Village ID	Village Name	9. School: 9.1 Those whose children go to school (%)	9.2 Level of satisfaction with education (%): (1)Yes, satisfied	(2)Almost satisfied	(3)Not satisfied	Total	9.3 Problems with school (%): (1)School is too far.	(2)The level of education is low due to low capability of teachers	(3)There are too many pupils/students in a class	(4)There are not adequate learning materials.	(5)Other	Total	10. Paid job: 10.1 Those with experience of trying to get a paid job (%)	10.2 Those who succeeded in getting a paid job (%)	10.3-(1) (if successful) Place of work (%): (1)Tehran	(2)Other cities outside Qeshm	(3)In Qeshm	Total	10.3-(2) (if not successful) Reasons (%): (1)There are no job opportunities.	(2).1His/her capability level is too low due to limited educational	(3) 2His/her capability level is too low due to limited	(4).3His/her work experience is limited.	(5).4He/she had no special connection	(6).5Other	Total
DOU-01	Basaidu	64	17	83	0	100	0	0	50	50	0	100	45	40	0	0	100	100	0	67	0	0	33	0	100
DOU-02	Derakou	80	38	63	0	100	57	14	14	14	0	100	0	-	-	-	-	-	-	-	-	-	-	-	-
DOU-03	Doustakou	80	50	50	0	100	75	0	0	25	0	100	20	0	0	0	0	0	0	0	100	0	0	0	100
DOU-04	Kani	90	11	89	0	100	78	0	0	22	0	100	30	0	0	0	0	0	0	100	0	0	0	0	100
DOU-05	Konar Seiah	70	0	100	0	100	0	50	0	50	0	100	50	0	0	0	0	0	0	75	0	0	0	25	100
DOU-06	Gouri	70	29	71	0	100	0	50	0	50	0	100	50	20	0	0	100	100	0	100	0	0	0	0	100
DOU-07	Moradi	80	50	50	0	100	80	0	0	20	0	100	20	0	0	0	0	0	0	100	0	0	0	0	100
DOU-08	Tomgaz	33	0	100	0	100	0	50	0	50	0	100	0	-	-	-	-	-	-	-	-	-	-	-	-
DOU-09	Chahou West	50	0	100	0	100	13	50	0	38	0	100	60	50	0	0	100	100	0	67	0	33	0	0	100
DOU-10	Chahou East	73	0	67	33	100	9	27	0	64	0	100	82	56	0	0	100	100	25	75	0	0	0	0	100
DOU-11	Doulab	50	0	100	0	100	0	45	0	55	0	100	25	100	0	0	100	100	0	100	0	0	0	0	100
DOU-12	Sar Rig	55	0	83	17	100	0	33	0	67	0	100	55	50	0	0	100	100	0	100	0	0	0	0	100
DOU-13	Aysheh-Abad	44	0	100	0	100	0	0	0	100	0	100	44	0	0	0	0	0	0	50	0	0	50	0	100
Sub-total		65	**18**	**78**	**4**	**100**	**25**	**26**	**3**	**46**	**0**	**100**	**38**	**34**	**0**	**0**	**100**	**100**	**3**	**74**	**6**	**3**	**10**	**3**	**100**
HEN-01	Hengam	70	75	13	13	100	0	67	0	33	0	100	20	50	0	100	0	100	0	0	100	0	0	0	100
HEN-02	Old Hengam																								
Sub-total		70	**75**	**12.5**	**12.5**	**100**	**0**	**67**	**0**	**33**	**0**	**100**	**20**	**50**	**0**	**100**	**0**	**100**	**0**	**0**	**100**	**0**	**0**	**0**	**100**
HOW-01	Ramchah	83	90	10	0	100	0	0	0	100	0	100	8	0	-	-	-	-	0	0	100	0	0	0	100
HOW-02	Tourgan	44	25	0	75	100	100	0	0	0	0	100	22	50	0	0	100	100	88	13	0	0	0	0	100
HOW-03	Kuvehee	50	100	0	0	100	100	0	0	0	0	100	67	0	-	-	-	-	-	-	-	-	-	-	-
HOW-04	Giahdan	67	75	0	25	100	100	0	0	0	0	100	75	33	0	33	67	100	86	14	0	0	0	0	100
HOW-05	Tonban	67	50	50	0	100	14	43	0	43	0	100	33	0	-	-	-	-	0	75	0	0	25	0	100
HOW-06	Kavarzin	73	63	38	0	100	0	40	0	60	0	100	0	#DIV/0!	-	-	-	-	-	-	-	-	-	-	-
HOW-07	Laft	27	33	33	33	100	0	0	0	100	0	100	64	14	0	100	0	100	100	0	0	0	0	0	100
HOW-08	Holor	67	86	14	0	100	100	0	0	0	0	100	75	56	0	100	0	100	100	0	0	0	0	0	100
HOW-09	Hamiri	70	71	14	14	100	50	0	0	0	50	100	70	29	0	0	100	100	60	0	0	20	20	0	100
HOW-10	Defari	53	20	60	20	100	21	36	0	43	0	100	32	17	0	0	100	100	80	20	0	0	0	0	100
HOW-11	Tola	75	22	56	22	100	75	0	0	25	0	100	75	89	0	0	100	100	50	0	50	0	0	0	100
HOW-12	Kabeli																								
Sub-total		61	**59**	**28**	**14**	**100**	**40**	**21**	**0**	**36**	**2**	**100**	**47**	**34**	**0**	**32**	**68**	**100**	**73**	**15**	**5**	**3**	**5**	**0**	**100**
RAM-01	Bangali	56	40	60	0	100	0	0	17	50	33	100	33	0	-	-	-	-	25	50	25	0	0	0	100
RAM-02	Jijan	90	33	56	11	100	83	0	0	0	17	100	100	100	0	0	100	100	-	-	-	-	-	-	-
RAM-03	Gorbehdan	50	40	20	40	100	29	29	29	14	0	100	100	80	0	0	100	100	0	0	33	67	0	0	100
RAM-04	Peyposht	36	100	0	0	100	-	-	-	-	-	-	100	100	0	0	100	100	-	-	-	-	-	-	-
RAM-05	Khaladin	45	63	38	0	100	50	0	17	17	17	100	100	91	0	0	100	100	0	0	0	0	100	0	100
RAM-06	Zainabi	45	43	57	0	100	25	25	25	25	0	100	100	100	0	0	100	100	-	-	-	-	-	-	-
RAM-07	Karavan	70	100	0	0	100	-	-	-	-	-	-	100	100	0	0	100	100	-	-	-	-	-	-	-
RAM-08	Kousheh	45	100	0	0	100	-	-	-	-	-	-	27	100	0	0	100	100	80	0	0	0	0	20	100
RAM-09	Kardova	11	33	33	33	100	38	38	25	0	0	100	100	56	0	0	100	100	25	13	13	25	13	13	100
RAM-10	Bagh Bala	67	11	78	11	100	46	46	0	8	0	100	56	0	-	-	-	-	100	0	0	0	0	0	100
RAM-11	Tomseneti	33	71	29	0	100	75	0	0	25	0	100	100	100	0	0	100	100	-	-	-	-	-	-	-
RAM-12	Tourian	45	50	38	13	100	11	33	22	33	0	100	18	50	0	0	100	100	0	100	0	0	0	0	100
RAM-13	Ramkan	50	82	18	0	100	33	0	0	67	0	100	63	27	0	25	75	100	60	20	10	10	0	0	100
Sub-total		50	**60**	**33**	**6**	**100**	**38**	**23**	**14**	**20**	**6**	**100**	**75**	**75**	**0**	**1**	**99**	**100**	**52**	**14**	**10**	**12**	**5**	**7**	**100**
SAL-01	Dehkhoda	90	44	56	0	100	0	33	0	67	0	100	70	29	0	0	100	100	0	0	0	38	63	0	100
SAL-02	Soheili	64	71	29	0	100	0	0	0	100	0	100	64	14	0	0	100	100	38	0	0	13	38	13	100
SAL-03	Haftrangou	70	43	57	0	100	0	0	29	57	14	100	100	20	0	100	0	100	11	11	0	44	33	0	100
SAL-04	Dourbani	90	33	67	0	100	0	0	25	75	0	100	60	17	0	100	0	100	0	57	0	0	43	0	100
SAL-05	Gomboron	50	80	20	0	100	0	0	0	100	0	100	80	0	-	-	-	-	0	0	0	0	100	0	100
SAL-06	Gouran	55	50	50	0	100	0	13	13	63	13	100	55	33	0	0	100	100	0	40	0	20	40	0	100
SAL-07	Melki	60	17	83	0	100	0	0	0	100	0	100	30	33	0	0	100	100	20	0	20	20	40	0	100
SAL-08	Tabl	50	17	83	0	100	20	0	0	80	0	100	50	17	0	0	100	100	19	13	19	25	25	0	100
SAL-09	Salakh	73	13	88	0	100	29	0	0	71	0	100	82	11	0	100	0	100	0	17	17	25	42	0	100
SAL-10	Naghasheh	57	0	0	100	100	43	0	14	43	0	100	100	0	-	-	-	-	0	14	21	29	36	0	100
Sub-total		66	**37**	**57**	**6**	**100**	**11**	**4**	**11**	**70**	**4**	**100**	**68**	**16**	**0**	**36**	**64**	**100**	**9**	**14**	**10**	**23**	**43**	**1**	**100**
SOU-01	Shibderaz	60	0	0	100	100	63	0	0	38	0	100	100	30	0	100	0	100	100	0	0	0	0	0	100
SOU-02	Messen	50	100	0	0	100	-	-	-	-	-	-	100	33	0	100	0	100	86	0	0	0	14	0	100
SOU-03	Borka Khalaf	40	25	50	25	100	50	0	0	50	0	100	100	40	0	100	0	100	100	0	0	0	0	0	100
SOU-04	Righoo	70	57	0	43	100	100	0	0	0	0	100	10	100	0	100	0	100	100	0	0	0	0	0	100
SOU-05	Zirang	73	75	25	0	100	0	33	0	67	0	100	36	0	-	-	-	-	0	25	25	25	25	0	100
SOU-06	Nakhl-E-Gol	56	0	40	60	100	43	0	0	57	0	100	100	22	0	100	0	100	86	0	14	0	0	0	100
SOU-07	Direstan	36	50	0	50	100	33	0	0	67	0	100	73	13	0	100	0	100	100	0	0	0	0	0	100
Sub-total		55	**47**	**16**	**37**	**100**	**50**	**4**	**0**	**46**	**0**	**100**	**74**	**28**	**0**	**100**	**0**	**100**	**86**	**2**	**5**	**2**	**5**	**0**	**100**
TOTAL		59	45	44	11	100	30	18	6	43	3	100	58	42	0	19	81	100	39	20	8	12	20	2	100

Source: JICA Project Team

Table A1.1.1 Individual Interview Survey of Each Village (4/6)

Village ID	Village Name	11. Household income												12. Marketing products produced by villagers										13. Sufficiency of food		14. Participation in CBO		15. Land ownership
		11.1 Income			11.2 Sufficiency of income (%)				12.1 Method of selling(%)				12.2 Place of selling(%)										
		Total income (IRR/year)																					
		Average	Maximum	Minimum	(1) Sufficient	(2) Almost sufficient	(3) Not sufficient	Total	(1)By ourselves	(2)Through trader	(3)Other	Total	(1)Market in nearby town/village	(2)Market in a big town in Qeshm	(3)Outside Qeshm	(4)Abroad	(5)Other	Total	13.1 Sufficient (%)	13.1 Not sufficient (%)	14.1 Those participating in any COB activities (%)	14.3 Have chance for participating in discussion of village's development (%)	15.1Those owing land (%)
DOU-01	Basaidu	617,818,182	2,760,000,000	60,000,000	36	64	0	100	50	50	0	100	25	25	50	0	0	100	100	0	18	9	91
DOU-02	Derakou	261,000,000	800,000,000	100,000,000	27	55	18	100	100	0	0	100	100	0	0	0	0	100	100	0	10	0	70
DOU-03	Doustakou	164,580,000	250,000,000	8,400,000	0	82	18	100	100	0	0	100	100	0	0	0	0	100	100	0	0	0	70
DOU-04	Kani	268,600,000	440,000,000	96,000,000	0	100	0	100	100	0	0	100	100	0	0	0	0	100	100	0	10	0	50
DOU-05	Konar Seiah	156,600,000	360,000,000	30,000,000	10	90	0	100	100	0	0	100	100	0	0	0	0	100	100	0	0	0	60
DOU-06	Gouri	370,200,000	960,000,000	120,000,000	20	80	0	100	50	50	0	100	100	0	0	0	0	100	100	0	30	0	70
DOU-07	Moradi	143,200,000	250,000,000	72,000,000	0	100	0	100	100	0	0	100	100	0	0	0	0	100	100	0	0	0	40
DOU-08	Tomgaz	207,288,889	600,000,000	22,800,000	56	44	0	100	25	75	0	100	100	0	0	0	0	100	100	0	11	0	22
DOU-09	Chahou West	117,500,000	216,000,000	18,000,000	30	50	20	100	100	0	0	100	100	0	0	0	0	100	100	0	20	0	60
DOU-10	Chahou East	547,545,455	2,000,000,000	24,000,000	45	27	27	100	100	0	0	100	100	0	0	0	0	100	91	9	45	0	55
DOU-11	Doulab	274,072,727	864,000,000	36,000,000	55	45	0	100	100	0	0	100	83	17	0	0	0	100	83	8	8	0	67
DOU-12	Sar Rig	396,900,000	1,000,000,000	25,000,000	55	36	9	100	67	33	0	100	67	0	0	0	33	100	100	0	27	18	82
DOU-13	Aysheh-Abad	521,333,333	1,800,000,000	36,000,000	67	33	0	100	100	0	0	100	100	0	0	0	0	100	100	0	11	0	67
Sub-total		**314,329,771**	**2,760,000,000**	**8,400,000**	**31**	**62**	**7**	**100**	**79**	**21**	**0**	**100**	**89**	**4**	**4**	**0**	**2**	**100**	**98**	**2**	**15**	**2**	**62**
HEN-01	Hengam	167,000,000	250,000,000	100,000,000	40	60	0	100	75	25	0	100	88	13	0	0	0	100	100	0	0	0	60
HEN-02	Old Hengam																						
Sub-total		**167000000**	**250000000**	**100000000**	**40**	**60**	**0**	**100**	**75**	**25**	**0**	**100**	**87.5**	**12.5**	**0**	**0**	**0**	**100**	**100**	**0**	**0**	**0**	**60**
HOW-01	Ramchah	232,083,333	400,000,000	100,000,000	83	8	8	100	88	13	0	100	50	50	0	0	0	100	100	0	0	0	50
HOW-02	Tourgan	14,200,000	28,000,000	4,800,000	22	22	56	100	57	14	29	100	50	17	33	0	0	100	56	44	0	0	22
HOW-03	Kuvehee	-	-	-	25	33	42	100	0	100	0	100	-	-	-	-	-	-	50	50	0	0	0
HOW-04	Giahdan	-	-	-	17	50	33	100	0	100	0	100	-	-	-	-	-	-	58	42	25	8	17
HOW-05	Tonban	463,333,333	3,600,000,000	30,000,000	58	42	0	100	88	13	0	100	100	0	0	0	0	100	100	0	0	0	67
HOW-06	Kavarzin	154,545,455	210,000,000	100,000,000	27	73	0	100	100	0	0	100	75	25	0	0	0	100	100	0	27	0	27
HOW-07	Laft	54,000,000	54,000,000	54,000,000	0	45	55	100	-	-	-	-	-	-	-	-	-	-	45	55	0	0	0
HOW-08	Holor	-	-	-	27	64	9	100	0	100	0	100	-	-	-	-	-	-	83	8	17	8	8
HOW-09	Hamiri	86,000,000	110,000,000	50,000,000	0	90	10	100	100	0	0	100	100	0	0	0	0	100	90	10	10	10	10
HOW-10	Defari	234,153,846	600,000,000	18,000,000	53	32	16	100	100	0	0	100	33	56	0	0	11	100	84	11	5	0	21
HOW-11	Tola	40,000,000	40,000,000	40,000,000	0	75	25	100	67	33	0	100	0	83	0	0	17	100	50	50	17	17	8
HOW-12	Kabeli																						
Sub-total		**228,496,667**	**3,600,000,000**	**4,800,000**	**31**	**47**	**22**	**100**	**80**	**16**	**4**	**100**	**51**	**39**	**5**	**0**	**5**	**100**	**75**	**23**	**9**	**4**	**21**
RAM-01	Bangali	52,800,000	96,000,000	6,000,000	0	38	63	100	100	0	0	100	100	0	0	0	0	100	44	56	0	0	100
RAM-02	Jijan	282,170,000	500,000,000	136,200,000	60	20	20	100	100	0	0	100	75	0	0	0	25	100	100	0	50	50	100
RAM-03	Gorbehdan	192,090,000	370,000,000	23,500,000	20	30	50	100	100	0	0	100	80	0	0	20	0	100	60	40	70	20	70
RAM-04	Peyposht	329,250,000	329,250,000	329,250,000	55	45	0	100	100	0	0	100	40	20	40	0	0	100	100	0	36	27	100
RAM-05	Khaladin	215,509,091	448,600,000	58,000,000	0	45	55	100	100	0	0	100	100	0	0	0	0	100	91	9	27	36	100
RAM-06	Zainabi	293,938,182	443,200,000	176,400,000	55	27	18	100	100	0	0	100	67	33	0	0	0	100	100	0	36	27	100
RAM-07	Karavan	227,660,000	348,600,000	147,000,000	20	30	50	100	-	-	-	-	-	-	-	-	-	-	70	30	40	20	100
RAM-08	Kousheh	157,454,545	340,000,000	72,000,000	64	18	18	100	100	0	0	100	100	0	0	0	0	100	100	0	18	0	64
RAM-09	Kardova	207,733,333	500,000,000	68,400,000	33	22	44	100	100	0	0	100	0	0	0	0	100	100	33	67	33	11	89
RAM-10	Bagh Bala	108,813,333	228,000,000	20,400,000	0	56	44	100	100	0	0	100	20	0	0	0	80	100	89	11	0	0	89
RAM-11	Tomseneti	253,466,667	360,000,000	123,400,000	11	56	33	100	67	33	0	100	100	0	0	0	0	100	56	44	33	44	100
RAM-12	Tourian	289,000,000	850,000,000	90,000,000	18	55	27	100	100	0	0	100	67	33	0	0	0	100	100	0	36	27	100
RAM-13	Ramkan	162,500,000	250,000,000	60,000,000	8	46	46	100	100	0	0	100	33	0	0	0	67	100	79	21	13	4	50
Sub-total		**242,932,984**	**3,700,000,000**	**6,000,000**	**26**	**38**	**36**	**100**	**98**	**2**	**0**	**100**	**57**	**9**	**4**	**2**	**28**	**100**	**80**	**20**	**29**	**19**	**86**
SAL-01	Dehkhoda	126,476,000	360,000,000	20,800,000	0	30	70	100	100	0	0	100	100	0	0	0	0	100	60	40	10	10	100
SAL-02	Soheili	180,890,909	600,000,000	48,000,000	9	27	64	100	100	0	0	100	67	0	0	0	33	100	55	45	18	9	100
SAL-03	Haftrangou	122,960,000	208,800,000	50,800,000	10	20	70	100	88	13	0	100	88	13	0	0	0	100	50	50	10	10	100
SAL-04	Dourbani	121,080,000	181,800,000	34,400,000	10	0	90	100	14	86	0	100	71	14	0	0	14	100	40	60	10	10	70
SAL-05	Gomboron	293,244,444	1,315,000,000	18,200,000	40	20	40	100	0	100	0	100	63	38	0	0	0	100	50	50	0	0	80
SAL-06	Gouran	164,336,364	480,000,000	45,600,000	0	36	64	100	33	67	0	100	100	0	0	0	0	100	45	45	18	18	91
SAL-07	Melki	111,820,000	261,600,000	18,200,000	10	0	90	100	0	100	0	100	0	17	0	83	0	100	20	90	10	20	100
SAL-08	Tabl	75,818,182	120,000,000	37,400,000	0	18	82	100	22	78	0	100	17	67	0	17	0	100	58	42	0	0	67
SAL-09	Salakh	217,325,000	420,000,000	30,000,000	0	11	89	100	20	80	0	100	100	0	0	0	0	100	55	36	9	9	82
SAL-10	Naghasheh	201,600,000	456,000,000	90,000,000	29	71	0	100	25	50	25	100	100	0	0	0	0	100	0	100	0	0	100
Sub-total		**157,153,196**	**1,315,000,000**	**18,200,000**	**10**	**22**	**68**	**100**	**32**	**66**	**2**	**100**	**65**	**19**	**0**	**12**	**4**	**100**	**45**	**54**	**9**	**9**	**88**
SOU-01	Shibderaz	62,400,000	96,000,000	36,000,000	0	50	50	100	29	71	0	100	100	0	0	0	0	100	80	20	10	10	30
SOU-02	Messen	48,000,000	48,000,000	48,000,000	8	50	42	100	29	71	0	100	50	0	0	0	50	100	67	33	0	0	33
SOU-03	Borka Khalaf	48,000,000	66,000,000	36,000,000	10	50	40	100	50	50	0	100	50	0	0	0	50	100	60	40	0	0	10
SOU-04	Righoo	-	-	-	10	20	70	100	33	67	0	100	100	0	0	0	0	100	30	70	0	0	20
SOU-05	Zirang	188,181,818	600,000,000	80,000,000	55	45	0	100	86	14	0	100	71	29	0	0	0	100	100	0	9	0	36
SOU-06	Nakhl-E-Gol	-	-	-	11	56	33	100	75	25	0	100	100	0	0	0	0	100	67	33	0	0	0
SOU-07	Direstan	-	-	-	0	36	64	100	100	0	0	100	0	0	0	0	100	100	73	27	9	9	9
Sub-total		**128,700,000**	**600,000,000**	**36,000,000**	**14**	**44**	**42**	**100**	**55**	**45**	**0**	**100**	**70**	**9**	**0**	**0**	**22**	**100**	**68**	**32**	**4**	**3**	**21**
TOTAL		236,422,059	3,700,000,000	4,800,000	24	44	32	100	67	32	1	100	67	16	3	3	11	100	76	24	14	8	58

Source: JICA Project Team

Table A1.1.1 Individual Interview Survey of Each Village (5/6)

Village ID	Village Name	16. Disaster and environment																17. Needs for development								
		16.1 Those who think diaster risk exists (%)	16.2 Kind of disaster risk(%)							16.3 Those who think environmental problem exists (%).	16.4 Kind of environmental problem(%)						Issues with highest priority (%)								
			(1)Flood/inundation	(2)High tide	(3)Wind	(4)Earth quake	(5)Ladn slide	(6)Other	Total		(1)Offensive Odor	(2)Air pollution	(3)Water pollution	(4)Noise	(5)Other	Total	(1)Water supply	(2)Education	(3)Health care	(4)Agriculture	(5)Livestock raising	(6)Opportunity	(7)Road	(8)Other	Total
DOU-01	Basaidu	0	-	-	-	-	-	-	-	0	-	-	-	-	-	-	0	9	45	0	0	36	9	0	100
DOU-02	Derakou	0	-	-	-	-	-	-	-	0	-	-	-	-	-	-	0	0	90	0	0	10	0	0	100
DOU-03	Doustakou	0	-	-	-	-	-	-	-	0	-	-	-	-	-	-	10	0	90	0	0	0	0	0	100
DOU-04	Kani	0	-	-	-	-	-	-	-	0	-	-	-	-	-	-	20	10	70	0	0	0	0	0	100
DOU-05	Konar Seiah	0	-	-	-	-	-	-	-	0	-	-	-	-	-	-	10	0	0	0	0	90	0	0	100
DOU-06	Gouri	0	-	-	-	-	-	-	-	0	-	-	-	-	-	-	0	10	30	0	0	60	0	0	100
DOU-07	Moradi	0	-	-	-	-	-	-	-	0	-	-	-	-	-	-	10	10	50	0	0	30	0	0	100
DOU-08	Tomgaz	89	0	100	0	0	0	0	100	0	-	-	-	-	-	-	11	0	0	11	0	78	0	0	100
DOU-09	Chahou West	10	0	0	0	100	0	0	100	0	-	-	-	-	-	-	20	20	0	0	0	60	0	0	100
DOU-10	Chahou East	0	-	-	-	-	-	-	-	0	-	-	-	-	-	-	45	9	18	0	0	18	0	9	100
DOU-11	Doulab	0	-	-	-	-	-	-	-	0	-	-	-	-	-	-	0	27	27	0	0	45	0	0	100
DOU-12	Sar Rig	0	-	-	-	-	-	-	-	9	0	0	100	0	0	100	27	9	27	0	0	18	0	18	100
DOU-13	Aysheh-Abad	0	-	-	-	-	-	-	-	0	-	-	-	-	-	-	11	33	0	33	0	22	0	0	100
Sub-total		**7**	**0**	**89**	**0**	**11**	**0**	**0**	**100**	**1**	**0**	**0**	**100**	**0**	**0**	**100**	**13**	**11**	**35**	**3**	**0**	**36**	**1**	**2**	**100**
HEN-01	Hengam	0	-	-	-	-	-	-	-	0	-	-	-	-	-	-	10	10	10	0	0	70	0	0	100
HEN-02	Old Hengam																								
Sub-total		**0**	-	-	-	-	-	-	-	**0**	-	-	-	-	-	-	**10**	**10**	**10**	**0**	**0**	**70**	**0**	**0**	**100**
HOW-01	Ramchah	0	-	-	-	-	-	-	-	0	-	-	-	-	-	-	8	17	58	0	0	17	0	0	100
HOW-02	Tourgan	100	0	0	0	100	0	0	100	33	67	0	33	0	0	100	67	22	11	0	0	0	0	0	100
HOW-03	Kuvehee	0	-	-	-	-	-	-	-	100	0	0	100	0	0	100	0	33	33	0	0	33	0	0	100
HOW-04	Giahdan	0	-	-	-	-	-	-	-	33	25	75	0	0	0	100	17	17	50	0	0	17	0	0	100
HOW-05	Tonban	0	-	-	-	-	-	-	-	25	0	0	0	0	100	100	33	8	33	0	0	25	0	0	100
HOW-06	Kavarzin	0	-	-	-	-	-	-	-	0	-	-	-	-	-	-	0	0	91	0	0	9	0	0	100
HOW-07	Laft	0	-	-	-	-	-	-	-	0	-	-	-	-	-	-	100	0	0	0	0	0	0	0	100
HOW-08	Holor	0	-	-	-	-	-	-	-	25	100	0	0	0	0	100	0	25	50	8	0	17	0	0	100
HOW-09	Hamiri	0	-	-	-	-	-	-	-	0	-	-	-	-	-	-	70	20	10	0	0	0	0	0	100
HOW-10	Defari	0	-	-	-	-	-	-	-	11	0	100	0	0	0	100	83	6	6	0	0	6	0	0	100
HOW-11	Tola	0	-	-	-	-	-	-	-	67	50	50	0	0	0	100	100	0	0	0	0	0	0	0	100
HOW-12	Kabeli																								
Sub-total		**7**	**0**	**0**	**0**	**100**	**0**	**0**	**100**	**27**	**27**	**24**	**39**	**0**	**9**	**100**	**44**	**13**	**31**	**1**	**0**	**11**	**0**	**0**	**100**
RAM-01	Bangali	100	0	0	0	100	0	0	100	44	100	0	0	0	0	100	0	11	89	0	0	0	0	0	100
RAM-02	Jijan	100	0	0	0	100	0	0	100	0	-	-	-	-	-	-	0	40	10	0	0	0	0	50	100
RAM-03	Gorbehdan	100	0	0	0	100	0	0	100	70	56	33	11	0	0	100	20	20	20	0	0	40	0	0	100
RAM-04	Peyposht	100	0	15	0	85	0	0	100	82	56	44	0	0	0	100	9	9	36	0	0	0	0	45	100
RAM-05	Khaladin	100	0	0	0	100	0	0	100	100	29	65	6	0	0	100	9	9	18	0	0	0	0	64	100
RAM-06	Zainabi	100	0	0	0	100	0	0	100	18	33	33	33	0	0	100	0	45	18	0	0	18	0	18	100
RAM-07	Karavan	100	0	0	0	100	0	0	100	0	-	-	-	-	-	-	0	10	10	0	0	20	0	60	100
RAM-08	Kousheh	100	0	0	0	100	0	0	100	0	-	-	-	-	-	-	18	0	45	0	0	36	0	0	100
RAM-09	Kardova	100	0	0	0	100	0	0	100	89	100	0	0	0	0	100	0	11	0	0	0	22	0	67	100
RAM-10	Bagh Bala	100	0	0	0	100	0	0	100	100	0	100	0	0	0	100	11	33	56	0	0	0	0	0	100
RAM-11	Tomseneti	100	36	0	0	64	0	0	100	0	-	-	-	-	-	-	11	44	0	0	0	0	0	44	100
RAM-12	Tourian	73	30	0	0	60	0	10	100	64	25	75	0	0	0	100	64	27	9	0	0	0	0	0	100
RAM-13	Ramkan	50	0	0	0	100	0	0	100	8	33	33	0	0	33	100	4	21	38	0	0	29	0	8	100
Sub-total		**90**	**6**	**1**	**0**	**92**	**0**	**1**	**100**	**41**	**44**	**50**	**4**	**0**	**1**	**100**	**11**	**21**	**28**	**0**	**0**	**14**	**0**	**26**	**100**
SAL-01	Dehkhoda	100	0	0	0	100	0	0	100	100	0	67	33	0	0	100	0	30	30	10	10	0	0	20	100
SAL-02	Soheili	82	22	0	11	67	0	0	100	91	21	43	36	0	0	100	18	0	45	0	9	0	0	27	100
SAL-03	Haftrangou	100	9	0	0	91	0	0	100	100	7	71	21	0	0	100	80	0	10	0	0	0	0	10	100
SAL-04	Dourbani	100	0	0	0	100	0	0	100	100	0	50	50	0	0	100	70	10	10	0	0	10	0	0	100
SAL-05	Gomboron	100	0	0	0	100	0	0	100	100	0	50	50	0	0	100	10	30	50	0	0	10	0	0	100
SAL-06	Gouran	100	0	0	0	100	0	0	100	100	9	45	45	0	0	100	64	9	18	0	0	9	0	0	100
SAL-07	Melki	100	0	0	0	100	0	0	100	100	14	45	41	0	0	100	70	0	0	0	0	10	0	20	100
SAL-08	Tabl	100	0	0	8	92	0	0	100	100	4	52	43	0	0	100	58	8	17	0	0	0	0	17	100
SAL-09	Salakh	100	0	0	0	100	0	0	100	100	0	50	50	0	0	100	0	33	22	0	0	0	11	33	100
SAL-10	Naghasheh	100	0	0	0	100	0	0	100	100	33	33	33	0	0	100	43	14	0	0	0	0	0	43	100
Sub-total		**98**	**3**	**0**	**2**	**95**	**0**	**0**	**100**	**99**	**9**	**50**	**41**	**0**	**0**	**100**	**42**	**13**	**21**	**1**	**2**	**4**	**1**	**16**	**100**
SOU-01	Shibderaz	0	-	-	-	-	-	-	-	0	-	-	-	-	-	-	60	0	0	0	0	30	0	10	100
SOU-02	Messen	0	-	-	-	-	-	-	-	8	100	0	0	0	0	100	0	17	25	8	0	50	0	0	100
SOU-03	Borka Khalaf	0	-	-	-	-	-	-	-	0	-	-	-	-	-	-	90	0	0	0	0	10	0	0	100
SOU-04	Righoo	0	-	-	-	-	-	-	-	0	-	-	-	-	-	-	80	0	0	0	0	20	0	0	100
SOU-05	Zirang	0	-	-	-	-	-	-	-	0	-	-	-	-	-	-	27	0	64	0	0	9	0	0	100
SOU-06	Nakhl-E-Gol	11	0	0	0	100	0	0	100	56	0	0	100	0	0	100	89	0	0	0	0	11	0	0	100
SOU-07	Direstan	0	-	-	-	-	-	-	-	64	86	0	0	0	14	100	0	0	27	9	0	64	0	0	100
Sub-total		**1**	**0**	**0**	**0**	**100**	**0**	**0**	**100**	**18**	**54**	**0**	**38**	**0**	**8**	**100**	**47**	**3**	**18**	**3**	**0**	**29**	**0**	**1**	**100**
TOTAL		42	4	4	1	91	0	0	100	35	21	45	33	0	2	100	28	13	27	1	0	19	0	10	100

Source: JICA Project Team

Table A1.1.1 Individual Interview Survey of Each Village (6/6)

Village ID	Village Name	18. Future job												19. About life											
		18.1 Intention to change the job(%)	18.2 Reason for changing the job(%)					18.3 Kind of job expected in the future (%)						19.1 Improvement of life in the last 20 years(%)					19.2 Any disruption by development	19.3 Housing		19.4 Development compared with other areas	19.5 Satisfaction with life	19.6 Interest in environment	19.7 Plan for moving
			(1)Income is too low.	(2) Poor living condition in the village	(3) To follow family or relatives	(4)Other	Total	(1)Tourism related job	(2)Marine products related job	(3)Energy related job	(4)Construction related job	(5)Other	Total	(1 Improved significantly	(2) Improved a little.	(3) Same as 20 years ago.	(4) It deteriorated.	Total	Those whose life was disrupted by development (%)	19.3.1 Those suffering from housing problem (%)	19.3.2 Those whose housing condition was Improved in 20 years (%)	Those who think they lag behind other areas in development (%)	Those who are satisfied with their lives (%)	Those interested in environmental issues (%)	Those who plan to another place in the future (%)
DOU-01	Basaidu	9	-	-	-	-	-	-	-	-	-	-	-	18	45	0	36	100	0	9	0	64	64	36	18
DOU-02	Derakou	0	-	-	-	-	-	-	-	-	-	-	-	0	80	0	20	100	0	0	0	80	50	50	0
DOU-03	Doustakou	0	-	-	-	-	-	-	-	-	-	-	-	0	60	0	40	100	0	0	0	90	50	40	0
DOU-04	Kani	20	-	-	-	-	-	50	50	0	0	0	100	0	100	0	0	100	0	0	0	100	60	40	0
DOU-05	Konar Seiah	40	25	50	0	25	100	0	67	0	0	33	100	0	60	0	40	100	0	0	80	100	60	70	30
DOU-06	Gouri	30	-	-	-	-	-	0	67	0	0	33	100	0	100	0	0	100	0	0	20	70	40	30	10
DOU-07	Moradi	10	-	-	-	-	-	0	100	0	0	0	100	0	90	0	10	100	0	0	0	80	20	30	10
DOU-08	Tomgaz	0	-	-	-	-	-	-	-	-	-	-	-	0	78	0	22	100	0	0	44	67	33	78	0
DOU-09	Chahou West	30	67	0	0	33	100	0	100	0	0	0	100	0	89	0	11	100	0	20	0	70	50	80	0
DOU-10	Chahou East	64	43	43	0	14	100	50	33	0	17	0	100	18	18	0	64	100	0	73	36	55	55	73	9
DOU-11	Doulab	17	50	0	50	0	100	50	50	0	0	0	100	0	45	0	55	100	0	0	75	58	75	50	0
DOU-12	Sar Rig	27	33	33	0	33	100	0	33	0	0	67	100	10	60	0	30	100	0	36	55	64	82	73	18
DOU-13	Aysheh-Abad	11	-	-	-	-	-	0	100	0	0	0	100	0	89	0	11	100	0	0	89	33	100	78	0
Sub-total		20	42	32	5	21	100	21	58	0	4	17	100	4	69	0	27	100	0	11	31	71	57	56	8
HEN-01	Hengam	10	0	100	0	0	100	0	0	0	0	100	100	0	100	0	0	100	0	20	0	0	80	20	10
HEN-02	Old Hengam																								
Sub-total		10	0	100	0	0	100	0	0	0	0	100	100	0	100	0	0	100	0	20	0	0	80	20	10
HOW-01	Ramchah	0	-	-	-	-	-	-	-	-	-	-	-	0	100	0	0	100	0	0	0	0	100	17	0
HOW-02	Tourgan	44	100	0	0	0	100	0	50	0	0	50	100	22	22	11	44	100	0	0	100	100	78	0	11
HOW-03	Kuvehee	33	100	0	0	0	100	0	0	0	50	50	100	0	10	30	60	100	0	25	92	75	83	75	0
HOW-04	Giahdan	58	100	0	0	0	100	20	20	0	20	40	100	0	10	30	60	100	0	58	83	92	58	92	0
HOW-05	Tonban	17	-	-	-	-	-	0	50	0	0	50	100	0	100	0	0	100	0	0	17	0	100	25	0
HOW-06	Kavarzin	0	-	-	-	-	-	-	-	-	-	-	-	0	91	0	9	100	0	0	0	0	100	36	0
HOW-07	Laft	55	100	0	0	0	100	0	0	0	100	0	100	0	0	0	100	100	0	36	82	82	36	100	0
HOW-08	Holor	58	100	0	0	0	100	0	33	0	33	33	100	0	8	67	25	100	25	75	75	100	42	100	0
HOW-09	Hamiri	20	100	0	0	0	100	-	-	-	-	-	-	0	63	0	38	100	10	40	40	50	60	40	0
HOW-10	Defari	21	100	0	0	0	100	0	0	0	100	0	100	0	67	0	33	100	0	26	21	47	74	37	11
HOW-11	Tola	33	75	25	0	0	100	0	0	0	100	0	100	0	100	0	0	100	0	83	25	83	67	58	25
HOW-12	Kabeli																								
Sub-total		30	97	3	0	0	100	5	24	0	38	33	100	2	50	14	34	100	3	32	46	56	73	53	5
RAM-01	Bangali	44	67	0	0	33	100	33	0	0	0	67	100	0	78	0	22	100	0	67	22	100	89	89	0
RAM-02	Jijan	40	67	33	0	0	100	40	0	20	40	0	100	60	40	0	0	100	70	10	90	20	80	50	0
RAM-03	Gorbehdan	80	100	0	0	0	100	13	0	13	13	63	100	20	60	0	20	100	20	80	40	50	50	90	10
RAM-04	Peyposht	36	0	100	0	0	100	0	0	0	100	0	100	0	45	0	55	100	27	0	100	0	64	73	9
RAM-05	Khaladin	55	33	67	0	0	100	0	20	20	60	0	100	18	73	0	9	100	9	27	73	18	73	73	0
RAM-06	Zainabi	18	0	100	0	0	100	50	0	0	50	0	100	55	36	9	0	100	0	18	91	0	64	73	0
RAM-07	Karavan	60	50	50	0	0	100	18	0	36	36	9	100	50	50	0	0	100	20	50	50	0	50	50	0
RAM-08	Kousheh	64	29	57	0	14	100	0	0	0	57	43	100	27	27	0	45	100	0	100	36	18	55	73	9
RAM-09	Kardova	78	25	50	0	25	100	14	14	29	14	29	100	22	56	0	22	100	0	0	100	89	56	56	33
RAM-10	Bagh Bala	56	100	0	0	0	100	0	0	0	40	60	100	56	33	0	11	100	0	33	11	67	100	100	33
RAM-11	Tomseneti	78	50	50	0	0	100	29	0	29	29	14	100	44	44	0	11	100	0	56	22	11	44	56	0
RAM-12	Tourian	36	50	50	0	0	100	0	0	25	25	50	100	9	82	9	0	100	9	82	45	64	82	91	0
RAM-13	Ramkan	33	88	0	0	13	100	0	33	0	67	0	100	5	38	33	24	100	8	33	54	38	75	79	13
Sub-total		50	57	36	0	8	100	13	5	17	39	25	100	26	50	6	18	100	12	42	57	35	68	74	8
SAL-01	Dehkhoda	50	60	0	20	20	100	33	0	67	0	0	100	30	30	0	40	100	10	50	60	90	90	90	20
SAL-02	Soheili	45	50	50	0	0	100	25	13	13	25	25	100	9	64	0	27	100	0	91	0	36	55	100	27
SAL-03	Haftrangou	60	83	0	0	17	100	50	0	0	0	50	100	60	20	0	20	100	10	90	40	90	100	90	10
SAL-04	Dourbani	80	100	0	0	0	100	50	0	0	0	50	100	20	40	0	40	100	0	80	40	100	80	70	30
SAL-05	Gomboron	70	71	14	0	14	100	57	29	0	0	14	100	10	20	0	70	100	10	100	10	90	90	80	20
SAL-06	Gouran	64	100	0	0	0	100	67	0	0	0	33	100	9	55	0	36	100	0	55	45	73	82	82	9
SAL-07	Melki	90	67	33	0	0	100	25	0	0	13	63	100	0	70	0	30	100	0	70	40	90	80	70	50
SAL-08	Tabl	50	100	0	0	0	100	17	17	0	33	33	100	8	33	0	58	100	0	67	25	25	92	58	0
SAL-09	Salakh	82	100	0	0	0	100	43	14	0	0	43	100	30	30	0	40	100	9	73	36	55	82	73	0
SAL-10	Naghasheh	86	100	0	0	0	100	63	13	13	13	0	100	0	71	0	29	100	0	100	0	100	43	86	57
Sub-total		67	80	10	2	7	100	43	10	7	10	31	100	18	43	0	40	100	4	76	30	73	80	79	21
SOU-01	Shibderaz	100	100	0	0	0	100	0	25	0	38	38	100	0	10	40	50	100	0	50	90	100	60	90	40
SOU-02	Messen	67	100	0	0	0	100	0	100	0	0	0	100	0	8	42	50	100	0	25	75	92	75	58	42
SOU-03	Borka Khalaf	50	80	20	0	0	100	-	-	-	-	-	-	0	33	44	22	100	0	10	10	100	60	90	0
SOU-04	Righoo	70	100	0	0	0	100	-	-	-	-	-	-	0	0	40	60	100	0	50	60	80	90	60	20
SOU-05	Zirang	0	-	-	-	-	-	-	-	-	-	-	-	0	100	0	0	100	0	0	0	0	100	18	9
SOU-06	Nakhl-E-Gol	89	88	13	0	0	100	-	-	-	-	-	-	0	13	25	63	100	22	67	11	100	56	67	44
SOU-07	Direstan	64	86	14	0	0	100	0	25	0	75	0	100	9	0	36	55	100	27	36	82	64	55	91	45
Sub-total		62	93	7	0	0	100	0	31	0	46	23	100	1	24	32	42	100	7	33	48	75	71	67	29
TOTAL		43	76	17	1	6	100	21	17	9	26	27	100	11	51	8	30	100	5	37	42	59	69	64	12

Source: JICA Project Team

A1.1.5 Result of key informants survey

The tables in the following pages show result of key informant survey of each village.

Table A1.1.2 Result of Key Informant Survey (1/4)

The name of village	Village No.	Village's history	Bonyad Maskan Planning	Constraint of village development	Main livelihood: Farming	Livestock raising	Fishing	Trading	Farm labor	Other labor work	Handcraft	Collecting forest products	Employed at office	Other
Baseidou	DOU-01	The background of development in the region is owing to closing to sea and having hill resort on the top of mountain.	Partially	Slope	0%	2%	77%	7%	0%	5%	2%	0%	2%	7%
Derakou	DOU-02	Cool air spots above the mountain in summer	Partially	Slope Lack of water	0%	0%	68%	3%	0%	13%	0%	0%	7%	8%
Doustakou	DOU-03	Good condition for fishing and agriculture (Palm grove)	Partially	Lack of water Bad soil	1%	0%	80%	3%	0%	7%	0%	0%	3%	7%
Kani	DOU-04	Fishing area and fertile soil		Lack of water Bad soil	0%	0%	92%	0%	0%	0%	0%	0%	2%	33%
Konar Seiah	DOU-05	Fertile soil and rainwater for agriculture (Palm grove)	Partially	Slope Lack of water	0%	4%	67%	0%	0%	11%	7%	0%	7%	5%
Gouri	DOU-06	Suitable for agriculture due to rainwater and flood	Partially	Slope Lack of water	2%	0%	63%	7%	0%	10%	0%	0%	3%	13%
Moradi	DOU-07	to avoid flood and get fertile soil, people want to live on the mountain	Partially	Slope Lack of water	5%	8%	63%	0%	2%	8%	2%	0%	0%	12%
Tomgez	DOU-08	Rich soil to grow up carrot, greens, watermelon and cucumber	Partially		0%	0%	85%	2%	0%	3%	0%	0%	0%	9%
Chahou West	DOU-09	Slope	Partially	Slope	0%	3%	75%	2%	0%	12%	3%	0%	2%	2%
Chahou East	DOU-10	Good agricultural conditions due to rainwater and	Partially	Slope Lack of water	0%	0%	50%	0%	0%	0%	0%	0%	0%	10%
Doulab	DOU-11	Easy access to sea, other villages and fertile soil	Partially	Slope Lack of water	0%	5%	60%	18%	0%	5%	0%	0%	5%	7%
Sar Rig	DOU-12	Suitable for agriculture due to rainwater and flood	Partially	Lack of water	0%	2%	48%	22%	0%	17%	2%	0%	5%	5%
Aysheh-Abab	DOU-13	Easy access to sea		Bad soil	0%	2%	90%	0%	0%	3%	0%	32%	0%	3%
Ramchah	HOW-01	Due to existence of water resources, suitable land, security and location near the sea, the village was formed and was thrived by agriculture	partially	Lack of water	2%	3%	67%	3%	0%	7%	3%	0%	7%	8%
Tourgon	HOW-02		totally	Lack of water	10%	7%	17%	0%	0%	0%	0%	0%	0%	0%
Kouvei	HOW-03	Located near the sea and local people could have related job with the sea	totally		0%	0%	40%	10%	0%	0%	0%	0%	0%	0%
Giadon	HOW-04	Due to infected disease in ancient times, the location of the village has changed. Creation of environment for building standards Hadi plan.	totally	Lack of water										
Tonbon	HOW-05		totally	Lack of water Influx of sand	1%	8%	47%	6%	0%	12%	2%	0%	3%	19%
Kovarzin	HOW-06	Suitable land for agriculture such as palm grove due to sufficient water. But recently because of lack water, earthquake in 2004 and far from the sea, population was decreasing	totally	Lack of water	0%	7%	53%	7%	2%	4%	2%	0%	3%	17%
Laft	HOW-07	Suitable land for agriculture such as palm grove due to sufficient water. And marine resources	totally											
Holor	HOW-08	was suitable land for agriculture but now is poor soil and lack of water for irrigation.	partially	lack of water	5%	5%	10%	25%	0%	20%	5%	0%	20%	10%
Hamiri	HOW-09	Suitable land for agriculture as well as livestock for 10-15 years ago	not considered	lack of water	28%	18%	30%	0%	8%	8%	0%	0%	0%	10%
Defari	HOW-10	Suitable land for agriculture and animal husbandry	partially	lack of water lack of access road	17%	17%	20%	17%	0%	13%	5%	0%	3%	8%
Tola	HOW-11	Close to city center, creating palm garden, suitable soil, fresh water wells	Only for urban extension	Lack of rainfall	0%	40%	8%	1%	0%	0%	0%	0%	8%	33%

Source: JICA Project Team

Table A1.1.2 Result of Key Informant Survey (2/4)

The name of village	Natural resources							Drinking water								Infrastructure	Education
	Ground water	Wood	Wild animals	Fishing	Farming	Domesticated animals for tourist	other biological recourses	Rain	Truck	Desalination	Well	Lake	Cistern	Tap	Mineral water		
Baseidou	2	3	0	3	0	0	0	1	1	2	0	0	0	0	0	Desalination system must improve, and the use of the beach should be optimized.	must go to Doulab village to go to high school for 3rd grade and higher education. Teacher's quality and facility are very low.
Derakou	3	3	0	3	0	0	0	3	3	1	2	0	0	0	0	Quality of road is poor	must go to Doulab village to go to high school for 3rd grade and higher education. Teacher's quality and facility are very low.
Doustakou	3	3	0	3	2	0	0	2	3	1	1	1	0	0	0	Poor asphalt road and harbor	must go to Doulab village to go to guidance school and high school. Teacher's quality and facility are very low.
Kani	0	3	0	3	0	0	0	1	2	1	2	0	0	0	1	weak mobile signal	must go to Doulab village to go to guidance school and high school. Teacher's quality and facility are very low.
Konar Seiah	0	3	0	3	0	0	0	1	3	1	1	0	1	0	0	Quality of road is poor	must go to Doulab village to go to guidance school and high school. But education level grows well.
Gouri	3	3	0	2	3	0	0	2	3	0	0	0	0	0	0	Commercial spot	Teacher's quality and facility are very low.
Moradi	2	3	0	3	1	0	0	0	3	1	0	0	1	0	0	Weak internet and poor asphalt	Only primary and guidance school
Tomgez	1	2	0	2	0	0	0	1	2	2	1	0	0	0	0	Road	Teachers are qualified. And going to Doulab village to go to higher Education.
Chahou West	3	3	0	3	1	0	0	1	2	2	0	0	0	0	0	Unpaved road and lack of water pipeline. Cost of electricity is high.	Educational facility is low. And going to Sar-Rig village to go to higher Education.
Chahou East	3	3	0	3	3	1	0	0	2	3	1	0	0	0	0	Road quality and unused gas pipeline	Educational facility is low. There is no high school in the village
Doulab	1	3	0	3	0	1	0	1	2	3	1	0	0	0	1	Quality of road is poor	Education facility is low, but teachers level is not bad
Sar Rig	1	3	0	3	1	0	0	0	3	2	0	0	0	0	1	Quality of road and internet are poor	training facility is low, but all of the school level is good
Aysheh-Abab	0	3	0	3	0	0	0	0	2	1	0	0	1	1	0	Quality of road is poor	Education facility is low but teachers level is not bad
Ramchah	3	3	0	3	3	0	1	0	2	2	0	0	0	0	1	far from main road and poor asphalt	Poor educational facilities. But teachers and school's quality is good
Tourgon	3	2	0	0	0	3	0	0	2	0	0	0	0	0	0	No water pipe	No school
Kouvei	0	0	0	3	0	0	0	0	0	3	0	0	0	0	0		the girls drop put due to no high school in the village
Giadon	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No gas network	No high school Primary and guidance school and teachers are good quality
Tonbon	3	3	0	3	1	3	0	1	1	2	0	0	0	0	1	unpaved road in the village	there is primary school but no high school
Kovarzin	3	3	0	3	2	0	0	1	1	2	0	0	0	0	1	Poor road quality and still remain of earthquake in 2004	there is primary school but no high school. In case of that, going to Tabl
Laft	3	3	0	3	3	3	3	0	0	3	0	0	0	0	0	Incomplete water supply network	There is all of the school level in the village. But it is difficult for teachers to commute there.
Holor	1	1	0	1	1	1	1	0	0	0	0	0	0	3	0	Asphalt with normal quality	There is all of the school level in the village and level of teachers is also good.
Hamiri	2	2	1	2	1	0	0	0	2	2	0	0	0	0	0	Not easy access to main road	there is primary school at Defari village but no high school. In case of that, going to Tabl
Defari	3	3	0	2	2	0	0	2	3	0	2	0	0	0	3	Not easy access to main road. And road quality is not good	Only primary school and facility is too law
Tola	3	1	0	3	0	0	0	0	0	0	0	0	0	0	0		No middle school and high school

Source: JICA Project Team

Table A1.1.2 Result of Key Informant Survey (3/4)

The name of village	Health	Heritage	Special symbolic	Goods	Public land	Links of environment	Links of other village	Geosite and tourist site	Major changes
Baseidou	Must go to Doulab village to visit to clinic (20km) or Qeshm city (120km).	Portuguese castle and English cemetery	Beach, Park and Mosque	Adornment	Park and beach	Sea	Doulab	Portuguese castle and English cemetery	Constriction of pier, desalination and gas station
Derakou	Must go to Doulab village to visit to treatment services or Qeshm city.	Cistern, Mosque and Park	Sport field, Mosque and Park	Adornment	Park and sport field	Sea and garden	Doulab, Baseidou		Road construction
Doustakou	Must go to Doulab village to visit to treatment services or Qeshm city.	Mosque	Beach and Mosque	Date and women craft	Park and sport field	Sea	Kani, Gouri and Moradi		Building school, paved road
Kani	Must go to Doulab village to visit to treatment services or Qeshm city.	Salt cave and Doran lake	Sport field, Mosque and Salt cave	Adornment, Sewing goods	Park and sport field	Sea and palm grove	surrounding village	Salt cave	Road and School construction
Konar Seiah	Must go to Doulab village to visit to treatment services or Qeshm city.		Beach, soccer field and groves	Handicraft	Park and beach	Sea and garden	surrounding village	Natural beach	Road and School construction
Gouri	Must go to Doulab village to visit to treatment services or Qeshm city.	Cistern, Old Mosque	Park and Mosque	Date and women craft	Park and sport field	Groves for recreation and tourism	surrounding village	Salt cave	Road and Mosque construction
Moradi	Must go to Doulab village to visit to treatment services.	Basira mountain and 30 wells at palm grove	Soccer field and groves	Date and women craft	Park, school and mosque	Basira mountain and sea	Gouri and Baseidou	Basira mountain	Construction of road, school. And garbage collection
Tomgez	Need better clinic Now is under Doulab village	Haft-Khaharan lake and 3 louvres	Beach and groves	Adornment	Park and sport field	Sea and garden	Doulab, Konar Siah		Construction of Road, Shelters for fisherman
Chahou West	Long distance to Clinic	Old cistern, houses	Beach, Park and Mosque	Handicraft and manufacturing small wooden boat	Water dam, Park and sport field	Sea and garden	Doulab and Sarrigan		Increasing facility and road
Chahou East	Need better clinic and we must go to Doulab village	Wind ward village, water dam and Chahou valley	Mosque, Palm grove and school	Handicraft and manufacturing small wooden boat	Water dam, Park and sport field	Sea and garden	Doulab and Sarrigan	Chahou valley	Park, school, road, sanitation
Doulab	Having clinic and treatment center but not all services	Old mosque and houses	Beach, Park and Mosque	Handicraft	Park, Dam, Mosque, school	Sea and garden	Sarriganm Tomgez, Chahoo	Kerman valley	development of facility and business
Sar Rig	Need clinic, doctor and 24 open pharmacy	Traditional architecture	Beach and sport grounds	Handicraft and clothes	Park, school and mosque	Sea and garden	Doulab and Sarrigan	Kerkerakoh	Construction of Road and school
Aysheh- Abab	Must go to Doulab village to visit to treatment services or Qeshm city.	Old cistern, houses and houses	Beach and sport grounds	Production of fishing tool, Handicraft and clothes	Park, school and mosque	Sea and garden	Doulab and Chahou		Embankment road parks and shelters
Ramchah	Only health center. So, must go to Qeshm for treatment services	Kharbas cave and Mosque	Mosque and sports ground	Date and types of shrimp and fish	Park, sports field and mosque	Sea and garden	Dargahan and Qeshm	Kharbas cave and Shah-Shahid shrine	Road, power etc.
Tourgon	No health center and treatment services	Chehel-Tanan school	Mosque	Handcrafts and fish drying	Seacoast	Sea and beach	Ramchah and Defari	Western cave	Electrical load
Kouvei	Only health center		Beach		Seaside park with 400m^2	Sea	Surrounding village		
Giadon	There is health center and two workers	Darhash dam					Surrounding village		Rural road and construction building
Tonbon	Just health center	water storage, mosque, wind tower destroyed by earthquake in 2004.	Mosque and sports ground	buying and selling camel	Mosque, soccer field and petrol station	Sea for fishing and pasture for camel	Table, Kovarzin and Noghasha	Hara Mangrove	Power supplies, construction of settlements, road, school health center and petrol stations
Kovarzin	There is health center, but we must go to Tabl or Qeshm in case of treatment services	water storage and mosque destroyed by earthquake in 2004.	Mosque and sports ground, Park and palm groves	Dates and local clothes and traditional fishing style	Park, sports field and mosque	Sea and garden	Soheil, Tabl, Laft		rebuilding of road, residential settlements
Laft	There are two health centers with midwife	Wind tower and old building	the coastal boulevard	Local women clothes		Sea	Commercial connection with surrounding village	Tourist site	Paved street, Islamic council, Library, School and Maternity clinic
Holor	Two health centers	Historical wells of village and great mosque		Leather crafts, local clothes, local pastries	Park, sports field	Sea and garden	Qeshm and Dargahan	Construction of beach park	
Hamiri	No health center and going to Qeshm for treatment services		Mosque, garden and palm groves	Passement Erie, Basket weaving, brocade and crop products		Garden and palm grove	Caboli, Tola and Defari		Power supplies, Road
Defari	There is health center, but we must go to Tabl or Qeshm in case of treatment services	Mosque	Mosque and sports ground, Park and palm groves	Dates, fishing craft and tailoring		Garden and farmland	Tourgon, Hamiri, Ramchah, Caboli and Qeshm	Kharbas cave (too much unknown due to unpaved road)	Road, Power supplies
Tola	There are health center and family doctor. But facility is not good.	Lake, Cemetery, old harbor	Mt. Shah Zaman	Dates		Industrial town and sea	Surrounding village	Mangrove forest	Expand residential area from 600 to 6,000 households

Source: JICA Project Team

Table A1.1.2 Result of Key Informant Survey (4/4)

The name of village	Life in village	Satisfaction of their lives	Migration
Baseidou	Improved	Almost are satisfied but need more job opportunity except fishing.	No
Derakou	Improved	Satisfied relatively	No
Doustakou	Improved	Satisfied relatively	No, But literate people are migrating
Kani	Somewhat improved	Satisfied relatively	No
Konar Seiah	Improved	Not satisfied	Population is growing
Gouri	Somewhat improved	Satisfied relatively	No
Moradi	Relatively improved	Satisfied relatively	No
Tomgez	Improved	Satisfied relatively. But for younger generation, they need job	No population is on the rise.
Chahou West	Improved	Satisfied relatively. But for younger generation, they need job	No
Chahou East	Relatively improved	Satisfied relatively	No
Doulab	Easy access to more amenity	Satisfied relatively	No
Sar Rig	Improved	Satisfied relatively. But for younger generation, they need job	No. But some couple has gone to other village
Aysheh- Abab	Improved	Satisfied relatively	No
Ramchah	Improved. But high cost	Not satisfied due to poor financial concerns and poor amenities	No
Tourgon	Not changed	Not satisfied	No
Kouvei	a little bit changed	want further improvement	No
Giadon	Improved	want further improvement	No
Tonbon	Improved. But high cost	almost satisfied	After earthquake was decreasing, but is increasing recently
Kovarzin	Improved relatively	Not satisfied due to poor job opportunity	After the earthquake, was decreasing, but is increasing now
Laft	Improved	Satisfied	No
Holor	Improved	almost satisfied	No
Hamiri	Improved	More business opportunity	No
Defari	Improved	Relatively improved	No
Tola	Improved	Not satisfied	No

Source: JICA Project Team

A1.2 Environmental Baseline Survey

A1.2.1 Introduction

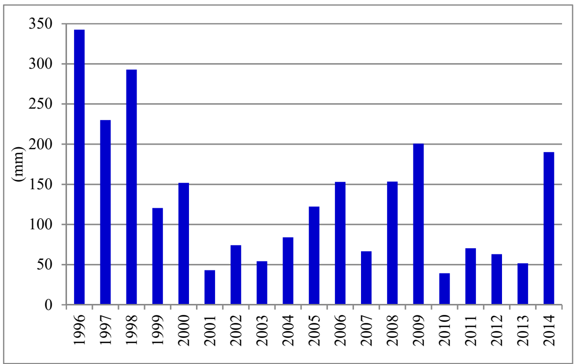
Qeshm Island has been developing rapidly because of its very special location in Iran for economy, industry, and tourism. Therefore, any kinds of decision making require full span attention to different aspects including economic, social, cultural, and environmental issues.

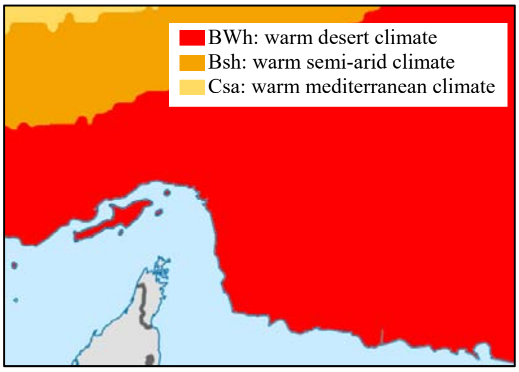
The following summarized report has been prepared with the cooperation of Hormozgan University as a part of the "Master Plan of Sustainable Development of Qeshm towards an Eco-Island" in a form of an evaluating report, and with the goal of acquiring preliminary knowledge of the environmental attributes of Qeshm Island. Detailed content of the environmental baseline survey report is referred to in the appendices at the end of this report.

A1.2.2 Monthly and annual atmospheric conditions

Climatic parameters play a very important role in the formation of the natural conditions and characteristics of an area, as well as in the evaluation of different environmental aspects. Particularly, some external factors, such as the air stream coming from outside of Qeshm Island, can lead to a pluvial year or drought in another year.

The meteorological data used in this report was obtained from the Meteorological Organization of Iran. The closest station to the study area was the synoptic station and the naval station of Qeshm Island. Based on the Koppen classification, Qeshm Island falls under the category of BWh (Warm desert climate), because its average annual temperature is more than 18 degrees, and more than 70 percent of its annual rainfall occurs during the six cold months of the year.





Source: Iran Meteorological Organization (http://irimo.ir/far/) and Peel, M. C., Finlayson, B. L., and McMahon, T. A. (University of Melbourne)

Figure A1.2.1 Yearly Rainfall and Koppen Map in Qeshm Island

A1.2.3 Natural conditions and biological environment

(1) Plant community of Qeshm Island

The natural appearance of the island includes trees and shrubs, which have grown quite distant from each other and have formed communities in some places. Generally, the vegetation on the island is affected by the flat land and the factors, such as excessive erosion by water and wind, sandiness of the soil, etc., which have led to low development of vegetation on the island. More than 140 species in 67 natural habitats of Qeshm have been identified based on previous research. However, due to the lack of elevation differences and uniformity of the climatic factors in the Island, there are no large differences for vegetation in the entire the island. The most important factor of Qeshm Island is the mangrove forests, which cover an area of almost 200 km^2. However, in recent years, this area has been reduced and degraded due to excessive use (feeding of leaves to livestock) of the mangrove forests. In order to solve this problem, 5 million saplings have been planted in the coastline from Baseidou towards the eastern side.

On the other hand, aquatic plants are another important part of plant communities in Qeshm Island, which can be classified as sea algae, flowering plants, and the group between land and sea.

In the northeast tidal coasts of Qeshm Island, 49 types of seaweeds and in southern coasts 125 types have been identified. Seaweeds are plants which have become compatible with living in areas covered in water. Seaweeds have great ecological significance because they can create dense beds, and in this regard, they are the most important communities of low depth waters of tropical areas.

(2) Animal community of Qeshm

The island is also home to some species protected under the International Union for Conservation of Nature (IUCN) Red category, as shown in the following table. This table does not include species classed as "Least Concern" by IUCN.

Table A1.2.1 Animals on the Red List in Qeshm

<table>
<tr><th>Type of animal</th><th>Scientific Name</th><th>IUCN Conservation Status</th></tr>
<tr><td>Land mammal</td><td>Gazella Dorcas</td><td>Vulnerable</td></tr>
<tr><td rowspan="3">Aquatic mammal</td><td>Balaenoptera musculus</td><td>Endangered</td></tr>
<tr><td>Balaenoptera Physalus</td><td>Endangered</td></tr>
<tr><td>Sousa chinensis</td><td>Near threatened</td></tr>
<tr><td>Birds</td><td></td><td></td></tr>
<tr><td rowspan="5">Reptiles</td><td>Chelonia mydas</td><td>Endangered</td></tr>
<tr><td>Eretmochelys imbricate</td><td>Critically endangered</td></tr>
<tr><td>Caretta Caretta</td><td>Vulnerable</td></tr>
<tr><td>Dermochelys Coriacea</td><td>Vulnerable</td></tr>
<tr><td>Uromastyx aegyptia</td><td>Vulnerable</td></tr>
</table>

Source: IUCN Red List (http://www.iucnredlist.org/)

A1.2.4 Legal system

The legal references related to environment have been reviewed. The following table displays the information related to this study.

Table A1.2.2 National Legislation related to Environment

Title	Target of the law/regulation	Necessary permit on this project
Article (50) of the Constitution of the Islamic Republic of Iran	Equal utilization of environmental resources Conservation of environment as public duty	N/A
Environmental Protection and Enhancement Act (1974) and its executive by-laws	Formation of environmental council, definition of fine for pollution	For certain activities in the Protected Areas by QFZO, approval of Department of Environment could be required.
The fair distribution of water	Using water resources (surface, ground water)	Water use permission would be necessary
The Law establishing the National Committee to reduce the effects of natural disasters	Formation of national committee for exchange of information to prevent and mitigate the effect of natural disasters.	N/A
By-law preventing water pollution	Prohibition of water pollution, determination of criteria for sewage disposal.	If the project uses sewage plant, the facility must follow the guideline.
Environmental health by-law	Regulation for the health of drinking water	N/A
Environment Protection Council Resolution No. 156 on the preparation of the environmental assessment report	Requirement of preparation of EIA, targeting specific project (petrochemical, refinery, power plant, steel, dam, airport)	If the project is applied with the condition, EIA is necessary.
Law for the prevention of air pollution	Prohibition of air pollution	If the project releases a pollutant, the facility must follow the regulation.
Criteria and establishment of industries	Classification and identification of industry groups based on the level of pollution and other environmental issues	Project planning must follow the categorization.
Act No. 249's High Council of Environmental Protection on environmental assessment and national development plans and major projects on the coast	Definition of the coastal environment and necessity of preparation of EIA	Project planning must follow the categorization.
Administrative law and the law on solid waste management	Regulation on waste management	If the project generates wastes, his regulation is allied.
Supreme Council of Environmental Protection regarding the determination of plans and projects subject to environmental assessment studies	Determination of 51 industries, including Oil and Gas industry, and activities required to undertake EIA studies.	Project planning must follow the categorization.
Coastal and built land Law	Definition of area of territorial land sea.	Project planning must follow the categorization.
Article (184) of the fifth program of economic development, social and cultural Islamic Republic of Iran	Announcement of strategic environmental assessment (SEA)	Project should consider the protocol.

A1.2.5 Topography, water Areas, wetlands and coastal areas

(1) Topography

Qeshm land consists of a series of low stalactites and stalagmites in salt domes having circular forms including layers and splits. These old formations have continued reaching the surface. The tectonic forces that have created the Zagros fold and thrust belt is continuing. The belt is divided into zones from northeast to southwest; with anomalies in a southwest direction. The belt is represented in Qeshm Island such as by rough stalactites with limestone highlands and plains in the west of the island, which is a mass of "wrinkle-like" mountains called salt mountains.

On the other hand, plain areas of Qeshm Island are mostly in the coastal areas which include erosion fields and stalagmites. In the farthest east side of Qeshm Island, the Ramchah field has developed at the north of the Dargahan and Kouvei fields. These fields start from Qeshm City and end in western side of Dargahan and Kouvei.

Lands with no or low slope covered most of Qeshm Island. That is, almost 69 percent of the total area of Qeshm Island is low slopes or slopes of less than 1% gradient. The low inclination is good for agriculture; however, for residential purposes there are some problems, the most important issue of which is the difficulty this causes for disposal of surface water or sewage.

(2) Water areas

In areas influenced by tidal fluctuations along the coast, the high or low tide means there is always either a wide expanse of shallow high-tide water or a wide expanse of exposed tidal flats for several hours each day. Therefore, due to the low depth of water the effect of destructive waves from different currents is mitigated.

Waves generated around the Qeshm Island in the Persian Gulf Winds categories follow the flow direction (toward the west and the northwest). Waves in the south and north coasts of Qeshm Island are vastly different. The southern coast is characterized by a lack of natural shelters, high energy and turbulent waves caused by strong southerly winds. As a result, more coarse-grained sediments of the southern coast of the northern coast are mainly sandy. The origin of sediments in this area is destructive- continental. Overall in the coasts of Qeshm Island, waves are short term and the long, turbulent and raging sea in the autumn and winter.

Generally speaking, the tidal current in Persian Gulf is towards the west and the northwest in high tide and in low tide is towards the south and the south east. The tide in Pol reaches up to 7 meters. In this situation, most of the coast goes under water and at the time of low tide, these areas come out like lagoons.

A1.2.6 River, hydrological conditions, and potential groundwater capacity

The special climatic conditions – large fluctuations in rainfall – of Hormozgan Province mean there is a high degree of uncertainty in surface water resources. Increased water consumption as well as the introduction of fresh water heaters as a main source of water are putting a strain on water resources, especially during the recent prolonged drought. These issues are threatening the future of Hormozgan Province.

A large part of the water resources problem is because much of the surface water in Hormozgan Province is in the form of floods, runoff and discharge from rivers in the Persian Gulf and Oman Sea. Another important factor is the high temperatures and dryness of the air which causes water to evaporate. Although there is a significant volume of surface water flowing in rivers in the province, most of this is only during the rainy seasons and floods, meaning the water quality is poor or salty. As a result, there is a lack of water resources for agricultural lands, drinking water and even industrial purposes.

Table A1.2.3 shows the condition of water consumption of Hormozgan Province in 2008, divided by water source.

Table A1.2.3 Status of Water Consumption of Hormozgan Province in 2008 by Source

(million m^3)

Segment	Surface	Underground	Desalinated	Sub Total	Total
Drinking	24.3	86.41	1.26	111.97	1,509.1
Industry	4.9	9.23		14.13	
Agriculture	20	1,363	-	20	

A1.2.7 Geology and soil

Qeshm Island is made up of alluvial quaternary geology and the end on the west and the south of the Zagros fold. Qeshm Island is in the south and the coastal zone of Zagros Folded Earth and is almost entirely made up of sedimentary rocks. Based on the tectonic and sedimentological evidence it can be considered kind of a part of the southern Zagros. Qeshm Island has a similar appearance to the Great Stalactite as well as similarities with the stalactites of Zagros. The effect of salt on the salt dome and the western part of the island shows quite obvious signs of morphological changes and major tectonic forces that have created this section of the island.

Qeshm Island belongs to Precambrian Stratigraphy Period, Palyvzvvyk (formation of Hormuz and the surrounding igneous rocks) and the formation during the Cenozoic Era and Quaternary Period (Mishan formation, Aghajari and Quaternary), respectively.

A1.2.8 Potential water sources

The existing water sources of the Hormozgan Province can no longer respond the demands due to excessive shortage of surface fresh water in the province and the uncertainty of getting water from rivers in the situations such as of recent droughts, which showed that most of fields of the province are in critical condition. This issue indicates the importance of planning for using replacement water sources and improving the use of the current water sources.

A1.2.9 Climate changes and their level

The long term meteorological data indicates the increased average temperatures and evaporation rates in recent years on the northern coast of the Persian Gulf. For this reason, a slight increase in temperature causes increases in wind speeds, evaporation of the water, and instability in the Persian Gulf water column. With regard to the amount of average rainfall in the Persian Gulf, it shows low ratio compared with the average evaporation. It could be due to variations in global climate changes in annual mean rainfalls dropped on the Persian Gulf. As a result of land subsidence in the Persian Gulf, the sea level as much as climate change are expected to increase. Therefore, the rate of sea level rise in the region is expected to be around twice of the global rate.

A1.2.10 Renewable energy

Iran is located in a region with almost 300 days of sunshine, making it one of the best regions in the world for the production of solar energy. The use of both solar and wind energy, eco-friendly and renewable energy alternatives, has a high potential in Iran, for various reasons such as easy access. While Iran's current share of renewable energy in total energy consumption is less than 1%, the average consumption of solar and wind energy in the world is more than 10 %. Regarding the other types of renewable energy, the following results have been showed in a previous study.

Table A1.2.4 Comparison of Renewable Resources in Optimum Energy Extraction Conditions

Energy type	Optimum Extracting condition	Current situation in the area
Waves	Existence of strong waves with the height of 3 m for a stable amount of time	Short period of time and height of the waves are between 0.5 and 0.7 m.
Stable Ocean currents	Using strong and stable oceanic currents	Due to low depth, there is a lack of the currents
Tidal	Optimal operation to flush difference method requires minimal water level in tidal difference is 5 m.	The estimated maximum elevation difference is 3 m.
Tidal Currents	There are tidal range between 3 m and 5 m per second, economy is estimated.	The highest tidal range between 3 m and 6 m per second.

Sources: The potential of waters of southern coasts of Qeshm Island (Panje Shahi and Afshin Mehr)

A1.2.11 Natural disasters and environmental pollutions

There are 18 significant faults on the Island with an average length of 104 km. The evaluation of strength and depth of the earthquakes shows that: 2 earthquakes over 7 Richter (1966 and 1977) have been recorded. Based on the existing data, concentration of earthquakes has been mostly in the northeast-southwest direction especially in the east of the island.

Qeshm Island is one of the areas in the north of Hormuz Strait which has been subject to high population growth. Qeshm Island has been one of the major hubs for import and export business after the Iranian Revolution; as a result, a large population has migrated to Qeshm Island from other cities in the same province and has pursued activities in the industries and new facilities. This migration has caused the construction of improper settlements especially in coastal areas, absence of proper urban and health services, lack of adequate potable water, lack of treatment or collection of solid waste and waste water from these settlements, which have affected adversely to the environment on the island. Unsound development has always been one of the major environmental challenges. As the society and population needs increase, a conflict begins between environment and development, and penetration into the marine territories increases day by day. Billions of tons of sand are taken from the most sensitive points at the sea with no regard for the lives of thousands of marine creatures. Therefore, one of the risks for seas and environment is a gradual drying up of the sea by Persian Gulf countries.

A1.2.12 Protection system for forests, environment and historical and cultural heritage

The following table shows the cultural or historical sites registered in the list of national heritage.

Table A1.2.5 Cultural or Historical Sites Registered in the List of National Heritage

No.	Name	Antiquity	Reg. Date	Location
1	Laft Tala wells	Historical-Islamic era	1977/10/27	Laft
2	Sheikh Zeinolebad shrine	Safavia	1977/10/27	10 km to the west of Qeshm City
3	Khorbas	Islamic era	1977/10/27	10 km to the west of Qeshm City
4	Koulaghan historical site	Before Islam	1977/10/27	35 km north of Qeshm City
5	Bibi Maryam shrine	7th century	1977/10/27	Tom senati
6	Salamon Shrine	Teimouri- safavi	1977/10/27	Old Laft
7	eshm Jame' mosque	Safavia era	1977/9/16	Qeshm City
8	Sheikh Barkh shrine and the mosque	3- 4th century Persian calendar	1977/9/16	Outside Kousha
9	Qeshm Portuguese castle	Safavia era	1977/9/16	Qeshm City
10	Gouron dam	End of Qajariah era	1979/12/15	Gouron
11	Mollahaji dam	End of Qajariah era	1980/11/13	North of Selakh
12	House of Jari Kulak	Pahlavi era	1980/11/13	Hormuz Island

A1.2.13 Environmental assessments including strategic environmental assessment (SEA)

Evaluation of legal grounds for SEA under Iranian law shows that this issue is only limited to the article no. 184 in the fifth development program of Islamic Republic of Iran. In this article, the need for formulation of a SEA mechanism in national, regional levels is emphasized.

A1.3 Baseline Survey for Tourism

A1.3.1 Tourism interview survey

(1) Objectives of survey

The objectives to conduct tourist interview surveys were to define the characteristics of tourist, and their satisfaction level of tourism products, facilities and services offered in Qeshm Island. The results of the survey were utilized for establishing target markets and segments, measures to differentiate from competing tourism destinations, selection of effective promotion channels/tools, and the upgrading/improvement of tourism products/facilities/services.

The survey was conducted 3 times in different period, high season, peak season, and low season, for visitors who departed from Qeshm at each entry point, Qeshm airport, Zakeri Port and Laft Port. The table below shows the survey period and the number of samples.

Table A1.3.1 Survey Details

	Survey Period	Airport	Zakeri Port	Laft Port	Total
High Season	March 12 to 15, 2016	149	199	150	498
Peak Season	March 20 to 24, 2016	145	200	155	500
Low Season	June 7 to 10, 2016	103	118	80	301
	Total	397	517	385	1,299

Source: JICA Project Team

(2) Summary of survey

1) Generation

More than 30% of passengers are 20's and 30's respectively. Totally, 60% to 70% of passengers who come to Qeshm are from 20's to 30's. Younger generation tend to visit Qeshm.

Table A1.3.2 Gender by Season and Departing Point

	Airport		Zakeri Port		Laft Port		Total	
	Male	Female	Male	Female	Male	Female	Male	Female
High Season	82	67	118	81	110	40	310	188
Peak Season	79	66	120	79	106	49	305	194
Low Season	85	18	80	38	57	23	222	79

Source: JICA Project Team

Table A1.3.3 Generation by Season and Departing Point

	Generation	Airport (%)	Zakeri Por (%)	Laft Port (%)	Total (%)
High Season	19 or less	7 (4.7)	11 (5.5)	13 (8.7)	31 (6.2)
	20-29	47 (31.5)	67 (33.7)	48 (32)	162 (32.5)
	30-39	50 (33.6)	57 (28.6)	54 (36)	161 (32.3)
	40-49	25 (16.8)	33 (16.6)	25 (16.7)	83 (16.7)
	50-59	11 (7.4)	22 (11.1)	6 (0.4)	39 (7.8)
	60-69	9 (6.0)	8 (4.0)	4 (2.7)	21 (4.2)
	70 or more	0 (0.0)	1 (0.1)	0 (0.0)	1 (0.0)
Peak Season	19 or less	8 (5.5)	6 (3.0)	12 (7.7)	26 (5.2)
	20-29	45 (31.0)	63 (31.5)	47 (30.3)	155 (31.0)
	30-39	35 (24.1)	74 (37.0)	52 (33.5)	161 (32.2)
	40-49	43 (29.7)	39 (19.5)	30 (19.4)	112 (22.4)
	50-59	9 (6.2)	11 (5.5)	12 (7.7)	32 (6.4)
	60-69	5 (3.4)	7 (3.5)	1 (0.6)	13 (2.6)
	70 or more	0 (0.0)	0 (0.0)	1 (0.6)	1 (0.2)
Low Season	19 or less	3 (2.9)	8 (6.8)	6 (7.5)	17 (5.6)
	20-29	43 (41.7)	44 (37.3)	30 (37.5)	117 (38.9)
	30-39	41 (39.8)	39 (33.1)	29 (36.3)	109 (36.2)
	40-49	11 (10.7)	18 (15.3)	9 (11.3)	38 (12.6)
	50-59	5 (4.9)	8 (6.8)	5 (6.3)	18 (6.0)
	60-69	0 (0.0)	1 (0.1)	1 (1.3)	2 (0.7)
	70 or more	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)

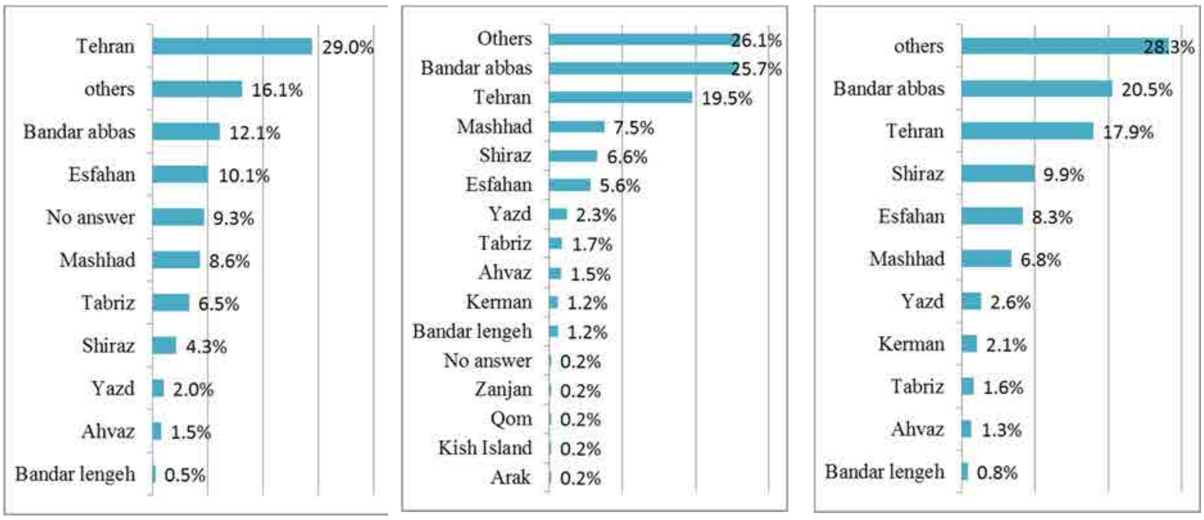
Source: JICA Project Team

2) Nationality

Domestic tourists are currently dominant in Qeshm. International tourists tend to use mainly airport rather than ports. Tourists whose purposes of visit are for sightseeing and business except visa extinction are observed from Austria, China, France, Germany, Italy, Netherland, Poland, Spain, Sweden, Switzerland, and United Arab Emirates.

3) Place of residence

It is obvious that quite a few passengers who visit Qeshm are from Tehran. Since others who are not specified are big number, it is assumed that passengers come from diversified places.



Airport Zakeri Port Laft Port

Source: JICA Project Team

Figure A1.3.1 Place of Residence x Departing Point

4) Purpose of visit

At the airport, 50.1% of passengers depart to the Island for sightseeing, 28.4% for shopping, and 13.3% for business. During the low season at the airport, the passengers whose purpose of visit is business increase. 45.2% of passengers depart from Zakeri Port and 48.5% from Laft Port for sightseeing, 41.5% from Zakeri Port and 38.5% from Laft Port for shopping, and less than 10% for business. It is assumed that majority of passengers whose purpose of visit is for shopping, however, they have started to enjoy sightseeing, too.

Table A1.3.4 Purpose of Visit by Season x Departing Point

	Purpose	Airport (%)	Zakeri Port (%)	Laft Port (%)	Total (%)
High Season	Sightseeing	108 (54.0)	110 (38.9)	85 (40.5)	303 (43.7)
	Shopping	62 (31.0)	124 (43.8)	90 (42.9)	276 (39.8)
	Business	23 (11.5)	33 (11.7)	25 (11.9)	81 (11.7)
	VFR	2 (1.0)	16 (5.7)	10 (4.8)	28 (4.0)
	Visa extension	5 (2.5)	0 (0.0)	0 (0.0)	5 (0.7)
	Total	200 (100)	283 (100)	210 (100)	693 (100)
Peak Season	Sightseeing	123 (61.2)	148 (53.4)	131 (66.5)	402 (59.6)
	Shopping	56 (27.9)	111 (40.1)	60 (30.5)	227 (33.6)
	Business	6 (3.0)	8 (2.9)	3 (1.5)	17 (2.5)
	VFR	8 (4.0)	9 (3.2)	2 (1.0)	19 (2.8)
	Visa extension	8 (4.0)	0 (0.0)	0 (0.0)	8 (1.2)
	Others	-	1 (0.4)	1 (0.5)	2 (0.3)
	Total	201 (100)	277 (100)	197 (100)	675 (100)
Low Season	Sightseeing	51 (31.5)	84 (42.6)	57 (36.5)	192 (37.3)
	Shopping	42 (25.9)	79 (40.1)	67 (42.9)	188 (36.5)
	Business	46 (28.4)	24 (12.2)	22 (14.1)	92 (17.9)
	VFR	7 (4.3)	9 (4.6)	2 (1.3)	18 (3.5)
	Visa extension	0 (0.0)	1 (0.5)	8 (5.1)	9 (1.7)
	Others	16 (9.9)	-	-	16 (3.1)
	Total	162 (100)	197 (100)	156 (100)	515 (100)
All Season	Sightseeing	282 (50.1)	342 (45.2)	273 (48.5)	897 (47.6)
	Shopping	160 (28.4)	314 (41.5)	217 (38.5)	691 (36.7)
	Business	75 (13.3)	65 (8.6)	50 (8.9)	190 (10.1)
	VFR	17 (3.0)	34 (4.5)	14 (2.5)	65 (3.5)
	Visa extension	13 (2.3)	1 (0.1)	8 (1.4)	22 (1.2)
	Others	16 (2.8)	1 (0.1)	1 (0.2)	18 (1.0)
	Total	563 (100)	757 (100)	563 (100)	1,883 (100)

Source: JICA Project Team

5) Type of travel

During high season and peak season, family travel is dominant, on the other hand, individual travel increases in low season.

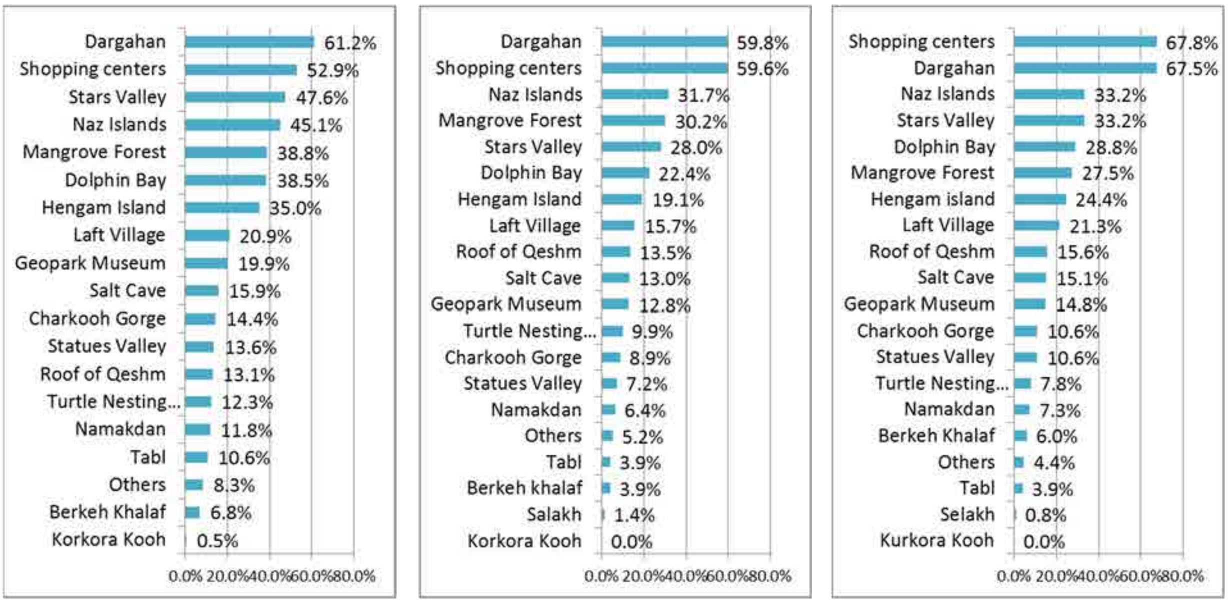
Table A1.3.5 Type of Travel by Season x Departing Point

	Type of Travel	Airport (%)	Zakeri Por (%)t	Laft Port (%)	Total (%)
High Season	Family	76 (51.0)	118 (59.3)	100 (66.7)	294 (59.0)
	Group	36 (24.2)	20 (10.1)	25 (16.7)	81 (16.3)
	Individual	29 (19.5)	56 (28.1)	25 (16.7)	110 (22.1)
	Tour	8 (5.4)	5 (2.5)	0 (0.0)	13 (2.6)
	Total	149 (100)	199 (100)	150 (100)	498 (100)
Peak Season	Family	111 (76.6)	172 (86.0)	125 (80.6)	408 (81.6)
	Group	12 (8.3)	11 (5.5)	22 (14.2)	45 (9.0)
	Individual	14 (9.7)	15 (7.5)	7 (4.5)	36 (7.2)
	Tour	8 (5.5)	2 (1.0)	1 (0.6)	11 (2.2)
	Total	145 (100)	200 (100)	155 (100)	500 (100)
Low Season	Family	24 (23.3)	45 (38.1)	27 (33.8)	96 (31.9)
	Group	3 (2.9)	18 (15.3)	8 (10.0)	29 (9.6)
	Individual	76 (73.8)	54 (45.8)	42 (52.5)	172 (57.1)
	Tour	0 (0.0)	0 (0.0)	3 (3.8)	3 (1.0)
	No answer	-	1 (0.8)	-	1 (0.3)
	Total	103 (100)	118 (100)	80 (100)	301 (100)

Source: JICA Project Team

6) Places to visit

Majority of tourists visit Dargahan and shopping centers. After the shopping, four attractions which those tourists visit at most are the Naz Island, Star Valley, Hara Mangrove Forest, and Dolphin Bay. The figure below shows which attractions tourists visit, according to departing point. The tourists who depart from the airport tend to travel around the most, followed by the tourists through the Laft Port, and the least being the tourists travelling through the Zakeri Port.



Airport Zakeri Port Laft Port

Source: JICA Project Team

Figure A1.3.2 Places to Visit x Departing Point

7) Average length of stay

Passengers who depart from the airport tend to stay longer at the Island. Next to the passengers from the airport, the passengers of Laft Port stay longer, since they come to the Island by car. The passengers of the Zakeri Port which include quite a few number of day visitors stay less.

Table A1.3.6 Average Length of Stay x Departing Point

	Airport	Zakeri Port	Laft Port	Average
High Season	3.46 days	2.31 days	2.65 days	2.76 days
Peak Season	3.60 days	1.95 days	2.77 days	2.68 days
Low Season	3.36 days	2.75 days	3.06 days	3.04 days
Average	3.49 days	2.27 days	2.79 days	-

Source: JICA Project Team

8) Places to stay

Passengers who depart from the airport tend to stay at hotel, on the other hand, quite a few of the passengers of Zakeri Port include 1 day visit. The passengers of Laft Port tend to stay at individual houses, even though it is illegal. All in all, 34.8% of the passengers stay at individual houses. On the other hand, the ratio of the passengers who stay at hotel is 20.2 %, however, it is assumed that the ratio becomes less than 20%, since this survey is sample survey and the real number of passengers who use Zakeri and Laft Port is 16 times bigger than the number of the airport.

Table A1.3.7 Places to Stay x Departing Point

	Places to Stay	Airport (%)	Zakeri Port (%)	Laft Port (%)	Total (%)
High Season	1-day visit	3 (2.0)	74 (37.2)	28 (18.7)	105 (21.1)
	Hotel	65 (43.6)	31 (15.6)	13 (8.7)	109 (21.9)
	Guest House	30 (20.1)	27 (13.6)	18 (12.0)	75 (15.1)
	Individual	50 (33.6)	63 (31.7)	75 (50.0)	188 (37.8)
	Tent	1 (0.7)	3 (1.5)	16 (10.7)	20 (4.0)
	Others	-	1 (0.5)	-	1 (0.2)
	Total	149 (100)	199 (100)	150 (100)	498 (100)
Peak Season	1-day visit	1 (0.7)	100 (50.0)	5 (3.2)	106 (21.2)
	Hotel	92 (63.4)	7 (3.5)	13 (8.4)	112 (22.4)
	Guest House	17 (11.7)	45 (22.5)	29 (18.7)	69 (13.8)
	Individual	35 (24.1)	24 (12.0)	53 (34.2)	133 (26.6)
	Tent	-	1 (0.5)	55 (35.5)	79 (15.8)
	Others	-	-		1 (0.2)
	Total	145 (100)	200 (100)	155 (100)	500 (100)
Low Season	1-day visit	24 (23.3)	43 (36.4)	18 (22.5)	85 (28.2)
	Hotel	19 (18.4)	7 (5.9)	15 (18.8)	41 (13.6)
	Guest House	7 (6.8)	17 (14.4)	12 (15.0)	36 (12.0)
	Individual	50 (48.5)	48 (40.7)	33 (41.3)	131 (43.5)
	Tent	1 (1.0)	3 (2.5)	1 (1.3)	5 (1.7)
	Others	2 (1.9)	-	1 (1.3	3 (1.0)
	Total	103 (100)	118 (100)	80 (100)	301 (100)
All Season	1-day visit	28 (7.1)	217 (42.0)	51 (13.2)	296 (22.8)
	Hotel	176 (44.3)	45 (8.7)	41 (10.6)	262 (20.2)
	Guest Houses	54 (13.6)	67 (13.0)	59 (15.3)	180 (13.9)
	Individual	135 (34.0)	156 (30.2)	161 (41.8)	452 (34.8)
	Tent	2 (0.5)	30 (5.8)	72 (18.7)	104 (8.0)
	Others	2 (0.5)	2 (0.4)	1 (0.3)	5 (0.4)
	Total	397 (100)	517 (100)	385 (100)	1299 (100)

Source: JICA Project Team

9) Average expenses

Passengers who depart from the airport tend to spend more on accommodations, comparing the passengers of Zakeri Port and Laft Port. The passengers of Laft Port have tendency to spend on meals and activities and shopping, but not on accommodations. Since the passengers of Zekari Port include 1 day visitors more than the others, the expenses become less than other passengers.

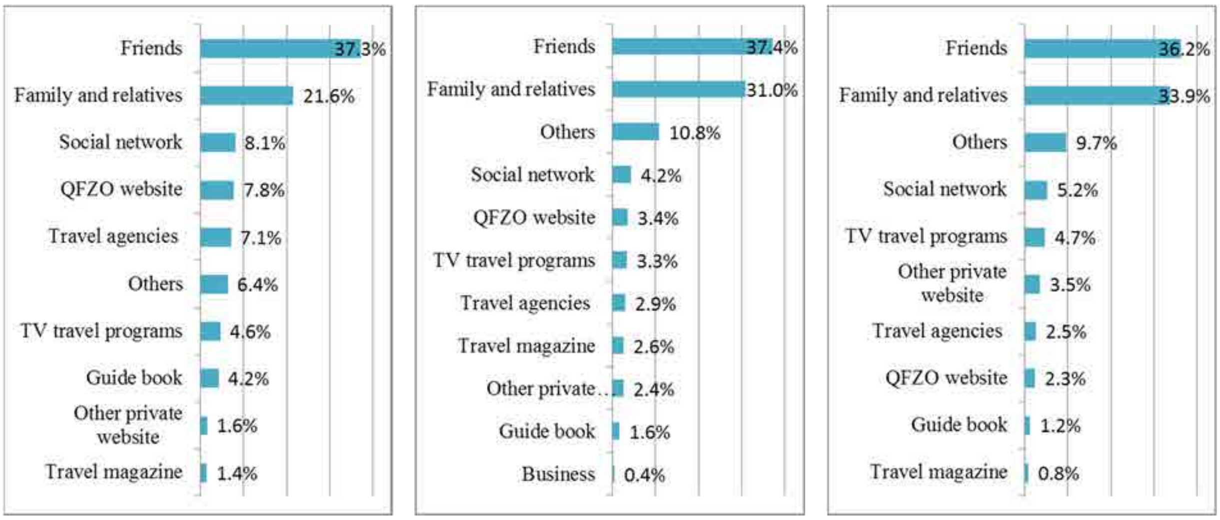
Table A1.3.8 Expenses x Departing Point

	Expenses (IRR)	Airport	Zakeri Port	Laft Port
High Season	Meals and Activities	10,116,779	9,258,543	11,128,000
	Accommodations	3,601,812	1,636,935	1,547,667
	Shopping	13,577,181	11,884,171	14,686,667
Peak Season	Meals and Activities	8,227,724	7,907,300	8,150,000
	Accommodations	5,963,372	2,721,650	5,170,452
	Shopping	15,000,000	11,877,500	12,160,694
Low Season	Meals and Activities	1,325,243	2,530,720	2,248,125
	Accommodations	781,942	668,305	1,069,375
	Shopping	4,818,447	7,835,424	8,101,875
All Season	Meals and Activities	7,145,894	7,200,261	8,083,896
	Accommodations	3,732,743	1,835,474	2,906,805
	Shopping	11,824,433	10,980,329	12,301,448

Source: JICA Project Team

10) Information source about Qeshm

It is observed that main information source about Qeshm is word of mouth through friends, family and relatives. Social network is one of the important channels. The ratio that passengers who depart from the airport receive information through travel agencies is relatively higher than those who use the ports. It is assumed that the passengers of the airport use package tour offered by travel agencies.



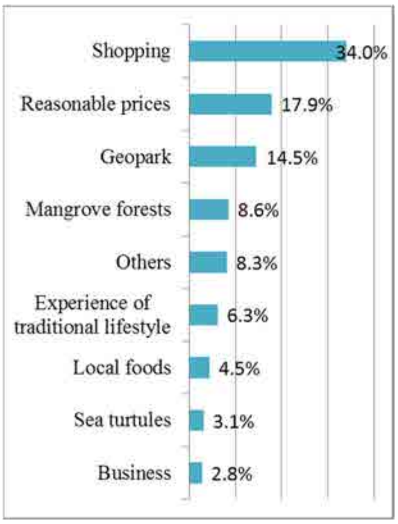
Airport | Zakeri Port | Laft Port

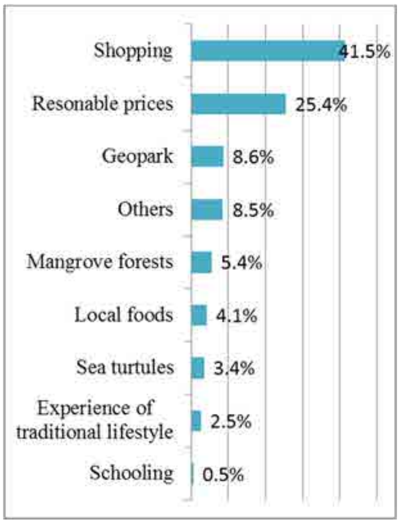
Source: JICA Project Team

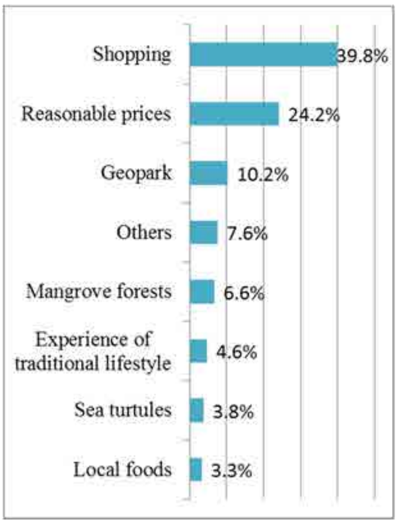
Figure A1.3.3 Information Source x Departing Point

11) Travel motivators

It is apparent that travel motivators of Qeshm are shopping and reasonable prices nevertheless departing points. Qeshm Geopark as a travel motivator ranked 3rd, next to shopping and reasonable prices. It implies that the geopark has become popular to attract tourists. New factors such as experiences of traditional lifestyle and local foods are also emerging.







Airport Zakeri Port Laft Port

Source: JICA Project Team

Figure A1.3.4 Travel Motivators x Departing Point

12) Satisfaction (Intention to come back and to recommend to others)

Nevertheless, the departing point, quite high ratio of the visitors shows intention to come back to Qeshm and recommend Qeshm to others. Since the word of mouth is main source of the information, it can be expected more and frequent visitors in near future.

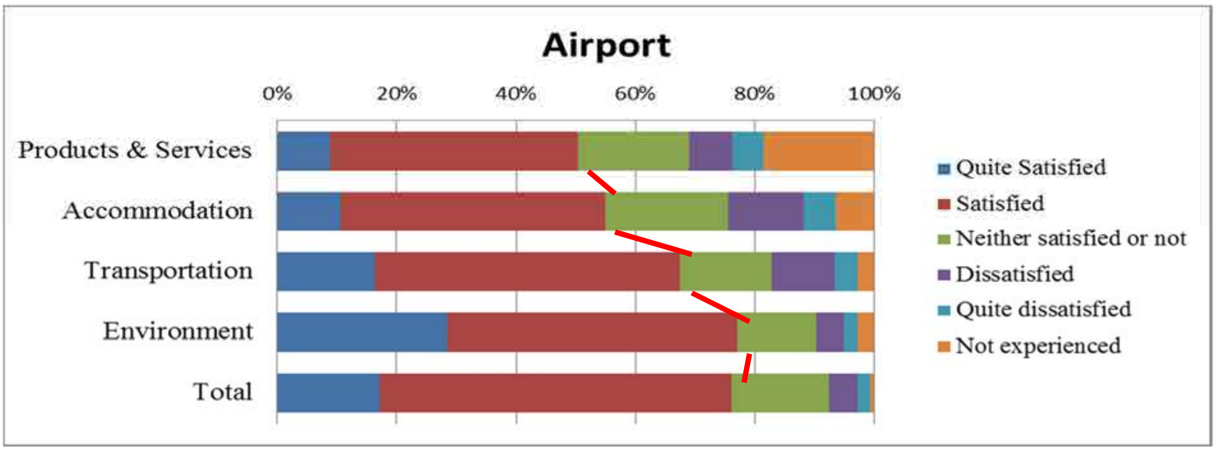
Table A1.3.9 Satisfaction x Departing Point

	Satisfaction	Airport	Zakeri Port	Laft Port
High Season	Intention to come back	86.5%	96.5%	95.3%
	Recommendation	91.3%	95.0%	91.3%
Peak Season	Intention to come back	77.9%	83.9%	83.9%
	Recommendation	83.4%	85.4%	84.5%
Low Season	Intention to come back	92.2%	96.6%	93.8%
	Recommendation	91.3%	93.2%	96.3%

Source: JICA Project Team

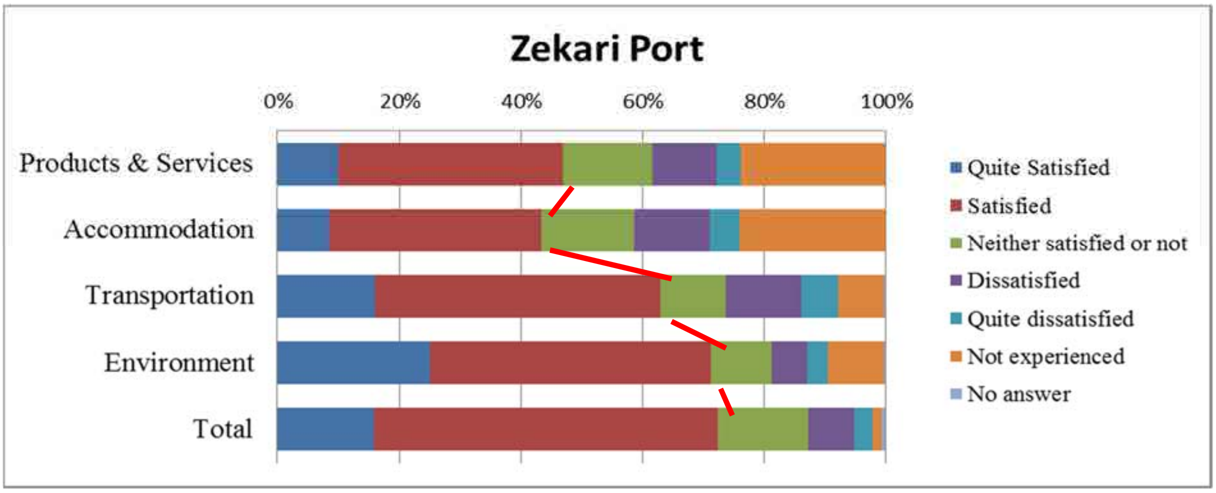
13) Satisfaction level

The figures below show satisfaction level on each service in Qeshm, tourism products and services, accommodation, transportation, environment and total. The characteristics of satisfaction level at each departing point are very similar. The level of total satisfaction and tourism environment are quite high around 70%. The satisfaction level of transportation is getting less. Half of the passengers are not satisfied with the level on tourism products and services, as well as, accommodations.



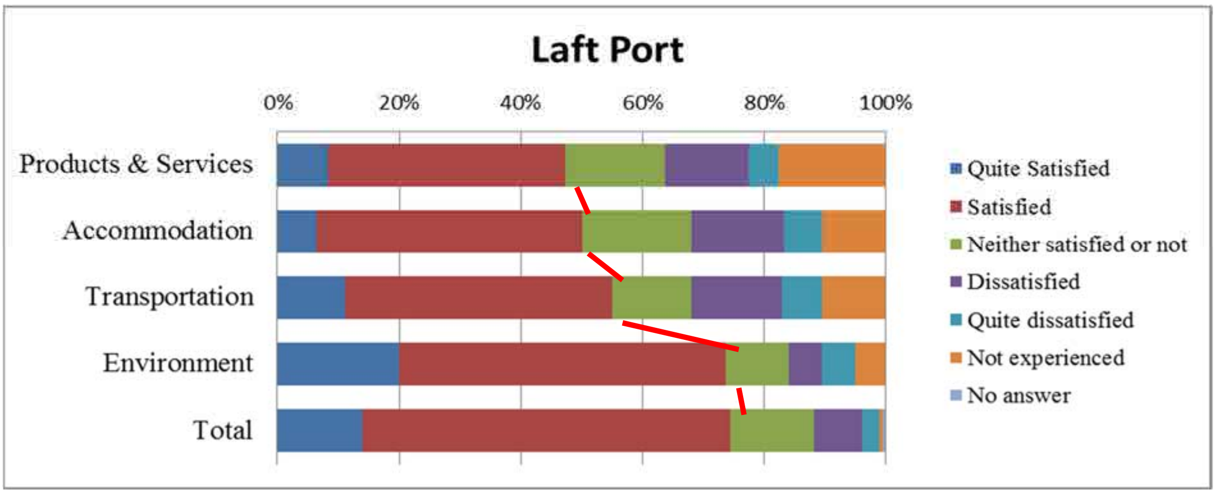
Source: JICA Project Team

Figure A1.3.5 Satisfaction Level on Each Service of Airport Users



Source: JICA Project Team

Figure A1.3.6 Satisfaction Level on Each Service of Zakeri Port Users



Source: JICA Project Team

Figure A1.3.7 Satisfaction Level on Each Service of Laft Port Users

14) Comments

Positive comments received show the strength of Qeshm and negative ones do weakness. It is necessary to take measures to enhance strength at most and to improve or tackle weakness of Qeshm as tourism destination.

Positive Comments

(a) There are very good attraction sites.
(b) Qeshm people are very intimate and friendly.
(c) Delicious local foods especially in tourist routes.

Negative Comments

(a) Hotel facilities and services are not satisfactory.
(b) Individual house is very low quality.
(c) Restaurant option is very limited.
(d) Food quality is not satisfactory.
(e) It is difficult to access to tourism information and not well provided.
(f) More tourists guide is necessary and should be allocated in the island.
(g) There is shortage in WC, facilities and equipment in tourism attractions.
(h) Transportation fee is expensive.
(i) Cities are not clean.
(j) Hygiene is not good.

A1.3.2 Tourism Industry Survey

(1) Objectives of survey

The objectives to conduct environment and socio-economic survey for tourism sector were to comprehend present situation of inbound tourism market in Qeshm island, and thus to extract issues to be improved or resolved. The result of the survey was expected to be utilized for determination of the direction of improvement, gauging forecasting of future change of demand and supply, improvement of working conditions for staff, and consideration of methods of dissemination of tourism information. The number of respondents of this survey is shown below. The related services include local guesthouses, restaurants, handicrafts shops, boat operators, and entertainment facilities.

Table A1.3.10 Business Category of Respondents

Category	Hotels	Apartment Hotels	Travel Agencies	Related Services
Number	44	19	38	40

Source: JICA Project Team

(2) Summary of survey

The biggest issue that surveyors faced was that respondents were reluctant to share their business and financial conditions, although it was important to know to analyze the issues on the ground. The present conditions grasped through the survey are summarized below.

1) Hotels

A total of 44 hotels were interviewed. These 44 hotels consist of 21 three-star hotels, 10 two star, 9 one star, and 4 not ranked hotels. Those hotels were established mostly between 2010 and 2014. There is a total of 1,282 rooms, on the other hand, 454 resident staff are employed. Out of the 454 staff, one-third is female. The average number of staff per one room is 0.37 persons. Observing guest origin, domestic tourists are from Tehran and international tourists are mainly from neighboring countries followed by East Asia. Main method of advertisement is through travel agency. The seasonal fluctuation is most problematized.

Table A1.3.11 Year of Establishment by Classification

Year	Three (21)	Two (10)	One (9)	Others (4)	Total (44)
1999 before	1	-	1	-	2
2000 - 2004	2	1	-	-	3
2005 - 2009	3	2	4	-	9
2010 - 2014	12	6	4	1	23
After 2015	3	1	-	3	7

Source: JICA Project Team

Table A1.3.12 Number of Rooms and Beds by Classification

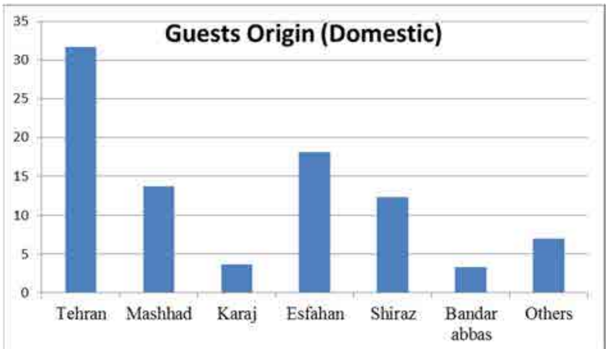
Classification	Three (21)		Two (10)		One (9)		Others (4)		Total (44)	
	Room	Bed	Room	Bed	Room	Bed	Room	Bed	Room	Bed
Qeshm	709	2,280	151	473	182	738	62	193	1,104	3,684
Dargahan	108	310	27	85	43	159	-	-	178	554
Total	817	2,590	178	558	225	897	62	193	1,282	4,238

Source: JICA Project Team

Table A1.3.13 Number of Resident Staff

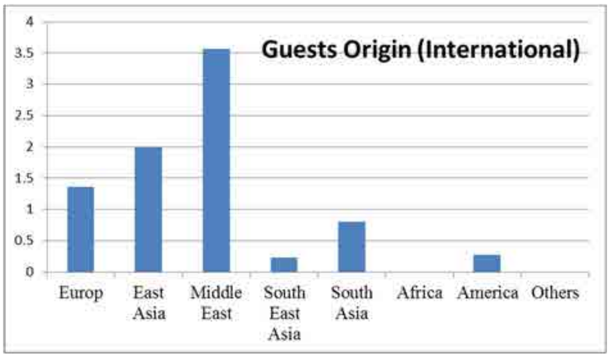
Classification	Three (21)	Two (10)	One (9)	Others (4)	Total (44)
Staff (female)	274 (92)	78 (27)	80 (20)	22 (12)	454 (151)

Source: JICA Project Team



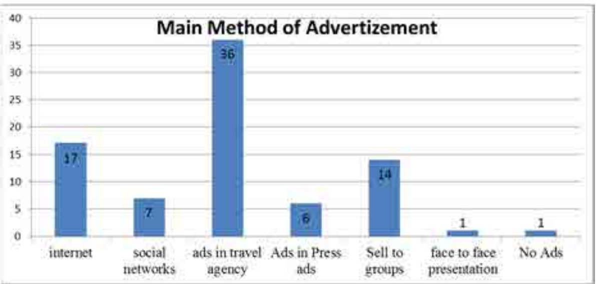
Source: JICA Project Team

Figure A1.3.8 Guest Origin (Domestic)



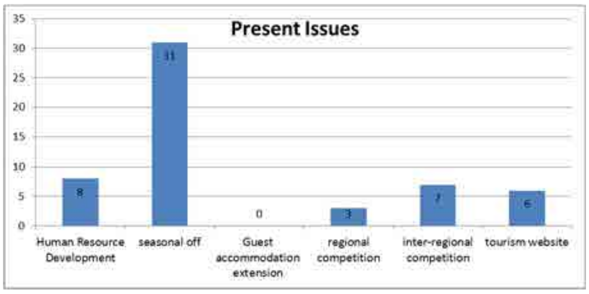
Source: JICA Project Team

Figure A1.3.9 Guest Origin (International)



Source: JICA Project Team

Figure A1.3.10 Main Methods of Advertizement



Source: JICA Project Team

Figure A1.3.11 Present Issues

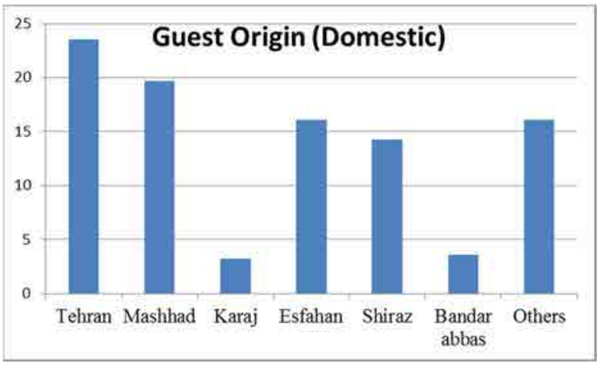
2) Apartment hotels

A total of 19 apartment hotels located in Qeshm were interviewed. Out of 19, one did not respond questionnaires, two are already shut down, and two were under construction. Apartment hotels were constructed mostly between 2005 and 2009. The average number of rooms per one apartment is around 11.7 rooms. The capacity of the apartment is relatively smaller than hotels. On the other hand, the average number of staff per one room is 3.43 persons, which is quite higher than hotels. However, the number of female staff is less than hotels. Observing guest origin, many of domestic tourists are from Tehran, however, it is more diversified comparing with hotels. International tourists are from Europe followed by South Asia. Main method of advertisement is through internet. Same as the issues of hotels, the seasonal fluctuation is most problematized.

Table A1.3.14 Present Situations of Apartment Hotels

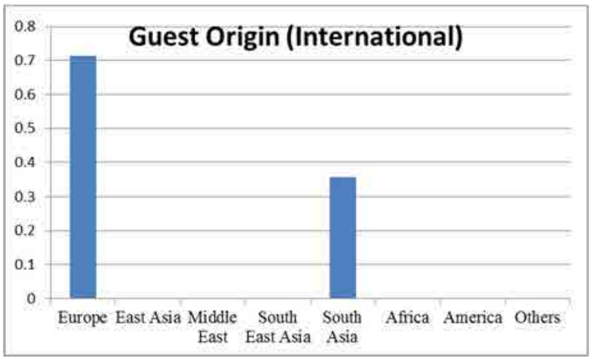
Year	1999 before	2000 - 2004	2005 - 2009	2010 - 2014	After 2015	Total
Number	2	2	6	1	3	14
Room	25	18	63	22	36	164
Staff (female)	78 (4)	74 (4)	191 (12)	110 (7)	109 (12)	562 (39)

Source: JICA Project Team



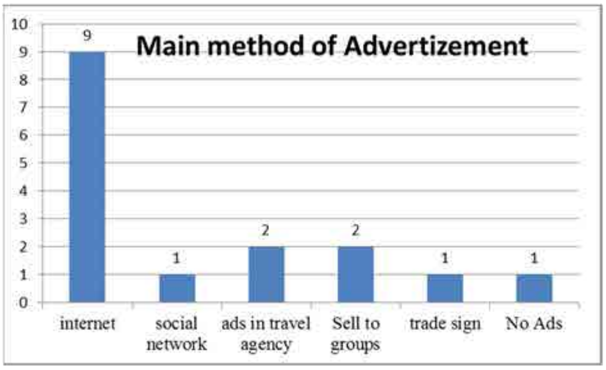
Source: JICA Project Team

Figure A1.3.12 Guest Origin (Domestic)



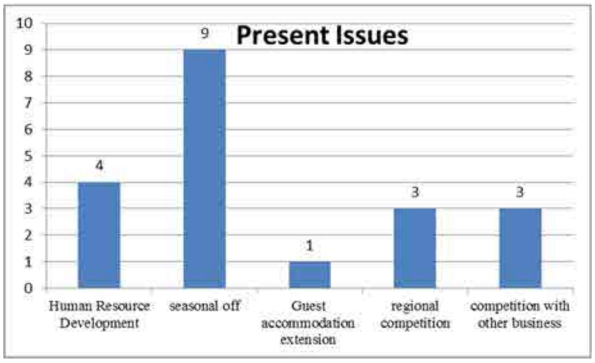
Source: JICA Project Team

Figure A1.3.13 Guest Origin (International)



Source: JICA Project Team

Figure A1.3.14 Main Methods of Advertizement



Source: JICA Project Team

Figure A1.3.15 Present Issues

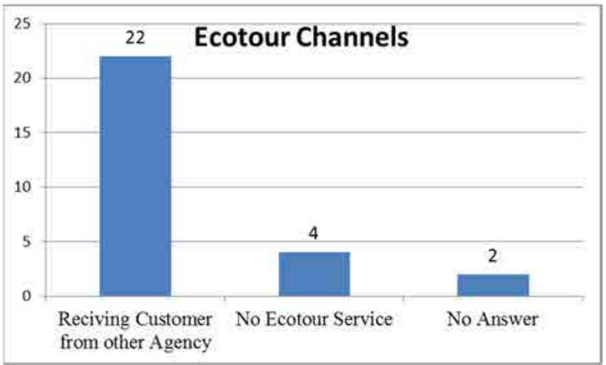
3) Travel agencies

A total of 38 travel agencies were interviewed. Out of 38 travel agencies, three did not respond the questionnaires and seven were already closed. A total of 120 employees work for travel agencies and more half of them are female. Out of 28 travel agencies, 22 travel agencies deal with ecotourists and they receive tourists from other agencies. Dolphin bay and Mangrove forest are main attractions for ecotours. Main methods of advertisement are diversified, such as internet, social network, and advertisement through travel agencies. Same as the issues of hotel industries, the seasonal fluctuation is most problematized.

Table A1.3.15 Present Situations of Travel Agencies

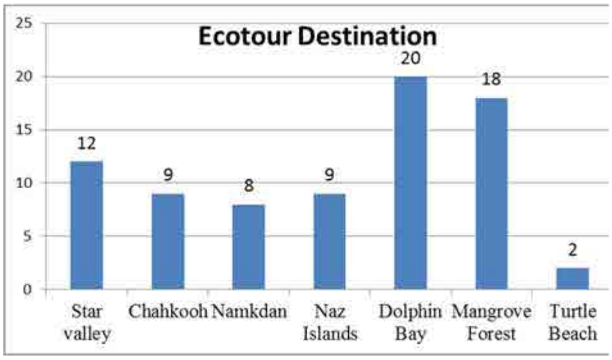
Year	1999 before	2000 - 2004	2005 - 2009	2010 - 2014	After 2015	Total
Number	1	2	9	13	3	28
Staff (female)	18 (14)	6 (3)	47 (21)	44 (29)	5 (2)	120 (69)

Source: JICA Project Team



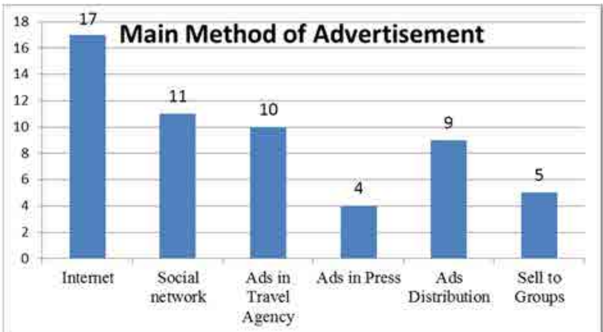
Source: JICA Project Team

Figure A1.3.16 Channels of Ecotour



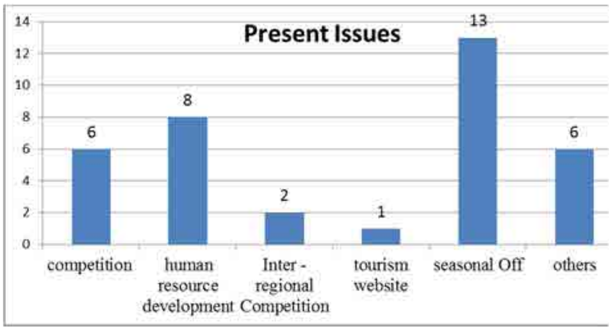
Source: JICA Project Team

Figure A1.3.17 Ecotour Attractions



Source: JICA Project Team

Figure A1.3.18 Main Methods of Advertizement



Source: JICA Project Team

Figure A1.3.19 Present Issues

4) Related services

A total of 40 tourism related business owners were interviewed. Out of 40, one business is shut down, two businesses are under construction, and one is village chief, therefore those four businesses are excluded. According to the list of the services, local guesthouse and traditional restaurant and teahouse become more popular. Especially, local guesthouses are established equally in rural area. The local guesthouses also fulfill the role of local guide and produce handicrafts. Those tourism related services are established mostly between 2010 and 2014. A little bit earlier before tourism businesses were well recognized, Hara Forest Boat & Sailing Cooperative Company which was established in 2009 has 140 members and contributes to employment. Observing guest origin, many of domestic tourists are from Tehran, followed by Shiraz and Esfahan. International tourists come from various regions, firstly Europe, secondly South Asia and followed by East Asia and Middle East. Regarding advertisement, they tend to utilize various kinds of channels not only paper-based promotion materials, but also online promotion. It is assumed that the direct promotion is more effective than utilizing a channel of travel agencies. As for the present issues, severe competition was problematized most. At the same time, limited length of stay at local guesthouses and seasonal fluctuation are also raised.

Table A1.3.16 List of Related Services

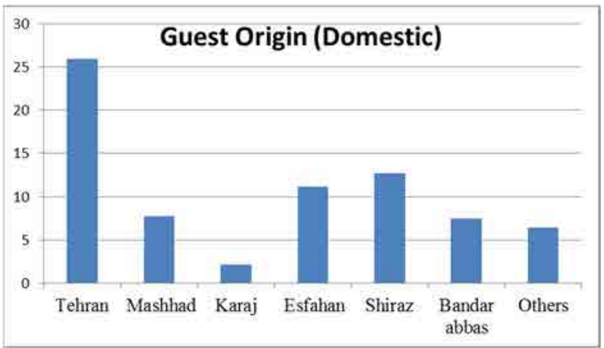
Category	Entertain-ments	Local Guesthouse	Restaurant Teahouse	Handicraft	Sailing Cooperative	Local Guide
Laft		1				
Tabl		3				
Sohli		2	1	2	1	
Haft Rangou		1				
Hengan		2				1
Noghasha		1				
Selakh		1	1			
Souza	1	1				
Borka Khelaf		1				
Giadon			1			
Rigoo	1					
Sar Rig		1				
Defari		1				
Dargahan			3			
Qeshm	4		5			
Total	6	15	11	2	1	1

Source: JICA Project Team

Table A1.3.17 Year of Establishment

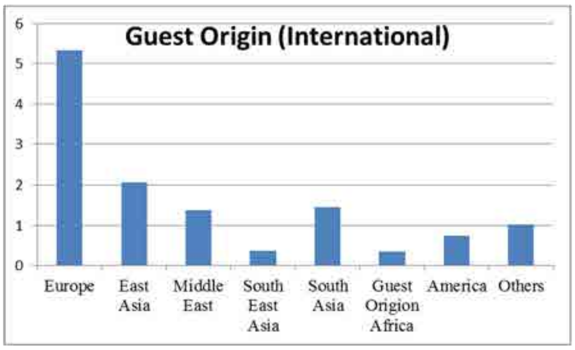
Year	1999 before	2000 - 2004	2005 - 2009	2010 - 2014	After 2015	Total
Number	1	3	6	15	7	32
Staff (female)	10 (6)	87 (14)	171 (19)	131 (34)	216 (58)	615 (131)

Source: JICA Project Team



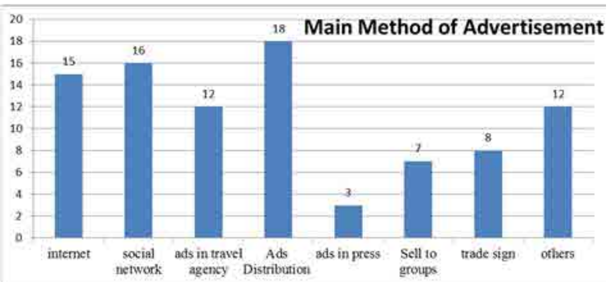
Source: JICA Project Team

Figure A1.3.20 Guest Origin (Domestic)



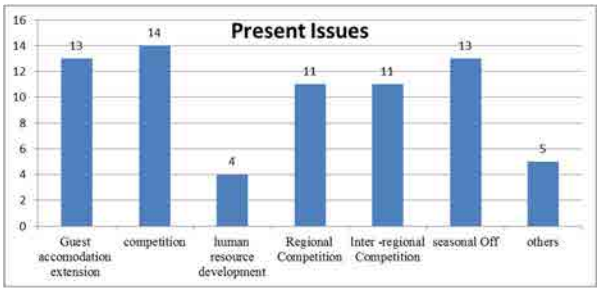
Source: JICA Project Team

Figure A1.3.21 Guest Origin (International)



Source: JICA Project Team

Figure A1.3.22 Main Methods of Advertizement



Source: JICA Project Team

Figure A1.3.23 Present Issues

APPENDIX 2 DETAIL TECHNICAL ANALYSIS OF ECO-QESHM MASTER PLAN

Table of Contents

APPENDIX 2 DETAIL TECHNICAL ANALYSIS OF ECO-QESHM MASTER PLAN A2-I
A2.1 Discrepancies between Prevision and Realization of SWECO Master Plan on Qeshm Land Use and Population A2-1
A2.1.1 Overall Remarks at the Scale of the Island A2-1
A2.1.2 Detail Remarks on Each Locality A2-3
A2.2 Date of Inland Ecosystem Management A2-10
A2.2.1 Existing conditions A2-10
A2.2.2 Proposal of geopark short term strategies A2-22
A2.3 Environmental Carrying Capacity A2-25
A2.3.1 Carrying capacity A2-25
A2.3.2 Effects of land development on seawater quality A2-28
A2.3.3 Tentatively Estimated Effects of Land Use on Seawater Quality A2-30
A2.4 Estimate of Solid Waste Amount and Waste Stream for Solid Waste Management A2-33
A2.4.1 Planning flow for development plan of solid waste management A2-33
A2.4.2 Forecast of Waste Amount A2-34
A2.4.3 Waste Stream A2-43
A2.5 Trial Calculation to Install Photovoltaic System for Renewable Energy Development .. A2-50
A2.6 Environmental and Social Consideration for Model Design of Landfill A2-57
A2.6.1 Legal framework of environmental and social considerations A2-57
A2.6.2 Provisional scoping (types and magnitudes of possible adverse impacts and Amitigation measures) A2-59
A2.6.3 Alternatives to the project activities including 'without project' option A2-60
A2.6.4 Result of the consultation with recipient government on environmental and social consideration including roles and responsibilities A2-61
A2.6.5 Terms of reference for environmental and social considerations A2-61
A2.6.6 Other relevant information A2-62

List of Tables

Table A2.1.1 Analysis of Discrepancies between Prevision and Realization of SWECO Master Plan on Land Use and Population A2-2
Table A2.2.1 Dominant Plant Species in Habitats in Qeshm A2-13
Table A2.2.2 List of Birds Recorded in Qeshm Island and Khran Straits A2-15
Table A2.2.3 Most Relevant Legal Texts in Regards to the Environment A2-20
Table A2.2.4 Geopark Major Tasks A2-24
Table A2.3.1 Possible Indices to Measure Effects on Coral Reefs with Thresholds A2-27
Table A2.3.2 Land Use Classification and Facilities to Link Land Development and Seawater Quality A2-28
Table A2.3.3 Main Indices to Use in Evaluating Effects of Land Development on Seawater Quality A2-28
Table A2.3.4 Reference Quality Standards for Water Quality Indices Applicable to Wastewater of Different Sources A2-29
Table A2.3.5 Ranges of Input Water Quality for Discharge of Different Sources A2-29
Table A2.4.1 Generation Rate and Composition of Ordinary Waste in Other Cities in Iran A2-35
Table A2.4.2 Generation Rate of Ordinary Waste for Planning A2-35
Table A2.4.3 Generation Rate and Composition of Ordinary Waste for Planning A2-36

Table A2.4.4 Population Forecast in Area Division A2-36
Table A2.4.5 Forecast of Ordinary Waste Generation A2-37
Table A2.4.6 Industrial Waste Amount per GDP in OECD Countries A2-38
Table A2.4.7 Construction and Demolition Waste per GDP in EU Countries A2-39
Table A2.4.8 Forecast of Industrial Waste Amount A2-40
Table A2.4.9 Hospital Waste Generation Rate for Planning A2-41
Table A2.4.10 Hospital Waste Generation Rate in Other Cities in Iran A2-41
Table A2.4.11 Hospital Waste Generation Rate in Qeshm Island A2-41
Table A2.4.12 Forecast of Hospital Waste Amount A2-42
Table A2.5.1 Hourly Power Consumption in High AC-usage Season when Residents are at Home A2-50
Table A2.5.2 Monthly Average Temperature in Qeshm Island A2-50
Table A2.5.3 Power Consumption and Load Factor Classified by Daytime and Nighttime in High AC-usage Season when Residents are at Home A2-51
Table A2.5.4 Hourly Power Consumption in Low AC-usage Season when Residents are at Home A2-51
Table A2.5.5 Power Consumption and the Load Factor Classified by Daytime and Nighttime in low AC-usage Season when Residents are at Home A2-51
Table A2.5.6 Hourly Power Consumption when Residents are not at Home A2-52
Table A2.5.7 Power Consumption and the Load Factor Classified by Daytime and Nighttime when Residents are not at Home A2-52
Table A2.5.8 Summary of Power Consumption by Season, Day and Night and Presence of Residents at Home in Japan (average) A2-52
Table A2.5.9 Results of Trial Calculation (Case-1, High AC-usage Season) A2-53
Table A2.5.10 Results of Trial Calculation (Case-1, Low AC-usage Season) A2-54
Table A2.5.11 Results of Trial Calculation (Case-2, High AC-usage Season) A2-55
Table A2.5.12 Results of Trial Calculation (Case-2, Low AC-usage Season) A2-56
Table A2.6.1 Results of Provisional Scoping A2-60
Table A2.6.2 Survey Items and Methodologies for Environmental and Social Considerations in the Project A2-62

List of Figures

Figure A2.1.1 SWECO Master Plan Land Use Plan compared to the Situation in 2016 .... A2-3
Figure A2.2.1 Jetties and Access Roads Identified and the Draft Zoning Plan in Hara Protected Area A2-22
Figure A2.3.1 Structure for Evaluation of Effects of Land Development on Seawater Quality by Using GIS A2-30
Figure A2.4.1 Flow of Planning the Solid Waste Management Sector Development Plan A2-34
Figure A2.4.2 Division of Area for Solid Waste Management A2-36
Figure A2.4.3 Waste Amount disposed of in the Tola Disposal Site during Iranian New Year 2016 .... A2-42
Figure A2.4.4 Waste Stream of Ordinary Waste in East Area A2-43
Figure A2.4.5 Waste Stream of Ordinary Waste in Central Area A2-44
Figure A2.4.6 Waste Stream of Ordinary Waste in West Area A2-45
Figure A2.4.7 Waste Stream of Non-Hazardous Industrial Waste A2-46
Figure A2.4.8 Waste Stream of Hazardous Industrial Waste A2-47
Figure A2.4.9 Waste Stream of Construction and Demolition Waste A2-48
Figure A2.4.10 Waste Stream of Hospital Waste A2-49
Figure A2.5.1 Average Electric Power Consumption per Household (residents at home) A2-50
Figure A2.5.2 Average Electric Power Consumption per Household (Residents not at Home) ... A2-52
Figure A2.6.1 EIA Procedure Implemented by the DoE of the QFZO A2-58
Figure A2.6.2 EIA Procedure Implemented by the DoE of Iran A2-59

A2.1 Discrepancies between Prevision and Realization of SWECO Master Plan on Qeshm Land Use and Population

A2.1.1 Overall Remarks at the Scale of the Island

In general terms, the population growth planned by SWECO in 1994 (Volume No. 3) has been overestimated of around the double of the reality: the Stage I population of 200,000 is anticipated to be reached around 2011 [Volume No. 6, page 9] when 2011 census identified a total of 111,159 inhabitants for the same target area.

Consequently, the area of land planned for residential and other uses has been evaluated with a limited success, when compared to the situation in 2016, that is to say 12 years after the preparation of SWECO master plan in 1994.

The main reason for the difference between SWECO planning and reality is that the expected goals in terms of industrial development and key infrastructure building could not be met (except for the international airport, Kouvei port, and Towla industrial zone). Obvious mistakes in planning or implementation led to the non-construction of whole planned operations, such as Shibderaz New town, Souza industrial zone or International University in Ramkon.

Regarding residential development, the growth rate of every existing settlements of the island has been estimated with a limited success, as shown in Table 1 and Figure 1. Even though the total of residential areas at the scale of the island has been planned with relative accuracy (3,660 ha planned for Stage I [2011] compared to 4,298 ha in reality in 2016), it is necessary to look into the details of the different geographical entities which growth has been estimated with a variable success, depending on the accuracy of SWECO analysis.

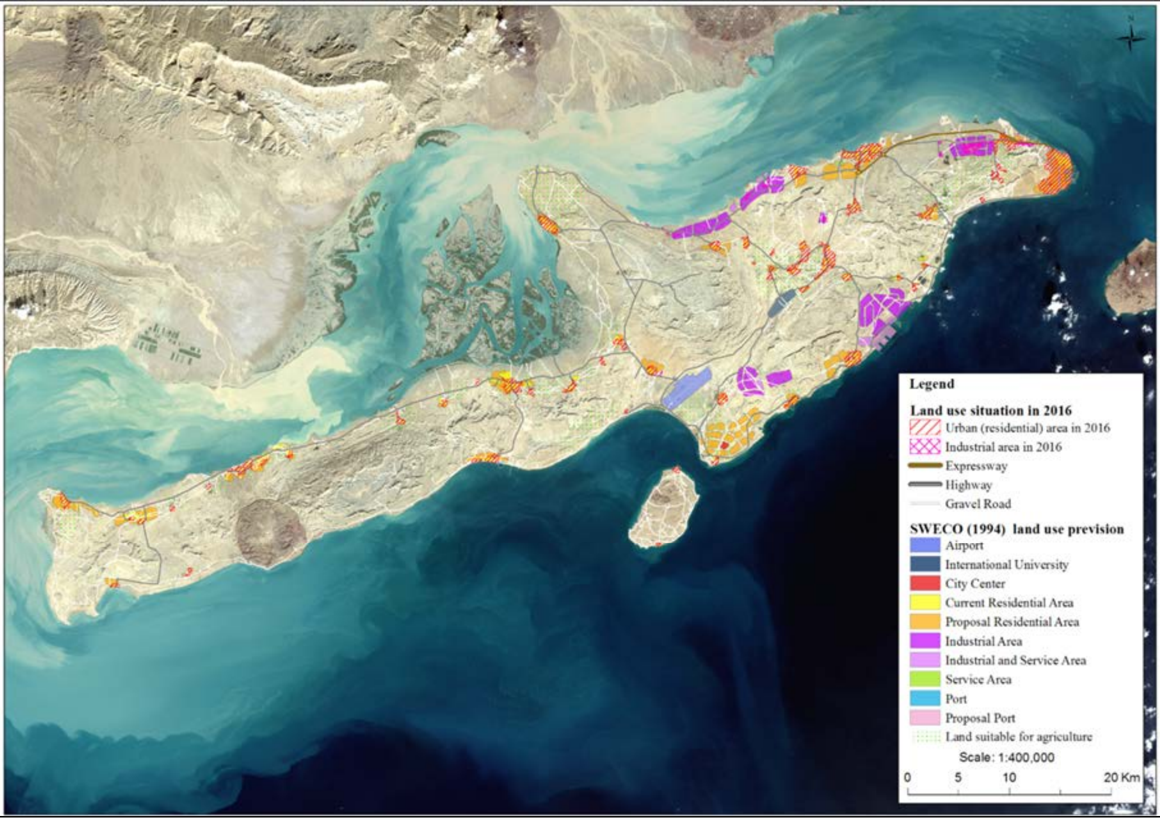
The review of SWECO approach of land use planning might be a key element for a better understanding of Qeshm specificities and for the proposition of a more accurate planning methodology.

Table A2.1.1 shows analysis of discrepancies between prevision and realization of SWECO master plan on Qeshm land use and population

Table A2.1.1 Analysis of Discrepancies between Prevision and Realization of SWECO Master Plan on Land Use and Population

	Current situation		SWECO prevision							
			Population				Residential area (ha)			
Village Name	**Population**	**Resid. area (ha)**	**Stage I**	**Gap**	**Gap (%)**	***Stage II***	**Stage I**	**Gap (ha)**	**Gap (%)**	***Stage II***
Qeshm and Towla	31,210	1,122	50,000	18,790	60%	*80,000*	550	-572	-104	*800*
Dargahan and Holor	14,255	428	30,000	15,745	110%	*60,000*	400	-28	-7	*750*
Shibderaz	456	32	40,000	39,544	8672%	*85,000*	400	368	1164	*950*
Souza	4,712	177	10,000	5,288	112%	*25,000*	200	23	13	*380*
Kouvei	4,224	149	10,000	5,776	137%	*15,000*	100	-49	-49	*190*
Tonbon	1,069	61	5,000	3,931	368%	*15,000*	100	39	64	*200*
Kovarzin	1,592	58	1,000	-592	-59%	*3,000*	80	22	37	*110*
Laft	4,105	175	3,000	-1,105	-37%	*4,000*	80	-95	-119	*100*
Peyposht	1,933	65	8,000	6,067	314%	*15,000*	140	75	114	*220*
Tourion plain cluster (all villages)	10,983	570	13,000	2,017	18%	*15,000*	300	-270	-90	*400*
Ramchah	3,679	97	5,000	1,321	36%	*15,000*	300	203	211	*400*
Mesen	2,002	65	1,000	-1,002	-100%	*7,000*	40	-25	-62	*100*
Tabl cluster (Tabl, Melki, Haft Rangou)	4,121	222	6,000	1,879	46%	*8,000*	100	-122	-122	*200*
Selakh	2,740	74	5,000	2,260	82%	*15,000*	120	46	63	*300*
Doulab cluster (Tomgez, Doulab, Sar Rig, Cachou, Aysheh-Abad)	4,875	173	5,000	125	3%	*15,000*	300	127	74	*560*
Baseidou cluster (Baseidou, Moradi, Gouri)	3,081	113	5,000	1,919	62%	*15,000*	300	187	164	*800*
Others	16,122	719	3,000	-13,122	-437%	*8,000*	150	-569	-379	*340*
TOTAL	**111,159**	**4,298**	**200,000**	**88,841**	**80%**	***400,000***	**3,660**	**-638**	**-17**	***6,800***

Notes: The order and the classification of cities and villages come from the SWECO master plan (Volume No. 6).
Figures for SWECO prevision comes from the SWECO master plan (Volume No. 6, Table 3 and 4, pages 24 and 25).
Stage I is planned by SWECO for horizon 2011 and Stage II for horizon 2021.
Population figures for current situation come from Census in 2011. Current land use is estimated using satellite imagery in 2016.



Source: JICA Project Team

Figure A2.1.1 SWECO Master Plan Land Use Plan compared to the Situation in 2016

<u>General notes about data mapping in SWECO master plan:</u>

(a) Even if it is not properly specified in the report, it can be assumed that the land use plan shown in Figure A2.1.1 displays the final image of planning, which corresponds to Stage II of development (calculation of the total of GIS polygons of residential land use gives 6,873 ha, which is close to the total of 6,800 ha given in the report for Stage II). Development at Stage I is not represented in any map in SWECO report;

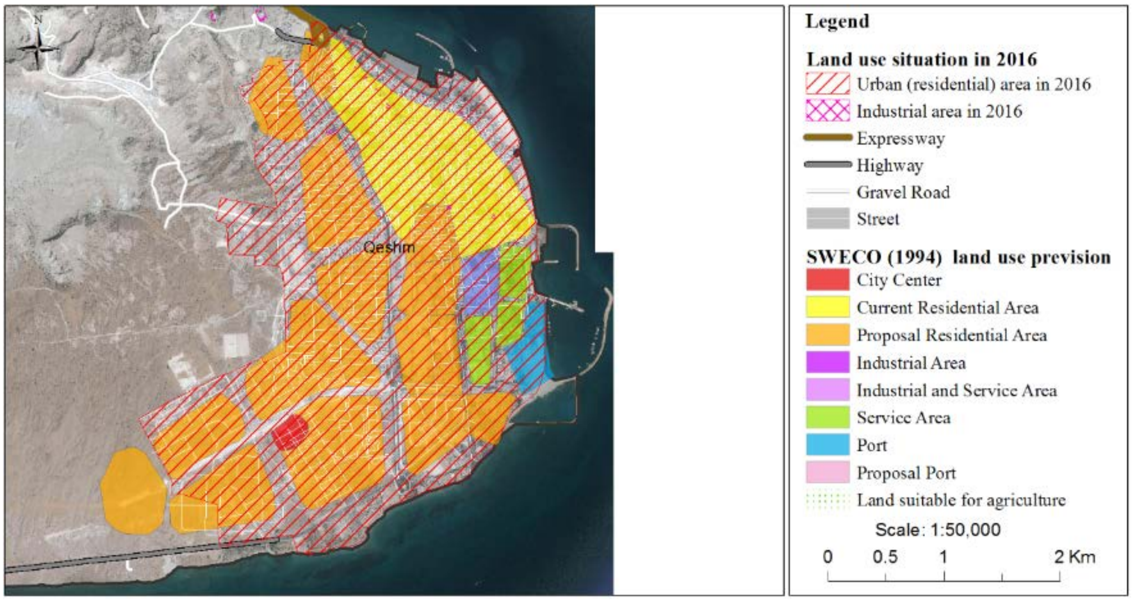
(b) As it can be seen on Figure 1, the geolocation of existing settlements has not been performed accurately at the time of SWECO master plan study (for example Melki and Haftrangou);

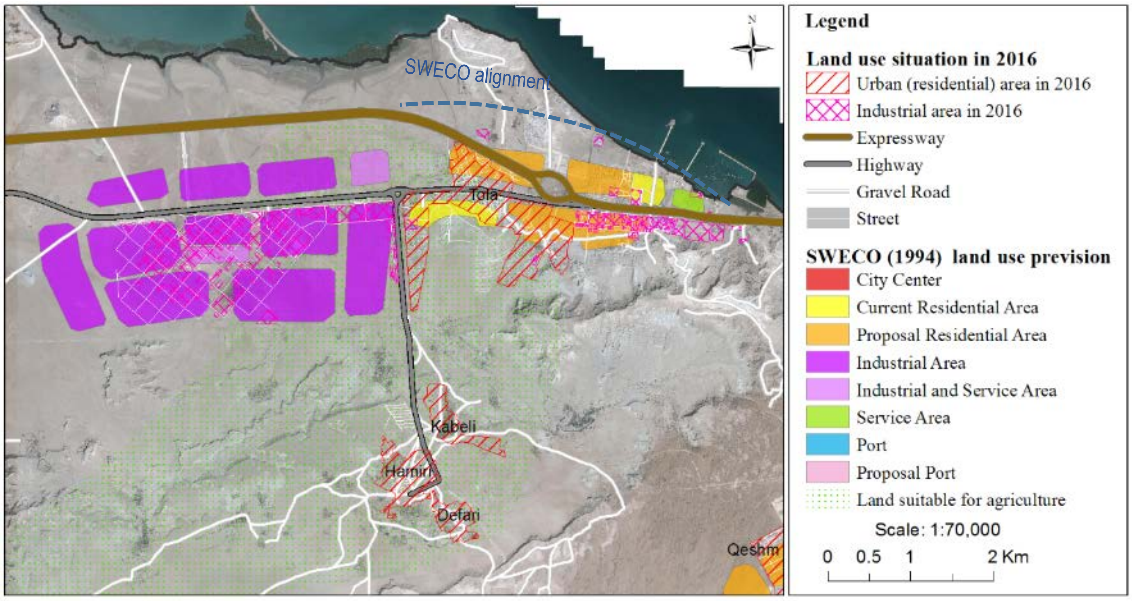
(c) Drawing of new developments is not accurate, in terms of both surface (area found in the report for each development do not match the area of the polygons in GIS) and relevancy and realism of the form to context (see Shiberaz New Town "eccentric" design). Even though land use mapping at this stage of regional planning shall be indicative and not specifically accurate, the study would have gain credibility with more realistic type of drawing (large zoning and not plot-style zoning).

A2.1.2 Detail Remarks on Each Locality

As explained above, a closer look into the details of the different geographical entities planned by SWECO, compared to their current situation, is necessary to be able to review the land use planning approach of the Swedish company. The following will focus on the major parts of the island and the discrepancies between prevision by SWECO and realization are the greatest.

(1) Qeshm and Towla





The planning of Qeshm and Towla is done through one of the five "Detailed Land Use plan" of SWECO master plan [Chapter 6 of Volume No. 6].

Most of SWECO recommendations in terms of urban planning of Qeshm city has been taken into consideration and is currently completed (residential development major areas and arterial network) or still under construction (corniche road of the northeast).

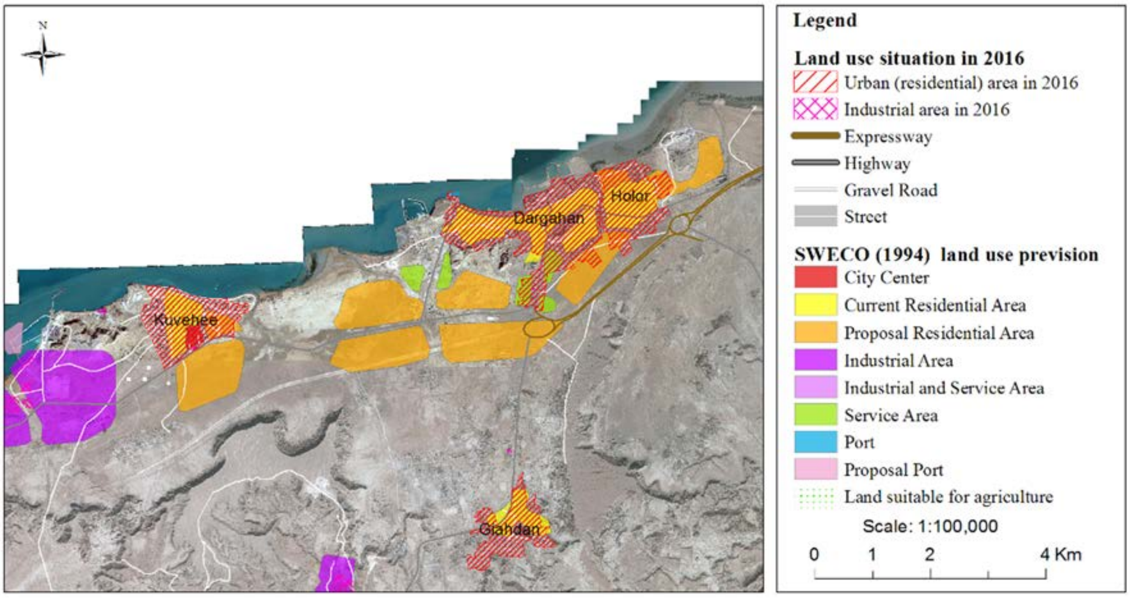
However, the City Center, planned by SWECO in the southern axis of development, *concentrated enough to create a sense of urban space [Volume No. 6, page 43]* was not constructed on do not even appear in 2013 Qeshm urbanization master plan. It seems that the latter favors a strengthening of urban functions in the center of the urban peninsula, behind Sam & Zal area.

Even though the population was overestimated at Stage I since the city could not reach 50,000 inhabitants (60%), the residential area was greatly underestimated (-104%), with the observed residential area in 2016 (1,122 ha) actually exceeding the forecasted surface of Stage II in 2021 (800 ha). The calculation of densities by SWECO shall be evaluated more precisely and refined.

Regarding Toula village, the idea of SWECO of *removing the traffic which is now passing through the village to another alignment, as a new main road north of the village [Volume No. 6, page 43]* has been properly implemented. Still, as it was not enough to *enable the village to become a small town [ibid]*, since the alignment of the highway has been changed to be constructed closer to Towla, it is actually constraining the urban development of the latter village on its northern side.

Towla industrial zone, which was planned even before SWECO master plan, has been consolidated by the latter, which added perimeter roads around the area on the eastern and southern sides, but those have not been built yet.

(2) Dargahan / Holor and Kouvei



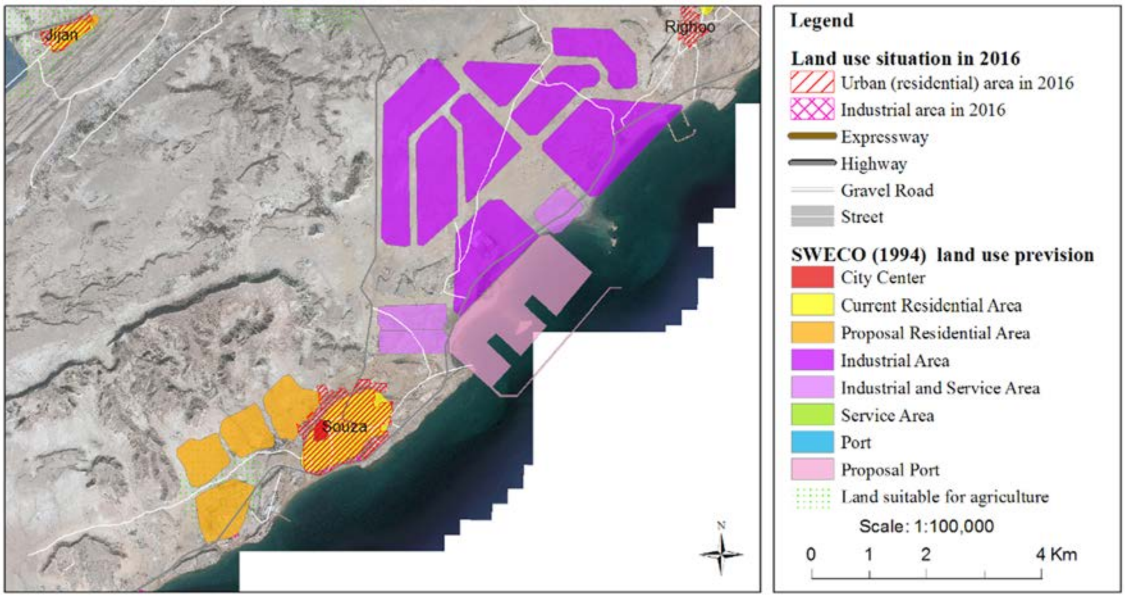
The planning of Dargahan and Kouvei is done through one of the five "Detailed Land Use plan" of SWECO master plan [Chapter 7 of Volume No. 6].

The urban growth of Dargahan and Holor, already anticipated by SWECO *to be directed to the area between the new main road and the existing built-up area [Volume No. 6, page 47]* has not been as strong as the Swedish company had forecasted it. Indeed, the population growth has been two times overestimated (110%) and the second main urban pole of the island that was expected to exceed 30,000 inhabitants in 2011 only reached 14,255 the same year. On the other hand, the expansion residential area was relatively well planned (-7%) for Stage I.

The urban development that is currently under implementation alongside the expressway has a lot of similarities with SWECO proposition for Stage 2. It shall be confirmed in Dargahan urban master plan whether or not the recommendation of SWECO master plan has been integrated.

The village of Kouvei did not grow as expected by SWECO consecutively to the construction of the jetty and the industrial facilities. Stating that *a strong and rapid growth of Kouvei would have negative consequences for the existing community [Volume No. 6, page 47]*, SWECO has "limited" the growth to a target population of 10,000 inhabitants at Stage I. The census of the same year confirmed that Kouvei has stayed relatively small (4,224 inhabitants) and that the impact of port activities on population growth has been greatly overestimated (137%).

(3) Souza

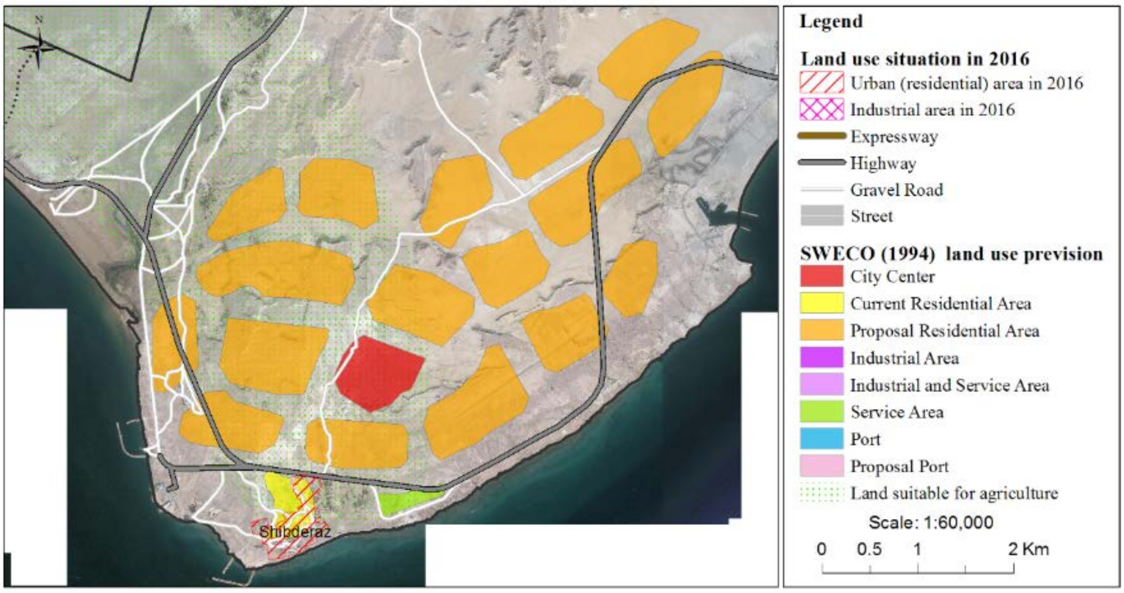


The planning of Souza is done through one of the five "Detailed Land Use plan" of SWECO master plan, in a chapter entitled "Land use plan Souza and industrial zone south" [Chapter 9 of Volume No. 6].

Nothing of the deep sea port, industrial zone, and railway, planned by SWECO in the vicinity of Souza, have been implemented. The relevancy of this planning alternative will be a major issue for the drafting of the new master plan.

Regarding residential growth of Souza, it has been largely overestimated (112%), especially because the port and industrial complex was not built. As Souza stayed a village under 5,000 inhabitants, the expected western urban development and the peripheral road was not implemented.

(4) Shibderaz

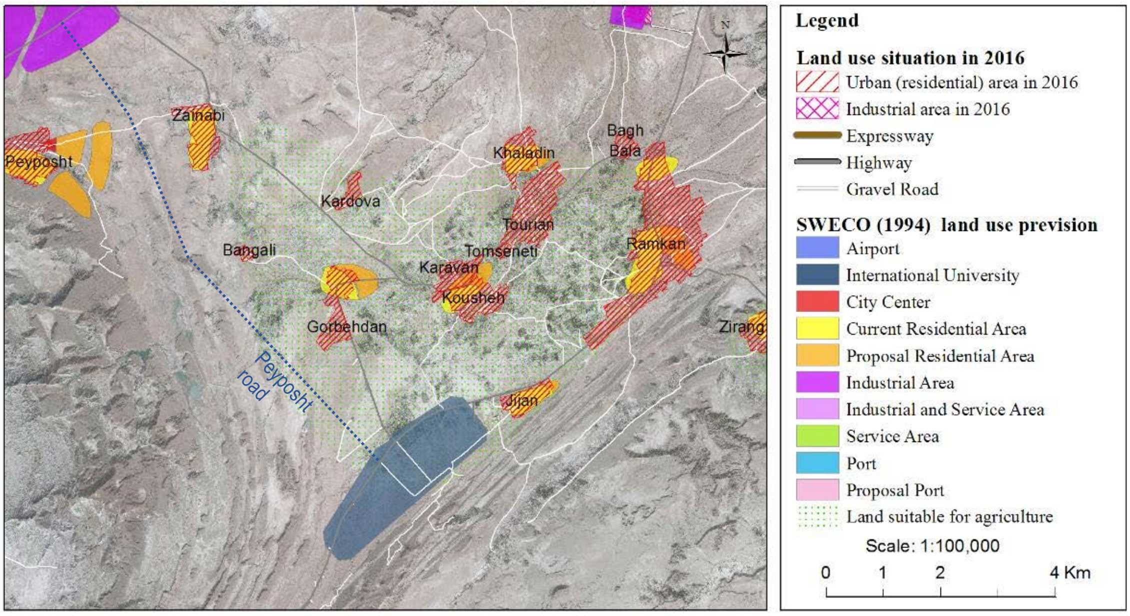


The planning of Shibderaz is done through one of the five "Detailed Land Use plan" of SWECO master plan, in a chapter entitled "Land use plan airport area, Shibderaz and industrial zone west" [Chapter 10 of Volume No. 6].

The Shibderaz New Town planned by SWECO to welcome 85,000 to 100,000 inhabitants, and especially new comers to the island and foreigners, was simply not implemented.

The plan for Shibderaz region prepared in 2013, has not abandoned the idea of building a new town, but it is proposed in a better harmony with surrounding environment, and in link with the fours villages of the region. The new town project shall be verified for smooth integration in the regional planning.

(5) Tourion cluster (all villages) and Peyposht



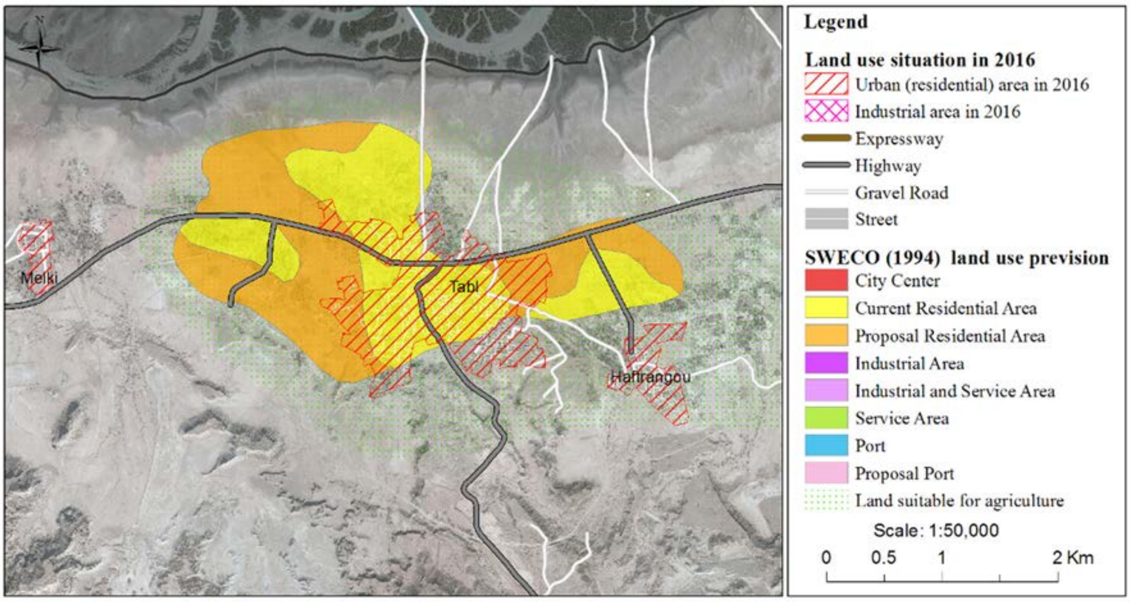
The planning of Tourion plain is one of the three "development briefs – other areas" of SWECO master plan.

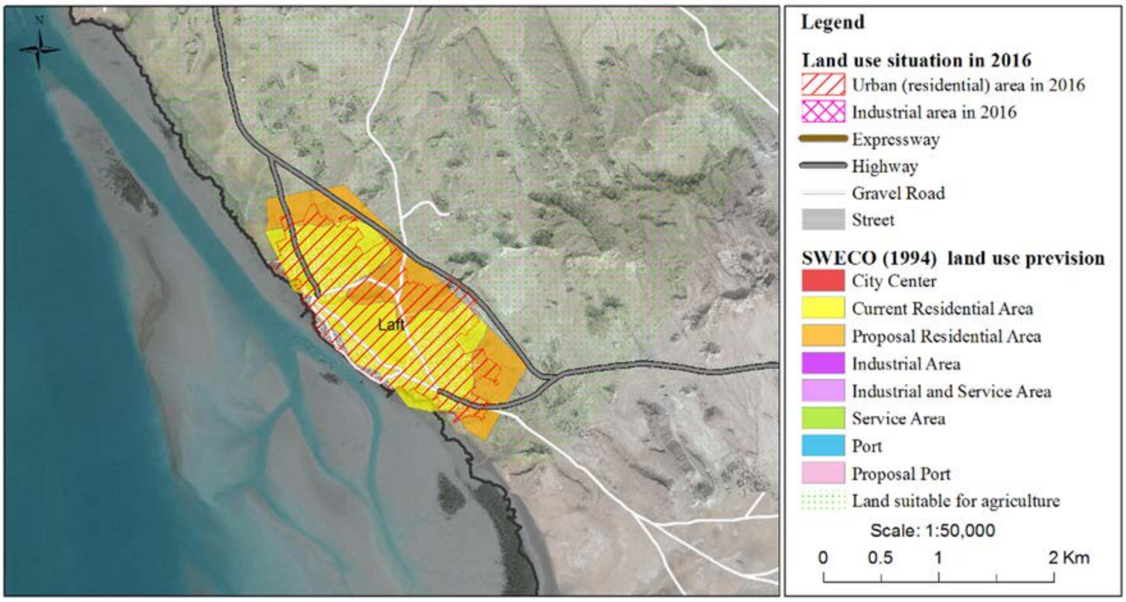
According to SWECO master plan, Tourion plain is *one of the areas on the island suitable for agriculture, [therefore] it is important that the area be preserved for this purpose.* SWECO master plan aimed at *developing economic activities in surrounding areas* while preserving the agricultural core of Tourion plain *with strict development controls [Volume No. 6, page 34].* Nothing is actually explained on any development control measures.

In addition, the plan from SWECO of reinforcing Peyposht as a major balance urban core of the area (up to 8,000 inhabitants on Stage I) and to construct *Peyposht road* as major North-South axis, in order to preserve the Tourion plain from residential development, did not work as expected. Peyposht stayed a minor settlement (1,933 inhabitants in 2011 so 4 times smaller than expected by SWECO), *Peyposht road* was not constructed and the majority of the urban development occurred inside the Tourion plain, especially in Ramkon village (soon to be officially promoted as a "city" by QFZO), Tourion village, or Kousha village, in which *pressure for development [was] already clearly perceived [Volume No. 6, page 33]*.

One of the reasons for this urban development might be explained by the land abandonment and the agricultural decline consecutive to long-term drought. Urban encroachment of cultivated areas has always been carefully avoided in Qeshm, thanks to the strict implementation of urban plans prepared by Bonyad Maskan. Further detail studies on urban development history shall be done to prove that the urban development of Tourion plain is not necessarily opposed (until now) to the conservation of agricultural fields.

(6) Tabl cluster (Tabl, Melki, Haftrangou) and Laft





The planning of Laft peninsula is one of the three "development briefs – other areas" of SWECO master plan.

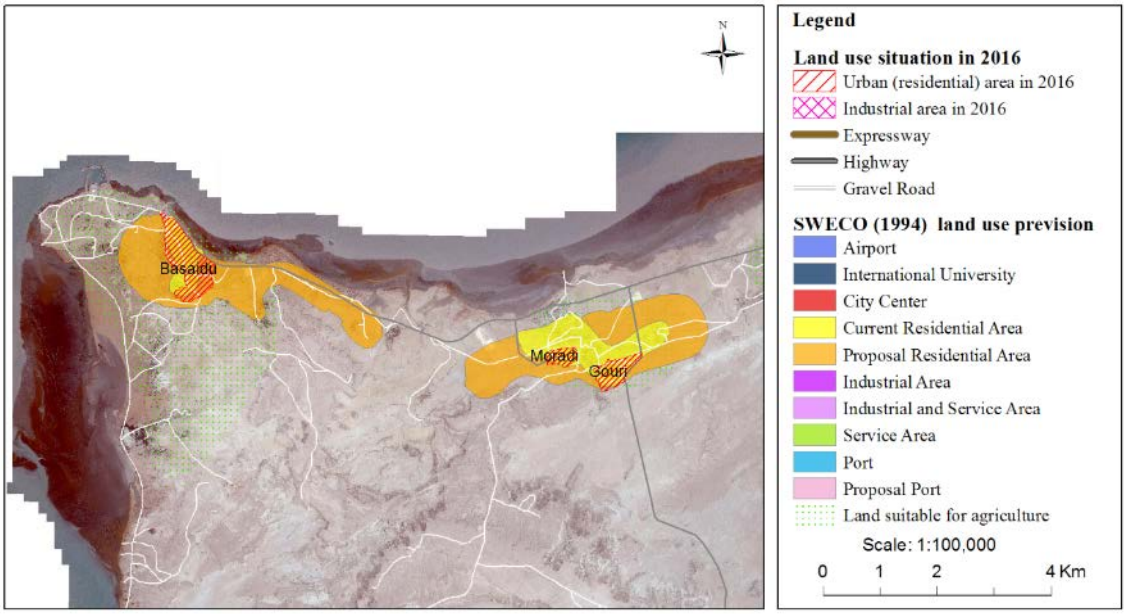
As defined by SWECO master plan, Laft peninsula is the *area that should be set aside* (of development, ed) *for environmental reasons and for natural conservation [Volume No. 6, page v]*. In the same way, due to the proximity of the *adjoining Hara Protected Area, development of Tabl and Laft must be severely restricted. Only very limited expansion of residential and other development should therefore be allowed in these areas [Volume No. 6, page 18]*.

For those reasons, Laft and Tabl residential future development has been set up to the minimum, with 80 ha for 3,000 inhabitants in Laft, and 100 ha for 6,000 inhabitants in the Tabl cluster including Melki and Haftrangou at Stage I (2011).

Unfortunately, the development of the environmentally-sensible villages of Laft and Tabl could not been limited as expected by SWECO. The current state in 2016 shows that more of the double of planned residential development has occurred, with 175 ha (-119%) of residential areas in Laft and 222 ha (-122%) in Tabl cluster in 2016, proving that SWECO figures have been greatly underestimated.

Regarding population, Laft and Tabl cluster have currently (2011 census) almost the same importance with 4,105 and 4,121 inhabitants respectively, but have been underestimated for the first (-37%) and overestimated for the second (+146%).

(7) Baseidou cluster



Baseidou cluster (including the small villages of Moradi and Gouri) is one of the four separate groups of villages alongside Tabl, Doulab and Selakh in the western part of the island where residential development [was] envisaged [Volume No. 6, page 18]. Similarly to the three other village groups, Baseidou cluster was planned to receive a population of around 5,000 on Stage I (2011).

Both population (+62%) and residential development area (+164%) have been greatly overestimated by SWECO, and the western part of the island didn't have the expected development.

A2.2 Date of Inland Ecosystem Management

A2.2.1 Existing conditions

(1) Flora

More than 180 plant species have been identified as listed below

Plant species in Qeshm

Abutilon fruticosum
Abutilon hirtum
Acacia salicina
Acacia ehrenbergiana
Acacia nilotica
Acacia oerfota
Acacia tortilis
Aeluropus lagopoides
Aerva persica
Aizoon canariense
Albizzia lebbeck
Alhagi manifera
Alhagi maurorum
Aloe vera
Ammi majus
Anabasis setifera
Anagalis arvensis
Anastatica hierochuntica
Andrachne telephioides
Aristida adscensionis
Arnebia hispidissima
Asphodelus tenuifolius
Astragalus crenatus
Astragalus annularis
Astragalus eremophilus
Astragalus hauarensis
Atriplex leucoclada
Avicennia marina
Bienertia cycloptera
Bienertia sinuspersici
Blepharis persica
Bolboshoenus maritimus
Bougainvillea globra
Caillonia hymenostephana
Cakile arabica
Calligonum comosum
Calligonum polygonoides
Calotropis procera
Capparis mucronifolia
Capparis spinosa
Cassia italica
Cenchrus biflorus
Cenchrus ciliaris
Cenchrus setigerus
Chenopodium murale
Chrozophora tinctoria
Cistanche tubulosa
Citrullus colocynthis
Cleome brachycarpa
Cleome dolichostyla
Coelachyrum piercei
Cometes surattensis
Commicarpus stenocarpus
Conocarpus erectus
Convolvulus cephalopodus
Convolvulus glomeratus
Convolvulus leptocladus
Convolvulus sericeus
Cordia myxa
Cornulaca aucheri
Cornulaca monacantha
Crepis sancta
Cressa cretica
Crotalaria persica
Cuscuta epithymum
Cycas revoluta
Cymbopogon parkeri
Cynodon dactylon
Cyperus conglomeratus
Cyperus rotundus
Delonix regia
Dodoneaea viscosa
Echinops gedrosiaca
Emex spinosa
Ephedra foliata
Eragrostis cilianensis

Eremopogon foveolatus
Erodium sp
Eruca sativa
Erucaria hispanica
Eucalyptus
Fagonia bruguieri
Fagonia glutinosa
Fagonia indica
Farsetia heliophila
Ficus bengalensis
Ficus benjamina
Ficus carica
Filago desertorum
Frankenia pulverulenta
Gaillonia hymenostephana
Gastrocotyle hispida
Gastrocotyle hispidissima
Geranium mascatense
Glossonema varians
Grantia aucheri
Grewia tenax
Gymnocarpus decander
Halimusx atriplex
Halocnemum strobilaceum
Halopeplis perfoliata
Halopyrum mucronatum
Hammada salicornica
Haplophyllum tuberculatum
Helianthemum lippii
Helianthemum salicifolium
Heliotropium bacciferum
Heliotropium ramosissimum
Herniaria hirsuta
Hibiscus rosa
Hyparrhenia hirta
Imperata cylindrica
Indigofera intricata
Kochia prostrata
Lasiurus hirsutus
Launaea capitata
Launaea cassiniana
Launaea mucronata
Lotus garcinii
Lycium shawii
Malva parviflora
Medicago laciniata
Medicago orbicularis
Medicago polymorpha
Melia indica
Melilotus indicus
Mesembrغanthemum nodiflorum
Moltkiopsis ciliata
Monsonia heliotropioides
Nerium oleander
Neurada procumbens
Ochradenus baccatus
Oldenlandia retrorsa
Oligomeris linifolia
Opunthia ficus indica
Panicum turgidum
Parkinsonia aculeata
Paroncychia arabica
Pennisetum divisum
Periploca aphylla
Phalaris minor
Plantago boissieri
Plantago ovata
Platychaetae glaucescens
Polycarpaea repens
Polycarpaea spicata
Polycarpon tetraphyllum

Prosopis cineraria
Prosopis juliflora
Pteropyrum aucheri
Pulycaria gnaphalodes
Reichardia orientalis
Rumex vesicarius
Salicornia europaea
Salsola baryosma
Salsola drummondii

Salsola imbricata
Salsola tomentosa
Salvadora persica
Schismus barbatus
Scrophularia deserti
Senecio glaucus
Sericostoma pauciflorum
Shaerocoma aucheri
Silene villosa
Solanum incanum
Sonchus oleraceus
Spergularia diandra
Sphaerocoma aucheri
Sporobolus arabicus
Stipa capensis
Stipagrostis plumosa
Suaeda vermiculata
Suaeda aegyptiaca
Suaeda maritima
Tamarindus indica
Tamarix dioica
Tamarix mascatensis
Taverniera spartea
Tephrosia persica
Tragus racemosus
Tribulus macropterus
Tricholaena tenerifae
Trigonella stellata
Trigonella uncata
Washingtonia robusta
Ziziphus spina-christi
Zygophyllum qatarense
Zygophyllum simplex

Source: JICA Project Team

The table below shows different types of vegetation observed and dominant plant species.

Table A2.2.1 Dominant Plant Species in Habitats in Qeshm

No.	Habitat	Dominant Species in the Plant Community
1	Low height lands with high level of underground water and low hills (Towla to Dargahan, Towla and Defari, Dourbani, Holor, Laft Kohneh to Peyposht, Laft to Kovarzin, Kani, Chahou Sharghi, Konar Sia, Baseidou)	*Salsola drummondii*
2	Eroding low lands, roadsides with low level of underground water (Holor, Laft to Kovarzin)	*Salsola drummondii-Atriprex leuocolada*
3	Village sides and low hills with low level of underground water (Between Giadon and Dargahan)	*Cornulaca monacantha Salsola- drummondii*
4	Dry low lands and on eroding hills (Shah Shahid, Zeinabi, Tonbon; Shibderaz)	*Salsola tomentosa*
5	Flat lands with eroding hills (Gazdan and Bangali; Baseidou to Moradi; Doustakou to Baseidou)	*Sorsola drummondii-Salsola tomentosa*
6	Flat lands with high level of underground water (Towla to Defari; Towla to Dargahan; Lands near the refinery; Laft Kohneh; Laft to Gavazzi; Chahou Sharghi	*Salsola drummondii-Aeluropus lagopides*
7	Sandy areas around villages with low level of underground water (side skirts of Zeinabi)	*Salsola tomentosa-Helitropium bacciferum*
8	Low height hills and sandy lands with low level of underground water (Qeshm to Kabeli, Shah Shahid, Posht Tanbeh, Southern coast of Qeshm, Rigoo, Souza, Souza to Mesen, Laft Kohneh, Tiab Kermoo to Noghasha, Selakh, Gomiran to Kargeh, Namakdan, Kani, Baseidou)	*Sphaerocoma aucheri*
9	Low height lands and hills with sands and low level of underground water (Southern coast of Qeshm, side skirts of Baseidou)	*Sphaerocoma aucheri-Heliotropium bacciferum*
10	In sandy lands with low to medium level of underground water (Selakh, Souza to Rigoo)	*Sphaerocoma aucheri-panicum turgidum*
11	Salty and low height lands with low level of underground water (Mesen; Namakdan)	*Suaeda vermiculata*
12	Seasonal Watercourses (Borka Khelaf, Souza)	*Sporobolus arabicus*
13	Salt marshes beside the beaches with high level of underground water (Shah Shahid, Posht Tanbeh, Dargahan, Holor, Peyposht, Towla to Giadon, Laft to Kovarzin, Chahou Sharghi, Konar Sia, Baseidou)	*Halocnemum strobilaceum*
14	Abandoned lands around villages with low level of underground water (Between Zeinabi and Giadon, Ramkon, Fijian, Khaladin, Kovarzin, Tonbon, Laft Kohne to Peyposht, Baseidou)	*Hammada salicornica*
15	Sandy lands with medium to high level of underground water (Rigoo Junction, Souza)	*Halopyrum mucronatum*
16	Low and salty lands with high level of underground water (Souza, Rigoo Junction, Borka Khelaf, Tabl to Sohil, Baseidou)	*Halopeplis perfoliata*
17	Sandy lands and coastal hills, side skirts of villages with low level of underground water (Southern coast of Qeshm, Borka Khelaf to Souza)	*Heliotropium bacciferum*
18	Flat lands with low level of underground water (Around Kovarzin and Khoorkhooran)	*Heliotropium bacciferum-Aeluropus lagopoides*
19	Eroding hills and rocky areas (Giadon, Tabl to Selakh)	*Platychaete glaucescens*
20	Sandy lands with low level of underground water (Side skirts of Qeshm)	*Panicum turgidum-Heliotropium bacciferum*
21	Side skirts of destructed areas and with low level of underground water (Shah Shahid, Besides Sade Khaki, Giadon, Tiab KErmoo, Shibderaz, Messes to Direston, Chahou Sharghi)	*Atriplex leucoclada*
22	Tidal coastal areas (Tabl, Laft, Sohil)	*Avicennia marina*
23	Flat lands with low level of underground water (Between Shibderaz and Noghasha)	*Atriplex leucoclada-Panicum turgidum*
24	Woodlands of the eastern area of the Island, in flat lands to relatively higher lands (Borka Khelaf, Dargahan, Towla, Hills towards Giadon, Khaladin, Selakh)	*Prosopis cineraria*
25	Sandy hills with low level of underground water (Around Zeinabi)	*Panicum turgidum-Tephrosia persica*
26	Small woodlands and seasonal watercourses (Shah Shahid)	*Prosopis koelziana*
27	Woodlands and sandy hills (Qeshm to Towla, Dargahan to Kouvei, Posh Tonbeh, Laft Kohneh, Tabl to Selakh, Selakh, Chahou Sharghi, Dourbani, Konar Sia, Gar Maghokooh, Baseidou)	*Acacia tortilis*
28	Very small segments in higher lands (Middle part of the island, Holor, Sideskirts of Dargahan, Kouvei, Melki, Doustakou, Baseidou)	*Acacia tortilis- Prosopis cineraria*
29	Seasonal water streams and eroding hills (Giadon to Ramkon, Gard Moghokooh Junction, Khaladin, and…)	*Eremopogon fovelatus-Salsola tomentosa*
30	Flat lands, rain holes, seasonal lakes and big watercourses (Sade Khalesi, Gomiran, Mesen to Direston, Mesen, Dare Koo)	*Tamarix mascatensis-Tamarix dioica*
31	Flat lands between eroding terraces and with high and low level of underground	*Taverniera spartea*

	water (Baseidou, Gomiran to Kargeh, Borka Khelaf)	
32	Side skirts of villages and farming lands with low level of underground water (Southern part of Qeshm, Namakdan, Goormi, Gard Moghookooh junction, Gomiran, Baseidou)	*Cornulaca monacantha*
33	Seasonal watercourses (Khaledin)	*Cymbopogon parkeri*
34	Seasonal watercourses and eroding hills (Terraces around Qeshm, Shah Shahid, Peyposht, Sade Khalesi, Souza, Gomiran to Kargah jetty, Giadon, Giadon to Ramkon, Khaladin)	*Eremopogon foveolatus*
35	Eroding hills and sandy and stony terraces with low level of underground water (Giadon to Ramkon, Sade Khalesi, Peyposht, heights near Sade Khaladin, Souza, side skirts of Qeshm)	*Gymnocarpus decander-Eremopogon foveolatus*
36	Coastal areas and low sandy hills (Gomiran to Kargeh, Borka Khelaf)	*Grntia aucheri*
37	Costal sandy hills with low level of underground water (Southern part of Qeshm, Kabli, Namakdan, Borka Khelaf to Souza, Dourbani, Giadon, Kovarzin, Laft Kohneh, Chahou Sharghi)	*Panicum turgidum*
38	Flat lands and coastal sandy hills with low level of underground water(Gouron to Chahou Sharghi, around Kovarzin, Around Laft Kohneh, Peyposht)	*Panicum turgidum-Salsola drummondii*
39	Lands between the terraces with low level of underground water (Around Rigoo)	*Sphaerocoma aucheri-Taverniera spartea*
40	Low and high hills and flat lands with low level of underground water and poor soil (Giadon, Jijiyon, Peyposht, Gard Moghokooh junction, Dourbani Terraces, Khaladin, Tabl to Selakh, Chahou Sharghi)	*Gymnocrapus decander*
41	Eroding hills with low level of underground water (Baseidou, Gerd Moghokooh, Giadon)	*Gymnocrapus decander-Salsola tomentosa*
42	Flat lands and areas in the eroding terraces with low and high level of underground water (Qeshm to Towla and Defari, Dargahan, Giadon, Peyposht)	*Zygophyllum qaterense*
43	Small communities in flat lands and low hills in the southern coasts with low level of underground water (Souza)	*Indigofera Intricata*
44	Destructed areas and low sandy hills with low level of underground water (around Souza)	*Moltkiopsis ciliata*
45	Deserted areas with low level of underground water (Towla to Dargahan)	*Lasiurus hirsutus*
46	Flat lands with low level of underground water (Shah Shaid, Mesen to Direston, Shibderaz, Tiab Kermoo, Chahou Sharghi)	*Atriplex leucoclada-Salsola tomentosa*
47	Salty lands with high level of underground water (Posht Tonbeh, Holor, Kovarzin, Chahou Sharghi, Baseidou)	*Aeluropus lagopoides*
48	Flat lands, side skirts of villages with low level of underground water (Zeinabi)	*Atriplex leucoclada-Cornulaca monacantha*

Source: Ghahraman et al. 2000. The Guide to Natural Vegetation of Qeshm.

(2) Fauna

A list of bird species recorded in Qeshm Island and the Khouran Straits is shown in Table A2.2.2.

Table A2.2.2 List of Birds Recorded in Qeshm Island and Khran Straits

	species	Common name	Habitat						Habitat model				Nest				Diet						Category in IUCN Red List (2016)
			Aquatic	Coastal zone	Meadows	Wood lands	Forests	Cultivation lands	Permanent	Summer	Winter temp.	Spring or fall migratory	Land	Tree	Aquatic plants	Buildings	Fish	Insects	Benthos	Herbivorous	Omnivorous	Other	
1	Ardea alba	Great White Egret	*								*		*				*		*				Least Concern
2	Accipiter badius	Shikra																					Least Concern
3	Accipiter nisus	Eurasian Sparrowhawk									*												Least Concern
4	Acrocephalus stentoreus	Clamorous Reed-warbler																					Least Concern
5	Actitis hypoleucos	Common Sandpiper		*					*				*					*		*		*	Least Concern
6	Alaemon alaudipes	Greater Hoopoe-lark									*												Least Concern
7	Alauda arvensis	Eurasian Skylark							*														Least Concern
8	Alcedo atthis	Common Kingfisher									*	*											Least Concern
9	Anas querquedula	Garganey																					Least Concern
10	Anthus spinoletta	Water Pipit									*	*											Least Concern
11	Aquila chrysaetos	Golden Eagle									*												Least Concern
12	Ardea cinerea	Grey Heron	*		*						*			*	*		*	*	*			*	Least Concern
13	Ardea goliath	Goliath Heron																					Least Concern
14	Ardeola grayii	Indian Pond-heron		*					*					*	*		*		*				Least Concern
15	Arenaria interpres	Ruddy Turnstone								*	*	*											Least Concern
16	Burhinus oedicnemus	Eurasian Thick-knee							*														Least Concern
17	Butorides striata	Green-backed Heron																					Least Concern
18	Calandrella cinerea	Red-capped Lark									*	*											Least Concern
19	Calandrella rufescens	Lesser Short-toed Lark									*												Least Concern
20	Calidris alba	Sanderling									*												Least Concern
21	Calidris alpina	Dunlin		*							*		*					*		*		*	Least Concern
22	Calidris falcinellus	Broad-billed Sandpiper									*	*											Least Concern
23	Calidris ferruginea	Curlew Sandpiper		*							*		*					*		*		*	Near Threatened
24	Calidris minuta	Little Stint		*							*		*					*		*		*	Least Concern
25	Calidris temminckii	Temminck's Stint		*							*		*		*			*		*		*	Least Concern
26	Charadrius alexandrinus	Kentish Plover		*					*				*					*		*		*	Least Concern
27	Charadrius asiaticus	Caspian Plover									*	*											Least Concern
28	Charadrius dubius	Little Ringed Plover		*								*	*					*		*		*	Least Concern
29	Charadrius hiaticula	Common Ringed Plover		*					*				*					*		*		*	Least Concern
30	Charadrius leschenaultii	Greater Sandplover									*												Least Concern

31	Charadrius mongolus	Lesser Sandplover									*												Least Concern
32	Charadrius morinellus	Eurasian Dotterel									*												Least Concern
33	Chlidonias hybridus	Whiskered Tern	*									*	*				*	*	*				Least Concern
34	Circus aeruginosus	Western Marsh-harrier	*						*						*						*		Least Concern
35	Columba livia	Rock Dove							*														Least Concern
36	Corvus ruficollis	Brown-necked Raven							*														Least Concern
37	Cuculus canorus	Common Cuckoo									*												Least Concern
38	Dromas ardeola	Crab-plover							*														Least Concern
39	Egretta garzetta	Little Egret	*				*		*				*	*	*		*		*			*	Least Concern
40	Egretta gularis	Western Reef-egret	*						*				*		*		*		*				Least Concern
41	Esacus recurvirostris	Great Thick-knee							*														Near Threatened
42	Falco cherrug	Saker Falcon									*												Endangered A2bcde+3cde +4bcde
43	Falco tinnunculus	Common Kestrel									*												Least Concern
44	Francolinus pondicerianus	Grey Francolin							*														Least Concern
45	Fulica atra	Common Coot										*											Least Concern
46	Galerida cristata	Crested Lark							*														Least Concern
47	Gelochelidon nilotica	Common Gull-billed Tern								*	*	*											Least Concern
48	Glareola pratincola	Collared Pratincole																					Least Concern
49	Haematopus ostralegus	Eurasian Oystercatcher		*								*	*						*				Near Threatened
50	Halcyon smyrnensis	White-breasted Kingfisher									*	*											Least Concern
51	Haliaeetus albicilla	White-tailed Sea-eagle																					Least Concern
52	Hippolais languida	Upcher's Warbler							*														Least Concern
53	Hirundo obsoleta	Pale Crag-martin																					Least Concern
54	Hoplopterus indicus	Red-wattled Lapwing								*	*												Least Concern
55	Hydrocoloeus minutus	Little Gull	*		*			*			*		*								*		Least Concern
56	Hydroprogne caspia	Caspian Tern		*								*	*				*	*	*				Least Concern
57	Larus argentatus	European Herring Gull	*					*	*				*								*		Least Concern
58	Larus cachinnans	Yellow-legged Gull								*	*	*											Least Concern
59	Larus canus	Mew Gull								*	*	*											Least Concern
60	Larus genei	Slender-billed Gull	*						*				*								*		Least Concern
61	Larus ichthyaetus	Pallas's Gull									*												Least Concern
62	Larus marinus	Great Black-backed Gull									*												Least Concern
63	Larus ridibundus	Black-headed Gull	*		*			*	*				*								*		Least Concern

64	Limicola falcinellus	Broad-billed Sandpiper		*							*		*					*		*		*	Least Concern
65	Limosa lapponica	Bar-tailed Godwit		*								*	*					*		*		*	Least Concern
66	Mergus serrator	Red-breasted Marganser																					Least Concern
67	Merops orientalis	Asian Green Bee-eater									*	*											Least Concern
68	Merops superciliosus	Olive Bee-eater									*	*											Least Concern
69	Milvus migrans	Black kite																					Least Concern
70	Motacilla alba	White Wagtail									*	*											Least Concern
71	Nectarinia asiatica	Purple Sunbird							*														Least Concern
72	Neophron percnopterus	Egyptian Vulture									*												Endangered A2bcde+3bcde+4bcde
73	Numenius arquata	Eurasian Curlew		*	*							*	*					*		*		*	Near Threatened
74	Numenius phaeopus	Whimbrel		*								*	*					*		*		*	Near Threatened
75	Nycticorax nycticorax	Black-crowned Night-heron	*			*		*			*			*	*		*	*					Least Concern
76	Oenanthe alboniger	Hume's Wheatear									*	*											Least Concern
77	Oenanthe isabellina	Isabelline Wheatear									*	*											Least Concern
78	Pandion haliaetus	Osprey							*					*			*						Least Concern
79	Passer domesticus	House Sparrow							*														Least Concern
80	Pelecanus crispus	Dalmatian Pelican	*								*				*		*						Vulnerable A2ce+3ce+4ce
81	Pelecanus onocrotalus	Great White Pelican	*								*	*			*		*						Least Concern
82	Phalacrocorax carbo	Great Cormorant	*								*		*	*			*						Least Concern
83	Phoenicopterus roseus	Greater Flamingo	*								*		*						*				Least Concern
84	Platalea leucorodia	Eurasian Spoonbill	*								*			*	*		*	*	*	*			Least Concern
85	Pluvialis apricaria	Eurasian Golden Plover		*				*				*	*					*		*		*	Least Concern
86	Pluvialis squatarola	Grey Plover		*								*	*					*		*		*	Least Concern
87	Pycnonotus leucotis	White-eared Bulbul							*														Least Concern
88	Spilopelia senegalensis	Laughing Dove							*														Least Concern
89	Sterna albifrons	Little Tern	*									*	*				*	*	*				Least Concern
90	Sterna anaethetus	Bridled Tern									*	*											Least Concern
91	Sterna bengalensis	Lesser Crested Tern	*						*				*				*						Least Concern
92	Sterna bergii	Greater Crested Tern	*								*		*					*					Least Concern
93	Sterna hirundo	Common Tern		*								*	*				*	*	*				Least Concern
94	Sterna repressa	White-cheeked Tern									*												Least Concern
95	Sternula saundersi	Saunders's Tern																					Least Concern
96	Sturnus vulgaris	Common Starling									*												Least Concern
97	Sylvia nana	Desert Warbler							*														Least Concern
98	Tadorna tadorna	Common Shelduck									*												Least Concern

99	Thalasseus sandvicensis	Sandwich Tern	*									*	*				*						Least Concern
100	Tringa erythropus	Spotted Redshank		*								*	*					*		*		*	Least Concern
101	Tringa nebularia	Common Greenshank		*								*	*					*		*		*	Least Concern
102	Tringa ochropus	Green Sandpiper									*												Least Concern
103	Tringa stagnatilis	Marsh Sandpiper		*								*	*					*		*		*	Least Concern
104	Tringa totanus	Common Redshank		*	*				*				*					*		*		*	Least Concern
105	Turdoides caudatus	Common Babbler							*														Least Concern
106	Vanellus indicus	Red-wattled Lapwing		*					*									*	*				Least Concern
107	Xenus cinereus	Terek Sandpiper		*								*	*					*		*		*	Least Concern

Source: Government of Iran. 1997. Ramsar Information Sheet (Khouran Straits). SWECO. 1994. Qeshm Free Area Master Plan Project: Master Plan Report., IUCN. 1995. A Directory of Wetlands in the Middle East.

(3) Geological values

Since the concept of the geopark is new and somehow controversial between geologists and geographers, the following tries to clarify the definitions used in the Project to narrow the meaning and simplify the work of the people who want to develop any plan for Qeshm Geopark in the future and decrease any misunderstanding.

(a) UNESCO Global Geopark: UNESCO Global Geoparks are single, unified geographical areas where sites and landscapes of international geological significance are managed with a holistic concept of protection, education, and sustainable development. A UNESCO Global Geopark uses its geological heritage, in connection with all other aspects of the area's natural and cultural heritage, to enhance awareness and understanding of key issues facing society, such as using our earth's resources sustainably, mitigating the effects of climate change and reducing natural disasters related risks. By raising awareness of the importance of the area's geological heritage in history and society today, UNESCO Global Geoparks give local people a sense of pride in their region and strengthen their identification with the area. The creation of innovative local enterprises, new jobs, and high-quality training courses is stimulated as new sources of revenue are generated through geotourism, while the geological resources of the area are protected (http://www.unesco.org). A geopark attains its goal through conservation, education, and geotourism (Torabi, 2012).

(b) Geoscience: The sciences (as geology, geophysics, and geochemistry) dealing with the earth (http://www.merriam-webster.com)

(c) Geotourism: Tourism that sustains or enhances the geographical character of a place—its environment, geology, culture, aesthetics, heritage, and the well-being of its residents (An article from National Geographic Magazine; http://voices.nationalgeographic.com/2011/11/16/unescos-geoparks-embrace-geotourism). According to this precept; the definition of "geotourism" can also cover the definition of "ecotourism" while in Qeshm Island it can be considered.

(d) Geosite: So far GGN does not present a clear definition for geosite. This definition looks fine: A geosite is a site or an "area", from a few square metres to several square kilometers in size, with geological and scientific significance, whose geological characteristics (mineral, structural, geomorphological, physiographic) meet one or several criteria for classifying it as outstanding (valuable, rare, vulnerable, endangered) (www.mern.gouv.qc.ca). It might be an engineered rock, a geologically significant natural heritage, industrial or mining heritage, a museum, public visiting area, etc. A geosite at least has one of these values; landscape beauty, sociocultural value, historical or scientific significance, or uniqueness.

(e) Geoproduct: Any innovative product, event or service which not only improves the local economy and present local products but also educates tourists and popularizes geological science. Their novelty should be evident to producers, suppliers, consumers or competitors (Torabi, 2012).

(f) Eco-Island: The JICA Project in Qeshm attempts to approach a comprehensive plan for Qeshm Island that can be compacted in "Ecological Island", an island that worries about the sustainability of the activities and projects. It looks that the concept of Eco-Island is very similar to the definition of UNESCO for an international geopark.

(4) Legal basis for conservation

The most relevant legal references related to the environment have been reviewed. The following table states the information related to this study.

Table A2.2.3 Most Relevant Legal Texts in Regards to the Environment

Title of the Legal Source	Domestic/ International	Subject
Article (50) of the Constitution of the Islamic Republic of Iran	Domestic	Focusing on the equality of generations in using environmental resources; Considering the conservation of environment as a public duty, Emphasis on the necessity of prohibiting destruction of the environment and pollution
Law on the Protection and Improvement of the Environment and its executive by-law	Domestic	Forming the council of environment protection and defining its activities; defining the options of the council; defining duties of environmental protection agency; defining the pollution of environment; defining fines for polluting caused
The law for fair distribution of water	Domestic	Emphasizing the public domain of water, defining regulations for using underground waters, defining regulations for using surface water, explaining the way of protecting water foundations, defining the regulation for fighting against crimes in the area
The law establishing the National Committee to reduce the effects of natural disasters	Domestic	Emphasizing the formation of the National Committee for the exchange of information, research, scientific research and to find reasonable solutions to prevent and mitigate the effects of natural disasters caused by hurricanes, floods, drought, frost, pests, air pollution, land of earthquakes and landslides Highlights fluctuations in sea and lakes, and rivers and so on, to determine the work of the Committee.
By-law preventing water pollution	Domestic	Defining water pollution, sources of water pollutants, solid waste, etc .; emphasizing on the prohibition of water pollution, determining the device responsible for monitoring and detection of water contamination, emphasizing standards related to water Pussy, determining how to deal with units of water pollutants; determining the criteria for sewage disposal.
Environmental health by-law	Domestic	Defining environmental health, drinking water, contamination of drinking water, health control, health centers, etc .; emphasizing the prohibition of any action threatening public health, emphasizing the prohibition of drinking contaminated water and determining the health ministry as an observer of the quality of public drinking water; the Committee to protect sources of drinking water; determining the criteria for the operation of health care, education and training, public places and centers, procurement, distribution, storage and sale of food, drink, health, and how to deal with offenders etc..
Environment Protection Council Resolution No. 156 on the preparation of the environmental assessment report	Domestic	Petrochemical requirements (at any scale), refinery (at any scale), power plants (with a capacity of more than one hundred megawatts of birth), steel, dams and hydraulic engineering, irrigation and drainage projects (with an area of more than one hundred hectares) and airports (with a runway length of over two kilometers) to prepare environmental assessment reports.
Law on how to prevent air pollution	Domestic	Defining air pollution and the emphasis on the prohibition of air pollution; Categories enhancing air pollution sources and determining the conditions and regulations governing each of these groups, determining the punishment of individuals and centers of air pollutants, determining how to enhance community awareness on air pollution.
Criteria and establishment of industries.	Domestic	Classifying and identifying industry groups based on the level of pollution and other environmental issues; Determining the range allowed for the establishment of each of the polymorphic industry groups, determining the general criteria for the establishment of industries.
Act No. 249's High Council of Environmental Protection on environmental assessment and national development plans and major projects on the coastal area	Domestic	Evaluating the definition of the coastal environment, emphasizing the need to prepare an environmental impact assessment report (independent of the scale and size) within the range of evaluating the coastal environmental assessment, preparation of other project reports, subject to the environmental assessment within the defined areas, especially the sensitive areas as well as the determination of these areas.
Administrative law and the law of solid waste management	Domestic	Defining wastes and classifying executive management of solid waste, waste processing, etc., determining how to educate and gather information in the field of waste management, determining how to obtain the financial costs of waste management;

		determining the conditions for landfills; determining requirements for cross-border transfers of special waste, the penalties for violation of the law.. .
Supreme Council of Environmental Protection regarding the determination of plans and projects subject to environmental assessment studies	Domestic	Determining 51 industries and activities required to undertake environmental assessment studies; Describing a brief outline and curriculum of evaluation reports and projects subject to environmental assessment.
Coastal and built land law	Domestic	Newly defined territory, territorial sea and privacy; Determining coastal lands; emphasizing on the land newly belonging to the government; exceptions determined by law; penalties and seizure of illegal activity in coastal areas.
Article (184) of the fifth program of economic development, social and cultural Islamic Republic of Iran	Domestic	Developing and implementing "strategic environmental evaluation system" at the national, regional and subject, determining the national body responsible for strategic assessment of the environmental council, environmental protection as part of the national development plans, and other related programs , compliance with the criteria approved by the High Council for environmental protection activities Coordinating Councils in regional development (responsible for strategic environmental assessment programs as regional development); delegating administrative tasks to the High Council for environment and provincial departments of environmental protection.
United Nations Framework Convention on Climate Change (UNFCCC)	International	Finding and implementing strategies to cope with the effects of climate change and the increasing concentration of greenhouse gases.
The Kyoto Protocol	International	Regulations relating to greenhouse gas emissions; the obligation of the Contracting States to reduce greenhouse gas emissions by 5% compared to the level of emissions in 1990 (in the interval 2008 to 2012).
Convention on Trans-boundary Environmental Impact Assessment (ESPPO)	International	Determining the legal obligations of the Parties regarding trans-boundary effects of the proposed development activities with an emphasis on finding ways of dealing with their trans-boundary environmental impacts.
United Nations Convention to combat desertification in countries seriously faced with drought and desertification (UNCCD)	International	Control measures to mitigate desertification and soil and water protection against drought.
Convention on the Prevention of marine pollution from waste and other materials (Marine Dumping)	International	Development, protection of the marine environment
Convention on the Prevention of marine pollution from ships (Marpol) 78/73	International	Pollution resulting from maritime transport.
Kuwait Regional Convention for Cooperation on the protection and development of the marine environment and coastal areas from pollution (Kuwait- 1979)	Regional	Dealing with the increasing risk of marine pollution to the environment and human health (in a limited geography of the Persian Gulf.)

Source: Jozi and Jafaripoor 2010.

(5) Threats by access roads to Hara Protected Area

Four access roads with asphalt pavement reaching the jetties in the mangrove forest in the Hara Protected Area were identified (Figure A2.2.1).

Source: Google earth, geotrack by JICA Project Team.

Figure A2.2.1 Jetties and Access Roads Identified and the Draft Zoning Plan in Hara Protected Area

A2.2.2 Proposal of geopark short term strategies

(a) Strategy 1: Attempt to regain the GGN logo again. Qeshm Geopark Office works hard for the island and the islanders presently. However, gaining, then keeping the GGN brand can assists to go ahead faster according to its objectives for example to respond this objective: Enhancement of a Middle East Regional Network of Geopark, establishment as the center (and best practice example) for a future Middle East Regional Network is a strategic objective for Qeshm Geopark (Eckhardt 2008).

(b) Strategy 2: Having a new Master Plan. Providing a new MP for Qeshm Geopark or revising the existing plan (2009), for whole island is more than a necessity, because the geopark boundary extended to the whole island and surrounding as the issues on the island are getting more challenging, complicated and sensitive due to the recent changes in the Persian Gulf region. Qeshm Geopark should understand its assets accurately and the outcome of JICA Project can basically be a good chance for further studies for geopark. On the other hand, Geopark Office does not know all economic potentials especially to improve locals' livelihood and all valuable geological phenomena in island to demarcate proper geosites. In that case, following objectives for Qeshm Geopark are considerable in the coming plans:

- ✓ Objective 1: Participating in conserving the natural values of Qeshm as a well-known heritage.
- ✓ Objective 2: Conserving and promoting geo-heritage of Qeshm Island together with the locals.
- ✓ Objective 3: Persuading locals to identify and improve their economy based on their knowledges.
- ✓ Objective 4: Capacity building to empower vulnerable groups like women.

- ✓ Objective 5: Protecting the valuable cultural diversity of the island.
- ✓ Objective 6: Enriching the touristic destinations in villages and natural recourses.
- ✓ Objective 7: Torch bearing of the Middle East and African geoparks.

All geosites should have a specific conservation plan since they have diverse characteristics.

(c) Strategy 3: Towards international networking: A plenty of international activities should plan and do in the Middle East, Africa and the world. For example thanks to the JICA Project Team closer collaboration between Japanese and Qeshm Geopark is expected. By now, Japan has 39 national geoparks while eight of them gloried in GGN brand so it looks Japanese Geoparks' Network (JGN, Since 2009) has a brilliant experience for co-working, bottom-up managing system, collaborating with private companies, networking, regional and international activities. In 2009 application of Itoigawa Geopark to the Global Geoparks Network was accepted and it became Japan's First Global Geopark.

(d) Strategy 4: Replanning the management system: Qeshm Geopark Office should have a strong managerial system to cover all main tasks has been shown in the following table through a very close collaboration with the stakeholders. The table below shows a proposed system for Major Tasks, according to objectives and experiences and includes the expectations from any other sectors.

Table A2.2.4 Geopark Major Tasks

Geopark Major Tasks	Anticipated Supportive Stakeholders	Importance (Max. 5)	Expected duties
Planning, Rural Development	QFZO Deputy for Infrastructures and Construction Engineering (DI)	5	Plans approval (management plan, geosites plans, detailed plans, rural plans...)
			Construct infrastructures
	QFZO Management for Budgeting and Programming	4	Budgets approval and speeding up payments to contractors
	Bonyad Maskan (Housing Foundation)	2	Modify the rural plans according to geopark criteria
Networking, Participating and Collaborating[1]	Qeshm County Governor	2	Organizing the councils and mayors of cities and villages
	County Bureau for Culture and Islamic Guidance	3	Support cultural and artistic activities implementing by geopark
	County Bureau for Cooperatives, Labour and Social Welfare	1	Promote investing in rural cooperatives according to geopark requests
Promoting and Marketing	QFZO Deputy for Socio-culture, Education, Sports, Tourism, … (DC)	5	Support geotourism, handicrafts, accommodations, adventure, events, and activities
	QFZO Deputy for Economy and Investments	3	Facilitating the enterprises introduced by geopark
	QFZO Public Relations	2	Promoting Qeshm Island as a sound geopark in mass media
Conserving Cultural Assets	QFZO Deputy for Socio-culture, Education, Sports, Tourism, … (DC)	4	Support social and cultural events and activities
	County Bureau for Culture and Islamic Guidance	3	Support social and cultural events and activities
	County Bureau for Education	5	Negotiating with ministry to localize educating thorough Qeshm Island
Protecting Geological Heritages	QFZO Deputy for Infrastructures and Construction Engineering (DI)	4	Controlling any usage from the geosites and report regularly to geopark
	County Bureau of Environment	4	Acting against any illegal usage from the geosites and reporting to geopark
	QFZO, Department of Environment	5	Watching any illegal usage from the geosites and reporting to geopark
	QFZO, Management for Industries	3	Permitting respecting to the criteria by geopark
	Court	5	Speeding up the dossiers titled by geopark
Performing Scientific and Educational Activities	QFZO Deputy for Socio-culture, Education, Sports, Tourism, …	3	Supporting scientific and educational activities by geopark
	County Bureau for Education	5	Sharing knowledge by bridging teachers to geopark experts. Sharing educational facilities in villages. Organizing seminars and field visits for students and teachers.
	Vocational Training Organization	3	Educating adults for hospitality, tour leading, or any new type of educating.

Source: JICA Project Team

Such big collaboration at least has these two requirements:

[1] With GGN, Private Companies, Local Small and Medium Size Businesses, NGOs

(a) A concrete collaboration between sectors is highly demanded, it is proposed to create two "advisory committees" in the county level as soon as possible. These advisory committees should discuss the objectives of Qeshm Geopark and how to reach it.
   i) Experts' Committee: Experts from all above sectors should gather each three months and discuss. The meetings should be managed by Geopark Office.
   ii) Administrative Committee: The managers of the above sectors should gather each six months and discuss the reports from the experts and make decisions. The CEO of QFZO should manage such committee or at least one of the deputies.

(b) A smart, quick, bottom-up and swift managing system. Here it is proposed some sketchy solutions that can be discussed by the committees' members:
   iii) Reforming the current situation to have a more quick system and much collaboration.
   iv) A new institute belongs %100 to QFZO.
   v) A new institute belongs %51 to QFZO.
   vi) A new management under the direct supervision of CEO of QFZO.
   vii) A new deputy in QFZO
   viii) Applying big and deep changes in the structure of QFZO to make it as a Geopark Organization.
   ix) Other solutions in other countries to be considered.

A2.3 Environmental Carrying Capacity

A2.3.1 Carrying capacity

(1) Definition of carrying capacity

Carrying capacity is usually defined with respect to population of a single biological species in an environment. The carrying capacity is the maximum population size of that particular species that the environment can sustain indefinitely, given the food, habitat, water, and other necessities available in the environment. To sustain this species, however, other species need to be present in the same environment either to provide food, habitat or any other conditions necessary for the survival of this species. Therefore, carrying capacity should be defined by biotope or specific habitat of many species sharing a common environment.

Nature as a collective biotope or any individual biotope has just an adequate mix and population size of species naturally within its carrying capacity. Within the biotope, certain species may become more dominant occasionally due to external factors such as changes in physical environment. This may affect the population of other species, which may, in turn, affect the dominant species. As long as such changes do not result in extinction of certain species, however, the carrying capacity should be restored.

A simple case of the deer-plant interaction clarifies the point. In Mississippi in the United States of America, the growth of deer population leads to the decrease of plants (deer food), threatening the carrying capacity of their own living habitat. Decrease in plants, in turn, results in decrease in deer population, which will help the recovery of plants and restoration of the original carrying capacity. This is expected if there is no human intervention such as supplemental feeding of deer during the lean period. Carrying capacity becomes an issue once there exist human interventions.

(2) Carrying capacity of Qeshm

Carrying capacity of Qeshm with respect to human population is at an issue. The carrying capacity of Qeshm for human population is naturally determined by water resource endowment so that the Qeshm population has been historically small. However, water availability is expanded by generating fresh water by desalination. That is, the carrying capacity can be expanded. The question now is to what extent the carrying capacity can be expanded.

To generate fresh water by desalination, electric energy is required. To generate electricity, abundant natural gas may be used. There exists a limit to the use of natural gas not only due to limited endowment of the natural gas but also due to adverse environmental effects associated with the extraction and use of natural gas and development activities by human beings made possible by much expanded water supply. Thus, the carrying capacity cannot be expanded indefinitely. Then, the question is to what extent the carrying capacity can be expanded without causing adverse environmental effects. To answer this question, it is necessary to define how to measure adverse environmental effects and thresholds of tolerance.

(3) Biodiversity

The concept of "satoyama" and "satoumi" has been applied to development planning for the Qeshm eco-island. Development and management of satoyanma and satoumi realize the increase in biodiversity through human-nature interactions. It is natural, therefore, to define carrying capacity as a limit that will not result in decrease in biodiversity. Then, the question is how to measure biodiversity.

As stated above, carrying capacity should be defined by biotope or specific habitat of many species sharing a common environment. A mixture of many species constituting any biotope represents biodiversity. For pragmatic measuring purposes, such a mixture may be represented by one or a few species for sustainability.

A mangrove forest represents a biotope, where many species are interacting in various ways. The mesh of mangrove roots offers a stable marine region for many young organisms. The areas where roots are permanently submerged offer habitats for such organisms as algae, barnacles, oysters, sponges, and bryozoans. Shrimps and mud lobster utilize muddy bottom. While mangrove crab offers nutrients to mangal muds, predation of plant seedlings by crabs is also common. Complexity of interactions makes it difficult to select a single species to represent the biotope, and mangrove family of plants itself may be taken as the representative species for this biotope.

A coral reef colony represents another biotope, widely known for rich biodiversity. It offers spawning areas for some species and safe shelters for some other species, especially their infants. Moreover, coral reefs provide ecosystem services to tourism, fisheries and shoreline protection. Its benefits go well beyond the areas of their presence. The biodiversity of coral reefs encompasses complex food chains with large predator fish eating smaller forage fish that survive on yet smaller planktons and so on. They depend eventually on plants as the primary producers. Coral reefs' primary productivity is very high, reported to be typically 5–10 grams of carbon per square meter per day (g-C/m^2/day) biomass production

(4) Coral reef as a biological indicator of biodiversity

1) Degradation of coral reefs

As indicated above, environmental carrying capacity (ECC) becomes an issue with presence and intervention of human beings. The carrying capacity for Qeshm may be defined as a limit that will not result in decrease in biodiversity. Satoyama and satoumi as applied to the Qeshm eco-island development represent increased biodiversity through human-nature interactions. Human interventions, however, often result in decrease in biodiversity, and in and around the Qeshm island, planned and on-going human activities are threatening the biotopes of rich biodiversity such as mangrove forests and coral reef colonies.

Degradation of coral reefs is caused by stresses due to human activities directly and indirectly. Major forms of stresses are as follows.

(a) Destructive fishing practices,
(b) Overfishing, particularly of herbivorous fish that leads to algal growth,
(c) Careless tourism such as boating, diving, snorkeling, and fishing as well as dropping anchors on reefs,
(d) Coral mining for economic uses,
(e) Pollution by industrial wastes, sewage, agro-chemicals and oil spills, including discharge of nutrients to cause algal overgrowth,

(f) Coastal development to cover reefs with sand, rocks and concrete, and dredge and blast to improve navigational access and safety for ships,
(g) Sedimentation due to erosion caused by construction activities and land use, and
(h) Climatic changes causing sea water temperature rises, leading to coral bleaching and diseases.

2) Coral reef as a biological indicator

As a coral reef represents rich biodiversity and is vulnerable to various stresses by human activities, it is meaningful to use it as a biological indicator of biodiversity. Effects of human activities on coral reefs are measured by many indices representing the quality of sea water. In general, coral reefs are adopted to waters with low nutrient contents, and need clean water to survive. Also, coral bleaching occurs when the symbiosis breaks down between corals and zooxanthellae, which is sensitive to sea water temperature rise and turbidity reducing sunlight penetration.

In view of these conditions, proper indices are selected to measure these effects on coral reefs. For each index, a threshold level may be defined to make judgements on whether effects are tolerable for any particular coral reef colony. Possible indices and thresholds are listed in Table A2.3.1.

Table A2.3.1 Possible Indices to Measure Effects on Coral Reefs with Thresholds

Index	Main causes	Threshold	Adverse effect*
Sea surface temperature	Global warming, desalination, cooling water, industrial effluents		S
PH of sea water	CO_2 emission, desalination		(S)
Turbidity	Surface runoff, erosion, solid wastes	TSS <	S
Nutrient contents	Sewage discharge, industrial effluent	Total-N <	M
Salinity of sea water	Desalination		M
Toxic chemical in sea water	Industrial wastes	Trace	S

Note: S: significant, M: moderate
Source: JICA Project Team

According to Prof. Fereidoon Owfi, most important index to measure effects on coral reefs is sea surface temperature, followed by turbidity. PH of sea water is also important, but it is closely associated with sea surface temperature, which affect CO_2 assimilation. Coral reefs may be less sensitive to nutrients unless excessive nutrients cause algal blooms. High salinity caused by desalination may not cause significant effects as long as it remains a local phenomenon. If effects of any human interventions such as urban and industrial development are quantified by these indices, sound judgements can be made on overall effects on coral reefs by collective use of all the indices.

3) Other possible biological indicators

Two other possible biological indicators of Qeshm biodiversity are bottle-neck dolphin (Tursiops truncates) and hawksbill turtle (Eretmochelys imbricate). Groups of bottle-neck dolphins are commonly found in the Hangom Bay and its surrounding sea. They are spotted off the southwestern coast and around the Larak Island as well. Nesting sites of hawksbill turtles are located in the Shibderaz area and part of the southwestern coast, where sandy beaches are present.

Population of bottle-nose dolphins is affected by the distribution of fish as their feed. As coral reefs provide spawning areas and safe shelters for some fish species, degradation of coral reefs may reduce the dolphin population. Such effects may be limited as long as coral reefs degradation is confined to some areas, since dolphins can swim around to find their feed in other waters.

Population of hawksbill turtles may be affected more by the presence of seaweed as their feed rather than coral reefs. It is affected by human activities not through the quality of sea water but through other conditions including alteration of sandy beach, artificial lights, and littering and oil spills on beaches as well as human presence on beaches itself. These conditions should be separately considered to assess effects of human activities, while assessing the environmental carrying capacity of Qeshm.

While a coral reef is used as a primary biological indicator of biodiversity of Qeshm, effects of coral reefs degradation on bottle-neck dolphins and hawksbill turtles should be further investigated and clarified. In the meantime, these biological indicators may be used in combination to ensure human activities would not undermine the biodiversity of Qeshm in any way and at any location.

A2.3.2 Effects of land development on seawater quality

(1) Framework for evaluating effects of land development on seawater quality

Land development for various uses affects seawater quality directly by discharge of wastewater as well as surface runoff, and indirectly through climatic changes and complicated physico-chemical processes. The direct effects are due mainly to use of water and electricity. In the Qeshm island, water and electricity uses are interacting one another as water for various uses are generated by desalination, which utilizes large amount of electricity, and power generation utilizes large amount of water for cooling and other purposes.

To evaluate effects of present and future land use on seawater quality, the following land use classes and sub-classes may be defined. All the land use sub-classes rely on desalination plants for water supply and power plants for electricity supply, which generate wastewater in one way or another. Wastewater generated by different land use sub-classes is treated by different facilities before discharged into sea as shown in Table A2.3.2.

Table A2.3.2 Land Use Classification and Facilities to Link Land Development and Seawater Quality

Main land use class	Land use sub-class
Settlement/residential use	Urban/residential
	Rural
Industrial development	Industrial estate
	Other industrial use
Special use	LNG plant
	Port and related facilities
Other land cover	Rocky areas
	Sandy/silty areas

Land-sea link
Desalination plant
Power plant
Residential WWTP
Industrial WWTP
Drainage system

Source: JICA Project Team

Wastewater generated by different facilities has widely varied quality, and measures by various indices. Main indices to be used to evaluate the effects of land development on seawater quality are summarized in Table A2.3.3.

Table A2.3.3 Main Indices to Use in Evaluating Effects of Land Development on Seawater Quality

Facilities	Wastewater	Indices
Desalination plant	Brine	Salinity
Power plant	Hot water	Temperature
Residential WWTP	Effluents	Water quality indices
Industrial WWTP		
Drainage system	Surface runoff	Sediment

Source: JICA Project Team

(2) Indices to Evaluate Effects of Land Development on Seawater Quality

Effects of desalination and power generation are measured respectively by salinity of seawater and temperature of seawater surface. Other water quality indices to be used to evaluate effects of land development on seawater represent effluent quality of discharges from wastewater treatment plant (WWTP) and quality of surface runoff. Surface runoff involves also sedimentation on coastal areas, but this effect may be small in the Qeshm Island. In fact, wave actions and tidal currents are the main sources of erosion and sedimentation in Qeshm as precipitation is extremely small. Effects of surface runoff on seawater quality appear mainly as sediment contents in seawater.

In addition to salinity and seawater temperature, water quality indices to be used in the evaluation include pH, BOD, SS and Total-N at least, and possibly COD, Total-P and Phenols as well.

(3) Reference data on selected water quality indices

For the selected water quality indices, reference quality standards are taken from representative cases and summarized in Table A2.3.4. Standards for WWTP in Japan mean the quality of wastewater that can be accepted by public WWTPs. Discharge standard in Japan means the quality of effluent that can be discharged into ambient water body. Discharge standard from industrial estate (IE) in Thailand means maximum levels of effluent quality from any industrial estates permitted by law in Thailand. Discharge standard for central WWTP in IE in Thailand means the quality of effluent that can be discharged into the central WWTP within any IE.

Table A2.3.4 Reference Quality Standards for Water Quality Indices Applicable to Wastewater of Different Sources

Index	Unit	WWTP in Japan	Discharge standard in Japan	Discharge standard from IE in Thailand	Discharge standard for central WWTP in IE in Thailand
Temperature	℃	45		40	45
pH		5~9	5~9	5.5~9.0	5~9
BOD	mg/l	600	160	20	500
SS	mg/l	600	200	50~150	200
Total-N	mg/l		200	50~150	200
Total-P	mg/l		16		
COD	mg/l		160	120~400	
Phenols	mg/l	5	5	1	

Source: JICA Project Team

(4) Data used to evaluate effects of land development on seawater quality

In the Qeshm island, practically all piped water for domestic, industrial, commercial and public use will be produced by desalination in the near future. Except water used for domestic purposes in rural areas, wastewater will be treated mostly by a secondary WWTP. Domestic wastewater in rural areas may be discharged into sea without treatment, mixed with surface runoff drained from rocky and sandy/silty areas. Effluents from industrial estates, LNG plants and ports with related facilities shall be treated properly before discharged into sea. The treatment level must be generally at secondary level at least, but effluent quality may vary depending of actual loads of wastewater and specific industries.

Considering uncertainties involved in effluent quality from specific sources in the future, a range is determined for water quality measured by selected indices of effluent from residential and industrial WWTPs and surface runoff. Based on the reference data presented above, the ranges are set as shown below for residential and industrial WWTPs and surface runoff.

Table A2.3.5 Ranges of Input Water Quality for Discharge of Different Sources

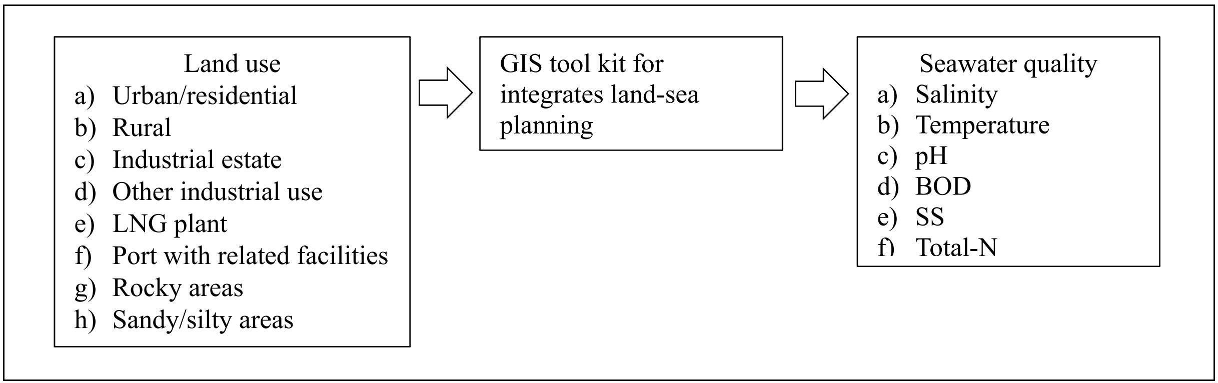
Index	Unit	Residential WWTP	Industrial WWTP	Surface runoff
Salinity	g/kg	NA	NA	0.1~1.0
Temperature	℃	NA	NA	30~45
BOD	mg/l	30~150	30~500	100~150
SS	mg/l	50~200	50~200	200~500
Total-N	mg/l	100~120	100~200	100~200

Source: JICA Project Team

For salinity and temperature of wastewater discharged from desalination and temperature of wastewater discharged from power generation, the range will be determined based on actual data of existing plants.

(5) Integrated Land-Sea Planning with GIS

With input from land development specified as described above, effects on seawater can be evaluated by using GIS as illustrated in Figure A2.3.1.



Source: JICA Project Team

Figure A2.3.1 Structure for Evaluation of Effects of Land Development on Seawater Quality by Using GIS

If the seawater quality is found unacceptable by any biological indicator, the scale of land development would be reduced. The maximum level of land development that would not cause any unacceptable results of seawater quality corresponds to the carrying capacity of the land-sea system.

Following the framework for evaluating effects of land development on seawater quality, the trial calculation was tentatively made.

A2.3.3 Tentatively Estimated Effects of Land Use on Seawater Quality

(1) Procedure

1) Prepare a simplified future land use (in 2036?) for each development area.

Land use class	Simplified land use class
Urban/residential	Residential
Commercial, public, institutional etc.	
Rural settlement	
Industrial	Industrial
Agriculture/orchard	Agricultural/orchard
LNG plant	Special purpose
Port and associated facilities	
Recreational	
Bare land: rocky/sandy/silty	Bare land
Sandy beach	Sandy beach

2) Assume quantity of wastes to be generated by broad land use class.

Two water quality indices are used:

(a) Sedimentation or TSS due to surface runoff, and
(b) Ammonium-N (NH4+) representing sewage quality from domestic and industrial uses.

Ammonium-N is used as some measured data around Qeshm are available as below.

Name	Date	Time	Water Temperature	Salinity	pH	NH4-N	NO2-N
Unit	-	-	oC	-	-	mg/L	mg/L
WQ-N1	26/4/2016	11:15	26.5	35.6	8.34	1.0	0.005
WQ-N2	26/4/2016	11:35	27.6	35.7	8.34	0.5	0.005
WQ-N3	26/4/2016	11:58	27.3	35.8	8.35	0.3	0.005
WQ-N4	26/4/2016	12:12	27.0	35.8	8.35	0.5	0.005
WQ-N5	26/4/2016	12:36	27.6	35.8	8.35	0.8	0.010
WQ-N6	26/4/2016	10:55	26.6	35.5	8.19	0.3	0.005
WQ-S1	10/5/2016	10:40	31.8	40.2	8.82	<0.2	<0.005
WQ-S6	10/5/2016	10:20	29.7	39.7	8.18	<0.2	<0.005

Since treated sewage is used for watering plants and other purposes, its discharge becomes part of runoff rather than discharge from point sources. Quantity of treated sewage may be converted to equivalent precipitation and added to the surface runoff.

3) Convert future land use into waste loads.

Two effects are distinguished: precipitation and treated sewage.

(a) Precipitation: The annual average precipitation in Qeshm is about 130mm with the maximum monthly precipitation of about 50mm occurring in January with four to five rainfalls. The maximum amount of rainfall is assumed at 20mm/day. Effects of rainfall during this critical rainfall period are quantified as most adverse effects on seawater with respect to TSS.
(b) Treated sewage: Effects of treated sewage is treated as additional waste loads during the critical rainfall period with respect to TSS and Ammonium-N.

4) Simulate the effects of surface runoff due to precipitation by applying GIS model.

For non-development area, i.e. bare land, natural precipitation is applied to simulate the effects of surface runoff. For development areas, effects of treated sewage are simulated as additional mm together with the natural precipitation. The additional mm of treated sewage contains TSS and Ammonium-N as waste loads. Results are combined with the effects of surface runoff due to the natural precipitation expressed as total quantity of TSS and Ammonium-N.

5) Convert the total quantity of TSS and Ammonium-N into concentration of these wastes in seawater by applying GIS model.

To be checked:

- How the precipitation data are put into the GIS model?
- For which time period and areal extent of sea, should the effects on seawater be evaluated?

The precipitation data are specified by land use class, where "precipitation" for any development area is sum of the natural precipitation and equivalent mm of treated sewage. Simulation is conducted for the critical precipitation period so that the effects om seawater may be measured also for the critical period. For the areal extent of sea, the coastal seawater up to the depth of 5m may be taken since the coral reefs along the southern coast of Qeshm are found at the depth of about 3m or deeper, and presence of coral reefs at depth more than 5m is unlikely due to difficult sun light penetration.

(2) Input data required

1) Basic input data

The following data are required at minimum to simulate the effects of land use on seawater quality.

(a) Amount of treated sewage from different land use classes,
(b) Quality of treated sewage from different land use classes, and

(c) Amount of water use for different purposes: domestic, industrial, agricultural and other.

2) Estimation of water use and sewage generation for different purposes

<u>Baseline conditions in 2011</u>

Based on the data on water demand and service population by desalination plant, the total water demand is broadly divided into domestic and industrial demand as shown below. For domestic water demand, per capita use of 130 liter /capita/day and water loss ratio of 25% are assumed for service areas of most desalination plants. For dominantly rural service areas, per capita use of 100 liter/capita/day and water loss ratio of 10% (as water is delivered mostly by tank rather than transported by pipes) are assumed. The total water demand in 2011 is calculated to be 19,908 m^3/day for domestic and 18,142 m^3/day for industrial use, respectively.

Location of desalination plant	Water demand (m^3/d)	Water-supplied population (p)	Domestic water use (m^3/d)	Industrial water demand (m^3/d)
Qeshm City	16,500	36,326	6,297	10,203
Baseidou	600	10,819	600	0
Dargahan	4,000	15,404	2,670	1,330
Souza	860	4,991	860	0
Hangom	250	410	71	179
Ramchah	1,000	4,327	750	250
Kouvei	4,000	4,999	866	3,134
Karavon	400	3,332	370	30
Tabl	440	3,526	392	48
Selakh	1,000	3,172	550	450
Mapna Plant	9,000	37,394	6,482	2,518
Total	38,050	124,700	19,908	18,142

Amount of wastewater generated from domestic use is assumed to be 80% of the water used or 15,926 m^3/day. Amount of wastewater generated from industrial use is assumed to be also 80% of the water used or 14,514 m^3/day. This corresponds to 33m3/day/ha. Assuming 50% recycling, total of 7,257 m^3/day is discharged as treated sewage from industrial use.

The data on land use distribution in Qeshm show the total buildup area is 1,993 ha and the total industrial area is 552 ha, respectively in 2016. It is assumed that these data represent the baseline conditions, and the buildup area corresponds to service area by desalination and the industrial area is the area where industries are actually located rather than the area of existing industrial estates.

By combining the water demand estimates and the buildup and industrial areas, average sewage generation from each land use class is calculated. That is, the average sewage generation from the buildup area is calculated to be 0.80 mm/day or 292mm/year, and the average sewage generation from the industrial area 1.31 mm/day or 480mm/year.

<u>Possible conditions in 2036</u>

The total population in Qeshm is projected to be 254,500 in 2036. This is broadly divided into 200,000 urban and 54,500 rural population. Assuming unit domestic water use at 200 liter/capita/day for urban and 150 liter/capita/day for rural population, the total domestic water demand is calculated to be 48,175 m^3/day. The total wastewater generation from domestic use is calculated to be 38,540 m^3/day or 80% of the water used.

The total employment in industries in Qeshm is projected to be 32,360 in 2036. This is converted to effective industrial land use of 1,618 ha at 20 employees/ha. The total amount of industrial water use is estimated to be 48,540 m^3/day at 30 m^3/day/ha derived from the present water use. This corresponds to sewage generation of 38,832 m^3/day. By assuming 70% recycling, the total amount of treated sewage to be discharged from industries is 11,650 m^3/day.

The total buildup area is calculated to be 3,523 ha at 75 persons/ha. The amount of treated sewage generation at 38,832 m^3/day from domestic water use is converted to equivalent precipitation of 1.10 mm/day or 402mm/year. The total amount of treated sewage discharged from industries at 11,650 m^3/day is equivalent to 0.73 mm/day or 263 mm/year.

3) Quality of wastewater from different sources

Quality of wastewater from different sources is determined for future conditions. Specifically, the total suspended solid should be determined for natural surface runoff, treated sewage from domestic and industrial uses, and the Ammonium-N content should be determined for treated sewage from domestic and industrial uses. Based on reference data from wastewater treatment plants in different countries, the following quality is assumed for different sources.

	Domestic sewage	Industrial sewage	Surface runoff
TSS (mg/liter)	50	50	20
Ammonium-N (mg/liter)	50	100	NA

(3) Trial calculation

Selakh is taken for trial calculation, and future land use is assumed as follows.

	Residential	Industrial	Agricultural /orchard	Special purpose	Bare land	Sandy beach
Area (ha)	90	40	40	200	2,500	50

Waste loads from surface runoff and treated sewage are estimated as follows.

Land use	Area (ha)	Precipitation (mm/month)	Sewage quantity (mm/month)	Waste concentration (mg/liter)		Waste load (ton/month)	
				TSS	Ammonium-N	TSS	Ammonium-N
Residential	90	50.0	33.0	50	50	1.485	1.485
Industrial	40	50.0	11.0	50	100	0.220	0.440
Agric./orchard	40	50.0	11.0	20	100	0.400	0.440
Special purpose	200	50.0	5.0	20	100	2.000	1.000
Bare land	2,500	50.0	0.0	20	0	25.000	0.000
Total	2,870			12.33	2.75	29.105	3.365

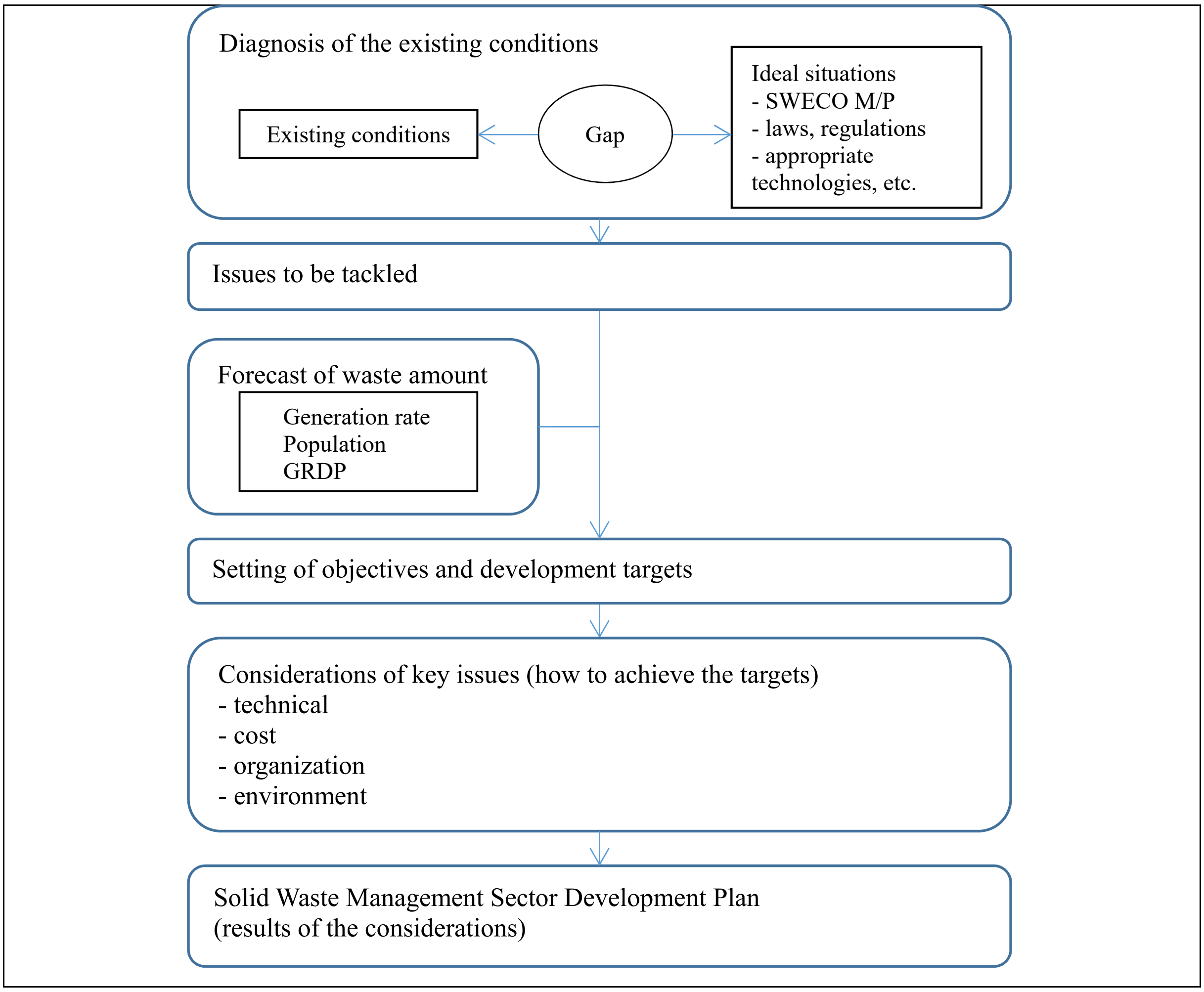
Receiving seawater body is assumed to be the coastal seawater up to the depth of 5m, which has the total water volume of some 6million m^3. Assuming complete mix of wastewater from the land with the receiving seawater within the critical month, the resultant concentration of wastes in seawater is calculated to be 4.85 mg/liter TSS and 0.56 mg/liter Ammonium-N. These are probably upper bounds of seawater quality as portions of waste loads are assimilated by plants, adsorbed by soil and sand, dissipated further in the seawater, and dispersed by sea currents.

The concentration of Ammonium-N as calculated is significantly higher than the concentration observed in several locations along the Qeshm coast. The TSS concentration is also high, but a portion of sediment may be trapped at the sandy beach rather than discharged into seawater.

A2.4 Estimate of Solid Waste Amount and Waste Stream for Solid Waste Management

A2.4.1 Planning flow for development plan of solid waste management

The figure below shows a flow of planning the solid waste management sector development plan. "Existing conditions", "issues to be tackled", and "objectives and development targets" are shown in the previous sections. This section presents "forecast of waste amount", "considerations of key issues", and "solid waste management sector development plan.



Source: JICA Project Team

Figure A2.4.1 Flow of Planning the Solid Waste Management Sector Development Plan

A2.4.2 Forecast of Waste Amount

(1) Ordinary Waste

1) Waste Generation Rate and Composition

A detailed study on amount and composition of ordinary waste has not been conducted in Qeshm. Therefore, such basic conditions for planning are set referring to existing information in other cities in Iran.

<u>Waste Generation Rate and Composition in Other Cities in Iran</u>

Several literatures which show results of detailed study on amount and composition of ordinary waste in other cities in Iran are available on the internet. The following table shows information which is thought to be appropriate as reference.

Table A2.4.1 Generation Rate and Composition of Ordinary Waste in Other Cities in Iran

City	Generation (kg/person/day)	Composition (%)					
		organic	paper	plastic	metal	textile	others
Mahabad	0.878	75.17	3.79	9.78	0.83	1.93	8.50
Tehran	0.84	69.66	9.37	6.82	1.53	1.89	10.73
Isfahan	0.69	68.97	4.10	17.80	1.38	2.90	4.85
Rasht	0.8	70.25	7.70	13.90	0.80	1.20	6.15
Sistan, Baluchestann	0.748	65.42	10.50	10.80	4.90	2.20	6.18
Average of Iran	0.64	72.63	8.92	4.50	2.24	2.52	9.19

Source: Erami, Shahmoradi and Maleki, 2015, "Municipal Solid Waste Management in Mahabad Town, Iran", Journal of Environmental Science and Technology

Waste Generation Rate in Bandar Abbas and in SWECO Master Plan

The JICA Project Team visited Bandar Abbas in May 2016 and interviewed a municipal officer who was in charge of waste management in the city. According to him, the city has a population of approximately 500,000 people and collects a waste amount of 300 ton every day. This leads to waste generation rate of 0.6 kg/person/day.

In the SWECO Master Plan, 0.8 kg/person/day was set as ordinary waste generation rate. This figure seems to be appropriate as waste generation rate for Qeshm taking into consideration ones in other cities.

Waste Generation Rate for Planning

Based on the information presented above, generation rate of ordinary waste for planning the sector development plan has been set as follows.

Table A2.4.2 Generation Rate of Ordinary Waste for Planning

Planning Phase	Year	Ordinary (kg/person/day)	
		Urban	Rural
Current	2016	0.800	0.600
	2017	0.810	0.605
Short	2018	0.820	0.610
	2019	0.830	0.615
	2020	0.840	0.620
	2021	0.850	0.625
Mid	2022	0.860	0.630
	2023	0.870	0.635
	2024	0.880	0.640
	2025	0.890	0.645
	2026	0.900	0.650

Planning Phase	Year	Ordinary(kg/person/day)	
		Urban	Rural
Long	2027	0.910	0.655
	2028	0.920	0.660
	2029	0.930	0.665
	2030	0.940	0.670
	2031	0.950	0.675
	2032	0.960	0.680
	2033	0.970	0.685
	2034	0.980	0.690
	2035	0.990	0.695
	2036	1.000	0.700

Source: JICA Project Team

Waste Composition for Planning

Based on the information presented above, composition of ordinary waste is set as shown in table below.

Table A2.4.3 Generation Rate and Composition of Ordinary Waste for Planning

<table>
<tr><th rowspan="2">Area</th><th colspan="6">Composition (%)</th></tr>
<tr><th>Organic</th><th>Paper</th><th>Plastic</th><th>Metal</th><th>Textile</th><th>Others</th></tr>
<tr><td>Urban</td><td rowspan="2">70</td><td rowspan="2">10</td><td rowspan="2">5</td><td rowspan="2">2</td><td rowspan="2">3</td><td rowspan="2">10</td></tr>
<tr><td>Rural</td></tr>
</table>

Source: JICA Project Team

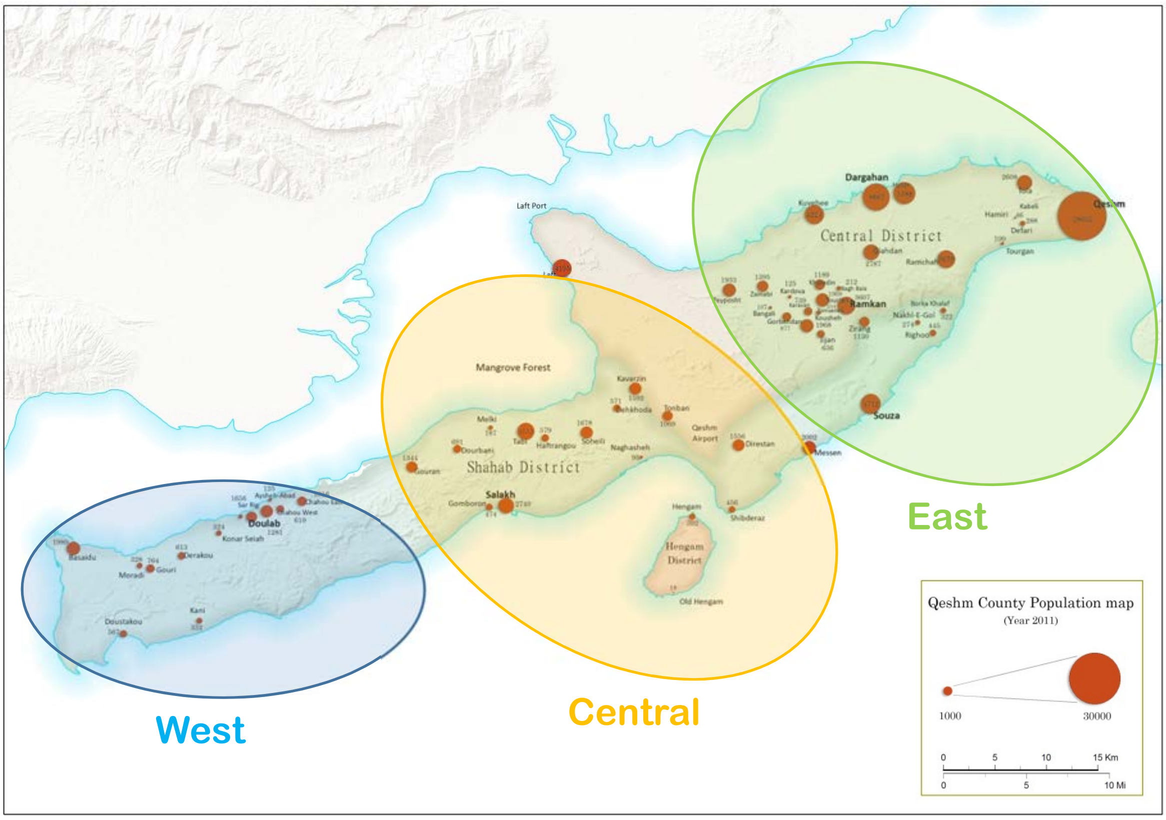
2) Area Division

The island is divided into three (3) areas of East, West, and Central to ensure the efficiency of collection and transport as shown in figure below. East Area is regarded as urban. Meanwhile, Central Area and West Area are deemed as rural.

Table A2.4.4 Population Forecast in Area Division

Phase	Year	East (urban)	Center (rural)	West (rural)	Total
Current	2016	91,806	25,712	11,082	128,600
Short	2021	108,047	29,403	12,550	150,000
Mid	2026	128,576	35,223	14,201	178,000
Long	2036	184,291	48,272	21,937	254,500

Source: JICA Project Team



Source: JICA Project Team

Figure A2.4.2 Division of Area for Solid Waste Management

3) Forecast of Ordinary Waste Amount

The table below shows forecast of ordinary waste generation based on the generation rates and the population shown in the previous sections.

Table A2.4.5 Forecast of Ordinary Waste Generation

Planning Phase	No.	Year	Waste Generation (ton/year)			
			East (urban)	Central (rural)	West (rural)	Total
Current	-	2016	26,807	5,631	2,427	34,865
	-	2017	28,039	5,831	2,507	36,377
Short	1	2018	29,314	6,039	2,591	37,944
	2	2019	30,634	6,253	2,677	39,564
	3	2020	32,055	6,476	2,768	41,299
	4	2021	33,522	6,708	2,863	43,093
Mid	5	2022	35,108	7,013	2,957	45,078
	6	2023	36,745	7,327	3,053	47,125
	7	2024	38,436	7,648	3,152	49,236
	8	2025	40,307	7,999	3,259	51,565
	9	2026	42,237	8,357	3,369	53,963
Long	10	2027	44,175	8,674	3,543	56,392
	11	2028	46,288	9,025	3,732	59,045
	12	2029	48,464	9,381	3,927	61,772
	13	2030	50,734	9,743	4,130	64,607
	14	2031	53,190	10,139	4,350	67,679
	15	2032	55,713	10,541	4,575	70,829
	16	2033	58,460	10,978	4,820	74,258
	17	2034	61,310	11,422	5,074	77,806
	18	2035	64,236	11,873	5,335	81,444
	19	2036	67,266	12,333	5,605	85,204

Source: JICA Project Team

(2) Industrial Waste

1) Waste Generation Rate

<u>Waste from manufacturing industry</u>

Amount and composition of industrial waste are vary depending on category and scale, etc. of industries. However, a certain relation can be found between industrial waste amount and Gross Domestic Product in a macro perspective. The table below shows industrial waste amount and its generation rate per GDP, both for non-hazardous and hazardous; 23 kg/1000USD GDP for the former and 5 kg/1000USD GDP for the latter. These generation rates are to be used for the planning.

Table A2.4.6 Industrial Waste Amount per GDP in OECD Countries

Country	Industrial waste		Hazardous waste	
	Waste from manufacturing industry		production	
	Total (1000 ton)	per GDP (kg/1000USD)	Total (1000 ton)	per GDP (kg/1000USD)
Australia	13,120	17	2,216	3
Belgium	14,520	40	4,479	13
Chile	1,830	8	423	2
Czech Republic	4,180	16	1,363	6
Denmark	1,210	6	826	5
Finland	15,200	86	2,559	15
France	20,350	10	11,538	6
Germany	48,690	18	19,931	7
Greece	4,920	17	295	1
Hungary	3,130	17	368	2
Ireland	3,260	19	288	2
Italy	39,040	23	7,179	4
Korea	49,870	40	3,502	3
Luxembourg	500	14	379	11
Netherlands	14,060	22	4,421	7
Poland	28,560	46	1,492	2
Portugal	9,760	42	1,624	7
Slovak Republic	2,710	25	485	5
Slovenia	1,450	26	117	2
Spain	16,360	13	2,991	2
Sweden	7,820	25	2,515	8
Switzerland	1,570	5	1,753	6
Turkey	11,410	13	1,018	1
United Kingdom	19,710	10	3,769	2
Average	-	23	-	5

Source: OECD, 2013, "Industrial and hazardous waste", in Environment at a Glance 2013 OECD Indicators, OECD Publishing, Table 1.14. Industrial, hazardous and nuclear waste, 2010 or latest available year

<u>Construction and demolition waste</u>

Qeshm Island is facing the increasing amount of Construction and Demolition Waste (CDW) due to the rapid economic development in recent years. Generation rate of construction and demolition waste in Qeshm is unknown. Therefore, the average generation rate, 46 kg/1000EUR GDP, in EU countries is to be adapted for the planning. This annual average can be converted to 36 kg/1000USD GDP as the exchange rate in 2012 was that EUR 1.00 was equal to USD 1.28.

Table A2.4.7 Construction and Demolition Waste per GDP in EU Countries

Country	GDP (Billion EUR)	CDW (1000 ton)	CDW/GDP (kg/1000EUR)
Belgium	388	24,570	63
Bulgaria	41	1,033	25
Czech Republic	161	8,593	53
Denmark	251	3,867	15
Germany	2,750	197,528	72
Estonia	18	657	37
Ireland	173	366	2
Greece	194	813	4
Spain	1,055	26,129	25
France	2,091	246,702	118
Croatia	44	682	16
Italy	1,615	52,966	33
Cyprus	19	965	51
Latvia	22	8	0
Lithuania	33	419	13
Luxembourg	44	7,079	161
Hungary	99	4,038	41
Malta	7	1,041	149
Netherlands	641	81,354	127
Austria	317	19,471	61
Poland	386	15,368	40
Portugal	168	928	6
Romania	134	1,325	10
Slovenia	36	535	15
Slovakia	72	806	11
Finland	200	16,034	80
Sweden	423	7,656	18
United Kingdom	2,041	100,230	49
Average	-	-	46

Source: Eurostat, "Waste generation by economic activity and households, 2012", and "GDP at current market prices, 2003-04 and 2012-14"

2) Forecast of Industrial Waste Amount

Based on the unit generation rates and the GRDP forecast, amounts of industrial waste in the future are estimated as below.

Table A2.4.8 Forecast of Industrial Waste Amount

Unit: kg/1000USD

Waste Generation Amount per GRDP	Industrial		Construction and Demolition
	Non-hazardous	Hazardous	
	23	5	36

Unit: ton/year

Planning Phase	No.	Year	GRDP	Industrial		Construction and Demolition
			1000USD	Non-hazardous	Hazardous	
Current	-	2016	889,028	20,448	4,445	32,005
	-	2017	953,989	21,942	4,770	34,344
Short	1	2018	1,023,514	23,541	5,118	36,847
	2	2019	1,097,898	25,252	5,489	39,524
	3	2020	1,179,074	27,119	5,895	42,447
	4	2021	1,265,882	29,115	6,329	45,572
Mid	5	2022	1,363,074	31,351	6,815	49,071
	6	2023	1,466,994	33,741	7,335	52,812
	7	2024	1,578,066	36,296	7,890	56,810
	8	2025	1,701,689	39,139	8,508	61,261
	9	2026	1,834,290	42,189	9,171	66,034
Long	10	2027	1,958,049	45,035	9,790	70,490
	11	2028	2,094,450	48,172	10,472	75,400
	12	2029	2,238,723	51,491	11,194	80,594
	13	2030	2,392,438	55,026	11,962	86,128
	14	2031	2,560,957	58,902	12,805	92,194
	15	2032	2,739,075	62,999	13,695	98,607
	16	2033	2,934,988	67,505	14,675	105,660
	17	2034	3,143,310	72,296	15,717	113,159
	18	2035	3,363,352	77,357	16,817	121,081
	19	2036	3,595,576	82,698	17,978	129,441

Source: JICA Project Team

(3) Hospital Waste

1) Waste Generation Rate

Payambar Azam Hospital which is the leading hospital in Qeshm provided the JPT with information about waste generation rates, 0.8 kg/bed/day for infectious, 1.5 kg/bed/day for non-infectious, and 2.3 kg/bed/day in total.

Checking these generation rates with ones in other cities in Iran, it can be seen that the generation rates in Qeshm are within the range.

In order to estimate the whole hospital waste amount generated in Qeshm Island, it is assumed that Payambar Azam Hospital generates 80% of the total amount at present. This assumption gives a hospital waste generation rate per population of 1.0 kg/person/year, as the table below shows.

Table A2.4.9 Hospital Waste Generation Rate for Planning

City	Total	Infectious		Non-infectious	
		kg/bed/day	%	kg/bed/day	%
Qeshm	2.30	0.80	35	1.50	65

Source: Payambar Azam Hospital, Qeshm, Iran

Table A2.4.10 Hospital Waste Generation Rate in Other Cities in Iran

City	Total kg/bed/day	Infectious		Non-infectious	
		kg/bed/day	%	kg/bed/day	%
Tehran	4.58	1.52	33.19	3.06	66.81
Yasouj	5.50	1.50	27.27	4.00	72.73
Babol	2.01	0.57	28.36	1.44	71.64
Tabriz	3.38	1.04	30.77	2.34	69.23
Isfahan	3.94	1.59	40.36	2.35	59.64
Average	3.88	1.24	31.96	2.64	68.04

Source: Ferdowsi, Ferdosi, Mehrani and Narenjkar, 2012, "Certain Hospital Waste Management Practices in Isfahan, Iran", International Journal of Preventive Medicne, Table 2 Average medical waste generation rate in different cities of Iran

Table A2.4.11 Hospital Waste Generation Rate in Qeshm Island

Item	Unit	Value
Generation per bed	kg/bed/day	2.3
Nos. of bed in Payambar	nos.	128
Total generation in Payambar	kg/day	294
Portion of Payambar to the whole island	%	80
Total generation in the whole island	kg/day	368
Total generation in the whole island	kg/year	134,320
Population in 2016	nos.	128,600
Generation	kg/person/year	1.0

Source: JICA Project Team

2) Forecast of Hospital Waste Amount

Applying the hospital generation rate of 1.0 kg/person/year to the population forecast, hospital waste amount in the future is estimated as the table below shows.

Table A2.4.12 Forecast of Hospital Waste Amount

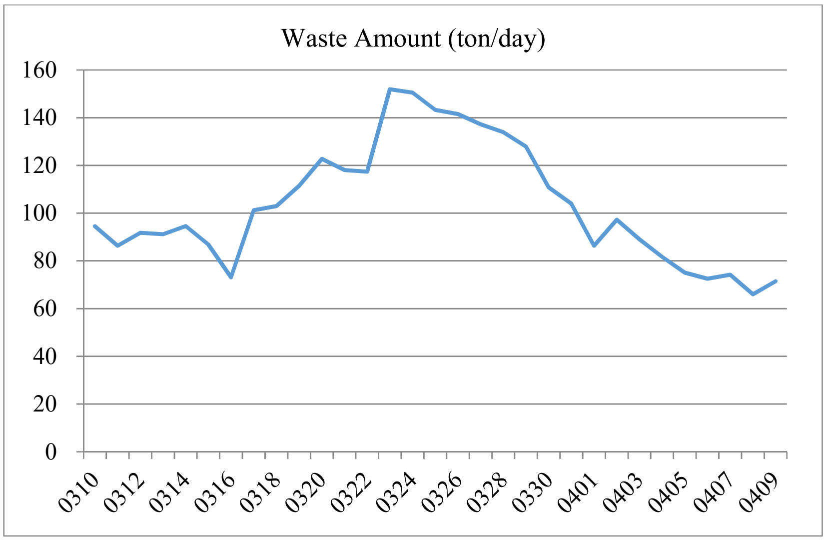
Unit: ton/year

Planning Phase	No.	Year	Population	Infectious	Non-infectious	Total
Current	-	2016	128,600	47	87	134
	-	2017	132,600	48	90	138
Short	1	2018	136,700	50	92	142
	2	2019	140,900	51	95	146
	3	2020	145,400	53	98	151
	4	2021	150,000	55	101	156
Mid	5	2022	155,200	56	105	161
	6	2023	160,500	58	108	166
	7	2024	165,900	60	112	172
	8	2025	171,900	63	116	179
	9	2026	178,000	65	120	185
Long	10	2027	184,100	67	124	191
	11	2028	190,800	69	129	198
	12	2029	197,600	72	134	206
	13	2030	204,600	74	138	212
	14	2031	212,200	77	143	220
	15	2032	219,900	80	149	229
	16	2033	228,300	83	154	237
	17	2034	236,900	86	160	246
	18	2035	245,600	89	166	255
	19	2036	254,500	93	172	265

Source: JICA Project Team

(4) Tourism Waste

Waste amount considerably rises during Iranian New Year as the figure below shows. This seems to be due to increased consumption of the insulars and the surging tourists. In the forecast of ordinary waste amount, it is assumed that the generation rate per insular gradually increases taking into account the increase of GRDP. Tourism waste is regarded to be included in this increase of the ordinary waste generation rate, as the tourism contributes to the GRDP. Therefore, generation rate for tourists is not to be set for planning. However, countermeasures in the actual operation have to be considered, such as to increase number of trips of waste collection per day, etc.



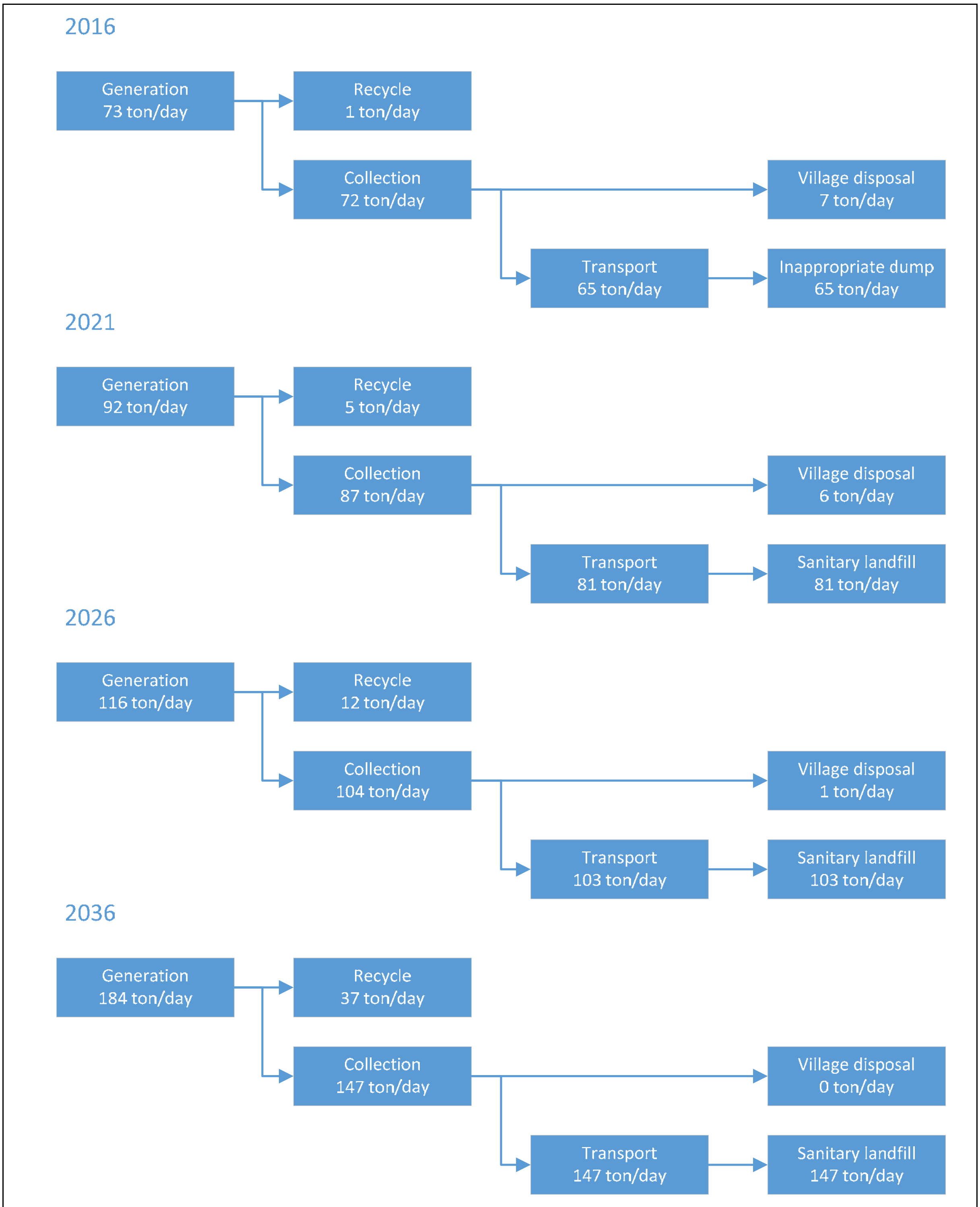
Source: Department of Environment, QFZO

Figure A2.4.3 Waste Amount disposed of in the Tola Disposal Site during Iranian New Year 2016

A2.4.3 Waste Stream

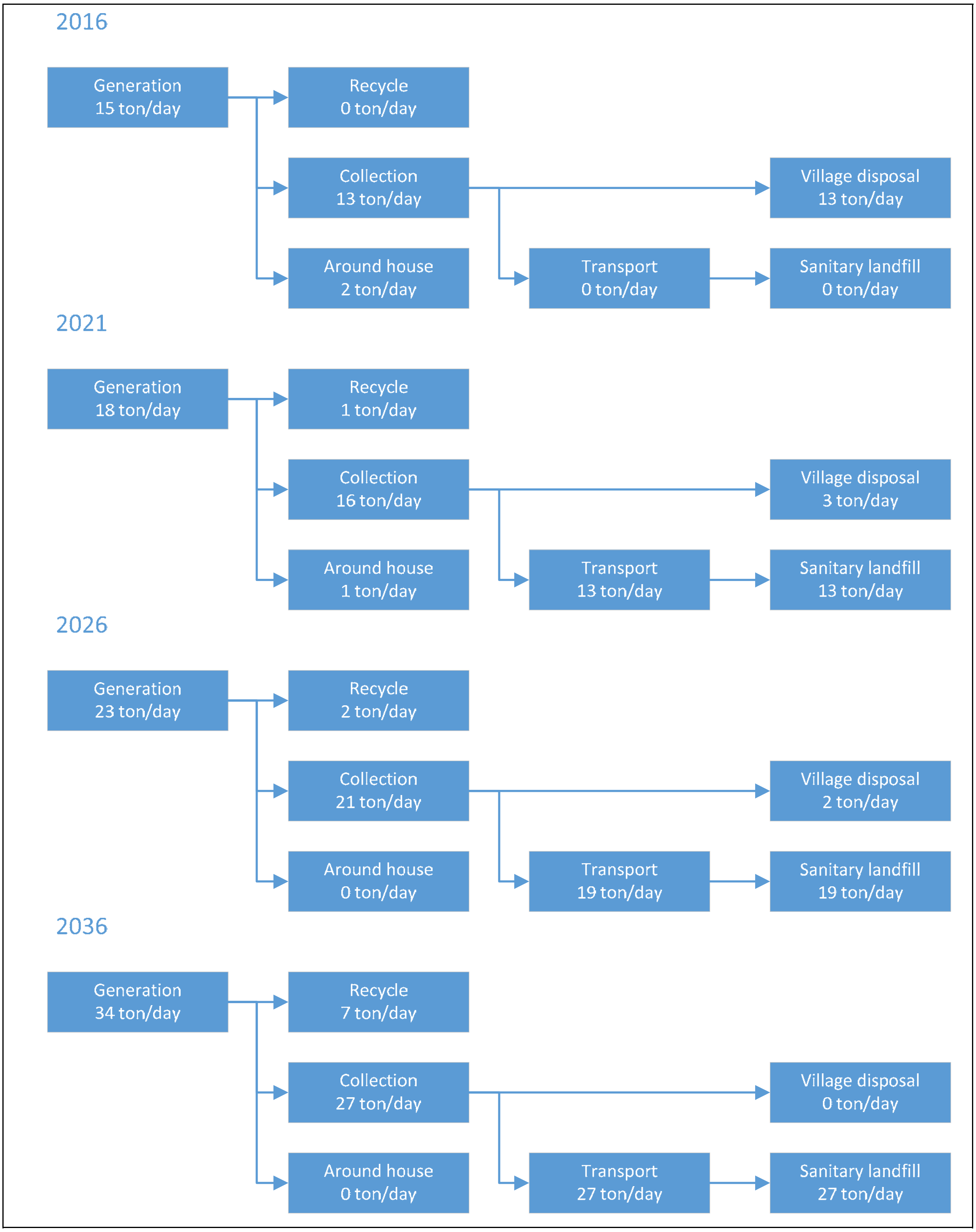
(1) Ordinary waste

The following figures shows waste streams of ordinary waste in East, West, and Central areas respectively.



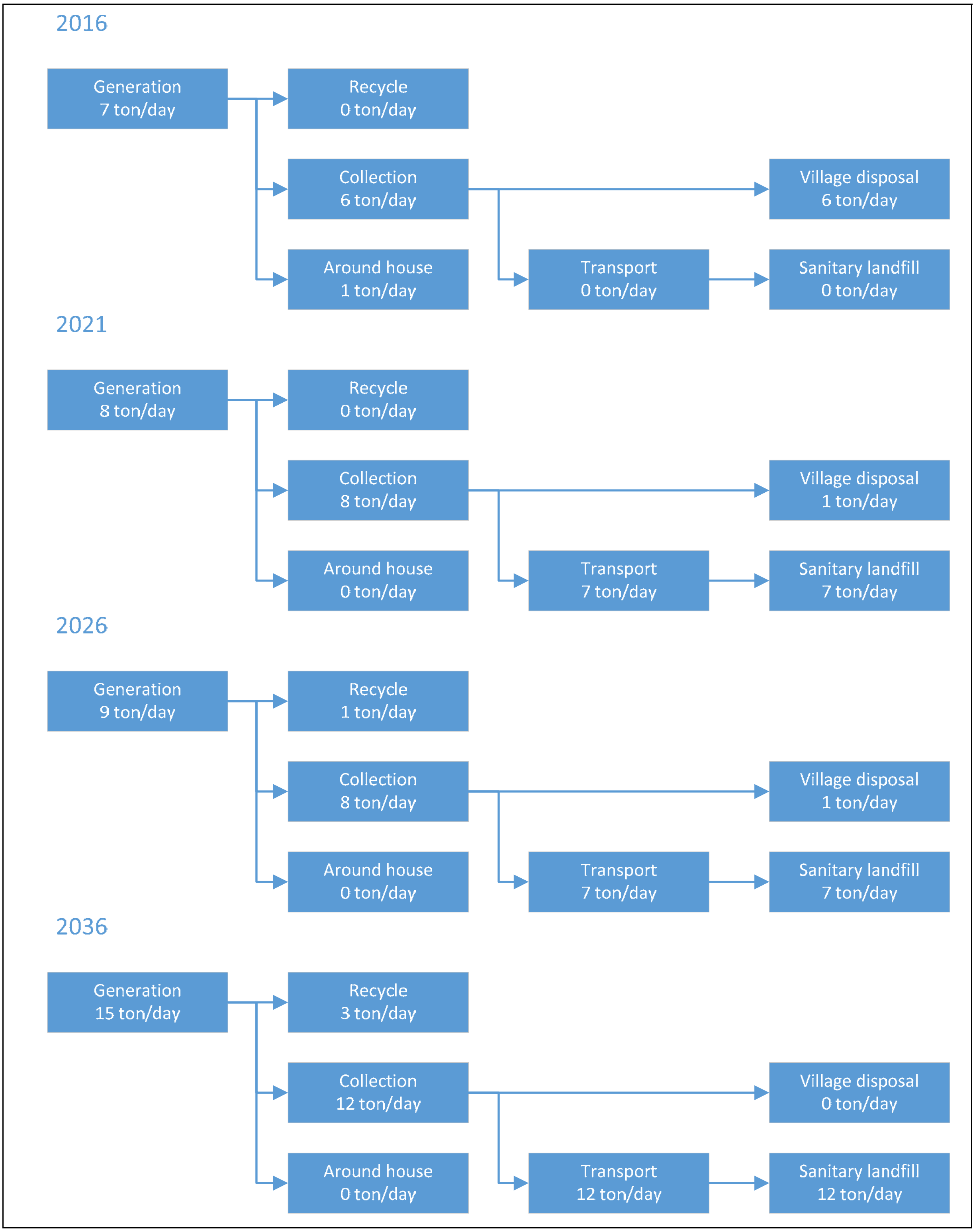
Source: JICA Project Team

Figure A2.4.4 Waste Stream of Ordinary Waste in East Area



Source: JICA Project Team

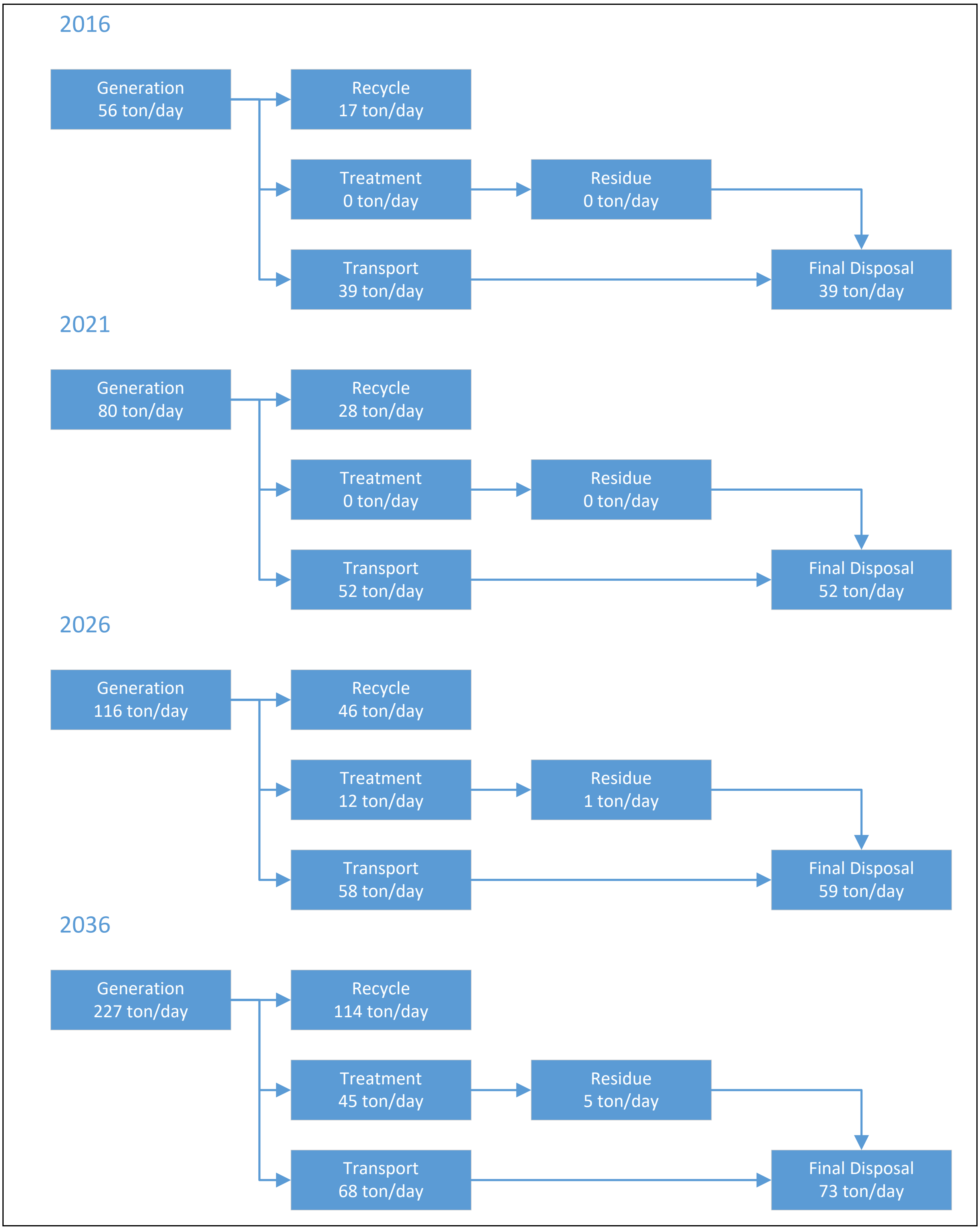
Figure A2.4.5 Waste Stream of Ordinary Waste in Central Area



Source: JICA Project Team

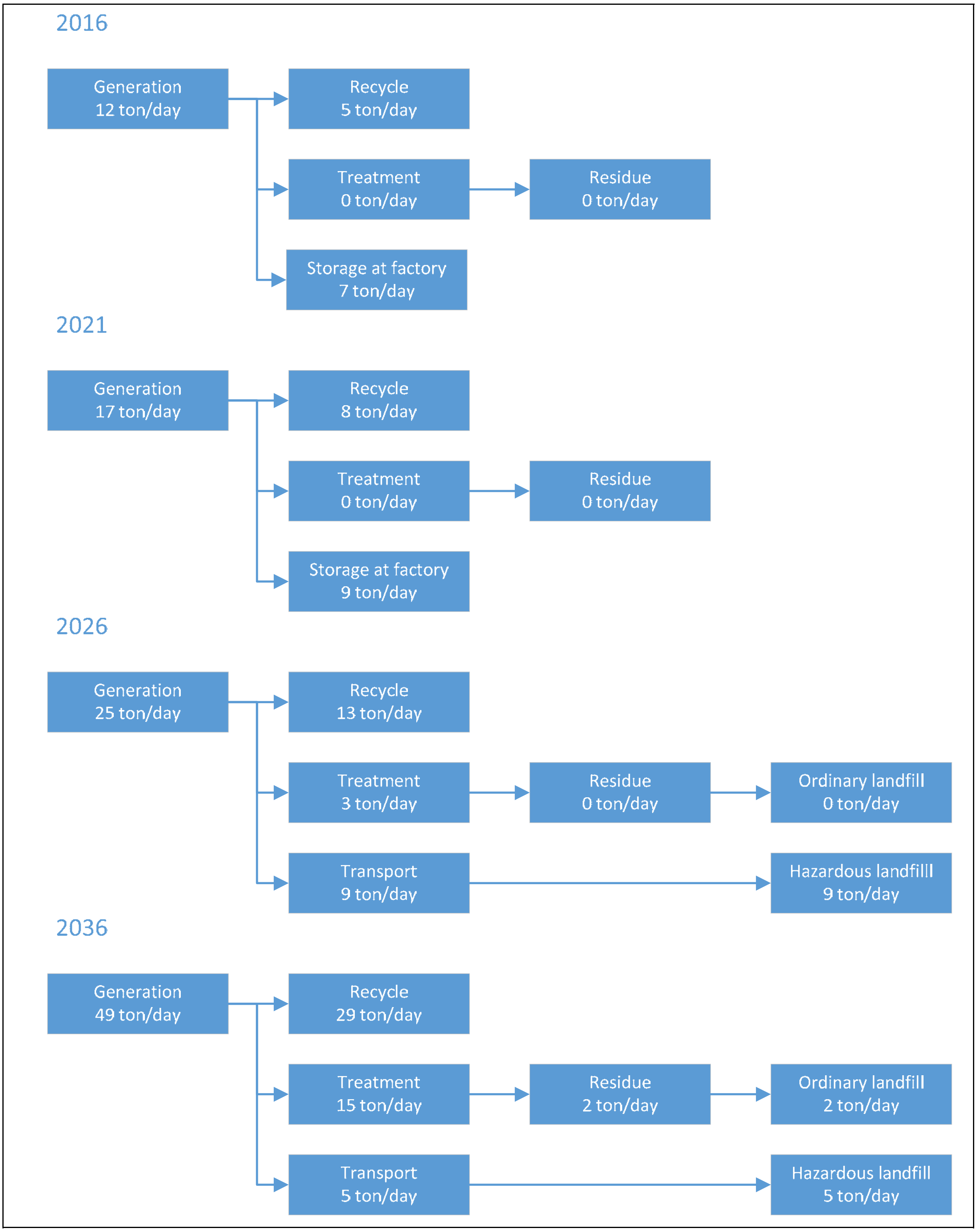
Figure A2.4.6 Waste Stream of Ordinary Waste in West Area

(2) Industrial waste



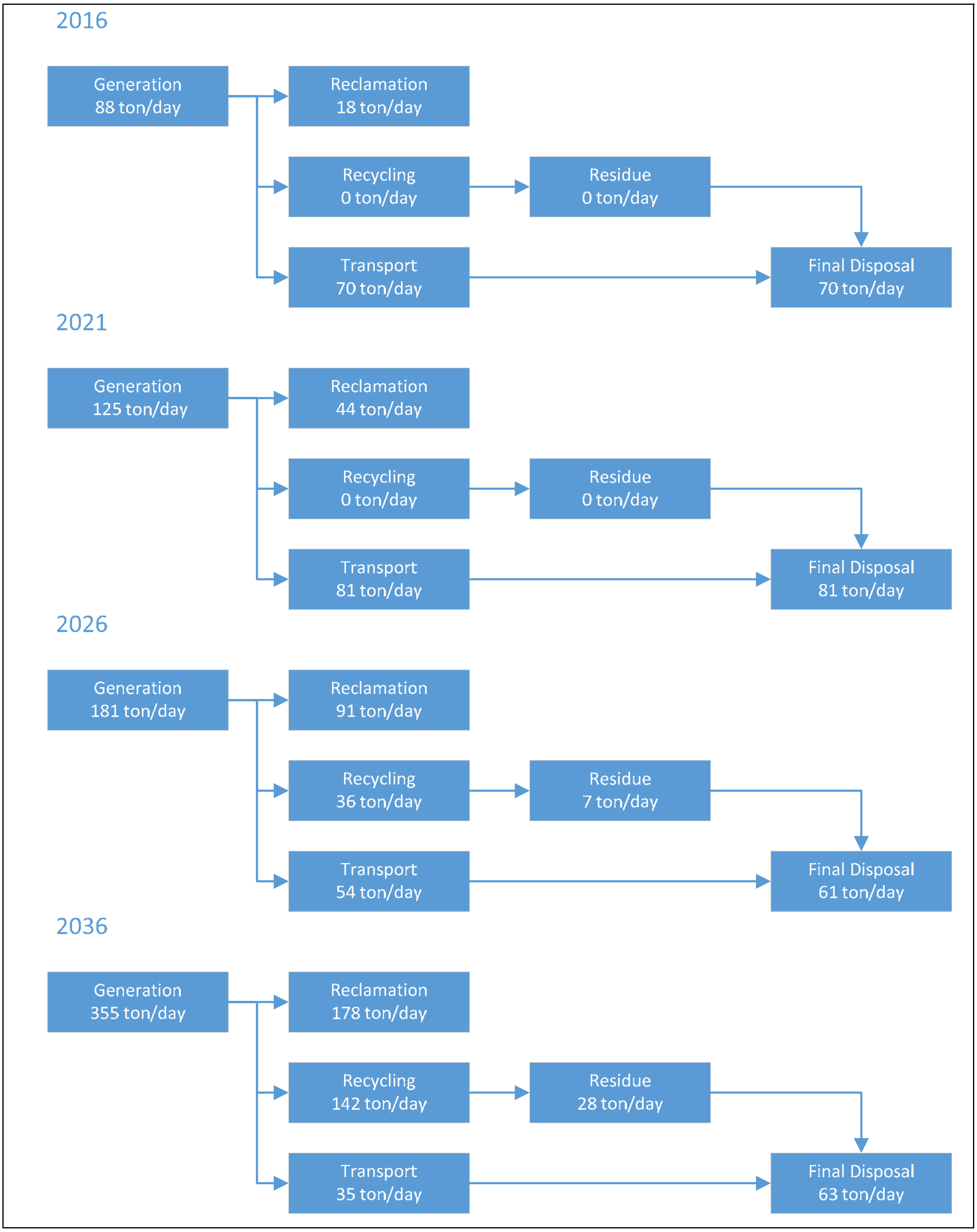
Note: Treatment with the hazardous waste and final disposal with the ordinary waste.
Source: JICA Project Team

Figure A2.4.7 Waste Stream of Non-Hazardous Industrial Waste



Note: Treatment with the hazardous waste and final disposal with the ordinary waste.
Source: JICA Project Team

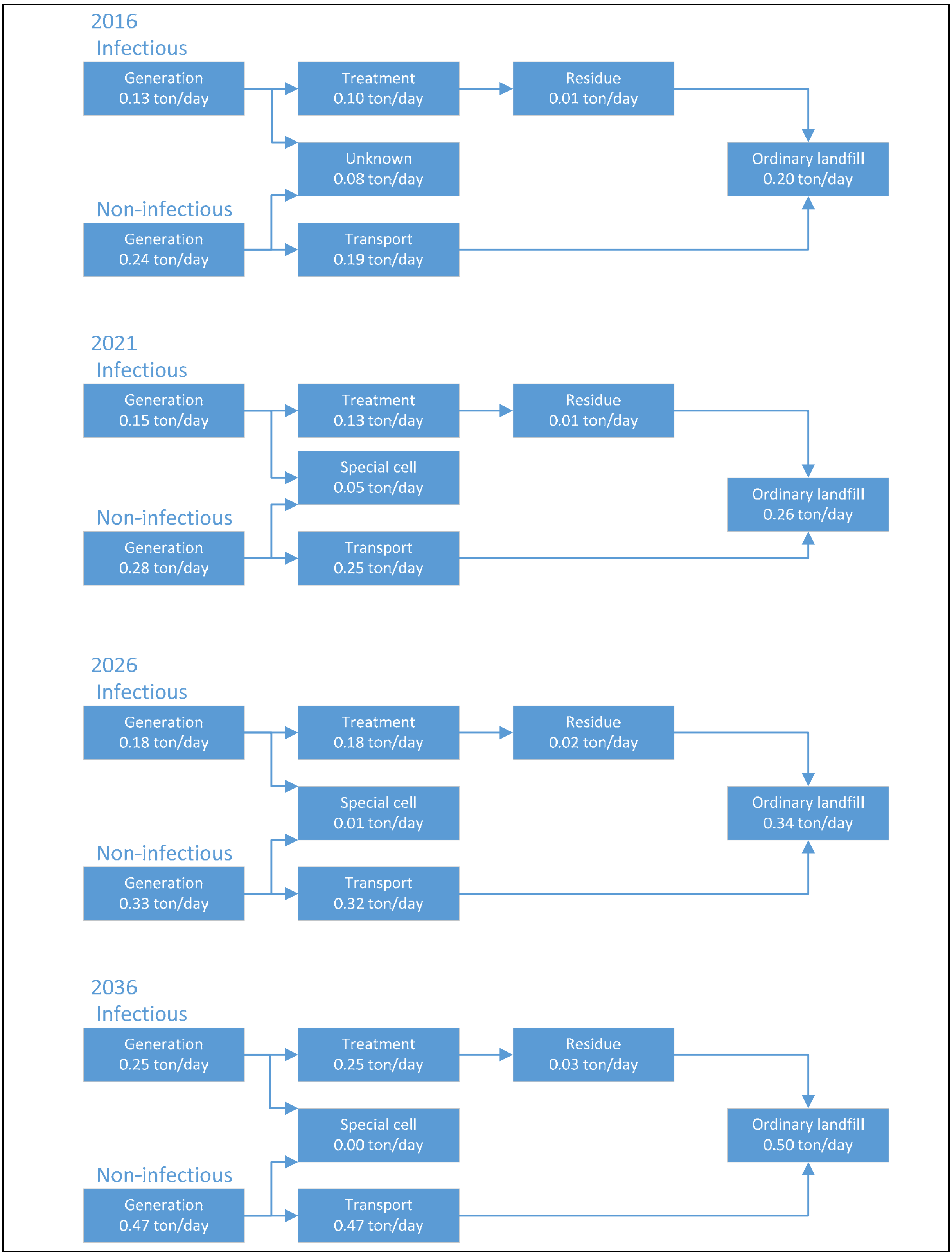
Figure A2.4.8 Waste Stream of Hazardous Industrial Waste



Note: Treatment with the hazardous waste and final disposal with the ordinary waste.
Source: JICA Project Team

Figure A2.4.9 Waste Stream of Construction and Demolition Waste

(3) Hospital waste

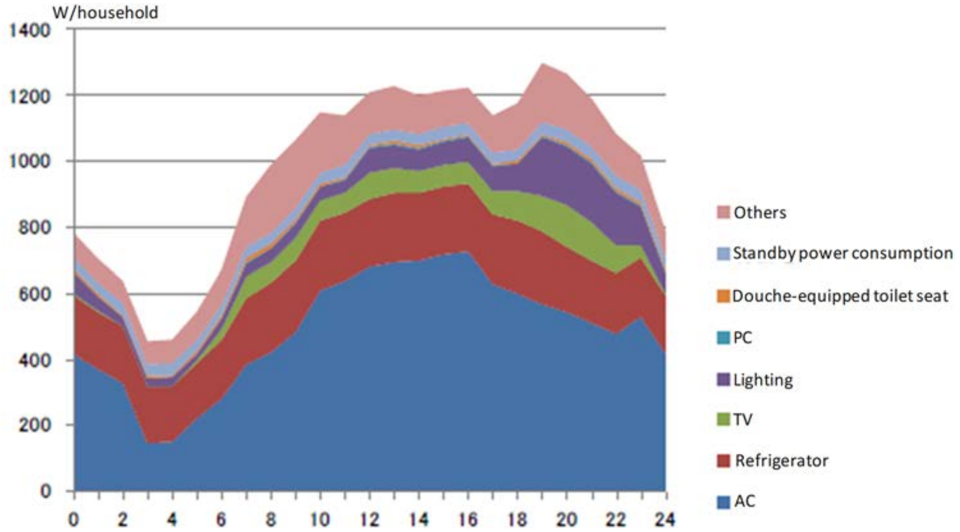


Note: Unknown means waste generated at small clinics where separation has not yet been practiced.
Source: JICA Project Team

Figure A2.4.10 Waste Stream of Hospital Waste

A2.5 Trial Calculation to Install Photovoltaic System for Renewable Energy Development

The following figure shows the power consumption curve for July 23rd, 2010 when the power system hit the peak load and the highest temperature in Tokyo at 34.9℃. It shows the average electric power consumption per household when the residents are present at their homes.



Source: The JICA Project Team based on "The estimation of the structure of power demand on the peak-demand day in the service area of the Tokyo Electric Power company" (The agency for Natural Resources and Energy at Ministry of Economy, Trade and Industry, May. 2011)

Figure A2.5.1 Average Electric Power Consumption per Household (residents at home)

The JICA Project Team has elaborated by reading the graph above to the table below, showing hourly power consumption data and hourly power consumption of AC data. Moreover, the tendency of these data has been adopted as the hourly consumption during high AC-usage season which ranges from May to October, when the average temperature exceeds 30℃ in the Qeshm Island.

Table A2.5.1 Hourly Power Consumption in High AC-usage Season when Residents are at Home

Time	0	1	2	3	4	5	6	7	8	9	10	11
Power consumption (W)	750	700	650	450	450	500	700	900	1000	1100	1150	1150
Power consumption of AC (W)	400	350	300	150	150	200	250	400	450	500	600	650
Time	12	13	14	15	16	17	18	19	20	21	22	23
Power consumption (W)	1200	1200	1200	1200	1200	1100	1150	1300	1300	1200	1100	1000
Power consumption of AC (W)	700	700	700	700	750	650	600	550	550	500	500	550
Total power consumption (Wh)	23,650											
Total power consumption of AC (Wh)	11,850											

Source: JICA Project Team

The table below shows the monthly average temperature in the Qeshm Island.

Table A2.5.2 Monthly Average Temperature in Qeshm Island

Month	Jan	Feb	Mar	Apr	May	Jun
Average temperature (℃)	18.9	19.7	23	27	31.1	33.1
Month	Jul	Aug	Sep	Oct	Nov	Dec
Average temperature (℃)	34.5	34.6	33	30	25.3	20.8

Source: JICA Project Team based on http://www.yr.no/place/iran/Hormozgan/Jaz%C4%ABreh-ye_Qeshm/statistics.html

The following table shows the power consumption as well as the load factor classified by daytime and nighttime in high AC-usage season when residents are at home, created based on Table A2.3.1.

Table A2.5.3 Power Consumption and Load Factor Classified by Daytime and Nighttime in High AC-usage Season when Residents are at Home

Power consumption during the daytime (Wh, 7-18)	12,400	52%
Load factor during the daytime (11 hours)		87%
Power consumption during the nighttime (Wh, 18- 7)	11,250	48%
Load factor during the nighttime (13 hours)		67%

Source: JICA Project Team

Next, the JICA Project Team has put together the hourly power consumption for the low AC-usage season with the assumption that power consumption of AC would be half of the high AC-usage season. The table below shows the hourly power consumption and hourly power consumption of AC in low AC-usage season when the residents are at home.

Table A2.5.4 Hourly Power Consumption in Low AC-usage Season when Residents are at Home

Time	0	1	2	3	4	5	6	7	8	9	10	11
Power consumption (W)	550	525	500	375	375	400	575	700	775	850	850	825
Power consumption of AC (W)	200	175	150	75	75	100	125	200	225	250	300	325

Time	12	13	14	15	16	17	18	19	20	21	22	23
Power consumption (W)	850	850	850	850	825	775	850	1025	1025	950	850	725
Power consumption of AC (W)	350	350	350	350	375	325	300	275	275	250	250	275

Total power consumption (Wh)	17,725
Total power consumption of AC(Wh)	5,925

Source: JICA Project Team

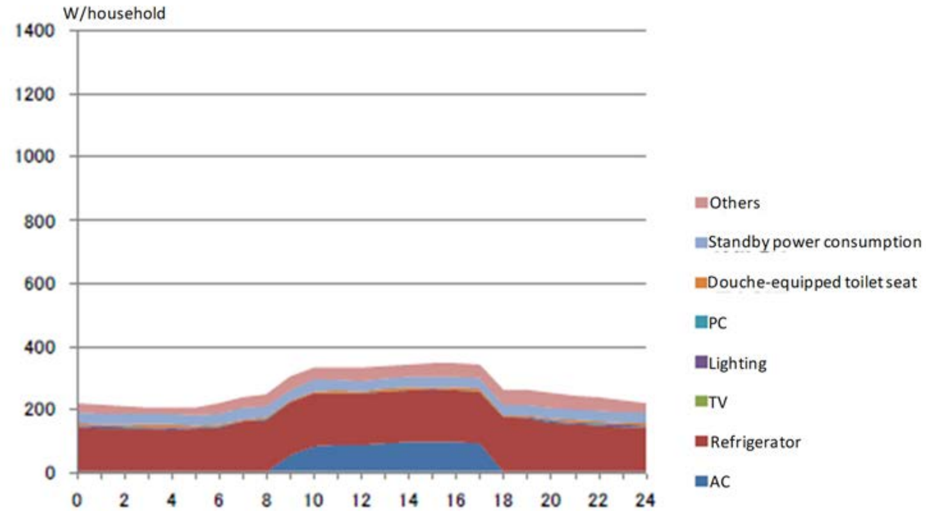
The following table shows the power consumption as well as the load factor classified by daytime and nighttime in low AC-usage season when residents are at home, created based on Table A2.3.4.

Table A2.5.5 Power Consumption and the Load Factor Classified by Daytime and Nighttime in low AC-usage Season when Residents are at Home

Power consumption during the daytime (Wh, 7-18)	9,000	51%
Load factor during the daytime (11 hours)		63%
Power consumption during the nighttime (Wh, 18- 7)	8,725	49%
Load factor during the nighttime (13 hours)		52%

Source: JICA Project Team

Next, the following figure shows the average electric power consumption per household when the residents are not at their homes.



Note: Power consumption by AC is for pets, etc.
Source: JICA Project Team based on "The estimation of the structure of power demand on the peak-demand day in the service area of the Tokyo Electric Power company" (The agency for Natural Resources and Energy at Ministry of Economy, Trade and Industry, May. 2011)

Figure A2.5.2 Average Electric Power Consumption per Household (Residents not at Home)

The JICA Project Team has elaborated by reading the graph above to the table below showing the hourly power consumption data when the residents are not at home.

Table A2.5.6 Hourly Power Consumption when Residents are not at Home

Time	0	1	2	3	4	5	6	7	8	9	10	11
Power consumption (W)	200	200	200	200	200	200	200	250	250	300	350	350
Time	12	13	14	15	16	17	18	19	20	21	22	23
Power consumption (W)	350	350	350	350	350	350	250	250	250	250	250	250

Source: JICA Project Team

The following table shows the power consumption as well as the load factor classified by daytime and nighttime when the residents are not at home, created based on Table A2.5.6.

Table A2.5.7 Power Consumption and the Load Factor Classified by Daytime and Nighttime when Residents are not at Home

Power consumption during the daytime (Wh, 7-18)	3,600	55%
Load factor during the daytime (11 hours)		25%
Power consumption during the nighttime (Wh, 18- 7)	2,900	45%
Load factor during the nighttime (13 hours)		17%

Source: JICA Project Team

The following table shows the summary of power consumption and load factor by season, day and night and residents' presence at home in Japan (average) based on the aforementioned examination.

Table A2.5.8 Summary of Power Consumption by Season, Day and Night and Presence of Residents at Home in Japan (average)

		Residents at home		No residents at home	
		Day (7-18)	Night(18-7)	Day (7-18)	Night(18-7)
High AC-usage season (May - Oct)	Power consumption (Wh)	12,400 (52%)	11,250 (48%)	3,600 (55%)	2,900 (45%)
	Load factor (%)	87%	67%	25%	17%
Low AC-usage season (Nov - Apr)	Power consumption (Wh)	9,000(51%)	8,725(49%)	3,600(55%)	2,900(45%)
	Load factor (%)	63%	52%	25%	17%

Source: JICA Project Team

Table A2.5.9 Results of Trial Calculation (Case-1, High AC-usage Season)

		Day (7-18)	Night (18-7)	Day (7-18)	Night (18-7)	Total day (7-18)	Total night (18-7)	Total	Current	PV systems
High AC-usage season (May - Oct)	Load factor	Residents at home		No residents at home						
		0.87	0.67	0.25	0.17					
	Days a year	184	184	184	184					
	hours a day	11	13	11	13					
	Power consumption with 100% load factor (kWh)	20,240	23,920	20,240	23,920					
	Power consumption with load factor above (kWh)	17,609	16,026	5,060	4,066					
Ratio of residents at home during daytime: 20% Ratio of residents at home during nighttime: 90%	Ratio of residents at home	0.2	0.9	(0.8)	(0.1)					
	Power consumption (kWh)	3,522	14,424	4,048	407	7,570	14,830	22,400	22,400	22,400
	Power generation (kWh)					6,451		6,451		6,451
	Power from grid with PV (kWh)					1,119	14,830	15,949	22,400	15,949
	Cost for buying power (USD)								896	638
	Power sold to grid (kWh)									0
	Income from selling power (USD)									0
	Cost benefit (USD)									258

Source: JICA Project Team

Table A2.5.10 Results of Trial Calculation (Case-1, Low AC-usage Season)

		Day (7-18)	Night (18-7)	Day (7-18)	Night (18-7)	Total day (7-18)	Total night (18-7)	Total	Current	PV systems
High AC-usage season (May - Oct)	Load factor	Residents at home		No residents at home						
		0.63	0.52	0.25	0.17					
	Days a year	181	181	181	181					
	hours a day	11	13	11	13					
	Power consumption with 100% load factor (kWh)	19,910	23,530	19,910	23,530					
	Power consumption with load factor above (kWh)	12,543	12,236	4,978	4,000					
Ratio of residents at home during daytime: 20% Ratio of residents at home during nighttime: 90%	Ratio of residents at home	0.2	0.9	(0.8)	(0.1)					
	Power consumption (kWh)	2,509	11,012	3,982	400	6,491	11,412	17,903	17,903	17,903
	Power generation (kWh)					6,346		6,346		6,346
	Power from grid with PV (kWh)					145	11,412	11,557		
	Cost for buying power (USD)								4,407	2,845
	Power sold to grid (kWh)									0
	Income from selling power (USD)									0
	Cost benefit (USD)									1,562

Source: JICA Project Team

Table A2.5.11 Results of Trial Calculation (Case-2, High AC-usage Season)

		Day (7-18)	Night (18-7)	Day (7-18)	Night (18-7)	Total day (7-18)	Total night (18-7)	Total	Current	PV systems
High AC-usage season (May - Oct)	Load factor	Residents at home		No residents at home						
		0.87	0.67	0.25	0.17					
	Days a year	184	184	184	184					
	hours a day	11	13	11	13					
	Power consumption with 100% load factor (kWh)	20,240	23,920	20,240	23,920					
	Power consumption with load factor above (kWh)	17,609	16,026	5,060	4,066					
Ratio of residents at home during daytime: 20% Ratio of residents at home during nighttime: 90%	Ratio of residents at home	0.2	0.9	(0.8)	(0.1)					
	Power consumption (kWh)	3,522	14,424	4,048	407	7,570	14,830	22,400	22,400	22,400
	Power generation (kWh)					13,977		13,977		13,977
	Power from PV for in-house (kWh)					7,570		7,570		7,570
	Power from grid with PV (kWh)					0	14,830	14,830		14,830
	Cost for buying power (USD)					0	593	593	896	593
	Power sold to grid (kWh)					6,408				6,408
	Income from selling power (USD)					1,577				1,577
	Cost benefit (USD)									1,880

Source: JICA Project Team

Table A2.5.12 Results of Trial Calculation (Case-2, Low AC-usage Season)

		Day (7-18)	Night (18-7)	Day (7-18)	Night (18-7)	Total day (7-18)	Total night (18-7)	Total	Current	PV systems
Low AC-usage season (May - Oct)	Load factor	Residents at home		No residents at home						
		0.63	0.52	0.25	0.17					
	Days a year	181	181	181	181					
	hours a day	11	13	11	13					
	Power consumption with 100% load factor (kWh)	19,910	23,530	19,910	23,530					
	Power consumption with load factor above (kWh)	12,543	12,236	4,978	4,000					
Ratio of residents at home during daytime: 20% Ratio of residents at home during nighttime: 90%	Ratio of residents at home	0.2	0.9	(0.8)	(0.1)					
	Power consumption (kWh)	2,509	11,012	3,982	400	6,491	11,412	17,903	17,903	17,903
	Power generation (kWh)					13,749		13,749		13,749
	Power from PV for in-house (kWh)					6,491		6,491		6,491
	Power from grid with PV (kWh)					0	11,412	11,412		11,412
	Cost for buying power (USD)					0	456	456	716	456
	Power sold to grid (kWh)					7,259				7,259
	Income from selling power (USD)					1,787				1,787
	Cost benefit (USD)									2,046

Source: JICA Project Team

A2.6 Environmental and Social Consideration for Model Design of Landfill

In the Project, the model design of the controlled landfill and the sanitary landfill are prepared to show the design approach, technologies and costs of landfill with environmentally improved conditions. Since the project site for the improved landfill site has not been determined yet, the design conditions are established to meet the natural conditions on the entire island. The model design will be reviewed to reflect the actual conditions of the project site after the location is determined. This section is to present the environmental and social consideration for the mode design of the landfill construction, however it should be reviewed before the landfill construction is implemented.

A2.6.1 Legal framework of environmental and social considerations

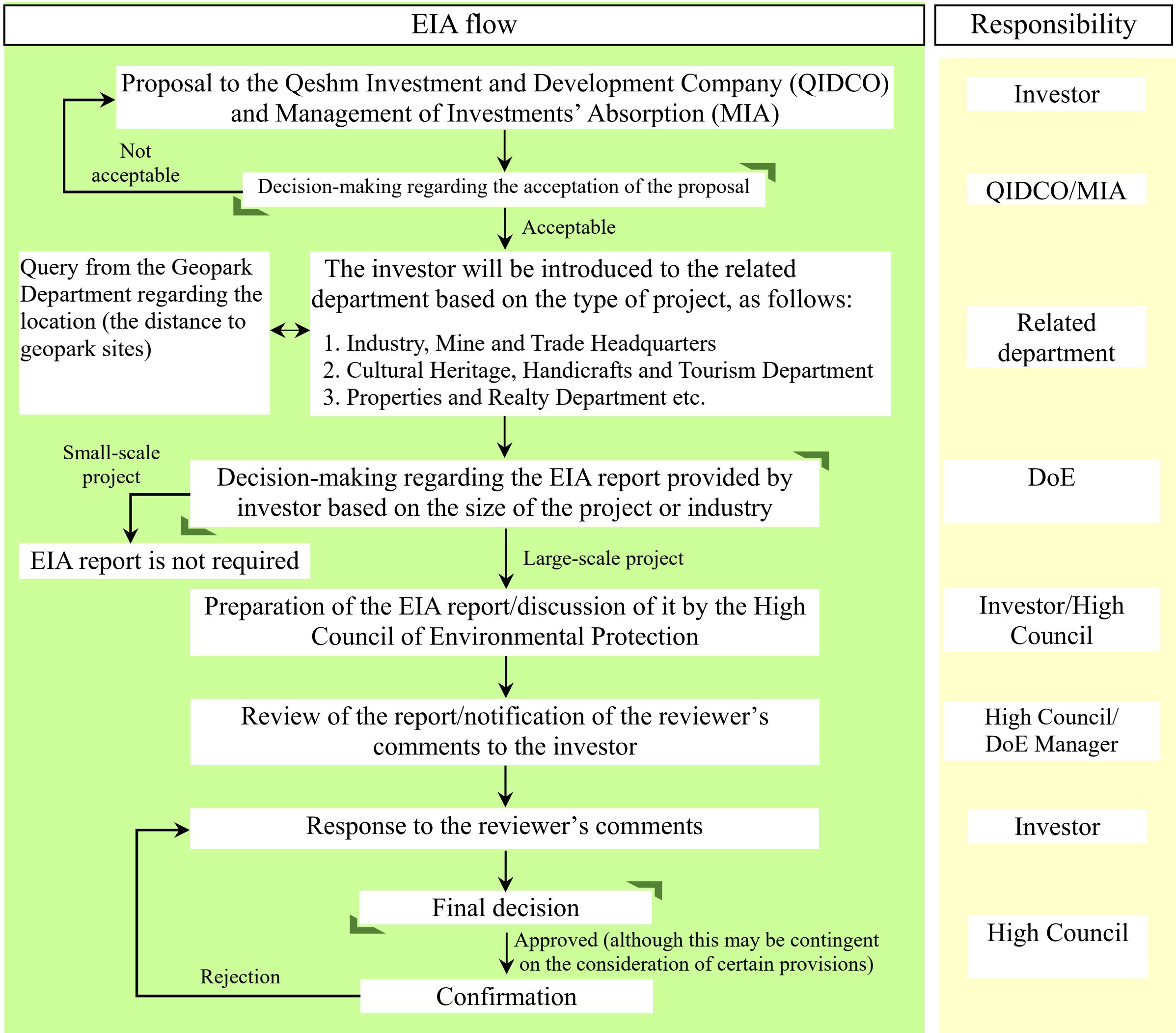
(1) Laws, regulations and standards related to environmental and social issues including requirements and procedures of Environmental Impact Assessment (EIA), stakeholder participation, and information disclosure

Main official documents related to the strategic environmental assessment, environmental impact assessment, and solid waste management are listed below.

- Implementation decree of article 184 of the 5th Development Plan of Islamic Republic of Iran: Strategic Environmental Assessment
- Article 105 of the 3rd development plan of Islamic Republic of Iran
- Article 71 of the 4th development plan of Islamic Republic of Iran
- Approval by High Council of Environment Conversation in their meeting for the subjects listed below on May 2, 2011, referring to the article 192-A of the 5th developmental plan of Islamic Republic of Iran
  i) Projects and plans which are required to submit EIA report
  ii) Outline of the brief EIA reports of projects and plans
- Waste management law
- Implementation guideline of waste management law (Decree No. H32561T/88482, dated on August 2, 2005)
- Executive criteria of ordinary waste elimination

The Department of Geoparks and Environment (DoGE), which is one of the subsidiary bodies reporting to the Cultural, Social and Tourism Deputy of the QFZO, was established with the responsibility for environmental management of 300 km^2 on the east side of Qeshm Island. Its jurisdiction was extended to the entire island when Qeshm was designated as an SEZ. As of September 2016, the DoGE has jurisdiction over Qeshm and Hangom.

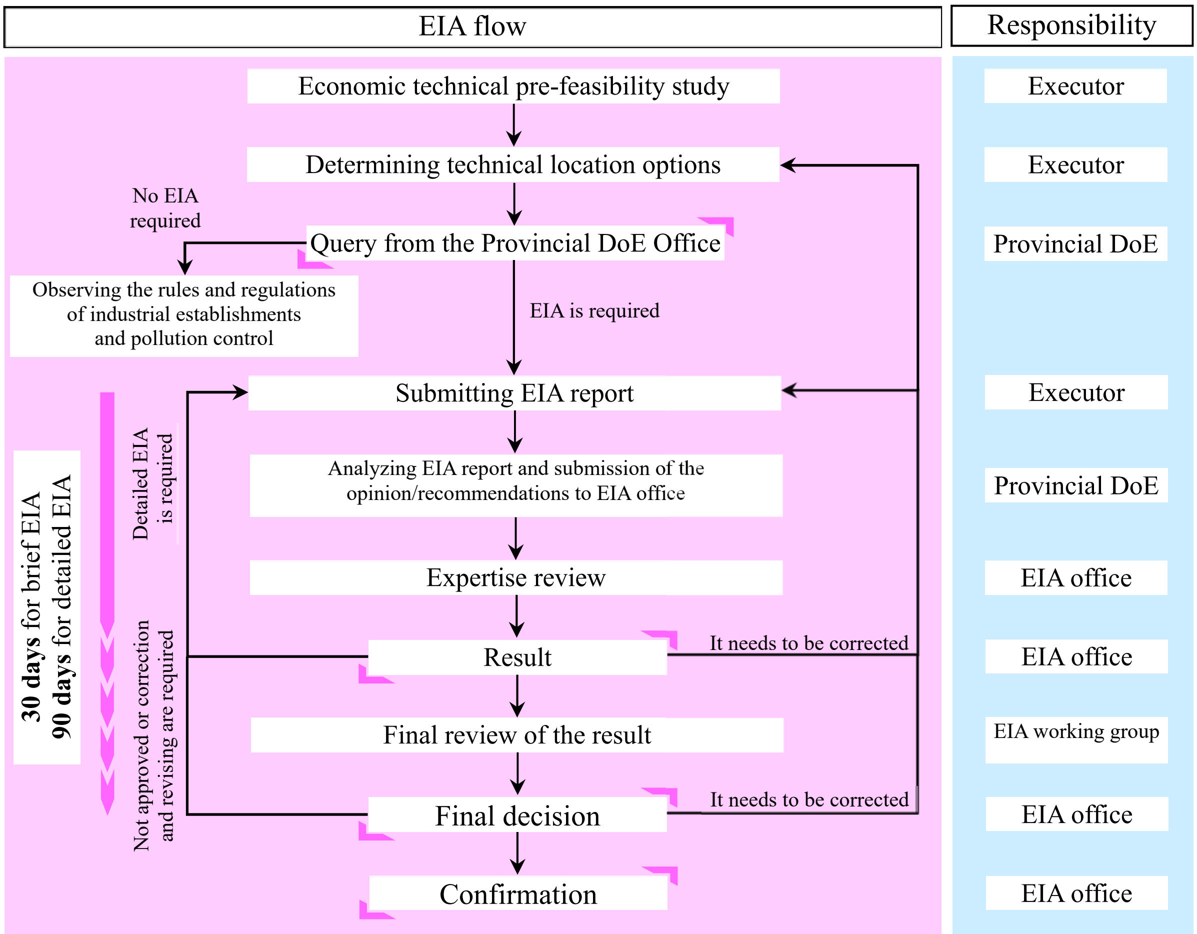
The DoGE has its own EIA procedure on the island, which is different to the procedure of Iran's national DoE due to the former being under the direct control of the President. It is simplified by the omission of certain steps in order to give priority to the island's special status as a FZ, including the areas for development, investment and trade promotion. The DoGE has the authority to arrange and simplify the EIA procedure, while the final decision must be undertaken by the High Council of Environmental Protection, which is composed of the member of central ministries and agencies. Although the simplified EIA procedure has been adopted, the DoGE has stated that it compares favorably with the other EIA in terms of quality due to the high level of expertise from council members.



Source: DoE of the Qeshm Free Zone Organization

Figure A2.6.1 EIA Procedure Implemented by the DoE of the QFZO

On the other hand, the DoE of Qeshm County, which is an organization under the DoE of Hormozgan Province, has three divisions: Human Environment, Natural Environment and Marine. It administered the EIA procedure on Qeshm Island before the DoGE of the QFZO was founded. Furthermore, even now, the DoE of Qeshm County has jurisdiction over the entire island because it simply transferred its authority for the evaluation of EIA report to the DoGE of the QFZO due to staff shortages (only four staff members were dispatched by the Department of Environment of Hormozgan Province).



Source: DoE of Iran, 2012, Human's Environmental Laws, Regulation Criteria and Standards

Figure A2.6.2 EIA Procedure Implemented by the DoE of Iran

(2) Relative agencies and institutions

1) Administrative jurisdiction for the EIA

It became obvious that the demarcation of environmental jurisdiction on the island was uncertain and that there were discrepancies between the DoGE of the QFZO and the DoE of Qeshm County. Concretely, the DoGE of the QFZO insists that it had the jurisdictional responsibility for the entire island because it administers the island as a FZ. On the other hand, the DoE of Qeshm County emphasizes that it essentially had environmental authority over the entire island.

2) EIA procedure

These two organizations also have different views regarding the EIA procedures. The DoGE of the QFZO emphasizes that the simplified EIA procedure was regarded as a legal formality because of the direct approval by the President. On the other hand, the DoE of Qeshm County, expressing its view that the DoGE of the QFZO should also obey the EIA procedure implemented by the DoE of Iran, does not approve of the EIA procedure implemented by the DoE of the QFZO. There is no administrative demarcation regarding the authority for EIA procedures on Qeshm Island.

A2.6.2 Provisional scoping (types and magnitudes of possible adverse impacts and mitigation measures)

Provisional scoping was carried out based on possible project plans (Construction of new sanitary landfills) for the waste management.

The results of the scoping are summarized in Table A2.6.1. Because this scoping is for identifying important items to be studied for comprehensive development master plan, tentative impacts to be managed by future detailed construction plan are excluded from the scoping.

Table A2.6.1 Results of Provisional Scoping

Impacts / Phase			Rating	
			Pre/During construction	Operation phase
Pollution	1	Air pollution	D	B+
	2	Water pollution	D	C
	3	Waste	D	B+
	4	Soil contamination	D	C
	5	Noise and vibration	D	D
	6	Ground subsidence	D	D
	7	Odor	D	B+
	8	Sediment quality	D	D
Natural environment	9	Protected area	C	C
	10	Ecosystem	C	C
	11	Hydrology	D	D
	12	Topography and geology	D	B+
Social environment	13	Involuntary resettlement	D	D
	14	The poor	D	D
	15	Indigenous and ethnic people	C	C
	16	Local economy such as employment and livelihood	D	C
	17	Land use and utilization of local resources	D	D
	18	Water usage	D	C
	19	Existing social infrastructures and services	D	D
	20	Social institutions such as social infrastructure and local decision-making institutions	D	D
	21	Misdistribution of benefit and damage	D	D
	22	Local conflict of interests	D	D
	23	Cultural heritage	D	D
	24	Landscape	D	D
	25	Gender	D	D
	26	Right of children	D	D
	27	Infectious diseases such as HIV/AIDS	C	D
	28	Labor environment (including work safety)	D	C
Others	29	Accidents	D	C
	30	Cross boundary impacts and climate change	D	D

Note:
A Significant positive/negative impact is expected. (Based on reliable operation plans for operation)
B+/- Positive/negative impact is expected to some extent.
C Extent of positive/negative impact is unknown. (A further examination is needed and the impact could be clarified as the study progresses).
D No impact is expected (except tentative impacts to be managed by future detailed construction plan).

A2.6.3 Alternatives to the project activities including 'without project' option

'Without project option' means no sanitary landfill site is constructed and will not take any action on the present situation. As the population of Qeshm Island increases and the economic activities are being accelerated through eco-tourism activities, following issues are expected to occur if 'without project':

- Solid waste will be overflowed from the existing landfill.
- Environmental pollution will be escalated due to the waste scattering, bad odor, etc.
- Citizen and visitor's interest in ecotourism will be weak without proper waste discharge.

A2.6.4 Result of the consultation with recipient government on environmental and social consideration including roles and responsibilities

DoE of QFZO recognized the contents of JICA Guideline for Environmental and Social Consideration and will determine the guideline and regulations for environmental and social consideration to be applied when the project is implemented. If JICA provides the financial source, the JICA guideline will be considered in EIA.

A proposal No. 1-5023 by DOE specifies the plans and projects subject to conduct EIA studies in appendix. The proposal was approved by High Council of Environment Conversation. According to this appendix, a landfill site at any scale in the southern coast lands (all southern coastal cities) is subject for the EIA study. In other areas (deserts and plans of the central, eastern and southern areas), the EIA study is required for a landfill site in province and county centers. The necessity of the EIA study will be determined by DoE of QFZO, when the financial source and location of the landfill site is decided.

A2.6.5 Terms of reference for environmental and social considerations

Terms of Reference (TOR) for environmental and social considerations to be conducted in this project are presented as follows:

(a) Review of existing development plan and development projects related to a landfill site;
(b) Analysis of alternatives for achieving the goals of the project;
(c) Scoping (clarify extremely important items on environmental and social impacts and its evaluation methods at the time of decision making of a landfill site);
(d) Confirmation of existing environmental and social conditions of the project area of a landfill site as baseline data (details are presented in Table A2.6.2 considering the items rated as B or C in the provisional scoping results);
(e) Confirmation of legal framework and institution of Qeshm Island on environmental and social considerations;
  i) Laws, regulations and standards related to environmental and social considerations (environmental impact assessment, resettlement, public participation, information disclosure and other);
  ii) Gaps between the "JICA Guideline for Environmental and Social Considerations (April 2010)" and legal framework of Iran on environmental and social considerations;
  iii) Institute of relative agencies responsible for implementation of projects and their roles on environmental and social considerations including EIA;
(f) Evaluation of likely impacts of the project above and comparative analysis of alternative of proposed projects, including 'without project' option;
(g) Examination of the mitigation measure (to be avoided, minimized and compensated);
(h) Examination of the monitoring methods (monitoring items, frequencies and methods); and
(i) Support to hold stakeholder meetings

TableA2.6.2 Survey Items and Methodologies for Environmental and Social Considerations in the Project

Environmental items	Survey items	Survey methodologies
Air quality	Ambient air quality (particle matters, NOx, SOx, etc.)	Comparing with environmental standards
Water quality	River and coastal water quality (BOD, suspended solid, etc.)	Comparing with environmental standards
	Discharged water quality (BOD, suspended solid, etc.)	Comparing with environmental standards
Groundwater quality	Water quality (pH, EC, Hardness, color, As, Ag etc)	Comparing with environmental standards
Noise	Noise level	Comparing with environmental standards
Protected area	Location of protected areas, restricted activities and environmental features	Confirmation / updating of present and future land use map
Ecosystem	Habitat distribution	Confirmation / updating of present and future land use map
	Species in the area, protected species	Confirmation / updating of present and future land use map
Hydrology	Map of water system	Collecting secondary data from relevant agencies
	Flow volume of rivers	Collecting secondary data from relevant agencies
	Groundwater level	Collecting secondary data from relevant agencies
Topography	Topographic map	Collecting secondary data from relevant agencies
Land use	land use map	Confirmation / updating of present and future land use map
	Distribution of informal settlers	Collecting secondary data from relevant agencies
Local community	Social characters of each barangay (population, ethnicity, religion, livelihood, lifestyle, culture, etc.)	Collecting secondary data from relevant agencies
	Infrastructure and social services (water supply, disposal of solid waste, etc.)	Collecting secondary data from relevant agencies
	Water use (irrigation, source of portable water, etc.)	Collecting secondary data from relevant agencies
	Infectious diseases (e.g. HIS/AIDS)	Collecting secondary data from relevant agencies
Cultural heritage	Distribution of cultural heritages (e.g. monuments)	Collecting secondary data from relevant agencies
Labors environment	Regulations related to working conditions and the actual working conditions, and Conditions of the workers related to the existing landfill such as waste pickers (e.g. population, gender ratio and income).	Collecting secondary data from relevant agencies
Flood	Record of flooding (frequency, area, damages, etc.)	Collecting secondary data from relevant agencies

A2.6.6 Other relevant information

None

APPENDIX 3 LANDFILL OPERATION GUIDELINES

Qeshm Free Zone Organization
(QFZO)

Japan International Cooperation Agency
(JICA)

THE PROJECT FOR COMMUNITY-BASED SUSTAINABLE DEVELOPMENT MASTER PLAN OF QESHM ISLAND TOWARD "ECO-ISLAND" IN THE ISLAMIC REPUBLIC OF IRAN

Landfill Operation Guidelines

April 2018

RECS International Inc.
PADECO Co., Ltd.
Kokusai Kogyo Co., Ltd.

Source:	LANDFILL OPERATIONAL GUIDELINES 2nd Edition, International Solid Waste Association
Modified by:	JICA Project Team

Table of Contents

CHAPTER 1 SITE ROADS 1-1
1.1 Introduction 1-1
1.2 Road Types 1-1
1.3 Site Approach and Entrance Road 1-1
1.4 Primary Access Road 1-2
1.5 Secondary Access Roads 1-3
1.6 Tertiary Access Roads 1-3
1.7 Conclusions 1-4

CHAPTER 2 THE USE OF DAILY COVER 2-1
2.1 Introduction 2-1
2.2 Objectives of Daily Cover 2-1
2.3 Consideration 2-1
2.3.1 Windblown Litter 2-1
2.3.2 Odor 2-2
2.3.3 Scavenging by Birds 2-2
2.3.4 Scavenging by Humans 2-2
2.3.5 Infestation by Flies and Vermin 2-2
2.3.6 Fires 2-2
2.3.7 Visual Appearance 2-3
2.3.8 Surface Water Control 2-3
2.4 Daily Cover Types 2-3
2.5 Daily Cover Application 2-4
2.6 Soil Use Plan 2-5
2.7 Conclusions 2-5

CHAPTER 3 BIRD CONTROL 3-1
3.1 Introduction 3-1
3.2 Background 3-1
3.3 Hierarchy of Controls 3-1
3.4 Operational Practices 3-2
3.5 Control Methods 3-2
3.6 Conclusions 3-3

CHAPTER 4 WHEEL CLEANING 4-1
4.1 Introduction 4-1
4.2 Options for Minimizing Nuisance 4-1
4.3 Hierarchy of Controls 4-1
4.4 Consideration 4-2
4.5 Conclusions 4-2

CHAPTER 5 LITTER CONTROL 5-1
5.1 Introduction 5-1
5.2 Hierarchy of Control Measures 5-1
5.3 Methods of Control 5-1
5.3.1 Load Control 5-1
5.3.2 Waste Handling 5-2
5.3.3 Portable Litter Screens 5-2
5.3.4 Litter Fencing 5-2
5.3.5 Bunds 5-2
5.3.6 Perimeter Fencing 5-3
5.3.7 Select Tipping Areas 5-3
5.3.8 Netted Areas 5-3

5.3.9 Designated Waste Transfer Areas ... 5-3
5.3.10 Methods for Handling Lightweight Waste ... 5-3
5.3.11 Restricting Operating Hours ... 5-3
5.4 Conclusions ... 5-3

CHAPTER 6 VECTOR CONTROL ... 6-1
6.1 Introduction ... 6-1
6.2 Background ... 6-1
6.3 Hierarchy of Control ... 6-1
6.4 Operational Practice ... 6-1
6.5 Monitoring ... 6-2
6.6 Eradication ... 6-2
6.7 Conclusions ... 6-3

CHAPTER 7 MANAGING THE WORKING FACE ... 7-1
7.1 Introduction ... 7-1
7.2 Placement of the First Layer of Waste ... 7-1
7.2.1 General ... 7-1
7.2.2 Construction of the First Layer ... 7-1
7.3 Working Face Management Procedures ... 7-2
7.3.1 Summary ... 7-2
7.3.2 Use the Smallest Area Practicable ... 7-2
7.3.3 Orderly Truck Movement and Unloading ... 7-3
7.3.4 Work Waste Together ... 7-3
7.3.5 Waste Compaction / Placement ... 7-4
7.3.6 Working Face Slope ... 7-4
7.3.7 Keep the Working Area Well Drained ... 7-4
7.3.8 Apply and Compact Cover Soil Promptly ... 7-5
7.3.9 Disposal of Specific / Difficult Wastes ... 7-5
7.4 Checklist ... 7-6
7.5 Conclusions ... 7-6

CHAPTER 8 WASTE COMPACTION ... 8-1
8.1 Benefits of Waste Compaction ... 8-1
8.2 Compaction Methods ... 8-1
8.3 Conclusions ... 8-2

CHAPTER 9 LANDFILL FIRES ... 9-1
9.1 Introduction ... 9-1
9.2 Characterization of Fire ... 9-1
9.3 Immediate Actions ... 9-2
9.4 Extinguishment Methods ... 9-3
9.4.1 Water Application ... 9-3
9.4.2 Excavate and Overhaul ... 9-3
9.4.3 Oxygen Suppression ... 9-4
9.5 Monitoring and Prevention ... 9-4
9.5.1 Temperature Monitoring ... 9-4
9.5.2 Leachate Management ... 9-5
9.5.3 Fire Prevention and Control Plan ... 9-5
9.6 Checklist ... 9-6

CHAPTER 10 STORM WATER AND SEDIMENT CONTROL ... 10-1
10.1 Introduction ... 10-1
10.2 Functions of Surface Drainage Systems ... 10-1
10.3 Key Design Elements ... 10-2

10.3.1 Over View 10-2
10.3.2 Storm Water Detention / Sedimentation / Storage Ponds 10-2
10.3.3 Primary Drainage Systems 10-2
10.3.4 Secondary Drainage 10-3
10.3.5 Temporary Drainage Systems 10-3
10.3.6 Active Area Drainage 10-3
10.3.7 Landfill Cap Drainage 10-4
10.4 Conclusions 10-4

CHAPTER 11 WASTE CONTROL AT LANDFILLS 11-1
11.1 Introduction 11-1
11.1.1 Definitions 11-1
11.1.2 Control Processes 11-1
11.1.3 Control Infrastructure 11-1
11.1.4 Levels of Control 11-2
11.2 Waste Control Chain of Responsibility 11-3
11.2.1 Generator 11-3
11.2.2 Carrier / Haulage Contractor 11-3
11.2.3 Landfill Manager 11-3
11.3 Operational Aspects of Waste Control 11-3
11.3.1 Security 11-3
11.3.2 Entry Point 11-3
11.3.3 Internal Control 11-4
11.3.4 Work Face Control 11-4
11.3.5 Reporting 11-5
11.4 Conclusions 11-5

CHAPTER 12 LEACHATE CONTROL 12-1
12.1 Introduction 12-1
12.2 Consideration of Leachate Control Measures 12-1
12.2.1 Appropriate Landfill Siting 12-1
12.2.2 Screening for and Restricting Liquid Waste Acceptance 12-2
12.2.3 Landfill Operational Techniques 12-2
12.2.4 Run-on and R un-off Controls for Precipitation 12-2
12.2.5 Liner and Leachate Collection Systems 12-2
12.2.6 Leachate Treatment 12-3
12.3 Conclusions 12-4

CHAPTER 13 ODOR CONTROL 13-1
13.1 Introduction 13-1
13.2 Odur Control Measures 13-1
13.3 Consideration of Odor Control Measures 13-1
13.3.1 Restriction on the Acceptance of Odorous Wastes 13-1
13.3.2 Properly Covering Wastes 13-2
13.3.3 Limiting Working Face Size 13-2
13.3.4 Properly Vent, or Collect, Extract and Treat Landfill Gas 13-2
13.3.5 Control of Leachate 13-2
13.3.6 Odor Masking 13-3
13.3.7 Landscaping and Buffer Zones 13-3
13.3.8 Working Face Location and Special Burials 13-3
13.4 Conclusions 13-4

CHAPTER 14 LANDFILL GAS MANAGEMENT 14-1
14.1 Introduction 14-1
14.2 Landfill Gas Generation 14-1

14.2.1 Phases of Landfill Gas Generation 14-1
14.2.2 Landfill Gas Generation Volume 14-1
14.2.3 Landfill Gas Generation Rate 14-2
14.2.4 Landfill Gas Composition 14-2
14.3 Landfill Migration and Emissions 14-3
14.4 Landfill Gas and Control 14-4
14.4.1 Passive Venting Systems 14-4
14.4.2 Active Control Systems 14-5
14.5 LFG Monitoring 14-5
14.5.1 LFG Migration Monitoring 14-6
14.6 Landfill Gas Utilization 14-7
14.6.1 Electric Power Generation 14-7
14.6.2 Direct-Use 14-8
14.6.3 Pipeline Quality Gas 14-8
14.6.4 Other Potential Uses of LFG 14-8
14.7 Conclusion 14-9

CHAPTER 15 GUIDELINE FOR SITE SAFETY AND SECURITY 15-1
15.1 Introduction 15-1
15.2 Employee Training 15-2
15.3 Personal Protective Equipment 15-2
15.4 Preparation for the Unusual 15-3
15.5 Construction, Repair and Maintenance in Confined Spaces 15-3
15.6 Blood-borne and Other Pathogen Safety 15-4
15.7 Accident Prevention Responsibilities 15-4
15.8 Signs that Communicate Effectively 15-5
15.9 Conclusions 15-5

List of Tables

Table 2.4.1 Types of daily covers 2-3
Table 2.4.2 Advantages and disadvantages of inert wastes used as daily cover 2-3
Table 2.4.3 Advantages and disadvantages of wastes derived materials used as daily cover 2-4
Table 2.4.4 Advantages and disadvantages of artificial/synthetic materials used as daily cover 2-4
Table 7.4.1 Checklist for the determination of the suitability of working face 7-6
Table 9.5.1 Relation between landfill conditions and temperature 9-5
Table 9.5.2 Relation between CO concentrations and fire at the landfill 9-5
Table 9.6.1 Checklist for monitoring landfill area 9-6

List of Figures

Figure 1.3.1 Site approach road 1-2
Figure 1.4.1 Primary access road 1-2
Figure 1.4.2 Barriers at a primary access road 1-3
Figure 1.6.1 Hard-core secondary access road 1-4
Figure 2.1.1 Application of daily cover 2-1
Figure 2.4.1 Application of Geotextile Matting 2-4
Figure 3.1.1 Birds at the landfill 3-1
Figure 3.5.1 Falcons used as bird deterrent 3-3
Figure 3.5.2 Spacing of wires 3-3
Figure 4.5.1 External Road Network 4-2
Figure 6.4.1 Typical rat often found at landfills 6-2
Figure 6.6.1 Typical trap that may be used at the landfills 6-2
Figure 7.2.1 Placement of the first layer of waste 7-1
Figure 7.3.1 Trucks unloading their waste 7-3
Figure 7.3.2 Compaction of the wastes at the landfill 7-4
Figure 7.3.3 Bulky waste 7-5
Figure 7.3.4 Low density wastes 7-6
Figure 8.1.1 Wastes compacted by bulldozer/compactors 8-1
Figure 8.2.1 Compaction slope (3:1) of the landfill area 8-2
Figure 9.1.1 Fire at the landfill 9-1
Figure 9.2.1 Fire at the landfill area 9-2
Figure 9.3.1 Protective Equipment to be used in the vicinity of a fire 9-3
Figure 9.5.1 A multi-channel read out box 9-4
Figure 11.1.1 Site roads reaching to landfill 11-2
Figure 11.3.1 Entrance to a sanitary landfill 11-4
Figure 11.3.2 Waste reception at the landfill 11-5
Figure 12.1.1 Typical leachate plant 12-1
Figure 12.2.1 Leachate collection and conveyance system 12-3
Figure 14.4.1 Landfill gas reception compound 14-5
Figure 14.5.1 Monitoring at landfill 14-7
Figure 14.6.1 Gas engines 14-8
Figure 14.6.2 Greenhouse heated by LFG 14-8
Figure 15.1.1 What not to do 15-1
Figure 15.3.1 A properly dressed laborer at the landfill 15-3
Figure 15.8.1 Typical safety sign 15-5

CHAPTER 1 SITE ROADS

1.1 Introduction

Road access is a vital part of landfill operation and must be appropriately planned and budgeted for. It is imperative that landfill site roads are adequate for their intended use in providing safe and unhindered access to and from the tipping face at all times. Access for landfill equipment also needs to be considered and often this needs to be on separate roads or equipment tracks.

Prevention of damage to vehicles and quick turnaround times are essential in maintaining good customer relations at a landfill site. In addition, maintaining continuous access to the tipping face reduces reliance on emergency tipping areas, and minimizes the risk of forced of site closure due to the tipping area becoming inaccessible.

All landfill roads need to be well graded, and kept mud and debris free to the extent practicable, and with adequate drainage. Maintenance must be given high priority as early action in addressing road problems will usually minimize the need for major repairs over the long term. Use of a graded running course on main site roads is usually essential to ensure all weather access – sometimes waste materials (either as- received or re-processed), can be used for this purpose.

1.2 Road Types

Landfill roads can be divided into four types:

- Approach roads and entrances (with approach roads usually part of a regional road network)
- Primary Access roads – Internal roads to reception / weighbridge and internal site road junction
- Secondary Access roads – Main internal roads to operational area
- Tertiary Access roads – Temporary roads within the operational area

Where possible, all main access routes should allow for two-way traffic flow. However, where this is not possible the provision of passing bays must be considered and is usually essential at other than very small sites. The design standard for each of these road types will be very different as described below.

1.3 Site Approach and Entrance Road

Main site approach road design should be to local highway standards, including road markings and speed limit signs, based on anticipated traffic usage. Drainage with cesspits is desirable to enable both the entry road and adjacent approach roads to be kept clean.

Care must be taken not to under-design the pavement construction as repairs related to pavement failure and pothole development in this crucial area can lead to significant difficulties, particularly if site user vehicles need to queue onto a public highway.

Entrances will typically be bell-mouthed, and sealed with either tarmac or concrete. A minimum distance into the site of 25m from the entry point is desirable before reducing road configuration to a lower standard. Entrance roads are usually provided with kerb and channel, a camber to ditches on either side, or sloped to a ditch running along one side of the road, to enable mud and water to drain to the side of the road.

In order to present a good image at the site entrance, visibility splays should be grassed and/or landscaped, with due regard to any sight distance or other height restrictions applicable, and should be regularly maintained. In addition, site entrance signage must be neat, functional, well-planned and located. A site approach road is shown at Figure 1.3.1

Figure 1.3.1 Site approach road

1.4 Primary Access Road

This type of access road typically runs from the site entrance to the site reception facilities and to the egress point of any wheel cleaning measures. It should be paved with either tarmac or concrete, have lane markings and be designed to allow for surface water runoff, either by cambering to ditches on either side, or by sloping to a ditch running along one edge. Appropriate drainage and silt traps (or cesspits) should be provided for litter, debris and sediment control. A primary access road is shown at Figure 1.4.1.

The road surface must be capable of being regularly watered down and swept. Installing speed humps should be avoided (these can be when wet and in winter), unless required for safety reasons. Speed humps can also make road sweeping difficult and prove to be collection points for mud and debris. However, where speed control is necessary, consideration should be given to chicane-type features to enable cars, but not waste haulage and other heavy vehicles, to manoeuvre around them.

Figure 1.4.1 Primary access road

To avoid the need for speed humps, barrier arms can be installed and may be an appropriate solution. Barriers help to control vehicle speed, prevent access to unauthorized vehicles and make it much easier to sweep, clean and maintain the site roads (Figure 1.4.2).

Figure 1.4.2 Barriers at a primary access road

1.5 Secondary Access Roads

Hard-core (gravel) roads, as shown at Figure 1.4, can be used to provide secondary access within the site active area. However, due regard should be given to the length of road and the length of time it will be utilized. It may be more economical over the long term, when both construction and maintenance costs are considered, to provide a sealed / paved road for main secondary roads and perimeter access roads.

Hard-core roads should always be properly designed and where roads are formed over waste usually will be underlain with geo-fabric to facilitate drainage and prevent stone being "punched" into the underlying formation. It is also important to ensure that the road surface is above that of the surrounding area and that there is sufficient cross-fall to promote surface water runoff.

Run-off control (water table drains) must be provided along the length of the road whenever possible. At the very least, provision must be made for surface water to shed at discrete locations. This is particularly important where the access road is in a cutting, or where safety bunds are required the edge of slopes.

Good quality hard-core (road aggregate) is a must for this type of construction. If recycled or recovered gravel is used, material contaminated with wood, plastic, paper or sharp materials should be rejected.

1.6 Tertiary Access Roads

This is the final type of access that traverses the active working area and forms a tipping area and by its nature is always formed on waste and temporary in nature.

However, as with secondary access routes, forward planning of operational areas is vital to ensure that maximum use and minimum maintenance of these roads is achieved.

Figure 1.6.1 Hard-core secondary access road

It is important that these roads and tipping areas are sufficiently well constructed as to provide adequate traction for vehicles accessing the working face in all weather conditions. Consideration should be given to the use of any suitable dry waste material, including construction waste, spoil or in certain cases household waste, for working face area access. Materials, particularly where waste materials are used, should be carefully selected to avoid an increase in puncture risk for road vehicle tires, and to avoid traction problems in the active maneuvering area.

If gravel aggregate is used, as with secondary access roads, a geo-fabric can be utilized to prevent the material being "punched" into the underlying waste and to assist in the recovery of the majority of material for re-use when the tipping area is shifted. Grading to provide drainage is not essential, but if it is possible to have the finished surface above waste level, less maintenance will be required. Ruts should be regularly addressed, mud scraped off and drivers encouraged to split their approach in working face apron areas to reduce rut formation.

Single-track roads should be avoided by providing a width of at least one-and-a half- tracks.

Compactors and other heavy site mobile plant should avoid crossing or using the tertiary access roads and separate tracks should be provided for machinery that needs to be moved away from the active area for maintenance.

The better tertiary access roads are maintained, the greater the corresponding reduction in the impact on other access routes. In particular, the carry-over of mud can be reduced and the effectiveness of wheel-cleaning measures can be improved by keeping tertiary access roads at a good quality level, although weather and the nature of available site road making materials can often impact on this aspect of operation.

1.7 Conclusions

It is important to give vehicle access high priority at any landfill site. Good access roads can contribute significantly to customer satisfaction by reducing vehicle damage and enabling quick turnaround times, as well as reducing site operations costs.

Road maintenance is of fundamental importance and appropriate design is essential to meet service requirements. Rutting and potholes will trap water, which can damage roads and potentially result in the need for major repairs, as well as disrupting face access. Recovered waste or other surplus site materials are often suitable for use in forming temporary site roads, but such materials should be carefully selected to avoid introducing problems with maintenance, or increasing puncture risk to road vehicle tires.

CHAPTER 2 THE USE OF DAILY COVER

2.1 Introduction

The regular application of daily cover soil (Figure 2.1.1), or an alternative such as tarpaulins or an artificial (alternate daily cover) material is perhaps the most fundamental control on direct effects arising from waste landfilling. Sites with poor daily cover practices are often subject to bird, odor, vermin, litter and surface water quality problems.

The most fundamental control to achieve good landfill performance is to regularly and completely cover the waste and to ensure it remains covered in all areas other than the active face, which should be kept as small as practicable.

Figure 2.1.1 Application of daily cover

2.2 Objectives of Daily Cover

The key objectives of placing daily cover are to:

- Minimize windblown-litter
- Control odors
- Prevent birds from scavenging
- Prevent unauthorized scavenging by humans
- Prevent infestation by flies and vermin
- Reduce the risk of fire
- Provide a pleasing appearance
- Shed surface water and minimize contamination of runoff.

2.3 Consideration

2.3.1 Windblown Litter

Windblown litter is created when waste is deposited and is not controlled by compaction and/or cover soil. The use of modern equipment such as a bulldozer or steel-wheeled compactor ensures that material capable of being windblown is compacted and worked into the waste surface. The regular application of daily cover throughout the day, and completely at the end of the day is a key control over litter at most sites. However, under some conditions (e.g., where a site is windy, where cover soil is in short supply, or where artificial cover methods such as tarpaulins are being used) this may not be enough on its own to provide effective litter control and additional measures to control litter may be needed (see the Guideline for Litter Control).

However, windblown litter can occur simply as a result of poor compaction of the waste, or as a result of weather conditions. Both are issues which can be effectively addressed by the regular application of daily cover soil.

2.3.2 Odor

While the placement of daily soil cover does not provide a completely sealed surface, it is shown to be an effective control on odor. But daily cover alone will not be an effective odor control measure at most sites. However, when combined with a proper cell development sequence, the use of thicker intermediate cover layers and a positive gas extraction system, daily cover provides a vital and effective odor control measure.

2.3.3 Scavenging by Birds

Scavenging by birds, particularly gulls or the like occurs as the waste is tipped and exposed as a food source is readily available. Prompt compaction and covering of the waste with soil (enhanced by minimizing the size of the working face) minimizes the availability of the food source. Regular application of a thick layer of soil will reduce the attractiveness of a site as a food supply to gulls and is essential to discourage birds like crows and raptors that tend to dig through the cover to unearth food waste. It is essential to recognize that while closing down the food supply by applying daily cover is an effective control measure, it may take some time for improvements (by way of reduced bird numbers) to be noted at sites where birds are well established due to conditioning of the bird population. In such cases, other control methods may also be needed (refer to Guideline on Bird Control).

2.3.4 Scavenging by Humans

Scavenging by humans occurs at some sites, particularly those in poor countries and where security measures are inadequate in preventing entry to the site at the end of a working day. The application of daily cover, combined with compaction of the waste in accordance with good landfill practice will reduce the ability to access and sort through the waste and make a site less attractive to scavengers. However, daily cover alone will not eliminate scavenging where the waste has a value locally: other methods will also be required.

2.3.5 Infestation by Flies and Vermin

Practical experience, supported by experimental work, has demonstrated that the regular placement of cover soil will prevent the emergence of flies. The soil cover layer has to be a minimum of 100mm thick to be effective in this regard. Application of a thick layer of daily cover (200mm minimum) has also been shown to be very effective in controlling rats and other vermin such as feral animals as over a period of time, it simply makes accessing the food source too difficult to be attractive to animals. Insecticides and rodenticides can be an effective supplement to daily cover practices, but are expensive to implement on a large scale and will provide only a short term response if daily cover practices are not kept at a high, consistent level.

2.3.6 Fires

Fires are a concern for the management of any landfills and have been synonymous with open dumps. Fires typically result from poor operational practice, including at open dumps where waste is often deliberately set on fire to create more space.

Daily cover reduces the ingress of air to the waste and hence promotes the onset of anaerobic conditions. It also isolates the waste from the surface and reduces the potential for accidental or deliberate fires being started.

2.3.7 Visual Appearance

The use of daily cover always improves the visual appearance of a landfill site. While at some sites visual appearance may only be an issue when the waste surface nears final levels, a neat site free of windblown litter sets the first key impression of the level of management applied at a site and is an essential consideration at a modern, well run landfill site. When viewed from the site boundary a well-managed, well- compacted, fully covered landfill surface can give a uniform appearance and be aesthetically pleasing to the eye. In this respect, the use of daily cover does enhance site performance and give the public and local community confidence in the operational standards being applied at a site, particularly where neighbors are in relatively close proximity.

2.3.8 Surface Water Control

Daily cover, when loosely placed will have little impact on surface water management However, as moisture is an essential component for waste degradation many believe it should be allowed to penetrate the waste to speed up the stabilization process.

As cells are developed, graded areas of daily cover are typically amended with the application of further soil as intermediate cover layers. These thicker soil areas are compacted, graded and sloped to surface water drains to ensure that runoff from larger completed cell areas is not contaminated by waste materials.

2.4 Daily Cover Types

The types of daily cover available can be split into three generic material types as shown in Table 2.4.1.

Table 2.4.1 Types of daily covers

Inert	Waste Derived	Artificial / Synthetic
Free draining soils	Paper pulp	Synthetic foams
Non draining soils	Pulped paper	Geotextile matting
Contaminated soils	Shredded wood	Plastic film
Foundry sand	Shredded tires	Synthetic mesh
Colliery waste	Shredded plastics	Hessian fabric
Quarry waste	Recycling process waste	Tarpaulins
River silts	Pulverized household waste	
	Compost	

There are clearly advantages and disadvantages from the use of each of these generic cover types as summarized in Tables 2.4.2, 2.4.3, 2.4.4 below.

Table 2.4.2 Advantages and disadvantages of inert wastes used as daily cover

Advantages	Disadvantages
Ease of application and availability	Consumes void space
Visual appearance	Wheel cleaning often necessary
Non combustible	Potentially dusty
Can be applied using on-site plant	Can be relatively impermeable to leachate and landfill gas
Can be permeable to landfill gas and leachate	Poor traction for certain materials
Good traction quality for some materials	

Table 2.4.3 Advantages and disadvantages of wastes derived materials used as daily cover

Advantages	Disadvantages
Utilizes a waste stream	Can be ineffective in controlling odors
Permeable to landfill gas and leachate	Processing required
Good running surface	Can attract birds and vermin
Preserves void space for waste	Possible fire hazard
May be biodegradable	Dust can be a problem particularly from shredded wood

Table 2.4.4 Advantages and disadvantages of artificial/synthetic materials used as daily cover

Advantages	Disadvantages
Useful on inclined surface	May not suppress odor
Readily deployed with modifications to existing plant	May not prevent fly infestation
Saves void space	Potential fire risk
Permeable to landfill gas and leachate and biodegradable	Useful as daily cover only
Good visual appearance	Cost
	Not suitable for trafficked areas
	Color
	Difficult to apply under adverse weather conditions
	Difficult to apply progressively during the working day

Figure 2.4.1 Application of Geotextile Matting

2.5 Daily Cover Application

Ease of application is a factor that needs to be taken in to account when selecting the type of daily cover for use at a particular site. When selecting natural cover soils, it should be noted that dry, friable soil materials are easier to place than wet "sticky" clays. However, each soil type has advantages and disadvantages and the reality is that most sites tend to use whatever is available on site, as effectively as is possible.

The surface upon which the daily cover is applied should be well compacted and free from major ruts and depressions. A poorly compacted and graded waste surface will result in more daily cover being used than is desirable, which will result in a loss of void availability for waste as well as higher disposal cost.

2.6 Soil Use Plan

It is important, when using site soils as daily cover, to ensure that the soils are used effectively. A cover soil plan can be developed, as follows:

- Ascertain the volumes of cover used on a day-to-day basis
- Stockpile soil cover close to the active face for ready access
- Ensure the machine operative is aware of the quantity available
- Ensure machine operator prepares the surface to minimize soil use and that previous layers are stripped back and stockpiled for re-use before fresh waste is placed each day
- Record actual volumes used
- Review cover usage regularly
- Amend planned usage to reflect the effectiveness being achieved.

2.7 Conclusions

It is difficult to be prescriptive about what materials should be used for daily cover and the issue must be considered on a site by site basis. However, it is clear that regular and thorough application of daily cover is a fundamental control for effective management of a modern, well-engineered landfill site.

Many of the outcomes achieved by the use of daily cover can be achieved (at least in part) by other means. However, daily cover provides a simple, robust control on many of the key effects of landfilling and generally speaking is an essential requirement at any well managed site.

CHAPTER 3 BIRD CONTROL

3.1 Introduction

Birds frequenting a landfill site do so mainly for food. They are seen as noisy and messy, and commonly they can be carriers of pathogens or they can be the cause of local nuisance through fouling of roofs and roof-water supplies. Also, in some instances birds can pose a threat to the safety of aircraft where landfills are located near commercial airports. If birds are given a dependable food supply and a safe environment (suitable resting or roosting areas) their rate of breeding will increase, as it is shown in Figure 3.1.1 this will the potential to attract more birds from a greater distance around the landfill site.

Figure 3.1.1 Birds at the landfill

3.2 Background

Before bird numbers can be controlled at a landfill, it is important to have an understanding of the requirements that birds have and what makes a landfill site attractive to them. All birds have three key drivers: food supply, rest, and the ability to breed. Landfill sites can offer a suitable environment for all of these, depending on the type of bird.

When a bird infestation issue is to be dealt with, it must be taken into account that birds can become quickly accustomed to the usual methods of bird control that are used. The method of control must therefore be varied, as required, to provide an effective overall control strategy. Provided that birds can be identified by species it is often possible to use their instinctive and learned behavior against them to minimize their level of nuisance. It is possible to keep disturbing accumulations of birds and to progressively remove their food sources, resting and roosting places, until the birds find the landfill site no longer attractive. This process is the key to an effective bird control strategy.

3.3 Hierarchy of Controls

- Operational Practices
- Gas Guns and Direct Shooting
- Heli-kites and Balloons
- Distress Calls
- Signal Pistols and Cartridges
- Falcons and Raptors
- Wires and Screens

3.4 Operational Practices

Effective management of the working face is the starting point when attempting to reduce bird numbers. All waste that could be a source of food should be compacted and covered with soil on an ongoing basis throughout the day, and completely by the end of each working day, thus removing access to the food source.

Restored areas and non-operational areas of the site are the next areas that require attention. It is essential that there are no areas of exposed waste, or areas where water can pond and allow the birds to stand, drink and clean themselves.

Where there are restored areas the grass should be allowed to grow while the landfill site is still operational. The grass should be allowed to grow to a height of at least

225mm, as this will deprive most birds of areas to rest as it makes it difficult for them to land and to take off. Many bird species also fear predators where long grass is present.

3.5 Control Methods

Once an effective suite of site operational control measures has been put in place, a number of direct methods of control can be employed. These control measures should be varied on a regular basis to ensure that the birds are continually unsure of the type of danger that they are being exposed to, and hence tend to react by re- locating.

Lethal methods of bird control are sometimes not acceptable and may contravene local legislation. Also, public concern over lethal methods of control may produce adverse local comment. However, shooting and poisoning do have a role at some sites and can be very effective as some species of birds "learn" from episodes of this and can be so deterred, sometimes in large numbers. Any shooting or poisoning programme should only be undertaken by licensed persons and under strict control. Firearms, ammunition and poisons need to be properly and securely stored on site.

Gas guns (bird scares) are a non-lethal alternative to shooting or poisoning that are simple to operate and can be very effective for short periods at a time. Their effectiveness depends upon the gas guns being moved around the site on a regular basis. However, this method of control can become a nuisance to neighbors, particularly if the hours of operation of the equipment fall outside usual business hours.

Heli-kites and balloons can be very effective for 2 or 3 days at a time and again must be moved around the site regularly. If these are left out on site over night during the summer periods in an unsecure area, theft and vandalism may be a problem.

Bird scaring tapes and broadcasting equipment are also available and can be effective when the speakers are mounted onto the compactor. Again the use of this type of equipment needs to be varied and used somewhat sparingly to obtain a satisfactory result. It is recommended that when purchasing this type of equipment the bird distress sounds are purchased in a digital format and used with appropriate equipment as cassette tapes may jam or become scratched and ineffective. The distress call mix needs to be site-specific to be effective.

Signal pistols with bird scaring cartridges can also be used. To use this equipment a firearms certificate may be required, a secure location required for storing pistols and cartridges, as well as specialist training in their use, as is the case with live firearms. As with the gas gun, this control method has the potential to be a nuisance to neighbors.

Falcons and other raptors which are shown at Figure 3.2 can be used as an active bird deterrent. Usually this is achieved by contracting a specialist company to fly birds of prey around the site. These can be very effective, but the falconer will need to be fully inducted in the requirements of any Health and Safety policy and should be treated as an external contractor working on site.

Figure 3.5.1 Falcons used as bird deterrent

Wires and screens can be used to limit bird flight and discourage birds from settling. The spacing of wires must be such that birds cannot readily fly between them (Figure 3.3). Screens must be close enough to the working area to prevent birds from landing and taking off and this method is only likely to be suitable for larger birds. As a last resort the working area can be completely enclosed, but this can lead to operational problems if the area enclosed is not large enough to allow vehicles to turn or high enough to allow them to tip. However, netting off and achieving an enclosed area does have the added advantage of providing additional litter control.

Figure 3.5.2 Spacing of wires

3.6 Conclusions

The methods described offer guidance on bird control measures that can be employed. To be successful it has been shown that methods of physical bird control or deterrents must be varied on a regular basis. All approaches that work well depend on human presence and human interpretation of the situation, backed by positive and appropriate action. This starts with effective control of the food source by covering the waste effectively and regularly, and thereafter by implementing a hierarchy of measures that ultimately result in the landfill being an unattractive place for bird roosting and breeding. Many species of birds which frequent landfill sites have become used to human presence, so affirmative action is often necessary to get on top of a bird problem. The key to success lies in not allowing birds to establish their presence at a landfill in the first place. However, if birds have established then a site-specific, targeted programme of control methods can usually overcome the problem, although in some cases this can take a considerable period of time to achieve.

CHAPTER 4 WHEEL CLEANING

4.1 Introduction

The arrangements needed at a Landfill to prevent mud or other debris carry over onto public highways are very much site-specific. Where licenses or permits are in place, conditions are usually included that are aimed at minimizing the carryover of mud or debris onto the public road network and such conditions are usually enforceable. Carry over of mud onto the highway can also be an offence under local legislation in some situations.

4.2 Options for Minimizing Nuisance

The following opportunities exist for minimizing mud and debris carryover and hence nuisance, and enable a hierarchy of controls to be put in place:

- Increasing the length of paved internal site roads (queuing length)
- Using paved access routes
- Mechanical road sweeping
- Wheel spinners (wet or dry)
- Wheel wash facilities (bath or spray)
- Adequately maintaining on site roads
- Use of daily cover.

4.3 Hierarchy of Controls

The following broad hierarchy of controls is suggested:

- Keep the working area and site access roads as free of mud as possible, and in a good state of repair.
- Use a paved road from the public highway to the site reception facilities and weighbridge, and from any wheel washing facility to the site exit. A longer length of road assists. Note that speed bumps will invariably shake mud from vehicles (even after a wheel wash) and increase the need for road cleaning operations as well as making road cleaning more difficult.
- Adopt mechanical road sweeping (either self-propelled or tractor drawn) is an essential routine maintenance activity on paved roads.
- Apply other vehicle cleaning methods selected to suit site conditions and use them as part of routine operations:
  - Shaker bars
  - Wheel spinner – dry / wet
  - Wheel wash (bath)
  - Wheel wash (spray)
  - Hand held water lance.

4.4 Consideration

The carryover of mud or dirty water onto public roads or footpaths is unsightly, can create a nuisance, and can result in accidents. It can also result in problems with regulators, or even prosecution under local laws.

The routine use of an appropriate mix of the techniques described above will be of great benefit in preventing the carryover of mud or other debris onto public roads. For each and every method to be effective, regular use and good maintenance of equipment and support facilities are essential. In some cases, the level of effort that needs to be applied to this aspect of site operations may be influenced by climate, mud or dust and may be strongly seasonal.

It is essential that where abatement equipment is available, that it is regularly used. The onus is always on the operator to ensure that the use, maintenance and effectiveness of these control measures are adequate and that these measures are a routine basis part of the landfill operation.

Where wheel-cleaning facilities are provided they must be located as far into the site as is practical in relation to paved site roads in order to minimize the carryover of fine mud or wash water, and to avoid the staining of public roads.

Even where it is considered that the measures that are being undertaken within a site are fully effective, it is both good public relations and usually a permit to license requirement, to carry out a regular programme of road sweeping in the immediate locality. Where there are pedestrian pavements located near the site, it should be noted that these too can become soiled and may need to be regularly swept, or cleaned by water/mechanical means.

4.5 Conclusions

The operator of a well-managed landfill will routinely devote resources to ensuring that there is minimal impact from the operations on the external road network (Figure 4.5.1).

Figure 4.5.1 External Road Network

This will minimize the potential for public complaints, or issues with local regulators. Careful, structured and routine attention to the hierarchy of control methods available will typically result in minimal nuisance from mud and debris from a landfill site and will reflect a professional, well managed landfill operation.

CHAPTER 5 LITTER CONTROL

5.1 Introduction

A frequent cause for concern for sanitary landfill management is the control of litter. Litter is unsightly, can result in water pollution and can be a nuisance to surrounding property. Hence issues related to wind-blown litter are a common topic at Site Liaison Committee Meetings, during the planning process for new landfills, and with regulators.

Depending on site conditions, litter can be difficult to control and manage. However, in almost all cases there are methods available that can keep the offsite impact of litter to a minimum. A site-specific strategy should be drawn up to manage the impact of litter. Importantly, whatever strategy is introduced, it is noted that this will only be as good as its implementation. To reduce the risk of opposition or complaints from neighbors, effective litter control, achieved via a hierarchy of measures, routinely and thoroughly applied, is an essential site management tool.

5.2 Hierarchy of Control Measures

A hierarchy of litter control measures is available, based firstly on load containment, load handling and tipping, and moving through to secondary measures such as mobile litter screens, nets and litter picking at site boundaries. Each is expanded on from the overall range of controls that comprises:

- Load control
- Waste handling
- Portable litter screens
- Semi-permanent fencing
- Bunds
- Litter fencing
- Select tipping areas
- Netted areas
- Designated waste transfer areas
- Methods for handling for lightweight waste
- Restricting operating hours

It is unlikely that any single control measure will be sufficient to combat litter escape at a site, and it is essential to develop and refine an effective set of control measures for each situation. These may also vary with location on the site, or seasonally.

5.3 Methods of Control

5.3.1 Load Control

While not strictly a "site-based" control it is common for litter accumulation along principal site access routes due to loss from waste vehicles to be an issue for landfill managers. This can be addressed by applying load and waste acceptance controls to site users. Typically these include measures such as requiring all normal loads to be covered with nets or tarpaulins. Dry or dusty loads should also be tarpaulin covered.

Regular inspections should be made of access routes with active litter cleanup as required (often a routine process). Regular inspections should also be made of incoming vehicles to ensure loads are covered, secure and not contributing to litter. The ultimate sanction is to refuse entry to insecure loads or to operators who do not comply with load management requirements.

5.3.2 Waste Handling

Most of the litter lost from landfill sites results from wind acting on the waste at the point of tipping, as well as initial compaction practices. Litter loss at the point of tipping can be minimized by:

- Carefully assessing the waste type being handled i.e. dense waste is less likely to blow about than un-compacted low density waste such as plastic.
- Not tipping loose waste into the wind.
- Using previously tipped waste to cover and/or provide shelter for more vulnerable (mobile) waste streams.
- Partially compact loose waste before pushing out.
- Using heavier waste to hold down loose waste.
- Pushing waste out carefully and compact as quickly as practicable.
- Keeping the working area as tight as practicable.

5.3.3 Portable Litter Screens

- Use portable litter screens routinely.
- Screens should be placed down-wind and as close to the working face as possible.
- Screens should be of good solid construction and robust enough to withstand handling and relocation by machines (preferably they should be provided with lifting eyes).
- Screens should be cleared frequently to prevent them from becoming overloaded and potentially being blown over.
- Screens need to be moved as frequently as changes in the wind direction dictate.
- Damaged screens should be repaired on a regular basis.

5.3.4 Litter Fencing

This type of fencing is usually semi-permanent (covering a significant landfill development area through until post-closure). Typically it comprises a metal or nylon chicken wire / fish netting type system and should surround the entire operational area. If it is not practical to surround the entire area, fencing should at the very least cover the downwind side of the common prevailing wind direction. A design that has been found effective is to use pole and netting fences with an internal return at the top end to catch litter that collects at and travels up the fence with the wind. This type of fencing is also used to protect restored areas. Again, regular maintenance is essential if such fences are to prove successful.

5.3.5 Bunds

Soil bunds placed downwind of the operational area can also provide good litter control. Under most circumstances, litter rolls along the ground. In this case it will tend to roll over the bund and deposit in the calmer space behind it. The resultant litter has to be regularly removed if the system is to remain effective.

5.3.6 Perimeter Fencing

Perimeter fencing is usually provided mainly for site security, but it can form a last line of defense for litter. However, cranked tops are usually provided which often consist of strands of barbed wire which can trap litter but also make it difficult to remove, so this type of design should be avoided whenever possible. For the same reason, brambles should not be allowed to grow up perimeter fences, or immediately in front of them.

Hedging should not be used as a control measure as it can often be difficult to clear.

5.3.7 Select Tipping Areas

In valley or quarry landfill sites it may be possible to identify different areas within the developed footprint of the site that are out of the wind, hence making it possible to have more than one working area available to cater for differing conditions. Alternative tipping areas should be identified for all sites where there is a problematic prevailing wind direction.

5.3.8 Netted Areas

Full netting systems that completely enclose the working face area and all loose waste are sometimes required at very windy or exposed sites. These systems can be either portable or permanent. The portable type can be moved to suit changing operations. However, this can be a costly and time-consuming task and is usually only adopted at open sites where other options are not effective.

A permanent netted area has disadvantages related to machine operation and load access. Net systems may also require double handling of waste, which has cost and possible odor implications. However, fully netted systems can be very effective and may be one of the most effective control options available at open, windy sites.

5.3.9 Designated Waste Transfer Areas

At some sites, litter control can be improved by using on-site waste transfer processes such as waste separation and waste containerization, or baling. Such measures are usually only employed if conditions are particularly adverse and large volumes of one particularly difficult waste type are being handled (e.g., non-recyclable plastic).

5.3.10 Methods for Handling Lightweight Waste

Some lightweight wastes such as plastic (other related non-littering wastes such as ash or sawdust) can also be managed by excavation of a pit into which they can be tipped in a controlled manner and then immediately covered to avoid wind mobilizing the wastes.

5.3.11 Restricting Operating Hours

At some sites windy conditions occur at particular times of the day, or seasonally. At such sites, particularly where load control can be managed by containerizing waste, or by holding it at transfer facilities, restricting operating hours can be a particularly effective measure for litter control. Where opening hours can be restricted to morning or evening calm periods for example, or where activities can be suspended entirely on windy days, management of litter potentially can be greatly simplified.

5.4 Conclusions

A range of management techniques is available for litter control at landfill sites. If carefully and routinely Applied there should be few sites where a high level of litter control cannot be achieved. However, there will be occasions where litter problems develop, both on and off-site and litter pickers should be deployed immediately when the windy weather abates to collect the litter. They should start from the furthest most point that litter has reached, and work back to the site boundary and then internally.

It is also good site public relations to have regular litter pickers deployed along the access roads and buffer zones around the site to collect litter whether it comes from the site or not. This engenders a sense of good will with neighbors, which can have significant benefits with regard to community relations.

There are clearly many techniques available to us for collecting litter. Some of the simpler control measures are relatively inexpensive to implement as they relate simply to applying good operational techniques. Other measures can be much more expensive and a hierarchy of measures needs to be developed specific to each site to provide the most effective overall solution recognizing that litter control must be given priority in order to avoid visual and environmental contamination problems from landfilling.

CHAPTER 6 VECTOR CONTROL

6.1 Introduction

At a landfill "vectors" can include rats and other rodents, foxes, feral cats and dogs, insects, birds and other animals, each of which can carry disease agents and be a threat to public health. Birds require special techniques of control and are addressed in a separate guideline. Each type of vector can live and multiply at a landfill and is potentially of concern to site operators, regulators, public health professionals, and the general public. Fortunately, vectors are controllable and should rarely, and even then only intermittently, be present on a well-controlled landfill.

6.2 Background

Vector control involves avoiding vectors from living and becoming established on the landfill by not providing sources of food and water, and/or shelter. The only vectors that should be observed in any significant numbers at a sanitary landfill should be those that happen onto the landfill - they cannot be allowed to establish on the site and so should only be observed intermittently.

6.3 Hierarchy of Control

Vectors are controlled by a hierarchy of control methods, all aimed at eliminating vectors tot e greatest practical extent. This hierarchy includes:

- Operational Practices
- Monitoring
- Eradication

6.4 Operational Practice

The most important control measure used to minimize vector problems at landfills is the application of daily cover. Cover should be present on all solid waste at all times, except the tipping face while it is being worked. Daily cover of at least 150mm of compacted soil or similar material or an effective layer of alternate daily cover (ADC) should be applied on finished portions of the daily cell during operation and at the conclusion of daily operations, and not less frequently than once per day. Alternative daily cover materials such as tarpaulins, foams, granular waste etc can be effective as vector control after careful site-specific evaluation.

Intermediate cover of 300mm (minimum) compacted soil should be used on all areas not at finished levels, but not to be further landfilled for a period of 30 days or more.

Final cover is typically applied as each area is brought to finished level through the operational life of the landfill.

There should be no uncontrolled or uncovered (stockpiled) waste, including litter, tires, brush, appliances, construction/demolition waste or even inert industrial waste on the landfill property. The only exception is compactable soil-like inert wastes, such as ash, but even this waste must be graded and compacted to avoid ponding water. Tires, for example, are known to allow insect breeding due to ponding of water, but can also harbor a variety of other vectors such as rats as shown in Figure 6.4.1.

Figure 6.4.1 Typical rat often found at landfills

There should be no ponding water on the landfill property except as designed for runoff storage or sedimentation. Sedimentation ponds can, however, aid vector reproduction if not designed and controlled properly so as to minimize stagnant water, nutrient build-up and plant growth.

Finally, the waste must be compacted and graded at reasonable maximum slopes (see the Working Face Guideline) to minimize voids within the waste that can harbor rodents in particular. Rodents and foxes can readily dig into cover soil, but have much more difficulty digging into compacted solid waste.

6.5 Monitoring

Landfill staff should monitor the levels of key vectors on a daily basis as part of daily management. The option also exists to contract pest control experts to monitor and control vectors as necessary. Such experts know where to look for evidence of problems and are able to interpret signs of vector activity. A simple monthly site walk-over can provide a baseline of vector activity so changes can be noted and translated into action. Observations of various droppings, sightings, tracks, insect counts, etc are useful indicators of activity. Written reports from regular walk-over assessments should be kept on file so changes that occur over time and in response to control measures can be assessed.

On-site personnel can also be trained and given the time to perform monitoring on a regular basis. However, operations staff may not have the expertise, even after training, to monitor vectors efficiently, and may overlook or minimize the importance of monitoring. Appropriate systems and professional support are therefore often an essential management requirement.

6.6 Eradication

Eradication of vectors (i.e., where a specific issue is evident beyond the scope of management using routine control measures), is usually best performed by professionals. They have knowledge of the most effective methods available, some of which may not be available to the operator, and are able to choose and implement the best methods. In some cases on-site personnel do carry out eradication (e.g. shooting gulls or other birds) as well as using widely available baits, traps (as shown in Figure 6.6.1) and other techniques.

Figure 6.6.1 Typical trap that may be used at the landfills

6.7 Conclusions

Vectors addressed in this Guideline are birds, insects, rodents and other feral animals. The key basis for control is prompt compaction of all solid waste and the application of compacted soil or other suitable cover, no less frequently than daily. There should be only one working face unless absolutely necessary for waste segregation or operational purposes, and there should be no debris or piles of stockpiled waste outside of the working face. Ponding of water should be limited to designed sedimentation ponds or water storage lagoons.

Monitoring and eradication of vectors and pests is usually best performed by specialist firms contracted for that purpose. However, this work can also be performed by on-site personnel, but only if they are given the appropriate training and time allowance such that they can do so, on a routine basis. Monitoring should be performed frequently and even then, only if there have been no problems noted over an extended period. As a minimum, monthly monitoring is recommended.

CHAPTER 7 MANAGING THE WORKING FACE

7.1 Introduction

The working face is the focus of activity at an operating sanitary landfill. It is the area where waste is deposited by trucks, levelled and compacted, and where daily cover is applied. It involves waste transport vehicle movement in a potentially congested area, heavy landfill equipment movement to work the waste and cover, and personnel to operate equipment and to spot and direct trucks. It is the one location at the landfill where waste is loose, uncontrolled and exposed. It follows that good working face management is critical to achieving a good overall standard of landfill operation, and minimized long-term impact. Conversely, poor working face management has the potential to result in blowing litter and debris, greater potential for accidents, inefficient use of airspace, aesthetic problems, traffic movement problems, uneven or increased long term waste settlement and vector problems.

7.2 Placement of the First Layer of Waste

7.2.1 General

The first layer of waste placed in a cell is crucial for the landfill operation. This layer needs to be placed as a loose cushion layer, sometimes referred to as a "fluff" layer (Figure 7.2.1).

Figure 7.2.1 Placement of the first layer of waste

This loose first layer is essential in order to avoid damage to the liner and leachate collection system as a result of equipment tracking, or the waste itself penetrating the liner components during initial cell filling. Damage to the base liner system can very easily occur if initial cell filling is not carefully managed and such damage can soon negate good design and construction, and compromise the containment performance of a landfill.

7.2.2 Construction of the First Layer

The correct procedure for the construction of the first waste layer is as follows:

- The access road to the working face must be constructed from the top of the cell to the bottom in a way that ensures that the landfill vehicles will traffic over soil ramps and not the bottom of the landfill cell.
- At the end of the access road a relatively wide temporary area must be constructed for the maneuvering of trucks.
- The first trucks must dispose of the waste at the end of the access road or a temporary movement area formed on the landfill base.
- Bulky or hard wastes capable of puncturing the liner must be removed.
- Depending on the waste type, the first waste should be deposited at a vertical layer thickness of at least 50 cm (often up to 1m or more if bagged street collection waste is used), and this layer must not be compacted, so it then constitutes a protection layer to the liner and leachate drainage system.

The above procedure ceases when the whole area of the landfill cell base is covered with waste to a depth of at least 50 cm (1m recommended), so that no landfill equipment can track in close proximity to the liner or the base drainage system of the landfill.

7.3 Working Face Management Procedures

7.3.1 Summary

The key elements of good working face procedure can be summarized as:

- Use the smallest area practicable
- Orderly truck movement and unloading on an all-weather surface
- Work wastes together
- Effective waste placement and compaction
- Maintain working face slope
- Keep area drained
- Apply and compact soil cover promptly.

7.3.2 Use the Smallest Area Practicable

The optimum area of the working face depends on the number of trucks that need to be managed, and on the landfill equipment. Ongoing reviews should be performed in order to regularly adapt the working face size to the expected traffic numbers and total waste input.

An unnecessarily large working face is difficult to control, expensive to run, and unsightly. The exposed waste can lead to vector problems and blowing litter and debris. Also, with a larger face area, landfill equipment has a bigger area to deal with and more cover soil is needed per ton of waste, which in turn reduces landfill airspace utilization and landfill equipment fuel efficiency.

Waste disposal should usually be confined to one operating working face at any time (there are some situations where more than one face is needed – usually where waste inputs are high at a large site or due to adverse weather conditions). The working face should be only as large as necessary to allow adequate truck movement and unloading space, as well as efficient operation of landfill equipment. In general, the width of the working face should allow approximately 4m of width per truck unit unloading. However, may be impractical to have 4m per truck available at all times if many trucks tend to arrive over a short period, in which case, a balance must be struck between the time spent queuing for the trucks and the width of the working face. The vertical height of the working face should normally be from 2 to 5 meters. Lower face heights tend to be wasteful of cover, except for small sites. Excessive cell and working heights result in a long working face slope that can be difficult to control, other than at sites where there is a large input of waste.

7.3.3 Orderly Truck Movement and Unloading

Traffic patterns should be established and must be obvious to drivers. This may require flags or other markers as well as a "spotter" giving traffic directions. For larger sites it may be necessary to have separate roads to and from the face for incoming and outgoing trucks. Drivers should wait for instructions before discharging their waste. There must be safety distance between each vehicle of 2-3 m and each truck should stop at least 2-3 m away from the working face.

There should be sufficient space to allow trucks to unload at the foot or top of the working face as appropriate, and drivers should be encouraged to spend as little time as possible at the working face, as shown at Figures 7.3.1.

Figure 7.3.1 Trucks unloading their waste

Trucks can potentially unload at the top or bottom of the working face. However, unless dictated by access road arrangements, it is generally better to unload at the bottom where there is better wind protection and the trucks are less visible. This mode of operation also allows landfill equipment to push waste up the working face, which provides more visibility and control, as well as greater compactable effort from landfill equipment. The difficulty with depositing waste at the bottom of the working face is that surface water and muddy conditions occurring during wet weather may hinder truck movement and cause mud-tracking problems.

After the waste is deposited, the crew of the truck should ensure that no bins, covers or other equipment is left at the working face before exiting the area.

7.3.4 Work Waste Together

It is generally best to mix the incoming waste and spread and compact it upon receipt at the working face. The aim is to achieve a homogeneous waste mass within the landfill, resulting in more uniform decomposition, liquid and gas flow, and settlement. One exception is waste that can be used for cover or roads, which is often segregated and stockpiled near the face for that use. Another exception is if large amounts of a particular waste arrive over a short period, in which case waste placement may be delayed, depending on waste characteristics, until other waste arrives that can be mixed in with the stored waste. Such storage (stockpiling) should be temporary and in any case must not be overnight.

7.3.5 Waste Compaction / Placement

Experience has shown that 3 to 5 passes of heavy equipment over waste placed in 300mm – 500mm loose layers provides the best compaction without unnecessary equipment use and expense. Fewer passes of the compactor result in a lower density of the compacted waste (Figure 7.3.2). More passes generally provide little additional compaction, but result in significant additional fuel use and wear and tear on equipment. However, a site-specific assessment of compaction performance should always be made as the requirements can vary widely depending on the equipment type and size, and the type of waste being handled.

Figure 7.3.2 Compaction of the wastes at the landfill

The optimum waste layer thickness being worked is a function of waste characteristics and equipment size. Waste that is wet and homogeneous with few large items may be compacted in thicker layers without compromising waste density, often with a bulldozer alone. On the other hand, waste containing large items such as appliances or wood may require more passes and thinner layers in order to break and compact it effectively. Similarly, large, heavy equipment such as compactors may be able to work effectively with thicker layers, whereas, smaller bulldozers or compactors may require thinner layers to provide good waste densities.

7.3.6 Working Face Slope

Steep working face slopes result in poor compaction of the waste, equipment maneuverability problems, and may present an equipment stability problem. Conversely, a flat working face, while allowing good compaction of the waste, requires more cover, results in more exposed waste, and can lead to water drainage problems. A slope of between 3 and 10H to 1V will prove optimal for most landfills. Working at a shallower slope allows compaction equipment to work perpendicular to the incline, allowing more rapid waste control during heavy waste input periods. However, slopes up to a steepness of 3H to 1V may be appropriate in certain circumstances, particularly with relatively dry waste.

Most of the time, the working slope provides the pattern for the expansion of the next cells of the landfill. In order to avoid using excessive amounts of soil cover material for appropriate slope formation, it is advisable to work very carefully at the beginning of landfill cell development to optimize face management.

7.3.7 Keep the Working Area Well Drained

Water can impede working face activity by slowing truck movement in muddy conditions and can cause traction problems for landfill equipment. It can promote mud-tracking problems and will also attract vectors. A general rule is to avoid flat areas on a landfill and to promote drainage away from the working face and into the waste mass within the operational area at all times.

7.3.8 Apply and Compact Cover Soil Promptly

Cover soil (or appropriate Alternate Daily Cover if used) should be applied to the working face whenever operations are suspended, such as at the end of the working day, or over weekends. In addition, cover should be applied more frequently across the top and to any exposed sides of the daily cells throughout the day if at all possible. All waste should be completely covered with a layer of cover soil (or appropriate alternative cover) at the end of each working day.

It is extremely important to ensure that the traction needs of vehicles are taken into account when applying daily cover. It must be remembered that site users vehicles are generally designed for road use and not the rough terrain encountered in the active areas of landfill sites.

7.3.9 Disposal of Specific / Difficult Wastes

Some waste types may need special management at the working face. In these cases the following general procedures should be adopted:

- Bulky waste that is able to be crushed or shredded (e.g. old furniture) should be deposited at the bottom of the working face, so as to be cut and crushed by the bulldozer (Figure 7.3.3).
- Bulky waste should be spread uniformly at the bottom of the working face and other solid waste should be deposited over the top of it.
- Special wastes that require specific burial (e.g. bagged asbestos, odorous waste, or sewage screenings and sludge) should be directed to an area separate from the main active face where a pit can be excavated in the fresh refuse and the waste deposited into the pit and immediately covered by general waste.

This process is generally best handled by separate equipment and at many sites a digger is used for this purpose.

Figure 7.3.3 Bulky waste

- Low density wastes (e.g. wood and green waste) (Figure 7.3.4) need specific treatment as they cannot be readily compacted. This type of waste should be pushed into thin layers and covered with general waste to enable efficient compaction of the overall waste mass.

Figure 7.3.4 Low density wastes

7.4 Checklist

The following checklist can help operators to assess the suitability of their working face and identify possible gaps that have to be covered. Where "No" is ticked in Table 7.4.1, remedial action must be considered.

Table 7.4.1 Checklist for the determination of the suitability of working face

Issue	Yes	No
Has the working face been designed by taking into account the number of trucks per day?		
Is the slope of the working face in accordance with landfill design and expansion patterns?		
Is there a detailed plan for the disposal of the first layer of waste in order to avoid damage to liner and leachate collection systems?		
Are there clear traffic patterns and instructions for the drivers?		
Do the spotters direct the drivers for tipping and unloading?		
Do vehicles keep a safety distance between them, and from the working face?		
Are there established procedures for removing non-accepted wastes?		
Are there established procedures for the handling of special but accepted wastes?		
Are the liner system and / or drainage systems around the working face area undamaged?		
Is the compaction appropriate?		
Is the working face appropriately sloped and drained?		
Is the cover applied to the working face properly?		
Is there a system for segregating prohibited wastes?		

7.5 Conclusions

The working face is the most critical part of any landfill operation. It is the center of vehicle, equipment and personnel activity; and it is the area where fresh waste is exposed. Hence the standard of the working face operation will affect overall landfill performance, both during operation and well into the future.

Keeping truck and landfill equipment movement orderly, keeping the working face as small as practicable, and operating the working face efficiently to control the waste are all critical to the overall quality of landfill operations. A well operated working face will reduce the impact of the landfill, increase acceptance by neighbors and regulators, and result in the efficient utilization of landfill air space.

CHAPTER 8 WASTE COMPACTION

8.1 Benefits of Waste Compaction

It is essential at any sanitary landfill, that the waste be compacted. First and foremost this will ensure that the available void space is maximized, but effective compaction has a range of other benefits, as follows:

- Compacted waste provides a stable surface for vehicles to move on and on which to establish access roads and tipping areas.
- Birds and rodents find it more difficult to dig into the waste to access food.
- Compaction helps to prevent litter escape from the site surface.
- Well compacted waste inhibits odor release.
- Well compacted waste reduces fire risk.
- Compaction displaces air and increases the rate of onset of anaerobic conditions.
- A compacted surface aids storm water runoff and provides a good base for applying cover soil.
- Well compacted waste consumes less airspace.

A thoroughly compacted waste pile is the first sure sign of a well-managed operation. Compaction is typically achieved using a bulldozer or a specialist waste compactor, as shown at Figure 8.1.1. Waste compactors can achieve relatively high waste densities (in excess of 1t/m3) and can result in very efficient airspace utilization. However, in some situations – for example at tropical landfills where the waste is often relatively wet and site conditions can also be very wet, a heavy bulldozer may provide a better, more efficient machine option. The term "compactor" in the following discussion covers either a specialist landfill compactor, or a bulldozer, or a combination of the two, as applicable.

A high waste density should always be targeted and this should be checked by regular surveys using airspace geometry (allowing for settlement) and waste tonnage data. Densities of > 0.85 t/m^3 should be readily achievable with modern equipment. Densities less than 0.6 – 0.7 t/m^3 significantly reduce landfill efficiency and will increase the risk of landfill fires.

Figure 8.1.1 Wastes compacted by bulldozer/compactors

8.2 Compaction Methods

Waste acceptance rates at the working face should be controlled so as to ensure that there is no excessive buildup of waste in the working area. This will enable the compactor to deal with the waste as it arrives. However, at most landfills waste typically arrives at an uneven rate throughout the day, with several peak periods. The site operator must either scale his equipment fleet to meet these peak periods or, to save on machinery costs; there can be some controlled stockpiling of waste in a designated area which can then be dealt with between peak periods that same day. This way a smaller machine fleet can often still meet the waste handling needs of a site.

The compactor, as it pushes the waste to its final point of disposal, will mix, track over, and crush or shred it. Once crushed/shredded and in place, the compactor should pass over the waste a number of times, but as a minimum four passes is typically used to achieve effective compaction. While the optimum amount of compaction is controlled by a number of variables, including the nature of the waste and the machinery used, there is usually little benefit from exceeding four passes over the waste.

It is best for the compactor to work in a pattern to ensure a consistent degree of compaction. This can be achieved by making the first machine pass at one side of the working face (say left to right), making an up and back machine pass, moving over one wheel width, making two up and back machine passes, moving over one wheel width, making 2 more machine passes up and back, and so on until the entire working face has been run over by the machine 4 times. This process is, however, dependent on the nature of the waste being compacted and the geometry of the working area. Waste with a high organic and moisture content (e.g. Asian waste) will likely require less than 4 machine passes to optimize compaction.

The waste should be placed in layers targeted at no more than 300mm-400mm in compacted thickness and where practical, compaction should be up-slope (typically

3H:IV-as shown at Figure 8.2.1) to maximize the compaction effort of the machine.

Figure 8.2.1 Compaction slope (3:1) of the landfill area

The waste layers should be formed into slopes to aid surface water run off following cover placement. Compacted slopes should, where possible, be diverted towards internal drainage paths as leachate and landfill gas will preferentially follow these layers. As a consequence it is better to have waste slopes at the directed into the waste mass to reduce the possibility of leachate build up and to minimize the potential for leachate breakout from the compacted waste faces.

8.3 Conclusions

Well-compacted waste is an essential component of good management at a landfill site and an efficient, practical method should be developed at each site to ensure a high degree of waste compaction is routinely achieved. Compaction methods create preferential pathways for the flow of leachate and landfill gas and therefore should be directed inwards towards drainage pathways within the waste mass to encourage the flow of leachate and landfill gas, and to minimize the risk of leachate breakout.

CHAPTER 9 LANDFILL FIRES

9.1 Introduction

Fire is one of the more serious risks that a landfill will face through its life. Fires are common at dumpsites, but serious fires are relatively infrequent at well-managed landfills. Landfill fires as shown at Figure 9.1.1, can cause serious damage to the infrastructure of a landfill and can be a major hazard for site staff. Additionally, landfill fires can create significant problems (in terms of health, air quality and social acceptance) with the surrounding community.

Materials that are landfilled can be the source of both surface and subsurface fires and waste typically has a high fuel energy value. Regional landfills can represent a huge stockpile of flammable material. Understanding landfill fires requires consideration of the fire triangle: fuel, air, and ignition source. Combustible materials in the waste such as paper, plastics and wood represent the main fuel. Oxygen is usually present in the wastes when deposited, or it can be drawn in through the surface. Finally there needs to be a source of ignition: sufficient heat to ignite the combustible material and sustain the combustion (e.g. hot ash), smoldering material, sparks, spontaneous combustion chemical reaction, or even arson.

Figure 9.1.1 Fire at the landfill

9.2 Characterization of Fire

Fires at landfills can be classified into four categories, corresponding to the level of alert:

- Level 1Alerts: Small fires occurring on the landfill property, but not actually involving landfilled waste, compost or stockpiled recyclables, e.g. car fires, bin fires, equipment fires, office fires.
- Level 2 Alerts: Small waste fires that can be contained by on-site resources within24 hours and fully extinguished within 48 hours. Level 2 fires will typically involve less than 200 m3 of burning material.
- Level 3 Alerts: Medium size waste fires or large fires at compost facilities that can be contained in less than one week and that can be fully extinguished in less than two weeks. Typically, 200 to 5,000 m3 of waste material is involved.
- Level 4 Alerts: Large or Deep Seated Landfill Fires that require more than two weeks to contain typically involving more than 5,000 m3 of burning waste.

Fire at the landfill area is shown at Figure 9.2.1.

Figure 9.2.1 Fire at the landfill area

9.3 Immediate Actions

Fires at Level 2 or 3 alert levels have the potential to turn into a Level 3 or 4 fire if an immediate and effective response plan is not applied. This is the reason why quick recognition and spotting of fires is essential. The prevention of the escalation of a fire is related to the delineation of flammable waste, the application of immediate soil cover, and the potential for access and immediate excavation of the landfill slopes.

It is very important also, in the case of a Level 4 fire, to have ensured exact spotting of the fire as well as an assessment of the current and potential extent it could attain. Spotting should be linked to mobilization of fire-fighting resources from the outset.

In any case, the first actions that must be taken at a landfill, during a fire of level 2 or above are:

- Shut-off of the landfill gas collection and management system (if present).
- Water services must be available for firefighting, including treated leachate if available.
- Standby electricity generators should be available for use, in case of power failure.

The following actions need to be taken in the case of a landfill fire of level 2 or above:

- Immediate spotting of the fire
- Call to the fire department
- Characterization of the fire – choice of alert level
- Appointment of an incident commander
- Application of communication plan
- Selection of the most appropriate firefighting equipment
- Activation of alternative working face
- Monitoring of the air emissions and the course of the fire
- Application of the communication plan for the local community
- Application of the evacuation plan for residential areas if necessary
- Use of soil reserves
- Use of health and safety equipment by staff (Figure 9.3.1)

Figure 9.3.1 Protective Equipment to be used in the vicinity of a fire

9.4 Extinguishment Methods

The approach taken to extinguishing a landfill fire depends on the type of fire. Selection may be dependent on the wind direction and intensity, the location of the flammable materials and the ability to mobilize personnel, fire department equipment and the potential for impact on local communities.

9.4.1 Water Application

Although water is an effective fire-fighting agent for near surface fires, ensuring that water reaches a deep-seated fire can be problematic. Water tends to flow along paths of least resistance in the waste such as through poorly compacted pockets. This process of channeling can result in significant short-circuiting, and inability of the water to reach the active burn zone at depth. Water does not readily penetrate cover layers composed of low permeability soils, especially if the cover has been compacted by vehicular traffic.

In situations where soil cover is present at surface or at depth, surface application of water is often ineffective. However, stripping of the soil cover should never be considered because it will facilitate air entry, which will accelerate the burn. To deliver water beneath cover soils, the preferred approach is to inject water into wells or other available injection points. Wells can be quickly drilled with a 150 to 300 mm diameter auger rig. Well screens can be dropped into the boreholes to keep them open. Water can then be deployed into the injection wells from tank trucks or pumped in directly if a fire hydrant or water body is located nearby.

Large volumes of water may be required as 5000 h of water is required to absorb the energy released by the full combustion of 1 tons of garbage. The use of foam and surfactants can reduce this volume markedly.

The firefighting team has to consider that the use of large amount of water for the extinguishing of a fire can produce large amounts of leachate, which may possibly, overload the leachate treatment facility or require temporary containment or ponding.

9.4.2 Excavate and Overhaul

For deep-seated fires, where water application may not be an effective fire-fighting tool the most appropriate method for extinguishing the fire is often to excavate and "overhaul" the waste.

The first step in controlling a fire in such way is the filling of parallel trenches previously excavated by the landfill operator. Next, smother the fire zone with a 2 to 3 m thick lift of refuse or soil and smooth (overhaul) the landfill surface. These actions reduce the amount of air fanning the burn, reduce the rate of burn and the amount of smoke that the fire emits, and make the landfill surface a safer work environment.

9.4.3 Oxygen Suppression

By limiting the amount of oxygen within the burn zone it is possible to extinguish a landfill fire over time, but this is usually a slow process.

This method is similar to excavating and overhauling, since it is based on the isolation of the burning section of waste from the rest of the landfill. Isolation is achieved by excavating around the burning mass, until inflammable material (usually soil or rock) is found. The excavated trench is filled with low permeability material in order to limit the flow of oxygen through the burning waste mass.

After applying this method, long term temperature and gas monitoring data needs to be collected in order to determine whether the selected method was effective or not. Also, the collection of the monitoring data indicates when the fire is extinguished and the materials from the trenches can be removed in order to fill them with waste.

9.5 Monitoring and Prevention

9.5.1 Temperature Monitoring

Monitoring of landfill internal temperature is very useful for establishing the risk of or extent of a fire, but only if the temperature is measured at depth. The best way to collect temperature measurements (and gas composition samples) is to drill a number of monitoring wells in and around the suspected fire zone. Air rotary rigs should not be considered since injection of large quantities of air could accelerate the fire and possibly trigger a methane explosion. In any event safety equipment, including respirators and ventilation fans, must be used by workers during such work.

To keep the holes open, the monitoring wells should be cased, preferably with slotted steel casing. Thermistors can then be lowered down the holes to measure temperatures at various depths (e.g. 5 m intervals) within the waste. To prevent convective currents between the various temperature intervals, the installation of foam baffles on the thermistor strings is recommended. A multi-channel read out box is used to measure temperatures at surface, as shown at Figure 9.5.1.

Figure 9.5.1 A multi-channel read out box

Temperature monitoring has proven to be a very useful procedure in prevention of landfill fires as well as in monitoring to confirm that the fire has been extinguished. In Table 9.5.1, the relation of landfill conditions and temperature is presented:

Table 9.5.1 Relation between landfill conditions and temperature

Temperature	Landfill Conditions
< 55 DC	Normal Landfill Temperature
55 – 60 DC	Elevated Biological Activity
60 – 70 DC	Abnormally Elevated Biological Activity
> 70 DC	Likelihood of Landfill Fire

Monitoring of gas composition provides very useful insight fire conditions at depth and the success of firefighting measures. Parameters that must be measured at various times include methane, oxygen, carbon monoxide and hydrogen sulphide. Of those four gases, the carbon monoxide is the most useful indicator of a subsurface fire. In Table 9.5.2 an empirical scale is presented that assists to the assessment of fire conditions in demolition landfills.

Table 9.5.2 Relation between CO concentrations and fire at the landfill

CO concentration (ppm)	Fire Indication
0 – 25	No Fire Indication
25 – 100	Possible Fire in Area
100 – 500	Potential Smoldering Nearby
500 – 1000	Fire or Exothermic Reaction Likely
> 1000	Fire in Area

The presence of oxygen at concentrations above 1% provides an indication that existing oxygen intrusion barriers (i.e. soil or membrane covers) are not effective in keeping oxygen out and that additional soil cover is required. On the other hand, a build-up of methane to levels in excess of 40 % is a positive indicator that oxygen is being successfully excluded and the biological regime is reverting to cooler anaerobic conditions.

During a landfill fire, sub-surface oxygen levels within the burn area are typically in the range of 15 to 21% oxygen. As firefighting and capping efforts progress, oxygen levels drop consistently and when the fire is extinguished the oxygen levels typically drop below 1%.

9.5.2 Leachate Management

Application of large quantities of water will invariably produce leachate. In many cases when extinguishing landfill fires, leachate management has proven to be a significant issue.

To minimize the environmental impacts of leachate, recirculation of firefighting water should be considered on projects where large volumes of water are used. Recirculation requires that leachate should be directed into settling ponds, preferably including filtration, and booster pumps may need to be brought on line to enable recirculated water to augment water supplies from nearby fire hydrants.

The use of foams and surfactants can greatly reduce the use of water for fire control and hence reduce the potential leachate problem.

9.5.3 Fire Prevention and Control Plan

It is very important for every landfill to have an established and maintained fire prevention and control plan. In this plan, essential issues related to the landfill must be included such as site characteristics, Fire Fighting Resources, Landfill Fire Alert Levels, Incident Command Structure, Fire Response Actions and Responsibilities, Firefighting methods, Landfill fire risk reduction strategies, Personal protective equipment etc all site personnel need to be aware of the plan, and trained in its application.

9.6 Checklist

The following checklist can help operators to assess their readiness to handle a landfill fire and identify possible gaps that have to be covered. Where "no's" are ticked in the Table 9.6.1 remedial action must be considered.

Table 9.6.1 Checklist for monitoring landfill area

Description	Yes	No
Buildings		
Workplace clean and orderly		
Emergency exit signs properly illuminated		
Fire alarms and fire extinguishers are visible and accessible		
Stairway doors are kept closed unless equipped with automatic closing device		
Appropriate vertical clearance is maintained below all sprinkler heads		
Fire extinguishers are serviced annually		
Corridors and stairways are kept free of obstructions and not used for storage		
The roads that lead to the buildings are clear and accessible to the fire engine		
Training		
There is a specific training program for fire prevention & extinguishment		
New employees are given basic fire training		
Job-specific fire training held for employees on a regular basis		
Personnel familiar with applicable Material Fire Data Sheets		
All personnel familiar with emergency evacuation plan		
Training documentation current and accessible		
The guests of the landfill are informed that have to follow the staff's instructions		
Landfill		
There is stockpile of earth close to the working face		
There is on site equipment to move earth		
Alternative working face has been planned		
There is adequate supply of water under pressure for fire-fighting purposes		
There is a water storage tank for fire-fighting purposes		
Fire-fighting equipment is readily available		
Record-keeping procedures for all fires		
Electricity generators are available for use		
There is suitable access road for the fire engine to reach the working face and the burning mass		
All the equipment maintenance procedures are followed		
All flammable materials are stored properly		
The most dangerous locations of the landfill for fire, are signed properly		

Description	Yes	No
The emergency telephone numbers (fire department, hospitals, police etc) are displayed in approachable places		
There is an adequate network of lightning conductors for protection from lightning strike		

CHAPTER 10 STORM WATER AND SEDIMENT CONTROL

10.1 Introduction

Landfills are engineering structures that generally result in a new landform being developed as a valley infill or mound. Invariably this occurs within a surface water catchment and the Landfill needs to be designed to cater for rainfall and storm water runoff during development, filling and for the permanent condition following closure.

With few exceptions, landfills are also significant earthworks projects. Landfill development typically requires earthworks for cell formation including in many cases, the placement of components such as compacted clay liners. In addition, operations generally require the placement of soil cover layers and final cap – typically also comprising soil materials. All such materials have the potential to generate sediment during rainfall events that result in runoff and this sediment can impact on downstream waterways if not adequately controlled.

Poor control of storm water can have very significant impacts not only on receiving waters downstream of the site (e.g., due to entrained litter, sediment and chemical contaminants), but also on the practicality and cost of site operations.

Providing adequate surface water drainage is therefore a critical component of any Landfill facility design and in many situations is a key driver of overall facility design.

10.2 Functions of Surface Drainage Systems

Landfills are typically subject to storm water running on or towards the footprint from the surrounding catchment, and also generate runoff from completed cell areas. All runoff, particularly from earthworks areas that are not stabilized by vegetation, has the potential to generate sediment. Runoff from active areas (where waste is being disposed, or in areas where waste is poorly controlled) has the potential to also become contaminated by organic and inorganic materials from the waste itself, and by leachate reaching surface water drains. This can potentially lead to significant contamination of runoff from the site and ultimately of surface receiving waters and even groundwater. The design of a Landfill storm water system therefore has a number of critical functions:

- Safely conveying surface run-on and runoff from the landfill and associated catchment to the discharge point for the site.
- Ensuring landfill operations are not compromised by poor surface drainage.
- Minimizing leachate generation by preventing surface water from entering the waste mass (to the extent practicable).
- Avoiding contamination of surface water by waste either directly or due to leachate breakouts and surface flows.
- Minimizing soil loss and erosion from borrow sources and completed landfill areas.
- Controlling sediment discharge and surface water contamination.
- Providing water storage for site use and firefighting (typically as an adjunct to sediment control using detention ponds).

10.3 Key Design Elements

10.3.1 Over View

At most Landfills, the surface drainage system has a number of key elements. Working upstream from the receiving water/discharge point these are:

- Storm water detention/sedimentation/storage ponds
- Primary drainage systems
- Secondary drainage systems
- Tertiary (temporary) drainage systems
- Supplementary systems such as pumping and diversion drains
- Landfill cap drainage.

10.3.2 Storm Water Detention / Sedimentation / Storage Ponds

Generally the principal design objective is to directly bypass and discharge (without treatment) clean runoff from any surrounding undisturbed catchment areas. At valley fill sites high level cut-off drains formed of stable permanent materials (grassed channels, concrete or riprap-lined channels) can sometimes be used to divert clean runoff right around the facility area. However, in almost cases significant clean water diversion may not be possible during the operating life of the landfill because runoff from the disturbed site area and parts of the contributing catchment may not be able to be practically separated. Such runoff will contain sediment and will under most flow conditions, require detention and settling processes in a storm water (sediment) pond prior to discharge.

Local Guidelines or regulations often govern storm water pond design. The key features normally required are:

- Ability to store runoff from moderate storm events for gravity settlement, sedimentation using chemicals (where required and appropriate) and slow discharge (usually via a siphon or other decant structure targeting the upper clear water zone)
- Ability to safely bypass overflows during larger events (service and emergency spillways)
- Provision of a deep water zone for sedimentation (sediment fore bay) with machine access for de-silting
- A controlled slow release outlet (decant outlet)
- Flow and water quality monitoring facilities
- Storage zones (on or off line) for surface water storage (where required)
- Typical design criteria for sediment ponds are:

Emergency spillway: Probable Maximum Flood flow

Service spillway: 1 in 50 to 1 in 100 year event

Full range decant time: Several weeks typically

Storm storage: 1 or 2 year critical event where practical

10.3.3 Primary Drainage Systems

Primary drainage systems can comprise both natural streams and channels and the engineered drains that form the permanent external drainage to the Landfill (that is outside the footprint).

Design requirements for primary (permanent) drainage vary greatly from location to location and are typically governed by factors such as local design regulations, site license requirements, climatic conditions and local materials and construction methods. Typical designs may include:

- Shotcrete and concrete-lined channels (including with energy dissipation)
- Rock-lined trapezoidal channels
- Broad, low gradient grassed channels
- Piped culverts and drains.

Normally open channel structures are used for primary drainage to optimize flow capacity and to reduce the risk of blockage.

Typical design criteria for primary drainage systems at Landfills are:

- Ability to convey 1 in 100 year flow within normal flow zone (with freeboard).

At flows beyond the design capacity of the system localized flooding can be expected. However, the selection of a return period of 1 in 100 years ensures that the risk of significant inundation and adverse effect on the Landfill during the typical life of a landfill facility (20-50 years) is relatively low.

10.3.4 Secondary Drainage

Secondary drainage comprises subsidiary channels, structures, piped drains, road culverts, mechanized pumping systems etc. that are either semi-permanent, or permanent. Typically such features are associated with major phases of Landfill development, related to cells, benches, or waste lifts, and are expected to have a required service life of 5-20 years. However, secondary drainage also includes the permanent drainage on the final cap.

Such systems are usually designed to provide a balance of construction cost and risk. Under storm events more severe than the selected design life it is expected that such drainage systems may suffer drainage and require repair and reinstatement and that there is the potential for impact on the Landfill operations area (for example due to secondary drain overflow into inactive cell).

At landfills where geomembrane cover systems are used, or where significant areas of sidewall geomembrane will remain exposed for periods of time, there is the potential for large volumes of runoff. This runoff occurs quickly and can impact on landfill operations and leachate volumes in a major way if not controlled. In such situations the use of surface gutter drains (generally formed of the geomembrane material itself) is essential.

Design requirements for secondary drains may be specified in the Landfill license, but are often determined on a site-specific basis considering climate, timing, risk and cost. Typically adopted design criteria are for such drains to be designed to convey the 1 in 5 to 1 in 10 year flow, with sizing for the maximum temporary catchment area that contributes to a particular drain.

10.3.5 Temporary Drainage Systems

Such systems relate to active areas, earthworks areas and areas that are being capped and rehabilitated up until the point where permanent conditions are reached. Design is usually site-specific, often based on local soil conservation/sediment control guidelines and on short-term experience gained on site for local drainage management.

10.3.6 Active Area Drainage

Drainage in the active area where waste is being disposed should be carefully managed. The main rule of thumb is that any rainfall or surface water contacting waste must be treated as leachate, so clearly minimizing this water volume is a key driver for design and operations. Runoff from such areas to the secondary drainage system needs to be avoided until intermediate cover is placed.

Features of active area drainage include:

- Slope surfaces inwards to a low point draining into the waste.

- Provide ample slope to keep the tipping area from flooding.
- Minimize the active area and hence storm water ingress into the waste mass.
- Apply intermediate cover regularly, and as soon as practicable to promote maximum "clean" runoff (albeit that the sediment component needs to be treated for a period of time).

10.3.7 Landfill Cap Drainage

Landfill cap drainage is implemented progressively as the landfill is capped and rehabilitated. Timing, settlement, cap construction method and contour are all key determinants of the final cap drainage configuration.

Ultimately the cap drains are permanent secondary drainage features on the site and hence need to be:

- Durable
- Require minimal maintenance
- Able to accommodate ongoing settlement.

Often the rate of and extent of settlement dictates the programme for establishing permanent cap drainage. For this reason a staged approach is often taken with drains formed and lined temporarily, and then re-levelled and permanently lined or vegetated when the bulk of landfill settlement has occurred.

Special cap drain configurations are adopted in areas of high rainfall or where exposed geomembrane caps are used. These can comprise site-specific designs such as masonry lined channels with energy dissipation and outfall structures, corrugated steel flumes, or geomembrane gutters and channels. All such features require careful detailing and site-specific design.

10.4 Conclusions

The design of the storm water drainage system at a landfill is key to optimizing operations, managing the risk of flood damage and avoiding adverse effects offsite due to sediment, leachate and waste contamination in site runoff.

The design of storm water system needs to consider both the permanent (completed) landform as well as the range of intermediate conditions that will occur.

A main (primary) drainage system needs to be configured to safely convey flows from the catchment within which the facility is sited in order to maintain the integrity of the facility over the long term. Further secondary and tertiary drainage features are designed for smaller contributory flows, for predominantly interim conditions, and generally carry a higher design risk to avoid over-design and excessive construction cost. The exception is the final cap drainage which ultimately becomes a permanent feature of the site following closure and hence needs to be conservatively sized and detailed.

Other site-specific features are generally employed to minimize surface water ingress to active areas, silt generation, downstream flooding, and sediment and contamination in storm water flows.

Combined with an effective Landfill liner (barrier) system and good operational practices, effective surface water control based on sound design and detailing is one of the most important environmental control features at any modern Landfill site. Storm water system design shortcomings can quickly become evident in severe climates or rain events, especially sites where rainfall is routinely high or monsoonal. This has the potential to compromise facility operation, result in large quantities of leachate needing to be dealt with, add cost, and cause downstream environmental impacts. Careful design of the storm water management system is therefore a key aspect of any Landfill development.

CHAPTER 11 WASTE CONTROL AT LANDFILLS

11.1 Introduction

11.1.1 Definitions

Control of waste accepted into a Landfill requires the use of protocols to routinely screen waste inflow and / or criteria to assess the admissibility of waste for handling and disposal. These criteria are aimed at determining whether particular waste should be accepted or rejected. All acceptable wastes are classified as permitted waste and those rejected are classified as prohibited waste in relation to the operating criteria for the facility.

Prohibited wastes can include specified waste categories such as tires, sludge that have not been dewatered, recyclable materials or hazardous waste. Other associated controls may include the specification of maximum allowable water content in sludge, and maximum allowable amounts of waste per annum for specific waste categories.

Waste control processes for a Landfill should be considered during the risk assessment process, before the development of operational procedures. The reason for this is that the permitted waste definition will affect the leachate and landfill gas generation and composition, and are also likely to affect the specifics of the containment system design and landfill development configuration. Therefore waste control protocols need to be established before any design and risk assessment can be conducted for a particular facility.

Waste control processes are also important in recording information about waste types that are subject to control, including:

- Establishing accurate information about deposited waste (quantities, timing).
- Recording the location of waste placement and issues around the potential environmental risk of the facility.

11.1.2 Control Processes

Control processes such as pre-determined waste acceptance criteria are usually statutory, or facility-specific – sometimes both. Statutory criteria may include reference to facility permit conditions, national waste management policies (e.g., related to hazardous waste), statutory guidelines and procedures, and other legal instruments.

These criteria are usually implemented jointly by both the facility operator and regulators. Facility permits often detail operational procedures, guidelines, and other procedures to be adopted by a facility. The fundamental objective of such control methods is to ensure adequate:

- Pollution control
- Operational and public safety
- Information management
- Optimization of Facility capacity.

11.1.3 Control Infrastructure

The primary means of Facility control is achieved by controlling access and entry points. Access to a Landfill is always via a site road (Figure 11.1), usually with a gatehouse and weighbridge. The perimeter of the landfill is usually delineated and secured by natural or artificial features such as ditches, dykes, or secure wire perimeter fences.

The site entry point is typically either continuously manned during the hours of opening (sometimes 24 hour security is also warranted), or may be automated where a high degree of upstream waste control is possible (applies to some transfer stations and to container-based waste transfer systems).

Figure 11.1.1 Site roads reaching to landfill

11.1.4 Levels of Control

The degree of facility control achieved can be are classified as a series of levels.

(1) Level 0: Uncontrolled

This occurs where the facility has no secure barriers to entry, which means that both users and other parties such as stray dumpers or scavengers can access the site without control. Such facilities are vulnerable to receipt of all types of waste and to unsafe operation. They contribute to environmental degradation as all types of wastes can end up in the facility and such sites are essentially "uncontrolled tip sites. Such a level of operation is not consistent with modern sanitary landfill practice.

(2) Level 1: Basic Site Access Control

This is when the facility is adequately delineated and secured at its perimeter, but with only unmanned entry point(s) which mean such facilities can apply some access control and can be closed or suspended to use by trucks by securing those entry points.

(3) Level 2: Site Access and Entry Point Control

This is considered the minimum operating standard for a modern Landfill. In this situation the site perimeter is fully secure and control of incoming waste loads is exercised at (typically) a single entry point. In addition to overall access control, loads are allowed into the site only when the entry is open and manned. At such facilities information about waste source, type and quantity can be acquired as part of the access control process.

(4) Level 3: Site Access, Entry Point and Operations Controls

This is considered the normal operating level for a modern sanitary Landfill. In this situation, in addition to waste acceptance controls at the site entry point (Figure 11.2), operations controls related to the tipping area (using a "spotter") as well as control over the placement and compaction of waste are employed.

(5) Level 4: Site Access, Entry Point, Operations and Waste Material Controls

Level 4 requires the use of specified pre-determined Waste Acceptance Criteria (WAC) to permit particular waste loads. This process is administered at the point of entry allowing only permitted waste into the facility. Detailed documentation, including inspection and when necessary on the spot testing of waste, are usually associated with this level of facility operation.

11.2 Waste Control Chain of Responsibility

11.2.1 Generator

Waste control commences with the generator of the waste who has the responsibility of disclosing accurate information about the waste. This can be achieved with a Waste Profile Form (WPF), or by simply packaging waste in appropriately color-coded bags.

For hazardous waste, which will only be accepted at certain sites, it should be mandatory for waste generators to accurately consign its waste using a Waste Consignment Note (WCN), or similar. Such waste declarations provide firm information about the waste and are necessary for administration of waste control at the Landfill facility and must be mandatory at sites accepting hazardous or scheduled waste.

11.2.2 Carrier / Haulage Contractor

Waste haulage contractors have the responsibility in the chain to ensure clear and correct documentation of information about the waste they are carrying to enable quick assessment at the facility. This can be transmitted with either a WCN or a Waste Manifest Form (WMF). It is an essential part of this process that waste generators endorse the haulage contractor and for corresponding waste to be delivered with the required documentation to the facility. The carrier should ensure it facilitates easy inspection or CCTV screening of loads by removing tarpaulins and / or correct positioning of delivery truck.

11.2.3 Landfill Manager

The Landfill Manager effectively assumes ownership of waste admitted into the Landfill and hence has final responsibility for ensuring the facility is operated in accordance with the predetermined waste control protocols. Therefore the Landfill Manager must ensure that all facility Waste Acceptance Criteria are met and, all information necessary for waste traceability is acquired at the entry point (weighbridge), or via the manifest system.

11.3 Operational Aspects of Waste Control

11.3.1 Security

All security measures and operating procedures should be in place prior to commencing site operations, as detailed in the Landfill Operations Guideline. All operating procedures and waste records should be appropriately and securely archived and properly secured as they constitute not only the recorded basis for site operations, but also fulfil a legal requirement that will usually exist for many years.

11.3.2 Entry Point

The site entry point, shown at Figure 11.3.1, should be manned during all hours of operation (and outside those hours as necessary) with personnel and equipment to:

- Weigh incoming waste
- Manually or automatically document waste information
- Screen incoming waste (visual inspection or automated CCTV camera screening).

The weighbridge should be capable of recording weights accurately from the computer system and should be calibrated regularly by the appropriate authority to ensure accuracy. Waste load weights should be recorded, together with details of the corresponding waste load. Where a weighbridge is not available, loads should be recorded in terms of truck volume.

Figure 11.3.1 Entrance to a sanitary landfill

At modern sites an identification and automatic information collation system for trucks/carriers is often installed that is capable of delivering information direct to the site's waste database. At other sites, information is manually gathered, and either recorded by hand, or preferably entered into a computerized database.

Personnel at the weighbridge must be adequately skilled and trained, including having the ability to carry out visual inspection of waste loads to establish the accuracy of declared load information. This can be done by using an access gantry, or with the assistance of a CCTV camera mounted above the weighbridge. Personnel at the entry point must be regularly briefed on site operations such that they can direct the load to the appropriate disposal point.

11.3.3 Internal Control

These control processes relate to operations undertaken within the facility once the waste load has been accepted across the weighbridge.

(1) Directions and Signage

Truck movement within the facility should be clearly laid out with signage and directions. Traffic directions should be clear, with routes to designated unloading areas clearly signed with arrows and identification boards to prevent incorrect unloading, traffic conflict and accident. For facilities that undertake night operations, internal truck routes should be well lit and the signs designed to be visible under night conditions.

(2) Communication

There should be provision for communication directly between the entry point personnel and the personnel at the waste unloading areas within the site to enable quick cross-checking of information related to waste loads, including waste load quantity and character, and to deal with any loads rejected as unsuitable at the tipping face.

11.3.4 Work Face Control

Control at the working face by the operating personnel is targeted at not only directing traffic, but also at "spotting" incorrectly described, prohibited or potentially hazardous waste loads. This requires physical inspection and if necessary, re-direction for testing of specific loads. In some situations a load may be rejected, and in a worst case scenario may be required to be re-loaded after tipping for removal from the site. A special area where any suspect loads can be carefully inspected should be provided in large scale landfill facilities.

11.3.5 Reporting

The waste types and quantities received at the Landfill should be recorded as a Waste Reception Report (WRR). At a large landfill such recording is usually carried out using an integrated weighing and data recording system, consisting of one or more weighbridges and computer which is shown at Figure 11.3. The recording system is often integrated with the payment and invoicing system. Key information that should be included in the WRR includes waste category, identification of the carrier, waste source, tonnage and any other special load features.

Figure 11.3.2 Waste reception at the landfill

The WRR should be provided to the regulator as required under the site license. The WRR data are used for statistical purposes, for charging the customers and as a tool for higher level waste strategy and control such as where a facility's permit conditions may include specific waste category limits by volume or weight.

If discrepancies develop between the entry point information and observations at the work face, the relevant parties should communicate immediately. This is particularly the case in respect of prohibited or hazardous waste, where license conditions may require notification to be sent to the regulator, and in addition the load rejected.

11.4 Conclusions

Close control of waste acceptance is a key tool in ensuring a high standard of site operations, and in meeting common license requirements which control the acceptance of hazardous and problem wastes for site design or operational reasons. A hierarchy of control measures can be applied, starting with overall site security and entry control for both personnel, and waste loads.

Achieving lose control over waste acceptance at the site entry point is the next level of control, coupled with careful recording and licensing processes for waste acceptance. Waste information recording, together with closely coordinated management of waste unloading and inspection within the site all combine to ensure that the waste that is tipped and compacted is what was declared by the generator / carrier and meets Landfill license requirements, ultimately aimed at ensuring satisfactory environmental performance of the site.

CHAPTER 12 LEACHATE CONTROL

12.1 Introduction

Leachate is the liquid generated from solid waste decomposition in a landfill. Leachate derives from precipitation, surface run-on from adjacent areas, liquids disposed of in the waste mass and the decomposition of organic material in the waste itself. As leachate forms and passes through the waste, organic and inorganic compounds become dissolved and suspended in the leachate. This process can be likened to the process of passing water through coffee grounds to make coffee. The dissolved and suspended constituents of leachate have the potential to cause groundwater and surface water contamination.

In addition to serving as a source of contamination, leachate typically has a strong odor (particularly young acetogenic leachate) and requires proper management. Appropriate leachate management measures include:

- Adopting best practice landfill design.
- Minimization/control1 of liquids entering the waste mass.
- Installation and operation of an engineered leachate collection and extraction system.
- Installation and operation of a leachate treatment system (Figure 12.1.1), and/or shipment of leachate to an off-site treatment facility.

Figure 12.1.1 Typical leachate plant

The impetus for these controls is achieving minimal build-up of leachate within the waste mass and on the liner system. Minimizing head on the liner system in term minimizes the potential for groundwater and surface water contamination.

12.2 Consideration of Leachate Control Measures

12.2.1 Appropriate Landfill Siting

A key consideration for siting a new sanitary landfill is the presence of sources of water infiltration (other than precipitation). In general, a landfill should not be sited in or near a surface water body, or a surface water floodplain. Landfill sites should avoid wetlands (existing or old), seepage areas and locations with shallow ground water. These areas have the potential for increased infiltration of water and the subsequent production of greater quantities of leachate at a landfill site.

Other siting considerations include the native soil structure and type. In general, a landfill should be sited where low permeability clay-like soils exist to prevent infiltration of leachate to the surrounding groundwater. Sandy and loam-like (that is, highly permeable) soils should generally be avoided when siting a landfill, recognizing that more extensive engineering will be necessary in such situations.

12.2.2 Screening for and Restricting Liquid Waste Acceptance

An initial step to reduce the generation of leachate is to prevent liquid wastes from entering the landfill through incoming waste loads. Ordinances to ban liquid wastes from landfills help in this process. Operationally, all landfill personnel should visually screen for liquid waste brought in by haulers and other customers for disposal. A close watch on waste loads should also be maintained at the tipping face. Vehicles entering landfill property may be chosen randomly for a formal screening of their waste loads. Loads containing containerized liquid wastes should be rejected for disposal.

12.2.3 Landfill Operational Techniques

Techniques used at the working face of the landfill can help to reduce the amount of infiltration (that is, precipitation) into the landfill. Appropriately compacting and covering completed cells promotes reduced waste infiltration and increased run-off away from the active area. Good compaction of waste and daily cover materials reduces waste settlement, thus, reducing the potential for depressions in the active area.

Depressions can fill with water (ponding) and allow precipitation to infiltrate directly into the waste mass. Temporary diversion berms can also be created near the working face to capture and direct surface water flow away from the active portions of the landfill. When depressions and ponding occur, particularly in intermediate and final cap areas, the water should be appropriately drained and the depression should be filled.

12.2.4 Run-on and R un-off Controls for Precipitation

Precipitation must be carefully managed at any landfill facility and surface water systems need to be able to cater for high rainfall events. Design and engineering elements can be implemented to promote run-off of this precipitation and to minimize water ponding and infiltration through the landfill surface.

Exposed surfaces of the landfill (often with intermediate or final cover) should be sloped to drain surface water away from the waste mass. In addition, diversion ditches, trench drains, and localized soil berms may be constructed to guide water away from the landfill active area. Similarly, diversion ditches, trench drains, and soil berms also may be employed to divert precipitation that would otherwise run-on to the landfill site from higher elevations. Another step that may be appropriate (particularly at tropical sites with high rainfall) to reduce the amount of rain that infiltrates into the waste is to use temporary plastic tarpaulins or HDPE geomembrane covers.

12.2.5 Liner and Leachate Collection Systems

Even with good operational practices and surface water controls, most landfills will generate leachate. This leachate must be managed so as to prevent contamination of groundwater and surface water. Leachate management is best accomplished through the installation of a landfill liner (for example, compacted clay, geomembranes, or both) and the installation and operation of an engineered leachate collection/conveyance (removal) system which is presented at Figure 12.2.1.

Landfill liners retard the movement of leachate into adjacent soils due to their low permeability. Landfill liners are usually comprised of either in-situ or re-compacted natural clay soils or geosynthetics (flexible membrane liners [FMLs]) or some combination of the two.

Natural soil liners should be clay soils with a low coefficient of permeability and sufficient thickness to significantly retard leachate loss to groundwater. The most common material used for flexible membrane liners is High Density polyethylene (HDPE), but other materials such as Linear Low Density Polyethylene (LLDPE) and polyvinyl chloride (PVC) are sometimes used.

Other materials used in liner systems are Geosynthetic Clay Liners (GCLs) and geotextiles / geocomposites. The most common high performance liner type usually comprises (top to bottom):

- Separation geotextile
- Leachate drainage layer
- Protection geotextile (if required)
- HDPE Geomembrane
- Compacted Clay Liner (CCL) / GCL

The range of performance can vary greatly, but two key principles need to be recognized:

- Minimizing the leachate head on the liner through active leachate extraction minimizes the risk of leakage.
- Any liner incorporating a geomembrane and CCL / GCL will be vastly superior in terms of containment to a clay liner alone.

To prevent lateral drainage of leachate above the liner system, a leachate collection and conveyance system should always be installed. Leachate collection systems comprise perforated piping installed above the liner and sometimes in other locations within the waste mass to enable the leachate to be drained and pumped to any one of a number of leachate treatment options. Both gravity flow and pumped systems are used but pumped systems are usually preferred as they enable liner penetrations to be avoided.

Figure 12.2.1 Leachate collection and conveyance system

12.2.6 Leachate Treatment

Leachate treatment options include the following:

- Direct discharge to a receiving body of water (only if permitted by regulations and the leachate is relatively weak);
- Discharge to publicly owned sewage treatment works sometimes with limited on-site pre-treatment;

- On-site physical, chemical, thermal, or biological treatment;
- Land application or land treatment;
- Recirculation back into the landfill;
- Passive evaporation to the atmosphere (often through aeration in holding ponds or storage lagoons); and
- Active evaporation units powered by electricity or landfill gas.

Selection of the most appropriate option at a particular site will depend on a range of factors including:

- Site location relative to sewage works
- Volume and strength of leachate generated
- Climatic conditions
- Nature of the waste
- Availability of land for on-site treatment
- Capital and operating cost considerations.

12.3 Conclusions

Prevention of leachate migration and contamination of ground and surface water can be accomplished through implementing effective operational practices and engineering controls at the landfill facility. Operational practices to divert local precipitation and surface water run-on to the waste mass are an effective means to reduce the quantities of leachate generated.

A good standard of engineering design of landfill liner and leachate collection/conveyance systems serves to reduce leachate movement outside the waste mass and to enable leachate to be extracted thus minimizing the head on the liner. The leachate can then be stored or pumped for proper handling and subsequent treatment with the most appropriate leachate treatment option(s) being a very site- specific decision.

CHAPTER 13 ODOR CONTROL

13.1 Introduction

Odor can occur at a sanitary landfill occur as a result of the biodegradation of wastes and may be associated with load transport, the tipping face, leachate and landfill gas (LFG). The emphasis when considering odor control in landfill design and operation should be on utilizing efficient operating and management practices, backed up by robust environmental management systems.

The sources of landfill odors are chemical compounds, present at trace levels in air. Leachate odors may result from uncontrolled leachate seeps from the waste mass, or from leachate holding ponds or lagoons present on site. LFG is primarily comprised of methane and carbon dioxide - both odorless gases. However, the trace constituents present in LFG include compounds offensive to the human nose and these odors become noticeable when excess LFG escapes from the surface of the landfill, flows from passive vents, or leaks from piping of active LFG collection systems.

The odor typically associated with the waste tipping face is also distinctive, and differs from LFG odor. Depending on site location and available buffer distance, odor can be a greater or lesser problem at a landfill site. However, where a site is within approximately 500m of neighbors, odor control is usually an important consideration. Control of odors from all these sources is important for community relations as well as for worker comfort. Through effective operational and design elements, landfill odors can be controlled effectively.

13.2 Odur Control Measures

The key odor control measures at a sanitary landfill are:

- Restrictions on the acceptance of odorous waste
- Properly covering the waste
- Limiting the size of the working (tipping) face
- Positively extracting, collecting and treating landfill gas (by flaring or for beneficial use)
- Controlling leachate, especially ponded leachate
- Using odor masking sprays where appropriate
- Use of buffer zones (maximizing separation distance)
- Careful planning of working face location.

13.3 Consideration of Odor Control Measures

13.3.1 Restriction on the Acceptance of Odorous Wastes

At sites where odor is a potential issue for neighbors (typically urban or sub-urban sites with limited buffer distance available), a key measure that can be adopted is placing restrictions or conditions on the acceptance of odorous waste. This can greatly reduce odor potential, but is not always possible if the landfill is the sole facility in the area.

Measures which may be considered include:

- Non-acceptance of highly odorous wastes without adequate stabilization or pre-treatment (e.g. use of lime for seepage wastes)
- Limiting waste acceptance to appropriate times of the day

- Use of special procedures, such as pre-arranged excavation of special burial pits, and having cover material and odor suppressant sprays ready at the time of waste delivery.

13.3.2 Properly Covering Wastes

Once layers of waste have been placed and properly compacted in the landfill, soil (or sometimes other alternate) cover should be placed over all the waste the same day and generally, progressively throughout the day. This soil cover serves to limit the escape of odor and limits the infiltration of rainfall that may enhance the gas production process within the landfill. In addition, the daily cover soil serves to adsorb odors as well through biochemical (bio filtration) processes and soil cover layers have been shown to be effective in oxidizing LFG and its components. Other materials such as wood chips are sometimes used, but are generally less effective than cover soil in terms of odor control.

Intermediate and final cap soil layers also play a key role in odor control. Research has shown the effectiveness of soil layers and the bacterial/microbial communities they contain in oxidizing methane and other LFG constituents. Simply put, applying continuous thick soil cover at regular intervals can have a major benefits for odor control, especially when combined with an active LFG extraction and treatment system.

13.3.3 Limiting Working Face Size

In general, the working face of the landfill should be minimized in line with the size of the operation. As a general guide it should be no more than 600 m^2 (say 30 meters wide and 20 meters in length). This serves to minimize the surface area from which fugitive refuse odors can escape.

13.3.4 Properly Vent, or Collect, Extract and Treat Landfill Gas

Leaving aside consideration of the hazards associated with LFG, because the trace constituents of landfill gas are the odor-causing agents, proper control of LFG emissions usually contributes significantly to the effective control of odor. Passive LFG systems simply vent LFG to the atmosphere. If such a system is used (for example at small or closed sites) attention should be given to the direction of prevailing winds in the design and location of vents in order to minimize odor nuisance to property neighboring the landfill. In general passive vents will not be effective as an odor control measure.

The most effective method of controlling odors from landfill gas is to design and install an active LFG collection system, with comprehensive coverage of the waste mass, and to subsequently flare or otherwise utilize the LFG. Typically, such active extraction systems include drilled vertical wells (spaced at about 1 well per 30m radius without significant overlapping), or horizontal trenches with connective piping. A vacuum is applied to the well and pipework system using a blower (extraction fan). Each drilled vertical or passive gas well when spaced correctly should be capable of extracting of the order of $70m^3$/hrs of landfill gas. Smaller "spike" gas wells can be installed quickly and in areas that are awkward for conventional drilling and can prove very useful for local control of odor.

Collected LFG is usually treated either by combustion in a flare, or in LFG engines for energy production. Modern enclosed (tube) flares can burn high volumes of LFG at up to 1000ºC with a residence time of typically 0.3 seconds and such a treatment option will effectively eliminate both the hazard and the odor associated with LFG and the trace organic compounds it contains.

13.3.5 Control of Leachate

Leachate can also be a significant source of odor at a sanitary landfill due to decomposing organic material and LFG dissolved in the leachate. Odor problems from leachate primarily arise due to leachate seeps from the side slopes of the landfill itself, or from leachate holding/treatment lagoons (if present at the facility).

When leachate seeps occur, they should be filled or covered, and sources repaired by improving the internal drainage of the landfill locally to prevent further breakout and to prevent runoff to nearby water bodies. The use of run-on and run-off controls and well-designed leachate management systems can lessen the frequency and severity of leachate seeps.

Maximizing internal drainage within the landfill through "windowing" of cell area and through providing vertical drainage via LFG wells, as well as ensuring intermediate cap layers slope into the landfill rather than out of it, are all keys to minimizing leachate breakout.

In general, minimizing the leachate head over the bottom liner of the landfill and removing leachate routinely as it accumulates is an important control to avoid leachate head build-up and hence an increased risk of surface leachate breakouts and surface seeps.

Odors from leachate holding ponds or treatment lagoons can be reduced through aeration, chemical treatment, or the use of physical covers including floating covers. In addition, leachate holding ponds (where used) should be located to maximize the available buffer zone (separation) to neighbors.

13.3.6 Odor Masking

Chemical odor masking agents are available for use at landfills and can be a very useful for localized odor control, particularly at the tipping face and for special burials of odorous waste. Odor sprays can provide an odor control "curtain" at the landfill perimeter, be applied direct to odorous loads, or used when old waste has to be excavated (for example to establish a retro-fitted LFG extraction system).

Odor masking chemicals come in a range of formulas and can mask or chemically neutralize odor-causing compounds. Odor masking agents when used in conjunction with a control system based on wind direction can prove useful in masking or scenting the odor and altering its hedonic tone, thus reducing the risk of odor nuisance. Masking agents can, however, be costly and may not be effective over long durations or under certain weather conditions (such as during high winds or heavy rainfall).

13.3.7 Landscaping and Buffer Zones

This approach can be used in conjunction with other controls to as an adjunct addressing odor problems. Odor nuisance in some cases is based on or exacerbated by perception. The visual impact of a landfill can increase the odor awareness of sensitive receptors. It is likely that breaking the line of sight has the psychological effect of lessening perception and is therefore a positive control for landfill operators that can be employed along with other measures – often a minimal cost. Measures can include mounded soil berms, landscape planting or panel fencing.

In addition, separating the working area from receptors using a buffer zone (sometimes created within the site), can be very beneficial in relation to odor management. However, it should be noted that both landfill face (waste) and LFG odor can potentially be detected over significant distances under adverse climatic conditions.

13.3.8 Working Face Location and Special Burials

A simple and effective way for the operator of a landfill to reduce odor complaints is to locate as far as way as possible from inhabited areas and sensitive receptions, including potentially moving daily operations on the site to suit weather conditions – particularly wind direction.

Even though sanitary landfill odors can be reduced by employing the toolbox of control techniques described, a certain level of odor will inevitably exist at the landfill working face. This can be significantly exacerbated by some types of odorous waste received. The availability of extra void space and hence alternative tipping face locations can help the operator to change the working face if wind direction changes. The use of (planned) special burials for known odorous loads as well as active control of such load odor using odor control sprays are also very effective techniques that can be added to careful selection of disposal location.

The level of odor at a site may vary seasonally, and wind direction will determine what neighboring property could be affected by landfill odors. Careful planning of working face location to accommodate wind location and seasonal variations in odor production can serve to reduce the nuisance to properties surrounding the landfill. Accepting certain types of odorous waste only by arrangement (i.e. during certain hours), adopting immediate burial and covering practices for odorous and restricting the quantity and type of odorous waste, are all key control method.

13.4 Conclusions

Controlling odors at a sanitary landfill is best achieved through a careful approach to the full range of operational, engineering and design controls. At most sites a key control can be introduced at the planning stage through maximizing buffer distance in and around a site. In most instances a minimum buffer distance to neighbors (including internal buffer) of 500m is recommended.

The next two key controls on odor are limiting the type, timing and method of acceptance of odorous wastes. Added to this are direct odor control methods including special burials, use of cover soil, and odor sprays. Beyond this, a hierarchy of controls exists, starting with effective cover practices and LFG control, through to specific measures for dealing with leachate seeps and ponds.

Dealing with factors outside of the landfill operator's control such low barometric pressure and wind direction to sensitive receptors, require the operator to implement a range of measures to manage odor effects. In most cases it is possible to prevent odor nuisance becoming an issue with the local community, but to achieve this, commitment is required from landfill management and operating personnel on a day to day basis for each control to work properly and efficiently. Careful planning from management personnel is the starting point for all odor control activities. As odors occur, it is best to identify the source and duration, and then apply corrective measures or work practices to control LFG and odor.

CHAPTER 14 LANDFILL GAS MANAGEMENT

14.1 Introduction

Landfill gas (LFG) is generated in all landfills where organic waste is disposed of. LFG is a natural by-product of the anaerobic biological decomposition of the organic portion of solid waste. Landfill gas consists primarily of Methane (CH_4) and Carbon Dioxide (CO_2), but may contain many other constituents in small quantities, including nitrogen, oxygen, sulphide, disulphides, mercaptans, volatile organic compounds (VOCs), ammonia, hydrogen, carbon monoxide, water vapor, and many other organic gases.

14.2 Landfill Gas Generation

14.2.1 Phases of Landfill Gas Generation

Decomposition of waste in a landfill occurs in several distinct phases, related to conditions in the landfill. The primary phases are:

- Phase I – Aerobic
- Phase II – Anaerobic Non-Methanogenic (Acetogenic)
- Phase III – Anaerobic Methanogenic (a non-steady phase)
- Phase IV – Anaerobic Methanogenic
- Phase V - Aerobic

Aerobic decomposition begins immediately the organic waste is disposed in the landfill and continues until all of the entrained oxygen is depleted from the voids in the refuse and from within the organic material itself. Aerobic bacteria produce a gaseous product which is characterized by relatively high temperatures (55 to 70°C approximately), high CO_2 content, and no CH_4. Other by-products include water, residual organics, and heat (in such a quantity to increase the landfill temperature to typically 55-70°C). Aerobic decomposition may continue for 6 or more months depending on the proximity of the waste to air at the landfill surface. This time frame for aerobic decomposition may be shortened if CH_4-rich LFG from below flushes oxygen from voids in the disposed refuse.

After all entrained oxygen is depleted from the refuse, decomposition enters a transitional (acetogenic) phase during which acid-forming bacteria begin to hydrolyze and ferment the complex organic compounds in the refuse.

Decomposition then enters a long anaerobic period which can be divided into several distinct phases. During this period CH_4-forming bacteria, which thrive in an oxygen deficient environment, become dominant. Anaerobic LFG production is typified by somewhat lower temperatures (38° to 55° C), significantly higher CH_4 concentrations (40 to 60%) and lower CO_2 concentrations (40 to 48%). Anaerobic gas production will continue until all of the biodegradable material is depleted or until oxygen is reintroduced into the refuse, which returns the decomposition process to aerobic conditions. A return to aerobic decomposition does not stop LFG production, but will retard the process until anaerobic conditions resume.

14.2.2 Landfill Gas Generation Volume

LFG will be generated in all landfills containing organic (decomposable) materials, although the total volume of production may vary widely over time. The total amount of LFG generated over the entire decomposition life of the landfill is mostly a direct function of the total quantity of organic material contained in the landfill, with some components decomposing rapidly, some at a moderate rate, and some over a much longer period of time. Therefore, the quantity of refuse available for decomposition is the primary factor in determining the total volume of LFG that will be generated over the life of the facility.

14.2.3 Landfill Gas Generation Rate

The rate at which LFG is produced is primarily a function of the types of waste involved, e.g., rapidly decomposing food waste versus longer-lasting paper, cardboard or other organic waste. The overall rate of decomposition for all refuse components in a given section of a landfill also is influenced by a variety of other factors, such as moisture content, refuse particle size, site configuration, compaction and pH. Basically, the better the conditions within a landfill are for the anaerobic bacteria, the faster the decomposition will take place, resulting in a faster overall LFG generation rate build-up. The optimum moisture content for LFG generation is approximately 60%. In areas of low to moderate rainfall the moisture content of the incoming and in situ waste is typically significantly less than this optimum moisture content. Therefore, recirculation of leachate can have significant benefits in optimizing landfill gas production. However, to avoid potential instability problems leachate recirculation should not increase pore water pressures within the waste mass.

14.2.4 Landfill Gas Composition

The typical constituents of LFG and the usual concentrations at which they are observed are:

Type of Landfill Gas	Concentrations
Methane (CH_4)	40 to 60%
Carbon Dioxide (CO_2)	35 to 45%
Oxygen (O_2)	< 1 to 5%
Nitrogen (N_2)	< 1 to 10%
Hydrogen (H_2)	< 1 to 3%
Water Vapor (H_2O)	1 to 5%
Trace Constituents	< 1 to 3%

Each of these constituents is discussed in more detail below.

Methane (CH_4) - is one of the two the main by-products of anaerobic decomposition. It is a colorless, odorless, tasteless gas which is lighter than air, relatively insoluble in water, and is explosive at concentrations of 5 to 15% by volume in air (the explosive range.)

Carbon Dioxide (CO_2) - is a by-product of both the aerobic and anaerobic phases of decomposition. It also is colorless and odorless, but is heavier than air, non- combustible, and highly soluble in water.

Oxygen (O_2) and Nitrogen (N_2) - Oxygen and nitrogen are typically found in LFG samples. Typically, the combined volumes of oxygen and nitrogen remain in LFG are less than 10% and their ratios are similar as in air, but, with higher proportion of nitrogen. High oxygen and nitrogen concentrations are typically a result of air intrusion through the cover of the landfill, air leaks into a LFG recovery or control system, or air leaks in the sampling train during collection of LFG samples.

Hydrogen (H_2) - In landfills, hydrogen typically is produced only during aerobic decomposition and the earliest stages of anaerobic decomposition. If hydrogen is present in anything more than trace concentrations in a mature landfill, it may indicate that areas of the site are not in the mature LFG generation phase for one reason or another.

Water Vapor (H_2O) - LFG typically is saturated with water vapor. The water vapor in LFG comes from water in the landfill that becomes entrained in the gas. Water vapor that condenses from LFG is the primary component of the condensate which forms in gas wells and extraction pipework. Consideration must always be given to proper handling and disposing of condensate as part of any LFG management effort.

Trace Constituents - LFG typically also contains small quantities (usually less than 1%) of volatile organic compounds (VOCs), and various other trace compounds. The presence of trace compounds in LFG usually is due primarily to the disposal of waste containing these compounds into the landfill. However, some may also be present because of natural decomposition processes within the landfill (e.g., hydrogen sulphide [H_2S] from the decomposition of gypsum board).

As many as 150 different compounds, mostly in the parts per million (ppm) or parts per billion (ppb) ranges have been identified in LFG, although not all landfills will have all of these compounds in their LFG. These gases may include harmful, toxic, or even carcinogenic compounds such as vinyl chloride, benzene, toluene, xylene, perchloroethlyene, carbonyl sulphide, siloxanes and various other chlorinated and fluorinated hydrocarbons. Other trace compounds found in LFG include mercaptans, which cause the distinctive odor associated with LFG.

The components of LFG are thoroughly co-mingled as they are produced during the decomposition process or as they move through the landfill, and will not separate into separate gases to flow in different directions.

14.3 Landfill Migration and Emissions

Once the LFG has been generated, the forces of convection (movement from areas of higher to lower pressure) and diffusion (movement from areas of higher to lower concentration) may cause the LFG to move through and out of the landfill via the "path of least resistance". If the LFG moves out of the landfill into the surrounding soils it is called "migration". If it moves out of the landfill through the landfill cover into the atmosphere it is called "emissions". In either case, the LFG can have significant impacts on the environment and human health and safety. Some of these impacts are discussed below.

Explosion and Fire - One of the two major constituents of LFG is CH_4. CH_4 is a colorless, odorless gas that is explosive in concentrations ranging from 5% (the lower explosive limit or LEL) to 15% (the upper explosive limit or UEL) by volume in air. At concentrations above 15% by volume, CH_4 is flammable. LFG may be explosive when all four of the following conditions are met:

- The concentration of CH_4 is from 5 to 15% by volume in air.
- The gases are in an enclosed space.

There are documented cases of spontaneous LFG explosions and fires causing death, injuries, and property damage. The presence of CO in landfill gas is a useful indicator of the presence of a fire.

Toxicity - LFG may contain toxic or carcinogenic compounds. Although these compounds generally do not pose a threat to human health or safety when confined to the landfill, their release into the atmosphere or the groundwater may create a potential health hazard. Therefore, LFG may present toxic hazards, both acute and chronic.

Acute toxicity may be of concern if trace constituents (mostly notable H_2S) are present in sufficient concentrations. Although H_2S is typically found in LFG at concentrations of only a few ppm, it has been documented in some landfills at concentrations above 3,000 ppm. H_2S has been shown to be deadly to humans at concentrations as low as 100 ppm. If LFG at a site has H_2S concentrations anywhere near these levels, an unprotected worker entering any enclosed structure into which the LFG has migrated could result in a fatality.

Chronic toxicity due to long-term exposure to LFG also may be a hazard. Many of the trace constituents of LFG are known or suspected human carcinogens. Some of the compounds that have been found in LFG at concentrations above their recommended long-term exposure toxicity thresholds and particularly at sites where industrial wastes are disposed of, this issue should be carefully examined.

Asphyxiation - Both of the major components of LFG, CH_4 and CO_2, are asphyxiates. In closed structures or areas where LFG could potentially accumulate, LFG may present an asphyxiation hazard.

Air Pollution - Many of the trace compounds found in LFG are known as constituents commonly found in smog or as reactants in smog formation. Therefore LFG may be a contributor to local air pollution.

Global Climate Change - CO_2 is a well-known greenhouse gas (GHG). Because landfill CO_2 is not derived from fossil fuel, but rather is part of the natural carbon cycle, it is typically not considered a contributor to global climate change. However, due to its higher infrared absorption capacity, CH_4 is actually a much stronger greenhouse gas than CO_2 by a factor of 21 (on a mass basis) in terms of global warming potential. Because of the CH_4 contribution, uncaptured and uncommuted (fugitive) LFG is considered potentially a significant contributor to global climate change.

Odor - Odors associated with LFG are a well-documented issue. The odors are due to many of the trace compounds found in LFG, particularly mercaptans and HsS.

Vegetative Stress – LFG migrating through soils can displace air in the interstitial soil spaces. If there are any plant roots in the area, the plants may suffocate and die.

Groundwater r Contamination - Many of the VOCs often found in LFGs are water soluble. In addition, dissolved CO_2 from LFG may form carbonic acid, which weathers formation minerals causing increases in groundwater hardness and alkalinity.

14.4 Landfill Gas and Control

Due to the potential impacts described above, all landfills of significant size (nominally >1Mt waste capacity) should have LFG collection and control systems installed that are designed and operated to minimize both LFG migration and emissions. At smaller sites sufficient LFG control may be achieved by passive venting. However, even small sites may warrant further control measures and each site should be carefully assessed as LFG control requirements are very site-specific.

LFG control is a term that encompasses all methods for controlling movement of LFG, including active collection, barriers, passive control and monitoring. The purposes of a control system include:

- Controlling subsurface LFG migration
- Controlling surface emissions and nuisance odors
- Protecting groundwater
- Controlling fires / fire risk in the landfill waste mass
- Collecting LFG for its energy benefit
- Protecting structures
- Reducing vegetative stress.

A note on hazard:

LFG can present very real and immediate risk and there are documented cases of fatalities due to LFG at landfill sites. Never sniff vents or wells – this could be fatal. Similarly, never attempt to make pipe connections without assessing risk and appropriately isolating the area.

LFG control methods can be divided into two separate system types, which are:

- Passive venting and/or barrier system (sometimes with flaring capability)
- Active collection and flaring or beneficial use systems.

14.4.1 Passive Venting Systems

No active mechanical means are employed for a passive venting system2. In the main, the pressure gradient created by gas generation within the landfill moves the gas toward a well or trench, which then intercepts the gas and conducts it to the surface.

There are two basic types of venting systems:

- Internal vents
- Perimeter trench vents.

Passive systems can be effectively used to control LFG migration, particularly at smaller or older sites. Passive venting alone should be avoided where practicable as the emissions will continue to contribute to global warming despite reducing the problems associated with LFG migration.

14.4.2 Active Control Systems

An active system uses a blower (extraction fan) to create a vacuum Figure 14.4.1 within the landfill and withdraw the LFG via a network of wells/trenches and pipework. The typical components of an active LFG control system include:

- Vertical gas extraction wells
- Horizontal gas collection trenches
- Collection piping to move the gas to a central location for processing
- Condensate traps and handling equipment
- Blowers or compressors
- Water knockout tanks, dehydrators or other scrubbers
- "Candlestick" or enclosed flares
- Other facilities to process the gas, and gas to energy equipment.

Figure 14.4.1 Landfill gas reception compound

Active systems typically provide the most effective form of control for LFG emissions and are a key feature for sanitary landfill operation at sites of significant capacity.

14.5 LFG Monitoring

To provide assurance that excessive LFG migration and/or emissions are not occurring, or to test the efficacy of an existing LFG control system, all landfills should have LFG monitoring systems. The type of monitoring system employed tends to be site-specific, depending on the issues that LFG poses. Typically different monitoring systems are used for migration and emission monitoring.

14.5.1 LFG Migration Monitoring

There are several aspects of LFG migration monitoring systems:

- Surface emissions monitoring
- Off-site migration monitoring systems
- Structures migration monitoring systems.

(1) Surface Emissions Monitoring

Surface emissions monitoring using a FID or similar device is a key check on the effectiveness of the landfill cap and extraction system that together form the main control and management component for LFG at a site. A build up in surface emissions of LFG can provide early warning of the need for changes or improvements in cap or LFG system implementation and possible offsite odor or LFG migration issues.

(2) Off-site Migration Monitoring

These systems typically are employed to monitor for CH_4 concentrations at a landfill site property boundary. They typically consist of a series of monitoring wells (Figure 14.5.1) or probes spaced at intervals around the site.

The spacing and positioning of the LFG migration monitoring wells is very important. In some places, arbitrary distance criteria (e.g., 300 meters) between probes have been mandated. However, because the probes only monitor discrete points, they may not truly indicate all migrating LFG. It is important to consider what is to be protected and the nature of site conditions in selecting the location for LFG migration monitoring probes.

(3) Structures Migration Monitoring

Depending upon the location and construction of a structure, the risk for accumulation of LFG within it needs to be considered and may vary considerably. Structures on a landfill site, or near a landfill, particularly those involving enclosed spaces, should be evaluated for exposure to LFG migration. The factors that should be considered in the evaluation include:

- Form of construction
- Subsurface conditions
- Surface conditions
- Subsurface connections
- Existing LFG monitoring and/or control systems or devices
- Distance from LFG source

For any structure where migrating LFG poses a risk, whether an active control system is in place or not, a permanent or portable CH_4 monitoring system should be employed. There are a number of permanent and portable combustible gas indicators on the market.

Figure 14.5.1 Monitoring at landfill

14.6 Landfill Gas Utilization

Though LFG can present a hazard to human health and safety and the environment, it can also be a very significant asset in relation to the energy potential of the CH_4 that it contains, and hence it's potential for use as a fuel.

The primary utilization modes for LFG which have been implemented successfully on a broad-scale are:

- On-site generation of electric power using LFG as a fuel within an internal combustion engine, gas turbine or steam turbine generator.
- Fuel gas for direct sale to industrial fuel gas consumers.
- Pipeline quality gas for sale to utility companies.

Each of these technologies is discussed in more detail below.

14.6.1 Electric Power Generation

The most common energy application for LFG is on-site generation of electricity using raw or partially processed LFG as a fuel. Typically, the LFG is used in a reciprocating internal combustion gas engine (Figure 14.6.1) or gas turbine driving an electrical power generator. Micro turbines have been used at a number of facilities and there are a few facilities that use the LFG as boiler fuel for a steam turbine generating facility as well.

Typical LFG clean-up for electric power facilities consists of filtration and mechanical dewatering, but treatment systems to remove H_2S and/or siloxanes is becoming more common in some locations as experience shows that a cleaner gas fuel can result in substantially reduced corrosion and reduced maintenance costs over the life of the equipment.

Figure 14.6.1 Gas engines

14.6.2 Direct-Use

In this application, the collected LFG typically is minimally processed and then sent to a nearby end-user (Figure 14.6.2), through a dedicated pipeline. The processing required to produce fuel gas from LFG is relatively minimal. It may range from selling the gas in its raw form, to the removal of moisture on up to the additional removal of siloxanes, H_2S, and/or non-methane organic compounds (NMOCs). This latter procedure is approximately equivalent to the pre-treatment step that precedes the production of pipeline gas.

Figure 14.6.2 Greenhouse heated by LFG

14.6.3 Pipeline Quality Gas

The production of pipeline quality gas from LFG requires more extensive processing in order to remove all virtually all moisture, trace organic compounds, CO_2, and air from the raw LFG. This results in virtually pure CH_4, with a good calorific value.

Of particular concern to many gas utility companies is the presence of halogenated compounds in raw LFG. Some halogenated compounds are not destroyed by combustion and may present a danger to consumers if they are released through a home gas stove or heater.

The production of pipeline quality gas from LFG is typically performed in two steps. The first step, known as pre-treatment, is the removal of moisture and trace components by refrigeration, dehydration, filtration, adsorption, or other processes. The second step is to separate the CO_2 from the CH_4 by one of the many processes commonly used for that purpose in the petroleum industry.

14.6.4 Other Potential Uses of LFG

Some other potential uses of LFG are presented below:

(1) Vehicle Fuel, Compressed Natural Gas (CNG)

Purified LFG may be compressed under pressure to approximately 3,000 pounds per square inch (psi) and is referred to as CNG.

(2) Vehicle Fuel, Liquid Natural Gas (LNG)

LFG may be purified, cooled (to approximately minus 260ºF), and compressed to a liquid form. When natural gas or LFG is compressed into a liquid form, it is known as LNG.

(3) Chemical Feedstock

To date, no practical application has been implemented using LFG as a chemical feedstock. The most likely use would be the utilization of the CO_2.

14.7 Conclusion

LFG is a natural by-product of the decomposition of biodegradable solid waste. LFG represents a hazard at landfill sites due primarily to its explosive and asphyxiation risk. Chronic exposure to LFG can also result in other contaminants (e.g. H_2S, vinyl chloride) being of concern even though they may be present in relatively low concentrations.

Management of LFG requires careful consideration of site-specific issues and risks, but for a range of reasons an engineered LFG extraction and destruction system is an essential part of the engineering of most landfills accepting significant amounts of degradable waste. However, the design of such systems is beyond the scope of this Guide.

Careful monitoring of confined space areas and for LFG migration away from landfill sites is part of any comprehensive Landfill Management Plan.

LFG is usually destroyed by combustion in an enclosed (tube) flare to maximize destruction efficiency, but it can also be used to produce energy – something that is increasingly becoming the norm at larger landfill sites.

CHAPTER 15 GUIDELINE FOR SITE SAFETY AND SECURITY

15.1 Introduction

Commonly, a landfill will be separated from surrounding properties by fences and/or other barriers, i.e. ditches, bodies of water extensive open space etc. and these to some extent provide a degree of security at a landfill site. However, 'site security' generally means achieving much more control than is represented by a simple fence or barrier. Site security includes controlling access onto the site and supervising the activities of all persons on-site.

Thus site security includes:

- Restricting entry to the site by using a fence or barrier all around the site and having one gate through which all vehicles and persons enter and leave.
- The employment of appropriately trained staff (Figure 15.1.1) to control access to the site by vehicular and pedestrian traffic.
- The maintenance of physical access control features and components such as gates, fences, bridges, moats and streams.
- The surveillance and control of all on-site visitors, site users, and employees.

Figure 15.1.1 What not to do

Since monitoring wells and other monitoring installations are rapidly becoming the method for measuring the success of the containment engineering at a landfill, their care is another important security focus. Wells and monitoring equipment must be protected from physical damage, the placement of foreign substances into wells, and the potential for infiltration of pollutants in their immediate vicinity.

Site safety, is maintained and/or achieved through careful planning, the provision and utilization of appropriate equipment, and through personnel training. Site plant and all structures should be equipped with fire extinguishers. A well-stocked first aid kit should be available on-site and first aid training should be considered essential for one or more of the operating personnel who spends the majority of the working day on the site. At least one person properly trained in first aid should be on site at all times.

All of these procedures, as well as emergency response procedures, should be documented in the Landfill Management Plan and should be the focus of regular training of site staff.

15.2 Employee Training

Employees should be adequately trained in the safety aspects pertaining to the operational area and the implementation of the primary safety rules, examples of which are as follows:

- Do not permit those under the influence of alcohol or controlled substances to work on, or use the site.
- Do not allow horseplay or idle time in the tipping area.
- Do not make the first compacting pass over deposited wastes with the tractor or compactor in reverse (full containers may spray their contents on the operator with little warning).
- Do not permit trucks to discharge waste within 3 meters of others.
- Complete separation of mechanical discharging trucks from those which must be hand unloaded increases safety and decreases the area of tipping face required. Hand unloading will require less space between trucks but requires a great deal more time to unload.
- Only allow drivers to enter the disposal area. Ensure the spotter is not distracted by external activity.
- Smoking at the tipping face or exposed surface shall be prohibited and considered a violation of safety rules.
- Salvaging, if permitted on site, should not result in tipping face activity or the deposit of salvaged material on the deposited waste, especially near the active working face.
- All site personnel should be required to sign in and out each time they arrive or depart from the site.

15.3 Personal Protective Equipment

All site users must be equipped appropriately. In most instances, bright colored jackets, shirts, coveralls or vests, sturdy shoes and gloves are considered to be essential. A strong management's lead in terms of personal safety is essential and establishes the basis for all landfill operations which cannot then be misinterpreted by others. Some additional safety items as shown in Figure 15.3.1, which should be considered, are:

- Hard hats
- Steel midsole and steel toe capped footwear
- Ear protection
- Dust masks
- Goggles or face masks
- Communication devices - air horns, whistles, intercoms, or radios.

Figure 15.3.1 A properly dressed laborer at the landfill

15.4 Preparation for the Unusual

Every facility manager must prepare for unusual events or occurrences on site. Managers who do not do so are forced to make decisions quickly and to defend those decisions after the event. For instance, it pays to keep in touch with local emergency services and therefore fire, police, and rescue squad or ambulance phone numbers must be appropriately and clearly posted on every building and in every vehicle on site. Emergency service personnel should be provided with an opportunity to review and inspect the site at least annually. The review will permit those personnel to become familiar with procedures and on-site personnel prior to their reaction to an actual emergency. Fire Training sessions might be an appropriate time to schedule such a visit.

In addition to the emergency service arrangements, certain landfill emergency plans are required by other agencies of government and an emergency response plan is an essential component of every Landfill Management Plan.

15.5 Construction, Repair and Maintenance in Confined Spaces

Construction, as well as repairs and maintenance to existing landfill facilities may mean working in enclosed (confined) spaces. Some examples of confined spaces are storm water pipes and manholes, sanitary sewer, manholes, and leachate control manholes. That is, spaces where natural ventilation is limited, and where gaseous contaminants can potentially make entry hazardous. Other instances are spaces where insufficient air may be present, and access or escape is potentially difficult.

Some of the confined space hazards to which a landfill employee may be exposed are as follows:

- Fire and/or explosion in the confined space due to the presence of methane in explosive concentrations with air (5-15% methane in air). The concentration of methane in landfill gas is typically around 50%.
- Asphyxiation due to inadequate oxygen supply is a very dangerous situation.

This can result from anaerobic conditions, LFG build-up, and the presence of Hydrogen Sulphide (H_2S). At low concentrations H_2S has an offensive rotten egg odor, but at higher concentrations it quickly numbs the olfactory senses such that the employee's nose – his first line of defense – can no longer detect its presence. This is a very dangerous situation and creates the potential for fatality. H_2S is one of the trace gasses that may accompany methane (CH_4) and carbon dioxide (CO_2) in landfill gas, but it can be a direct hazard in situations where concentrations are high.

When it is necessary for someone to enter and work in a confined space on or near a landfill, specific procedures should be clearly established and carefully followed, including:

- No confined access should be made by a lone individual, no matter how pressing the need may appear to be.

- An entry procedure should be documented and approved prior to any confined space entry.
- Before entering any confined space a check must be made for explosive concentrations of methane, as well as oxygen and H2S levels. Usually strong odor near a confined space is an immediate indication of a dangerous situation.
- Natural ventilation or mechanical ventilation may be essential but of itself may not be sufficient to make the entry safe.
- If ventilation does not assure safe entry, specialists should be involved and specialist equipment used such as breathing apparatus.

In summary, the Landfill Manager for a site which has confined spaces, must have a safe entry procedure documented, his employees trained for entry, and the appropriate equipment to hand in serviceable condition. Records of confined space entries must be maintained on site – even if the space is entered by a contractor or public utility representative.

15.6 Blood-borne and Other Pathogen Safety

Where a landfill elects to take biomedical waste, written procedures must describe the appropriate training, equipment and medical support given to the landfill staff. Managers are required to review their sites and prepare a written report, which assesses worker exposure to blood-borne and other pathogens which can occur through

- Medical waste and related sharps
- Sewage screenings and sludge's
- Secondary pathogen waste sources (e.g. food processing wastes).

This issue is particularly relevant at developing country sites where various degrees of scavenging may be occurring, without suitable attention to waste control and hence to managing this risk pathway.

15.7 Accident Prevention Responsibilities

The Landfill Manager is responsible for the initiation and maintenance of accident prevention programs and for frequent and regular safety inspections of job sites, materials and equipment. Training in site safety measures should become a regular activity.

At many landfills, appointment of a Health and Safety Inspector / Manager may be appropriate to address the following:

- First aid and medical services
- Fire protection and fire prevention plans
- General housekeeping, especially within structures
- Illumination of work areas
- Sanitation and drinking water provisions
- Personal protective equipment (as well as training for its use) to ensure:
  - Visibility
  - Protection from direct injury such as lacerations
  - Protection from LFG and dust
  - Protection from noise
- Motor vehicle and equipment maintenance/condition (including Rollover Protection Systems, seat belts, back-up alarms etc).
- Asbestos management plans and/or procedures

- Hazardous waste acceptance plans and/or procedures (note that to exclude hazardous waste also requires a plan).
- The benching and/or bracing of trench construction on site
- Safe work procedures.

The Landfill Manager or Health and Safety Manager should prepare a written summary (risk assessment) with recommendations and conclusions for each item listed – even if the comment is as brief as "Through a stringent random screening programme we plan to exclude all listed hazardous waste." Accidents on site are never planned but the Manager will almost always be required to describe the plans, programs and training that were implemented to prevent such an occurrence. The better the contingency planning and the more consistent its implementation, the easier it will be to respond to accident incidents and subsequent investigations. A key site management objective is to never have an accident for which a response is required.

15.8 Signs that Communicate Effectively

Both security and safety can be enhanced through the placement of appropriate signs (Figure 15.3). Typically entry signs will show the hours of operation, the name of the owner/operator, and provide site and emergency phone numbers. Often the entry sign will also state the disposal fees and any limitations on waste types accepted that the site owners may impose on users.

Other signs within the site can be used to direct traffic to the gatehouse, office, or to the tipping face. Where distinctions are made between mechanical and hand unloading points, signs may be used to provide that information.

Figure 15.8.1 Typical safety sign

Other site features that may be identified using appropriate signage include property limits, the location of observation wells, leachate facilities, salvage and materials storage areas, and gas vents and wells. Where necessary bi-lingual signs may increase performance and add to the safety of on-site personnel, and add to the overall level of security of the site.

However, a site operation that respects neither personnel safety, nor site security cannot be improved simply with a few signs. On the other hand, the use of well-designed signs, carefully placed on-site, can and should result in better communication of the requirements for site security and personnel safety.

15.9 Conclusions

With well documented safety and security procedures, landfills can be very safe places of work. Training in, and the understanding of site safety procedures is essential if the key aim of minimizing harm is to be achieved. Maintaining security and safety at any landfill is an ongoing, active process, and procedures should be regularly reviewed for relevance and applicability. What must not be forgotten is that there are no short cuts to safety and that safety in all aspects of site operation is at the core of an effective landfill operation.

APPENDIX 4 LANDFILL MONITORING MANUAL

Qeshm Free Zone Organization
(QFZO)

Japan International Cooperation Agency
(JICA)

THE PROJECT FOR COMMUNITY-BASED SUSTAINABLE DEVELOPMENT MASTER PLAN OF QESHM ISLAND TOWARD "ECO-ISLAND" IN THE ISLAMIC REPUBLIC OF IRAN

Landfill Monitoring Manual

April 2018

RECS International Inc.
PADECO Co., Ltd.
Kokusai Kogyo Co., Ltd.

Source:	LANDFILL MANUALS LANDFILL MONITORING 2nd Edition, Office of Environmental Enforcement, Environmental Protection Agency
Modified by:	JICA Project Team

Table of Contents

CHAPTER 1 INTRODUCTION 1-1
1.1 General 1-1
1.2 Legislation 1-1
1.2.1 Landfill Directive 1-2
1.2.2 Other Legislation 1-2
1.3 Landfill Monitoring 1-2

CHAPTER 2 MONITORING PROGRAM 2-1
2.1 Purpose of the Programme 2-1
2.2 Scope of Programme 2-2
2.3 Monitoring Programme Design 2-3
2.4 Review of Programme 2-6
2.5 On-site Records 2-6
2.6 On-site Laboratory Facilities 2-7
2.7 Safety Precautions 2-7

CHAPTER 3 QUALITY ASSURANCE/QUALITY CONTROL 3-1
3.1 Purpose 3-1
3.2 Definitions 3-1
3.3 Quality Assurance Plan 3-1
3.3.1 General Quality Management 3-1
3.3.2 Field Operations 3-2
3.3.3 Laboratory Operations 3-2
3.4 Quality Schemes 3-2
3.4.1 Laboratory Accreditation 3-2
3.4.2 Inter Laboratory Testing Schemes 3-3
3.4.3 Other Sources of Information on Data Quality 3-3
3.5 Sub-contracting of Analyses 3-3

CHAPTER 4 SURFACE WATER 4-1
4.1 Introduction 4-1
4.2 Monitoring Locations 4-1
4.3 Monitoring Frequency and Parameters for Analysis 4-2
4.4 Biological Assessment of Surface Water Quality 4-2
4.5 Sediment Sampling 4-3
4.6 Trigger Levels 4-3
4.7 Sampling Guidelines 4-3
4.7.1 Introduction 4-3
4.7.2 General Sampling Guidelines 4-4
4.7.3 Sampling Equipment 4-5

CHAPTER 5 GROUNDWATER 5-1
5.1 Introduction 5-1
5.2 Monitoring Locations 5-1
5.3 Design and Construction of Boreholes 5-2
5.4 Monitoring Frequency and Parameters for Analysis 5-3
5.5 Trigger Levels 5-3
5.6 Sampling Guidelines 5-4

CHAPTER 6 LEACHATE 6-1
6.1 Introduction 6-1
6.2 Monitoring Locations 6-1
6.3 Monitoring Frequency and Parameters for Analysis 6-2

6.4 Toxicity Testing 6-2
6.5 Sampling Guidelines 6-2

CHAPTER 7 LANDFILL GAS 7-1
7.1 Introduction 7-1
7.2 Landfill Gas Safety 7-2
7.3 Landfill Gas Within and Outside the Waste Body 7-2
7.3.1 Introduction 7-2
7.3.2 Monitoring Locations 7-2
7.3.3 Monitoring Frequency and Parameters for Analysis 7-3
7.3.4 Trigger Levels 7-4
7.3.5 Monitoring Surface Emissions 7-4
7.4 Landfill Gas Combustion Plants (Enclosed Flares & Utilization Plants) 7-5
7.4.1 Introduction 7-5
7.4.2 Monitoring Locations 7-5
7.4.3 Monitoring Frequency and Parameters for Analysis 7-5
7.4.4 Design Certification of Flares 7-6
7.5 Sampling Guidelines 7-6
7.5.1 Introduction 7-6
7.5.2 Landfill Gas within and Outside the Waste Body 7-6
7.5.3 Flares and Utilization Plants 7-7

CHAPTER 8 ODOR 8-1
8.1 Introduction 8-1
8.2 Odor Assessment 8-2
8.3 Frequency of Monitoring 8-2
8.4 Analysis Techniques 8-3

CHAPTER 9 NOISE 9-1
9.1 Introduction 9-1
9.2 Monitoring Locations 9-1
9.3 Frequency of Monitoring and Parameters for Analysis 9-2
9.4 Emission Limits 9-3
9.5 Noise Monitoring Equipment 9-3

CHAPTER 10 OTHER ASPECTS 10-1
10.1 Meteorological Data 10-1
10.2 Dust/Particulate Matter 10-1
10.2.1 Introduction 10-1
10.2.2 Dust deposition 10-1
10.2.3 PM_{10} 10-2
10.3 Topography & Stability 10-2
10.3.1 Introduction 10-2
10.3.2 Topographical Surveys 10-3
10.3.3 Stability 10-3
10.4 Ecology 10-4
10.5 Archaeology 10-4

CHAPTER 11 REPORTING OF MONITORING 11-1
11.1 Routine Reporting 11-1
11.2 Annual Environmental Report 11-1

CHAPTER 12 GLOSSARY 12-1

CHAPTER 13 SAMPLING PROTOCOLS (APPENDIX A) 13-1

CHAPTER 14 STANDARD FORMS (APPENDIX B) ... 14-1
14.1 B.1 Example of a Landfill Gas Monitoring Form ... 14-2
14.2 B.2 Example of a Chain of Custody Form ... 14-3
14.3 B.3 Example of a Sample Analysis Report Form ... 14-4
14.4 B.4 Example of a Rivers Ecological Assessment Field sheet ... 14-5

CHAPTER 15 MINIMUM MONITORING REQUIREMENTS (APPENDIX C) ... 15-1

CHAPTER 16 MINIMUM REPORTING VALUES (APPENDIX D) ... 16-1

CHAPTER 17 SAMPLING EQUIPMENT & ANALYTICAL TECHNIQUES (APPENDIX E) ... 17-1

List of Tables

Table 2.1.1 Key Phases of Monitoring at a Landfill ... 2-1
Table 4.4.1 Q values and quality class ... 4-3
Table 7.3.1 Landfill gas trigger levels for boreholes outside of the waste body ... 7-4
Table 8.3.1 Odor descriptors and possible chemical cause ... 8-2
Table 13 A.1 Design of a Sampling Protocol ... 13-2
Table 15.C.1 Minimum baseline monitoring requirements for a Non-Hazardous landfill ... 15-1
Table 15.C.2 Parameters for monitoring of groundwater, surface water & leachate ... 15-2
Table 15.C.3 Typical leachate monitoring requirements for Non-Hazardous landfill ... 15-3
Table 15.C.4 Typical landfill gas monitoring requirements for a Non-Hazardous landfill ... 15-3
Table 15.C.5 Typical Landfill Gas Flare and Utilization Plant Monitoring Regime ... 15-4
Table 15.C.6 Minimum meteorological monitoring requirements ... 15-5
Table 16.D.1 Guideline Minimum Reporting Values ... 16-1
Table 16.D.2 Recommended core determinants for trace organics analysis & guideline ... 16-3
Table 17.E.1 Groundwater & Leachate sampling equipment ... 17-1
Table 17.E.2 The relationship between measured gas parameters & monitoring purpose ... 17-2
Table 17.E.3 Characteristics of various gas sensors ... 17-3
Table 17.E.4 Monitoring methods & techniques for flares & utilization plans ... 17-4

List of Figures

Figure 2.3.1 Design of a landfill monitoring program ... 2-4
Figure 4.7.1 Procedure for Collecting a Representative Water Sample ... 4-5
Figure 11.2.1 Graphical presentation of results at a groundwater borehole ... 11-2

CHAPTER 1 INTRODUCTION

1.1 General

The Environmental Protection Agency (EPA) is required, under the Environmental Protection Agency Act, 1992 to specify and publish criteria and procedures for the selection, management, operation and termination of use of landfill sites. This document replaces the original 'Landfill Monitoring' manual, and is one of a series of manuals on landfilling which have been published to fulfill the Agency's statutory requirements.

This manual, along with the others in the series, is designed to assist landfill operators to conform to the standards required, including the BAT (Best Available Techniques) principle, and to ensure that the long- term environmental risks posed by landfills (including closed landfills) are minimized through effective monitoring and control.

There are many potential environmental problems associated with the landfilling of waste. These problems include possible contamination of the groundwater and surface water regimes, the uncontrolled migration of landfill gas and the generation of odor, noise, dust and other nuisances.

In the past, landfill sites in Ireland were rarely engineered and the absence of an environmental monitoring programme, meant that the impact of the landfill on the surrounding environment was not assessed. However, over the past decade standards and practices have been steadily improving and many new technologies have been adapted or specifically designed to control and monitor the processes within a landfill. Henceforth, it is expected that landfill sites will be selected, designed, managed and monitored using BAT to comply with the Waste Management Act, 1996, the Council Directive on the landfill of waste (99/31/EC) and Council Directive concerning integrated pollution prevention and control (96/61/EC).

1.2 Legislation

Regulation of waste management in Ireland is through the Environmental Protection Agency Act, 1992, the Waste Management Act, 1996 and the Protection of the Environment Act, 2003.

The Waste Management Act, 1996 provides for the introduction of:

- measures to improve national performance in relation to the prevention, reduction and recovery of waste; and
- a regulatory framework for the application of higher environmental standards, particularly in relation to waste disposal.

These measures include for example, the Waste Management Plans, which Local Authorities are responsible for preparing under Section 22 of the Waste Management Act, 1996 and the Waste Management (Planning) Regulations, 1997; and which must have particular regard to waste prevention and waste recovery. Section 26 of the Waste Management Act, 1996 requires the Environmental Protection Agency to prepare a national hazardous waste management plan. This must also have particular regard to prevention and minimization of the production of hazardous waste and to the recovery of hazardous waste.

The Waste Management Act, 1996 designates the Agency as the licensing authority for landfills. The Waste Management (Licensing) Regulations, (1997 – 2002) provide for the licensing by the Agency of waste recovery and disposal activities.

1.2.1 Landfill Directive

The Council Directive on the landfill of waste (99/31/EC) came into force on the 16th July 2001. The Directive sets stringent operational and technical requirements for waste and landfills, and provides for measures, procedures and guidance to prevent or reduce negative impacts on the environment and on human health.

The Directive category landfill sites into three types; inert, non-hazardous and hazardous, with varying controls on their design and operation depending on the perceived hazard they pose to the environment. The monitoring requirements for a landfill accepting inert waste will be different from one accepting non- hazardous waste, which will in turn be different from a facility accepting hazardous waste.

The Directive requires that landfill sites be monitored at specified minimum frequencies during their operational and aftercare phases.

Certain categories of landfills may, subject to certain conditions, be exempt from the monitoring requirements of the Directive such as landfill sites for non-hazardous or inert waste in isolated settlements if the landfill site is destined for the disposal of waste generated only in that isolated settlement.

1.2.2 Other Legislation

The requirements of all legislation relevant to a particular aspect of the environment should be borne in mind when developing and undertaking monitoring programs. The primary reasons for monitoring are to meet the requirements of legislation and to meet the specific requirements of the waste license.

Legislation is open to change and therefore this document does not attempt to go into details on all the legislation relevant to different aspects of the environment. However it is important to mention some legislative requirements in relation to groundwater and surface water.

The primary legislation governing groundwater is the Directive on the protection of groundwater against pollution caused by certain dangerous substances (80/68/EEC). The Directive is transposed into national legislation by the Local Government (Water Pollution) Regulations 1977-1999. The objective of the Directive is to ensure the effective protection of groundwater by preventing the discharge of List I substances and limiting the discharge of List II substances into groundwater by a system of authorization or licensing. The Groundwater Directive seeks to control groundwater pollution by halting or limiting List I and List II discharges to an aquifer; it does not actually set standards for water quality in an aquifer.

In December 2000 the Water Framework Directive (2000/60/EC) came into force and it established a strategic framework for managing the water environment and sets out a common approach to protecting and setting environmental objectives for all groundwater and surface waters in the European Community. The Directive is intended to replace many pieces of current water quality legislation and to provide a comprehensive system of environmental protection for surface water and groundwater.

1.3 Landfill Monitoring

The landfilling of waste poses a potential long-term threat to the environment. It is important therefore that landfills are located, designed, operated and monitored to ensure that they do not to any significant extent:

- harm the environment,
- endanger human health,
- create an unacceptable risk to water, soil, atmosphere, plants or animals,
- create nuisances through noise or odors, or

- adversely affect the countryside or places of special interest

The purpose of this revised manual on landfill monitoring is to provide guidance on the design and implementation of an effective and efficient monitoring programme which will allow an accurate assessment of the impact of the landfill on the surrounding environment. A well designed monitoring programme will in turn allow for the early recognition of adverse environmental effects and facilitate rapid corrective action.

CHAPTER 2 MONITORING PROGRAM

2.1 Purpose of the Programme

The monitoring programme is an essential component of the management plan for a landfill site. It provides operators with information to assess the effect of the landfill on the surrounding environment and assists in ensuring that the landfill is operated and controlled to the specified standards. There are three key phases of monitoring at a landfill and these are summarized in Table 2.1.1.

Table 2.1.1 Key Phases of Monitoring at a Landfill

Phase	Type of monitoring	Reason
Prior to landfill operation	Baseline	Site investigation, environmental impact assessment, preparation of a waste license application.
During the operation of the landfill	Compliance / Assessment	Comply with waste license.
Aftercare and restoration of the landfill	Compliance / Assessment	Comply with waste license, preparation of license review application, surrender of license.

The objectives of a monitoring programme are:

- to establish baseline environmental conditions;
- to detect adverse environmental impacts from the landfilling of waste;
- to provide information for the assessment of an application for a waste license, review of a waste license or surrender of a waste license;
- to demonstrate that the environmental control measures are operating as designed;
- to assist in the evaluation of the processes occurring within the waste body;
- to demonstrate compliance with the license conditions;
- to provide data for emission inventories;
- to provide data to inform the public;
- to provide data for the improvement and updating of monitoring programs;
- to assist in an investigation in the event of a trigger level or emission limit value being breached

Landfill monitoring is an interactive process incorporating the findings of the site investigation, the environmental impact assessment, environmental monitoring results, risk assessment and the conclusions reached in the investigations.

The following are common terms used in monitoring programs.

Emission Limit Values

These are values, including concentration limits and deposition levels established in the license. No specified emission from the facility can exceed these emission limit values. In addition, the license requires that no emissions should result in significant impairment of, or significant interference with the environment beyond the facility boundary.

Trigger Levels

These are values that would require certain actions to be taken by the site operator should they be attained or exceeded. A breach of a trigger level may indicate a significant increase of a contaminant concentration in an environmental medium. These values are generally set by the Agency in the license or else may be set by the operator. They may be siting specific and be established from the baseline monitoring results.

Baseline Monitoring is monitoring in and around the location of a proposed facility so as to establish background environmental conditions prior to any development of the proposed facility. In the case of existing facilities, baseline monitoring serves as a reference point to which later monitoring results are compared. The information gathered can be used to evaluate the future compliance monitoring data and to identify potential impacts of the landfill on the environment.

Compliance Monitoring is periodic monitoring undertaken by either the licensee or the Agency at specified frequencies to determine if there has been a release of contaminants to the environment and to demonstrate compliance with the license conditions. It includes taking measurements of process conditions, process emissions and levels in receiving environments and the reporting of the results of such measurements to demonstrate compliance with limits specified in the license or other legislation.

The information provided by compliance monitoring is also valuable for other environmental and management activities (e.g. for optimizing processes, protecting sensitive ecosystems and informing the public of the effectiveness of environmental protection measures).

Assessment Monitoring is investigative monitoring which is initiated after the detection of a release of a contaminant to the environment or on attaining a trigger level. The purpose of the assessment programme is:

- to identify the source of release;
- to characterize the nature, extent and rate of release;
- to evaluate the risk to the environment and to human health;
- to evaluate measures to prevent or minimize further releases; and
- to provide information for the design and implementation of corrective measures.

2.2 Scope of Programme

Monitoring is required throughout the life of a landfill. It extends from the pre-operational phase (baseline monitoring) through to the operational and aftercare phases (compliance and assessment monitoring) of the landfill. The scope of the programme should initially be identified from the investigation process, the environmental impact assessment and the nature of the waste being deposited. It should include all environmental media likely to be significantly impacted through the operation of the landfill. For a non- hazardous waste landfill provision for the monitoring of the following, as a minimum, should be made:

- surface water,
- groundwater,
- leachate,
- landfill gas and landfill gas combustion products,
- odors,
- noise,
- meteorological conditions,
- dust/particulate matter,

- topography and stability,
- ecology, and
- archaeology

2.3 Monitoring Programme Design

The steps to be taken in designing a monitoring programme are shown in Figure 2.1. The design of the monitoring programme will, to a large extent, depend on site conditions identified during the site selection and investigation processes. Such conditions may include:

- the degree of isolation of the site;
- the geological, hydrogeological and hydrological regimes;
- the containment measures proposed;
- the characteristics of the waste to be deposited; and
- the risk of adverse impacts on the various aspects of the environment

It is desirable that the monitoring programme be developed using an integrated approach. Such an approach requires an understanding of the interaction and inter-relationship of the different environmental media. For example, it is important to understand how a discharge to the aquatic environment impacts on the biological quality of a river. An integrated approach would assist in the location of monitoring points and permit a greater understanding of the overall impact of the site on the environment.

The monitoring programme should address the following topics:

General & site specific objectives

These should be identified at an early stage and include:

- establishment of a reference database from baseline monitoring results;
- identification of areas and receptors vulnerable to contamination;
- compliance with license conditions; and
- adherence to guidance issued by the Agency

Selection of suitable monitoring points

The selection of suitable, representative monitoring points is essential in the collection of valid data. The number and location of monitoring points is site specific and depends on:

- geological, hydrogeological and hydrological regimes of the area;
- the topography of the site;
- the proximity of people and building developments; and
- the location of sensitive ecological habitats

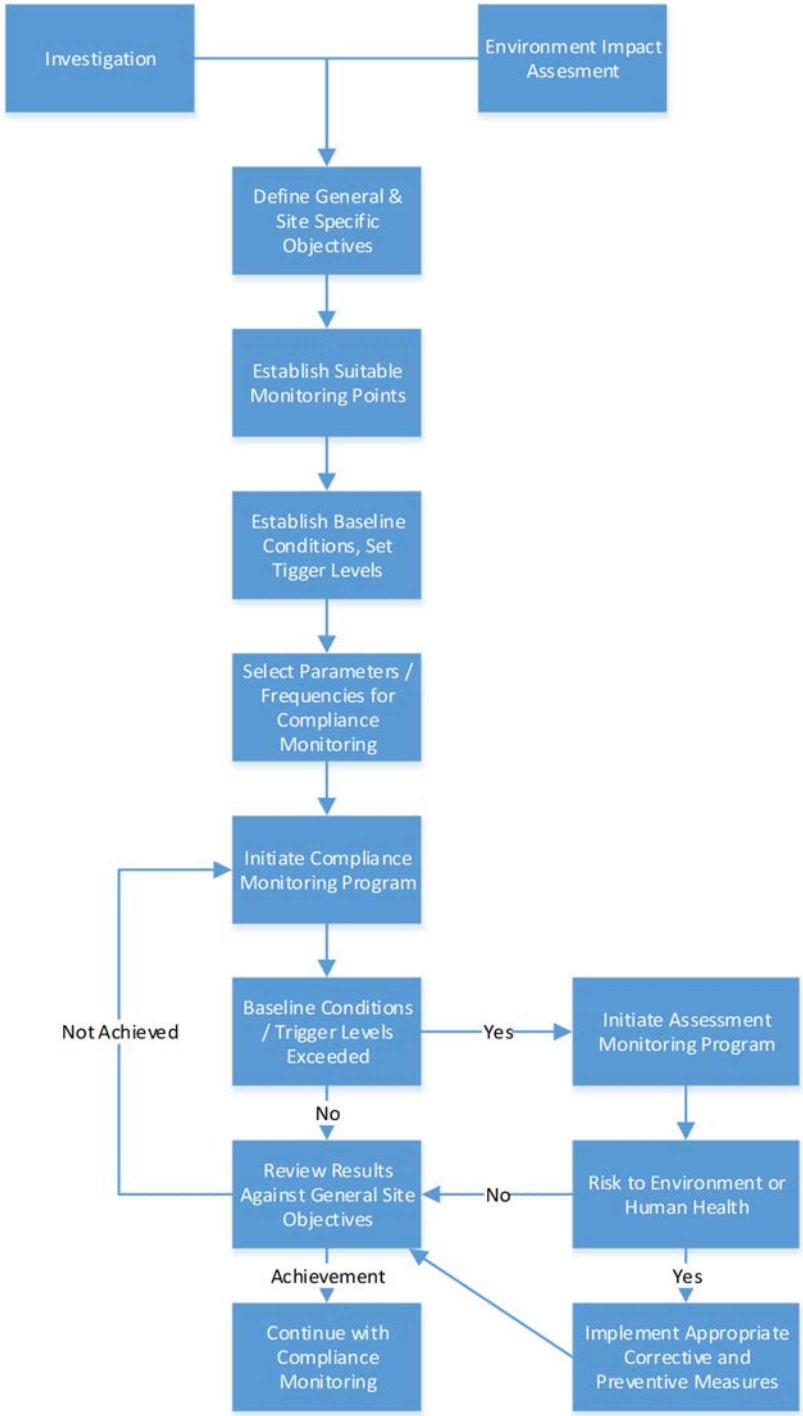


Figure 2.3.1 Design of a landfill monitoring program

Ease of access by sampling personnel and safety issues also need to be taken into account when selecting suitable monitoring locations. Monitoring for parameters such as surface water, groundwater, noise and odors will usually include monitoring points that are not located within the boundary of the facility. Permission from the respective owners may be necessary in some cases.

Consideration should also be given to the potential for dual use of monitoring points. For example, the use of groundwater boreholes for monitoring off-site landfill gas migration should be considered.

Possible monitoring locations can be grouped into the following: source, pathway and receptor positions.

- **Source positions.** These are positions within or at the exit from a process such as:
  - before and after abatement equipment,
  - within a flue for emissions to air,
  - at an outlet from an effluent pipe for wastewater emissions.
- **Pathway positions.** These are positions in the receiving environments (e.g. air or water) where the flow and dispersion require monitoring because they affect compliance with ambient limits such as:
  - in a river, for monitoring of river flow,
  - in the air, for monitoring of atmospheric dispersion conditions
- **Receptor positions.** These are the sensitive positions in receiving environments where pollutants after emission, or impacts (e.g. noise, odor) from sources and dispersion along pathways are, e.g.:
  - at point of maximum ground-level concentration or deposition,
  - at a position occupied by the most exposed person(s),
  - across a local ecosystem, e.g. a catchment, or an area of forest or farmland

Identification of Monitoring Points

All monitoring locations should be marked on a drawing or map so that they are readily identifiable during subsequent visits. An up to date drawing of all monitoring points should also be held at the facility office.

The monitoring programme must state clearly the positions (e.g. River A at grid reference 'xxx yyy'), a local description of the monitoring location, how it can be accessed and where samples and measurements are to be taken. Reference to a GPS based location citing the datum used would also be useful (e.g. WGS 84).

Standardization of the names of monitoring points is recommended, e.g. surface water - SW, groundwater – GW, etc. All permanent sampling locations should have a marker detailing the location name and type of sample. The location marker should be easily visible from a distance. Different color coding for the different types of samples, e.g. surface water, groundwater, leachate, etc. can improve efficiency in locating monitoring points. Access to points should be kept clear where possible. Locating monitoring points may be particularly difficult during the spring/summer months due to prolific plant and weed growth.

Monitoring parameters

Within this document parameters are suggested for baseline monitoring of surface water, groundwater and characterization of leachate. Depending on the baseline monitoring data, the type of waste deposited and the level of containment at the site, it may be necessary to review the monitoring parameters and adapt them to reflect accurately the contaminants most likely to arise and adversely affect the environment.

Monitoring frequencies

The monitoring frequencies for a landfill may vary according to the age of the site, the type of waste accepted for disposal and the location of the site. Increased monitoring above the minimum requirements may be necessary to ensure that sensitive environmental media are adequately monitored. Some factors that would indicate the need for increased monitoring include:

- evidence of negative impacts or a decrease in environmental quality when compared with baseline conditions or the results of previous monitoring;
- non-compliance with a license condition, e.g. if an emission limit value or a trigger level is

breached;

- change in site operations;
- increased extraction of surface waters or groundwater in the vicinity of the landfill;
- change in adjacent land use; or
- building developments adjacent to the site

Monitoring Equipment

There are numerous instruments commercially available for sampling and monitoring at landfill sites. Limitations are inherent in all types of monitoring equipment and the conditions of use may also give rise to difficulties in obtaining reliable results. Sampling and monitoring equipment must therefore be chosen carefully to ensure that the objectives of the monitoring programme are achieved. Some factors that may need to be considered when assessing the equipment are:

- suitability of the equipment for measuring the required parameters,
- equipment conforming to recognized standards,
- sensitivity/detection level,
- calibration requirements,
- maintenance requirements,
- ability to be decontaminated after being in contact with pollutants and toxins
- ease and safety of operation,
- portability of equipment where required,
- type of power source required,
- durability,
- cost, and
- intrinsically safe

Sampling and Analytical Methods

The monitoring programme should detail the sampling and analytical protocols to be employed to ensure that the measurements obtained are valid and reliable. Further information on the design of sampling protocols is given in Appendix A. Analytical procedures for surface water, groundwater and leachate should be capable of meeting the requirements of Tables D.1 and D.2 in Appendix D.

Quality Assurance and Quality Control Procedures

Quality assurance is an integral component of any monitoring programme. Operators should develop a quality assurance plan as part of the programme to ensure that data obtained are accurate, precise and representative of the medium being investigated. Further information on quality assurance is given in Chapter 3.

2.4 Review of Programme

The monitoring programme should be reviewed periodically by the operator, assessed against its objectives and updated as necessary. Such reviews are essential to ensure the quality, effectiveness and continued suitability of the programme. This review could be carried out during the preparation of the yearly Annual Environmental Report or as part of a license review application.

2.5 On-site Records

All monitoring results have to be interpreted and reported to the Agency at the frequencies outlined in the license and must be available for inspection if requested by Agency personnel during site inspections or audits. A summary report of emissions and results and an interpretation of environmental monitoring must be included in the Annual Environmental Report of the facility. As part of the requirements of a waste license, environmental information relating to the facility must be available to the public.

It is desirable that a Data Management System is established for the collation, archiving, assessing and graphically presenting the environmental data generated.

2.6 On-site Laboratory Facilities

It is recommended that in the case of larger facilities that an on-site laboratory is provided and maintained. This could provide basic laboratory equipment and apparatus necessary for process control testing such as balances, ovens, distilled water and proprietary test kits and a designated storage area for monitoring equipment such as pH and conductivity meters and sampling apparatus.

This would allow the quality of surface waters or the efficiency of an on-site leachate treatment plant to be checked if a problem was suspected. Adequate equipment maintenance and quality control is also necessary.

2.7 Safety Precautions

Safety must be carefully considered before monitoring begins and appropriate precautions followed. It is recommended that every monitoring programme should include a requirement that a risk assessment based on a safety audit be used to develop a safe working-plan covering the following points:

- confirmation that the equipment and facilities which will be used are safe and adequate (e.g. electrical and sampling equipment, walkways, ladders);
- guidance or briefing on how to safely access locations where monitoring is to be done;
- availability of an appropriate number of qualified personnel;
- reminders concerning risks and precautions in relation to physical, chemical and biological dangers;
- availability of personal protective equipment (PPE); and
- safety training of staff, including training in emergency and evacuation procedures (e.g. by site induction and safety course). FÁS run a Safe Pass Health and Safety Awareness Training Programme that aims to ensure that all construction site and local authority personnel have a basic knowledge of health and safety issues

CHAPTER 3 QUALITY ASSURANCE/QUALITY CONTROL

3.1 Purpose

A monitoring programme for a landfill is a substantial undertaking in terms of both time and money and will generate substantial quantities of data over the lifetime of a landfill. It is important that the data produced is representative, necessary and valid and that it allows the accurate assessment of the impact of the landfill on the environment.

Errors within the sampling or analysis processes may prejudice the analytical results and invalidate the interpretations and conclusions drawn from them. The selection of and adherence to the principles of quality assurance and quality control should provide the necessary controls to minimize potential sources of error by ensuring that:

- the entire process, including field and laboratory operations, are adequately documented;
- adequate training is given to all field and laboratory staff involved;
- the integrity of the samples is maintained during sampling, transportation and storage; and
- the appropriate analytical techniques are used

3.2 Definitions

A Quality Assurance (QA) system is a set of operating principles which, if strictly followed during sample collection, transportation and analysis, will produce reliable data.

Quality Control (QC) is an integral aspect of Quality Assurance and focuses on ensuring that the data produced are inherently accurate and precise. The QC programme should specify the techniques used to measure and assess data quality, sample replication requirements and the remedial actions to be taken when quality objectives are not realized.

3.3 Quality Assurance Plan

The Quality Assurance (QA) Plan is a document that outlines the quality assurance principles under which the monitoring programme will be conducted. The plan should be prepared in advance of the monitoring programme and should define the overall management strategy designed to ensure the quality of the implementation of the programme. It should include documented lines of decision making, sampling and analysis conventions and procedures for sample handling, transport and preservation.

The QA Plan can be broadly divided into three sections: general quality issues, quality during field operations and the quality during laboratory operations. A selection of topics to be addressed under each of these headings is outlined below.

3.3.1 General Quality Management

- Overall objectives of the monitoring programme,
- Standard Operating Procedures for laboratory and field activities,
- Responsibilities and qualifications defined for each staff member involved,
- Designation of a Quality Assurance Officer (with authority for corrective action),
- Training (field & laboratory),

- Maintenance of Training Records,
- Quality Assurance reports,
- Report approval mechanisms,
- Document control procedures,
- Auditing procedures.

3.3.2 Field Operations

- Sampling programme design,
- Sampling protocols (further information is given in Appendix A),
- Documentation such as field data forms and chain of custody forms (further information is given in Appendix B),
- Instrument calibration,
- Sampling equipment (appropriateness, cleaning, maintenance records),
- Procedures for collection & preservation of samples,
- Procedures for transport & storage of samples (methods, labelling).

3.3.3 Laboratory Operations

- Laboratory documentation,
- Standard methods of analysis such as National/International standards (NSAI/ISO/CEN methods), 'Standard Methods for the Examination of Waters & Wastewater' (Eaton et al, 1998), UK Standing Committee of Analysts "Blue Book" series, or similar,
- Validation of method performance to include detection/reporting limits, recovery, uncertainty of measurement,
- Laboratory instrument calibration and maintenance,
- Performance evaluation utilizing in-house QC samples and/or Certified Reference Materials (CRMs),
- Control charts (or tables) to monitor precision and accuracy of data,
- Review of QC sample results (permanent record, replicates, verifications),
- Procedures for data evaluation (comparison with previous results, statistical methods) and notification of exceedances of emission limit values to the client,
- The structure, compilation, certification and verification of monitoring reports forwarded to the Agency,
- Retention of samples until such time as results are reported to the client.

3.4 Quality Schemes

3.4.1 Laboratory Accreditation

It is desirable that laboratories undertaking analyses be accredited to ISO/IEC 17025 (1999). It is important that consideration is given to the Scope of Accreditation of the laboratory to ensure that it is relevant to the test(s) required.

Non-accredited laboratories may require to be verified by the site operator to ensure the application of documented quality controlled practices.

3.4.2 Inter Laboratory Testing Schemes

In accordance with Section 66 of the Environmental Protection Agency Act 1992, the Agency operates an inter calibration programme for the purpose of assessing analytical performance and ensuring the validity and comparability of environmental data from laboratories that submit data to the Agency. It also provides for the establishment of a register of Quality Approved laboratories that would normally be expected to send data to the Agency. The register lists, on a parameter by parameter basis, those laboratories that performed satisfactorily in the EPA inter calibration programme for the previous year. The register is updated annually and may be viewed on the Agency's web site at www.epa.ie. At present this register is limited to water and wastewater.

Laboratories analyzing leachate and complex wastewaters should assess the need for additional participation in inter-laboratory proficiency schemes more suited to these matrices as a supplement to internal quality control programs.

Where practicable other parameters such as landfill gas, noise, dust and odor monitoring should be undertaken by laboratories that participate in appropriate quality schemes. The Source Testing Association (STA) provides guidance on best practice for sampling of stacks and this may be applicable to flares and utilization plants. Further information may be found at www.S-T-A.org.

Details of proficiency schemes within the EU may be found at the European Information System of Proficiency Testing Schemes (EPTIS) website at www.eptis.bam.de.

3.4.3 Other Sources of Information on Data Quality

- 'Handbook on the Design and Interpretation of Monitoring Programs' Technical Report NS29 (WRc, 1989a).
- 'A Manual on Analytical Quality Control for the Water Industry' Technical Report NS30 (WRc, 1989b).
- ISO/IEC (1999) 17025 '*General requirements for the competence of testing and calibration laboratories'*. This publication sets out the criteria required to enable laboratories to meet current accreditation requirements.
- ENV/ISO (1997) 13530 'Water Quality - Guide to Analytical Quality Control for Water Analysis' available from the NSAI.
- ISO (1991a) 8258 'Shewhart Control Charts'.
- Certified reference materials and other reference standards are widely available from a number of commercial sources many of whom also provide technical information
- Valid Analytical Measurement (VAM) Programme. This programme is coordinated by the Laboratory of the Government Chemist (UK) and is aimed at improving the quality of analytical information.

3.5 Sub-contracting of Analyses

It is not uncommon to find site operators sub-contracting the sampling and/or analysis of waste facilities to third party consultancy or laboratory services. The commercial sector for such work is expanding and there are now several companies with experience of such work.

In such cases it is necessary to ensure that the Quality Plan and any subsequent contract documentation makes full reference to the detail of all aspects of the monitoring process including such aspects as borehole purging techniques, sample filtration/preservation, storage, transport and analysis turnaround. This can be especially important in respect of some parameters such as those for microbiology, metals, and organics.

While many companies will apply the principles set out above it is important that operators satisfy themselves as to the technical and analytical competence of third parties before reporting of such analytical data. It is important when comparing contract details to ensure the comparability of service delivery and, most importantly analytical performance. In this regard the range of parameters covered and their practical reporting limits can vary significantly between one service provider and another. This is particularly true in the case of organic analysis where lower reporting concentrations are often closely linked to the complexity of sample pre-treatment and concentration procedures

Procedures should be put in place so that any exceedance of an emission limit value or a trigger level is communicated by the laboratory to the licensee as soon as possible so that further measures can be implemented.

CHAPTER 4 SURFACE WATER

4.1 Introduction

The Landfill Directive requires that surface water, if present, be monitored at representative points. The surface water environment on and off a landfill site may comprise of:

- streams, rivers, canals and ditches,
- lakes, reservoirs and lagoons,
- wetlands,
- estuaries, and
- coastal waters

The purpose of a surface water monitoring programme is to verify the quantity and quality of the surface water on a periodic basis and to detect any significantly adverse environmental impacts resulting from landfill activities or resulting from construction activities at the landfill.

Contamination of the surface water regime by a landfill site may arise due to:

- intentional discharges (e.g. discharge of treated leachate); or
- unintentional discharges (e.g. leachate escape, contaminated surface water run-off, accidental spillages)

The design of the surface water monitoring programme should be site specific, and should take into account such factors as the nature of the drainage system, water levels, flow characteristics and the groundwater/surface water inter-relationship

4.2 Monitoring Locations

The location of surface water monitoring points will be site specific and will depend on the nature of the drainage system around the landfill site. Table C.1 in Appendix C outlines minimum baseline surface water monitoring requirements for a non-hazardous landfill. The monitoring points should allow information to be collected on the quantity and quality of the water both upstream and downstream of the landfill and should be representative of the particular site conditions. The investigation process will identify those surface water bodies at risk and the location of the monitoring points should reflect the results of the investigation.

The following guidelines should be observed when assessing suitable locations for monitoring points:

- for flowing water bodies (e.g. rivers and streams), monitoring should be undertaken at not less than two locations, one upstream and one downstream of the landfill. The downstream monitoring point should be located immediately downstream of the mixing zone. More than one monitoring point should be chosen downstream of the discharge if information on the extent of impact or recovery is required;
- for static freshwater bodies (e.g. lakes), a minimum of two monitoring points should be located radiating away from the landfill site and should be in an area that is representative of the water body as a whole;
- surface water draining from the landfill site should be monitored before discharge to the receiving surface waters;
- the inlet and outlet points of any surface water holding and settlement ponds at the landfill should be monitored so that their efficiency can be determined and so that any potential sources of

contaminants can be identified;

- if applicable, any effluent discharge points from the landfill should be identified and monitored before discharge to the receiving surface waters;
- the accessibility of the monitoring location and the safety of personnel when sampling should be assessed;
- the measurements to be made and the sampling method to be used at each location should be considered;
- conflict with other potential pollution sources and pathways should be avoided, e.g. cattle drinking or crossing points, farmyard run-off, tributary streams

4.3 Monitoring Frequency and Parameters for Analysis

For baseline monitoring, each monitoring point should be monitored quarterly for a minimum of one year prior to the commencement of activities at the site.

The frequency of compliance monitoring during the operational and aftercare phase is site specific and will be governed by the waste license and should take into consideration the characteristics of the surface water regime and its vulnerability to contamination.

For baseline monitoring, the parameters listed in Table C.2 in Appendix C should be included in the determination of the surface water quantity and quality. Tables D.1 and D.2 in Appendix D outline the guideline minimum reporting values for those parameters required to be analyzed.

Where contamination of the surface waters is suspected, then surface water flow will have a large bearing on the extent of the contamination. Surface water flow may be:

- rapid, with the result that contaminants can be spread to receptors in a matter of minutes or hours rather than days or longer;
- of high volume, offering large dilution of contaminants; or
- seasonally variable and liable to rapid fluctuations over short time periods resulting in large variations in dilution potential

Therefore risk assessment should be cautious and take account of the lowest flows in surface watercourses. At least one sample over the course of a year should be taken at a time of low flow conditions.

4.4 Biological Assessment of Surface Water Quality

Chemical analyses of surface waters are essential both in identifying possible contaminants and in quantifying their concentrations. However, chemical analyses only provide an instantaneous picture of water quality. Since contaminants often interact and occur in complex mixtures, such analyses alone will frequently give little indication of the potential biological impacts. Therefore, as part of the integrated approach to monitoring at a landfill, operators should undertake periodic biological assessments of the quality of the surface waters surrounding the landfill. Ideally, all the components of the aquatic biota (the micro- and macrofauna and flora) should be utilized but in practice macroinvertebrate community analysis is found to be satisfactory for routine biological water quality monitoring purposes.

One of the most common methods employed to assess surface water quality is monitoring changes in the diversity and density of macroinvertebrates that inhabit the substrata. With increasing pollution there is often a decrease in faunal diversity and an increase in numbers of specific tolerant forms. The sensitivity and tolerance to pollution varies considerably from species to species and it is possible to relate certain faunal groups to particular pollution levels.

The biological information gathered by this method can be presented as a biotic index, which is a system that relates the benthic community composition and water quality. A five-point scale of numerical values has been in use in Ireland since the 1970's with the intermediate indices Q1-2, 2-3, 3-4 and 4-5 used to denote transitional conditions. The Q scheme, as it is known, is related to water quality as shown in Table 4.4.1.

Table 4.4.1 Q values and quality class

Biotic Index (Q value)	Quality Status	Quality Class
Q5, Q4-5, Q4	Unpolluted	Class A
Q3-4	Slight pollution	Class B
Q3, Q2-3	Moderate pollution	Class C
Q2, Q1-2, Q1	Serious pollution	Class D

(Source: McGarrigle et al., 2002)

Details of the classification system used in the Q scheme may be found in the Agency's report on '*Water Quality in Ireland 1998-2000*', (McGarrigle et al., 2002)

Fisheries Assessment
An assessment of the fisheries status of a river may be necessary in some cases. This may be of particular importance where treated leachate is discharged directly into a river or to provide baseline data of the status of a river adjacent to a proposed landfill. The relevant Regional Fisheries Board should be contacted to ascertain if there is any current information on the fish species or fish populations present in the river or if any electrofishing surveys have been undertaken. The Fisheries Board should also be able to provide information on whether the river is a designated salmonid or coarse fishery.

4.5 Sediment Sampling

Occasionally there may be a requirement to take samples of bottom sediment deposits, e.g. at a landfill that is located beside an estuary. Sediment samples can provide a very sensitive means of identifying impacts on surface water by contaminants such as trace metals that are readily adsorbed onto sediment from flowing water. This can sometimes provide an indicator of the long-term accumulation of pollutants carried by a watercourse. It is important that sampling locations are depositional in nature that comparable upstream and downstream sites are used and that sampling depth is chosen to reflect recently deposited sediment. It is important that cross-contamination is avoided between sites when sampling.

4.6 Trigger Levels

The licensee may need to determine normal levels and trigger levels for parameters such as TOC and conductivity for the water entering surface water management features such as settling and holding ponds. If these trigger levels are breached, then it may be necessary to close off the outlet from the ponds to the receiving waters, investigate the source of the contamination and implement measures to treat the contaminated surface water.

4.7 Sampling Guidelines

4.7.1 Introduction

Monitoring of surface waters may involve obtaining samples for physical, chemical or biological analysis. There is a variety of sampling equipment available for these purposes, but its suitability will depend on the nature of the investigation and the intended use of the sample. Sampling of sediments may also be required from time to time.

The principal purpose behind a sampling programme is to collect samples that accurately reflect the quality of the medium being investigated. The analytical data from these samples will be used in the interpretation of the environmental impact of the landfill and therefore it is important that the composition of the samples remains unaltered before analysis. All types of sampling and monitoring equipment have inherent limitations which may cause difficulties in obtaining sufficiently reliable results.

4.7.2 General Sampling Guidelines

The general procedure for taking a representative sample of leachate, groundwater or surface water is illustrated in Figure 4.1. General sampling guidelines are outlined below.

- All staff involved in the taking of samples should receive appropriate training and be familiar with the sampling procedure and equipment to be used.
- Appropriate protective clothing should be worn which may include the use of high visibility vests, hard hats, eye protection, gloves and protective footwear.
- Appropriate vaccinations should be received by sampling personnel.
- Before sampling, arrangements should be made with the relevant laboratories for the analysis of the samples taken.
- Only sampling containers supplied or recommended by the laboratory carrying out the analysis should be used. Further information may be found in ISO 5667-3 (1994).
- Sampling personnel should be familiar with any preservatives and/or storage temperatures required for the parameters to be analyzed.
- In general, containers should be filled to the brim to avoid the inclusion of air in the sample, unless there is a 'fill-to' mark, for example in pre-preserved bottles.
- All equipment should be checked to ensure that it is in working order and if necessary is calibrated.
- All samples should be put into appropriately labelled containers and detailed field sheets should be used (e.g. site, time, date, sample code, personnel, weather etc).
- The chain of custody for all samples should be documented (Appendix B.2 provides an example of a Chain of Custody Form).
- Samples should be stored in a cool box or similar environment, out of direct sunlight and delivered to the laboratory with minimum delay, ideally on the same day and preferably within 24 hours of sampling.

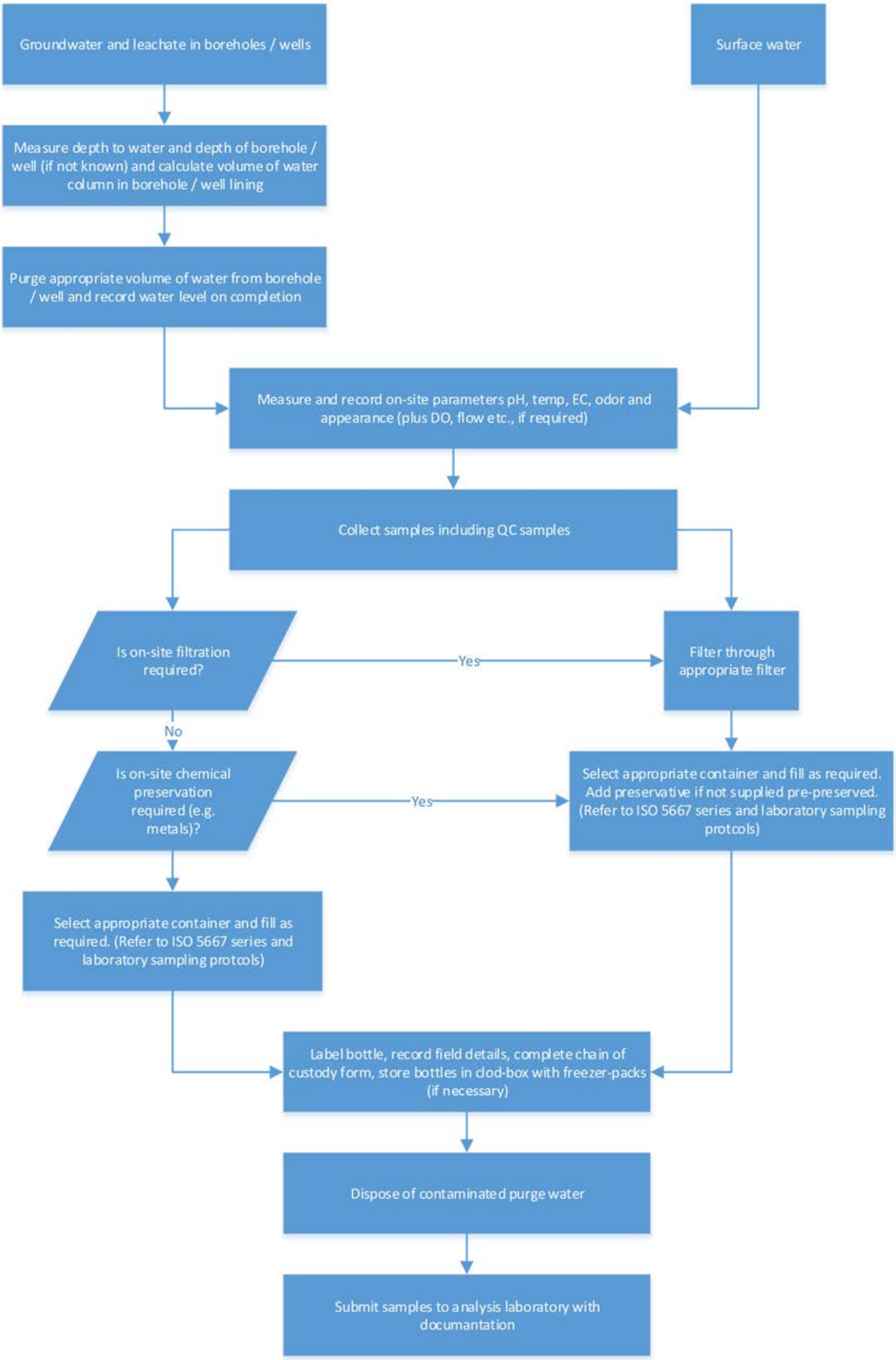


Figure 4.7.1 Procedure for Collecting a Representative Water Sample

4.7.3 Sampling Equipment

Flow/Volume

Water movement plays an important role in the dilution and dispersion of contaminants and physical parameters such as surface water speed and flow may be measured in a number of ways. These include:

- floats, timed over a specified distance,
- velocity tubes,
- current meters,
- and weirs

The choice of appropriate method depends on the dimensions of the water course (e.g. profile, gradient) and flow rate as well as other factors.

Further guidance on measuring surface water flow is provided by ISO 8363 (1986).

The volume from a discharge point (or outfall) may be measured by fitting the discharge point with an integrated flow meter, in which flow measurement consists of timed readings of the meter. Flow-meters should be fitted and calibrated to the manufacturer's instructions. Pipe diameter, gradient, effluent chemical characteristics and flow volumes must be considered in the specification and installation of flow meters.

Flow emerging from a pipe can sometimes be measured by the timed filling of a container (e.g. volume collected in 10 seconds flow). However, health and safety considerations, particularly for contaminated discharges may preclude use of this method. Discharge measurements should be timed to take account of cyclic (e.g. daily) or rainfall dependent variations in flow.

Chemical parameters

For the analysis of chemical parameters in the field such as pH, temperature, dissolved oxygen and electrical conductivity, a variety of instruments and kits are commercially available which are calibrated and relatively easy to operate.

The simplest equipment for taking spot surface water samples is a bucket or a wide-mouthed bottle dropped into a body of water and hauled out after filling. The use of extendible rod bucket samplers allows improved access to mid-stream samples compared with bankside sampling. Discrete depth samplers are used where sampling at selected depths is needed.

Automatic sampling equipment may also be required. These are portable and are often highly automated. There are two general types of automatic samplers. Time-dependent samplers collect discrete, composite or continuous samples but ignore variations in flow whereas volume-dependent samplers also collect these sample types and take into account variations in flow. In the case of fixed locations, the storage of composite samples under refrigeration or the sampler itself under refrigeration is desirable.

When sampling surface waters, the following guidelines should be followed:

- Special care should be taken to avoid cross contamination of samples. New or decontaminated sampling devices should be used for each sampling location. Sampling devices should be adequately cleaned before reuse.
- Sampling of surface water should commence at the least contaminated location first and then end at the most contaminated location.
- When sampling flowing watercourses, avoid disturbing water upstream of the sample location. If possible stand downstream of the sample point and collect water into sample containers in the flow of the water.
- The sampling location should be chosen with care. Safe and permanent access to all on-site sampling points should be provided. Common sense should be used at all times.
- Where possible a representative sample should be taken such as in the middle of a stream at mid-

depth. Samples should be taken from the fastest flowing part of the watercourse, where possible and stagnant areas should be avoided. Sediment in the sample should also be avoided.

- Other observations of the water quality should be noted such as presence of litter, sewage fungus, surface scum, oil, weeds, algae, presence of aquatic life, odor, river or tidal condition, e.g. river in flood, ebb tide.

Further guidance on surface water sampling may be found in ISO 5667 Parts 4 (1987) and 6 (1990)

Biological sampling of macroinvertebrates

For macroinvertebrate biological assessment, there should be a minimum of two sampling sites, one upstream (background site) and one downstream (impact site) of the likely discharge point from the landfill. Monitoring should be undertaken annually as a minimum and should usually be undertaken in the summer- autumn period (June-September) when flows are likely to be relatively low and water temperatures highest. Surveys during this period are likely, therefore, to coincide with the worst conditions to be expected in those sites affected by discharges.

The simplest and most commonly used method for taking samples for biological analysis is the 'kick' sample. For this technique, the substratum of the water body is vigorously disturbed with the foot and the dislodged macroinvertebrates are collected in a pond net. In shallow waters stones can also be turned over by hand in front of the net.

Measurements of dissolved oxygen saturation and water temperature, as well as observations on macrophyte and algal abundance, substratum type, water appearance and other biological and physical features are also recorded, in addition to the specific information on the nature of the macroinvertebrate fauna. An example of a Rivers Ecological Assessment Field sheet is provided in Appendix B.4 and it is recommended that this be used.

Biological sampling techniques are rapid and inexpensive. However there are potential problems in comparing results between sites with different flow regimes, substratum types and so on, and also between individual operators in the case of extensive survey programs (Mason, 1996).

Other types of invertebrate sampling equipment include:

- Surber samplers– this combines a quadrat with a net and is designed to give a quantitative collection of macroinvertebrates;
- Cylinder samplers – these are suitable for shallow, still waters such as ponds or shallow, coastal lagoons;
- Grabs and corers – these are suitable for sampling deeper waters such as lakes and rivers.

Further guidance on sampling methodology is outlined in McGarrigle and Lucey (1983).

Sampling of bottom sediment deposits

Bottom sediment deposits may be sampled by grabs or dredges designed to penetrate the substrate as a result of their own mass or leverage. These are devices with spring loaded or gravity activated jaws which enclose a defined surface area and allow sampling of unconsolidated sediment. In selecting the type of dredge to be used, the habitat, water movement, area of sample and boat equipment available need to be considered.

A core sampler is used when information concerning the vertical profile of sediment is of interest.

Further guidance on sediment sampling may be found in ISO 5667 Part 12 (1995).

CHAPTER 5 GROUNDWATER

5.1 Introduction

Groundwater is that part of the subsurface water which is in the saturated zone. The saturated zone is the subsurface zone in which all interstices are filled with water. The top of the saturated zone is called the water table and can be identified by measuring the water level in a borehole which extends into the saturated zone. Groundwater is a major natural resource of both ecological and economic value and its protection is of prime importance.

The fundamental objectives of a groundwater monitoring programme at a landfill are to assess groundwater quality and quantity and to determine the effectiveness of the environmental control systems in order to ensure the continued integrity of the groundwater quality and quantity. These objectives are achieved through the collection and analysis of representative groundwater samples.

The efficiency of a monitoring programme is dependent on a thorough understanding of the hydrogeological conditions of the site, coupled with the appropriate location and construction of monitoring boreholes.

5.2 Monitoring Locations

Monitoring boreholes should be installed at appropriate locations and depths to:

- provide samples representative of the quality of groundwater upgrading of the site,
- provide samples representative of the quality of groundwater downgradient of the site,
- permit an accurate water level or pressure (piezo metric) level of groundwater to be measured and recorded to an elevation expressed as meters above ordnance datum, and
- provide data to show the direction of groundwater flow (minimum of three monitoring boreholes necessary)

For groundwater monitoring at a landfill, the Landfill Directive specifies a minimum of one upgrading and two downgradient boreholes. Table C.1 in Appendix C outlines minimum baseline groundwater monitoring requirements for a non-hazardous landfill.

In reality, a number of site specific factors will determine the actual number and locations of the boreholes required. Such factors may include:

- the area of the landfill,
- heterogeneity of the aquifer(s),
- permeability of the aquifer(s),
- groundwater abstraction,
- groundwater flow velocities,
- anticipated composition of leachate (based on expected wastes types),
- baseline water quality,
- proximity of potential external influences such as contaminated lands,
- proposed containment system,
- license requirements,
- ease of access to the borehole by sampling personnel; and

- safety issues

The location for groundwater boreholes should be based on the information derived from the site investigation. Monitoring locations may include:

- existing groundwater discharges and abstractions, e.g. springs, water supply boreholes or wells;
- existing monitoring points, e.g. those installed for other monitoring purposes by adjacent landowners or for site investigations;
- construction of new boreholes. This allows the monitoring points to be located and designed specifically to meet monitoring objectives

Existing structures should only be used if they are capable of fulfilling the monitoring objectives of the site. Borehole logs and design details are essential to evaluate the usefulness of existing monitoring points. This is because boreholes could be screened at different intervals or screened into a different aquifer to the one that is required to be monitored. The use of trial pits is generally not acceptable for groundwater monitoring.

The groundwater monitoring programme at a landfill site should contain the following information:

- number and location of boreholes – the precise location of the boreholes should be recorded on the logs using a grid reference and marked on a drawing or a map,
- depth of boreholes,
- screen area/level,
- pump tests, yield information etc,
- information on soils,
- borehole construction material,
- nested borehole configurations,
- direction of groundwater flow,
- groundwater recharge and discharge areas, and
- groundwater abstraction points in the vicinity of the landfill

5.3 Design and Construction of Boreholes

Detailed construction drawings or borehole logs for each monitoring point should be produced. When constructing new boreholes, the method of drilling, lining materials, screen design and sealing method should all be given careful consideration to ensure the monitoring objectives are met. Following installation, each monitoring borehole should be cleaned out and developed to remove silt and other fine materials from the lining, gravel pack and surrounding strata.

Further information on the construction of new boreholes is available from the Geological Survey of Ireland (GSI). Details of all borehole logs including precise location should be submitted to the GSI to contribute to the knowledge pool of the national groundwater database.

Until guidelines are developed in Ireland, subsoils should be logged using standard procedures outlined in the British Standards Institution publication BS 5930 (1999). The GSI have prepared decision-making field sheets on the basis of these standards and can supply them on request.

In order to facilitate groundwater sampling and protect boreholes the following is recommended:

- each borehole should have standpipes that are approximately half a meter above the ground, cased in metal, set in concrete, and surrounded by protective poles. These measures will help to avoid accidental burial of boreholes during landslides and also protect against accidental damage from plant and machinery
- the borehole should be capped to avoid damage or blockage to the tubing and the casing should

be padlocked so that there is no access to the borehole other than by authorized personnel

- the borehole should be at least 50mm in diameter so that a representative sample can be obtained. However, boreholes with diameters wider than 50mm can be very time-consuming to purge and thus can reduce the number of samples that can be taken in a day
- the borehole should have a marker detailing the location name and type of sample and this should be visible from a distance. It is useful if all groundwater monitoring points are coded a particular color.

Most groundwater monitoring boreholes will require periodic maintenance. Any boreholes that become damaged should be repaired or replaced as soon as possible. Boreholes and wells that are no longer required need to be made safe, structurally stable, backfilled or sealed (e.g. with bentonite) to prevent groundwater pollution and flow of water between aquifer units and to prevent confusion with active monitoring points.

5.4 Monitoring Frequency and Parameters for Analysis

Baseline data are those that are characteristic of conditions in the absence of any impacts arising from landfill operations. For the determination of baseline water quality, each monitoring location should be monitored at quarterly intervals for a minimum of one year prior to the operation of the site. A groundwater contour plan with flow direction should also be produced to provide baseline information.

The frequency of compliance monitoring during the operational and aftercare phase is site specific and will be governed by the waste license and should take into consideration the hydrogeology of the site and the landfill design.

Table C.2 in Appendix C lists the parameters to be used in baseline monitoring of groundwater quality. Tables D.1 and D.2 in Appendix D outline guideline minimum reporting values for those parameters required to be analyzed. Parameters for baseline monitoring should include specific indicators to ensure early recognition of changes in water quality (Section 5.5 provides further information). Throughout the life of the landfill the baseline monitoring parameters chosen should be re-analyzed at intervals not exceeding twelve months.

Monitoring of groundwater levels will be required on a more frequent basis. The Landfill Directive requires level monitoring to be undertaken every six months as a minimum during the operational and aftercare phases of the landfill.

5.5 Trigger Levels

The Landfill Directive states that significant adverse environmental effects should be considered to have occurred in the case of groundwater when an analysis of a groundwater sample shows a significant change in water quality. A trigger level must be determined taking account of the specific hydrogeological formations and groundwater quality in the location of the landfill and must be laid down in the waste license where possible.

To determine trigger levels, a review of the baseline monitoring results should be undertaken including a statistical summary of all data on certain specific indicators. Trigger levels should be evaluated by control charts with established control rules and levels for each downgradient well.

When setting trigger levels it is important to consider the following:

- the substances for which the trigger levels should be set – this may depend on the type of waste which will be accepted in the landfill and the subsequent type of leachate which will be formed.
- the levels at which they should be set – typical groundwater quality in the area needs to be assessed
- the monitoring locations for which they should be set - the specific hydrogeological formations in

the location of the landfill should be identified and trigger levels should be set for each of the downgradient monitoring points that are included in the overall groundwater monitoring programme

The Landfill Directive recommends setting trigger levels for certain parameters such as pH, TOC, phenols, heavy metals and fluoride.

For a typical non-hazardous landfill accepting biodegradable wastes, trigger levels should be set for substances such as ammonia, TOC and chloride as a minimum. Other appropriate substances for determining trigger levels for non-hazardous landfills may include some volatile/semi-volatile organic compounds.

> Further guidance on setting environmental quality objectives and standards for groundwater may be found in the Agency's Interim Report 'Towards Setting Guideline Values for the Protection of Groundwater in Ireland' (2003a).

An assessment monitoring programme should be implemented after the detection of a release of a contaminant to the groundwater or on attaining a trigger level. When a trigger level is reached, verification is necessary by repeating the sampling. If repeat sampling shows that the trigger level has been breached then a contingency plan including possible remedial actions must be prepared and implemented. The assessment programme may require an increase in monitoring frequencies, installation of extra monitoring boreholes and/or additional analyses of the contaminant transport patterns.

A number of computer based contaminant transport models are available. These require data regarding the location and concentration of contaminant sources, the distribution of effective porosity, fluid density variations and natural concentrations of solutes distributed through the groundwater regime. Contaminant transport may be estimated by using the model to compute the direction and rate of fluid movement. Contaminant loading on the groundwater system may then be estimated from solute-transport equations and flow model predictions.

Following the completion of the assessment monitoring programme, the appropriate corrective measures should be implemented to reduce the impact of releases on the environment and to minimize further contaminant releases from the landfill.

5.6 Sampling Guidelines

A variety of devices may be used for both groundwater and leachate sampling. The equipment used ranges from simple bailing devices to sophisticated multilevel samplers. Sampling devices should be chosen based on the parameters that are to be monitored, the compatibility of the rate of borehole purging with borehole yield (for groundwater), the diameter of the groundwater borehole or leachate well and the depth from which the sample must be collected.

Bailers are commonly used sampling devices and theoretically do not cause alteration to the sample as no suction or pressure is applied. They are used to collect discrete samples from specific depths or to collect average samples from the water they pass through. Pumps can be used for both purging of boreholes as well as for sampling. They can be used to obtain samples from specific depths and generally have adjustable flow rates to minimize agitation or aeration of the samples. The advantages and disadvantages of some of the equipment more commonly used in groundwater and leachate sampling are outlined in Table E.1 of Appendix E.

Liquid levels in boreholes or wells can be measured by a variety of devices of which the most commonly used are electric tapes fitted with a liquid sensor.

General guidelines for sampling were previously outlined in Section 4.7.2. In addition, when sampling groundwater, the following guidelines should be followed:

- It is recommended that sampling commences with upgrading boreholes.

- In order to obtain a representative sample of groundwater, stagnant water must be removed from the borehole. A purging trial should be undertaken to observe the behavior of field determinants (e.g. conductivity, pH, temperature) continuously or at intervals during purging. A sufficient volume (normally at least 3 borehole volumes) should be pumped during the trial to demonstrate genuine stabilization of the pumped water chemistry. The results of the trial may then be used to determine the standard purge volume for the borehole. Generally, purging of three times the borehole volume is sufficient to allow a representative sample to be taken.
- For a borehole that becomes dewatered before three volumes are purged, then the sample should be taken as soon as sufficient water is in the borehole. If the recharge is slow it may be possible to carry out other monitoring on site and return later to take a sample.
- Purged water should be disposed of away from the borehole to prevent its recirculation.
- Any odors from the borehole should be noted on a field sheet.
- Special care should be taken to avoid cross-contamination of samples. Equipment used to sample leachate wells should never be used to sample groundwater boreholes as it can lead to a risk of cross-contamination. New or decontaminated tubing, valves, bailers or water level measurement devices must be used for each groundwater borehole.
- All reusable equipment should be thoroughly cleaned after use using a non-phosphate laboratory detergent and then fully rinsed with distilled water.
- Sometimes there may be dedicated borehole tubing already located in the groundwater borehole and this may be used provided that it is clean. Tubing can be left in the groundwater borehole between sampling. If removed, the lengths of tubing used should be rinsed out with clean tap water or distilled water and labelled with the location and borehole where they were used. Care must be taken to ensure that tubing is not contaminated by contact with soil or other contaminated materials during storage. Before reuse, any tubing should be thoroughly rinsed as above before reinsertion into the borehole.
- Separate samples should be taken for chemical and bacteriological examination.
- Samples for bacteriological examination must be taken using sterile techniques. Contamination may occur from dirty tubing or poor sampling technique. Removal of in-situ tubing is not desirable for microbiological sampling unless contamination by the tubing is expected. It is essential that the delivery end of the tubing be thoroughly cleaned using a disinfectant medium and rinsed before commencement of purging or sampling. Samples for bacteriological examination should be transported in a cool box or similar refrigerated environment to the laboratory preferably within 6 hours of sampling.
- Samples for chemical analysis should be transferred to appropriately labelled sample containers being careful to avoid agitation or turbulence or any air spaces or bubbles that could result in the loss of volatile organic compounds or excessive oxygenation of the samples. For VOC analysis low flow sampling or diffusion samplers may be more suitable.
- Samples for metal analysis should be filtered through a 0.45μm membrane filter and acid preserved.
- It is recommended that samples for metal analysis be filtered as soon as possible after sampling and preferably within 24 hours to minimize compositional changes. On-site filtration and preservation is recommended for samples where precipitation of metals may occur in transit. However, for most sample types it may be more practical to filter the sample as soon as possible on return to the laboratory.
- Special care and attention is required when sampling groundwater used as drinking water for private dwellings.

Monitoring of groundwater when used it is as drinking water for private dwellings in the vicinity of a landfill facility.

In this case the following procedure is recommended:

- When sampling from a tap, it is important that all fittings are removed and that the sample comes directly from the tap itself. Mixer style taps should be avoided if possible.
- Check that the water is coming directly from the borehole and not via a storage tank.
- It is important that any water within the system be purged before sampling. This may be done by running the tap before taking a sample (about 2-3 minutes for a tap in regular service and up to 10 minutes for a tap that is out of service).
- When taking a bacteriological sample, the tap should first be purged as above. The tap should then be turned off and sterilized by either gently flaming or wiping with a solution of 1% v/v Sodium Hypochlorite. Anti-bacterial wipes based on quaternary ammonium salts or similar substances may be equally effective, and often more practical, for sterilizing surfaces. Attention should be paid to the manufacturer's recommended contact times. Allow the tap to run for a few minutes at moderate flow after sterilizing before taking the sample. The bottle should then be filled directly from a low flowing water stream avoiding any contact with the bottle cap.
- It is generally helpful to take samples for chemical analysis before disinfecting the tap to minimize the potential for cross-contamination.

CHAPTER 6 LEACHATE

6.1 Introduction

Leachate may be defined as any liquid percolating through the deposited waste and emitted from or contained within a landfill. This leachate picks up suspended and soluble materials that originate from or are products of the degradation of the waste. If this leachate is allowed to migrate from the site it may pose a severe threat to the surrounding environment and in particular to the groundwater and surface water regimes.

Effective environmental protection requires an understanding of the composition and volumes of leachate being generated and the implementation of control measures. The composition of leachate within a landfill is unique as the characteristics of the leachate will vary depending on the wastes deposited. The main factors that influence the generation of leachate include:

- meteorological conditions at the site,
- waste composition,
- waste density,
- waste age,
- depth of landfill,
- moisture content,
- rate of water movement, and
- lining system (if any)

Further information on leachate management systems is available in the Agency's manual 'Landfill Site Design' (2000).

The purposes of a leachate monitoring programme are:

- to confirm that the leachate management systems are operating as designed;
- to provide information on the progress of decomposition of the waste; and
- to provide information for the potential revision of groundwater and surface water monitoring parameters

6.2 Monitoring Locations

The Landfill Directive requires that sampling and measurement of leachate (both volume and composition) must be performed separately at each point at which leachate is discharged from the site. Each cell in a landfill should be treated as a separate unit for the purpose of determining the number and location of leachate monitoring points.

Table C.3 in Appendix C summarizes typical leachate monitoring requirements for a non-hazardous landfill. The precise location of these monitoring points will be decided on a site specific basis, but they should be located taking into account the likely flow-paths of the leachate within the cell, so as to provide samples representative of the leachate composition.

On-site processes such as leachate treatment plants or other leachate management schemes should also be monitored e.g. treated leachate discharged from a site and leachate storage lagoons.

6.3 Monitoring Frequency and Parameters for Analysis

The frequency of leachate monitoring at a landfill site will be site specific and governed by the waste license. It should be reviewed on a regular basis to reflect changes in:

- quantity and types of waste deposited,
- operational practice,
- size of operational cell, and
- the effectiveness of the leachate drainage and collection system.

The Landfill Directive specifies minimum monitoring frequencies for leachate volume and composition during the operational and aftercare phases of a landfill. Monitoring of leachate levels within the waste body is important to ensure that the leachate head is successfully controlled. The volume of leachate discharged or transported from a landfill should be recorded on an ongoing basis.

A representative sample of leachate from each monitoring location should be taken for analysis. Table C.2 in Appendix C lists the parameters to be analyzed for characterization. Tables D.1 and D.2 in Appendix D outline guideline minimum reporting values for these parameters.

The composition of leachate is variable and depends on a number of factors including:

- age of the landfill,
- composition of the waste,
- the rate of decomposition within the landfill,
- the amount of rainwater infiltration, and
- temperature

Therefore, the parameters to be analyzed should reflect these influences and should provide for the anticipated characteristics of the leachate.

6.4 Toxicity Testing

Occasionally toxicity limits may be set in a waste license or toxicity testing of a substance may be required, e.g. if treated leachate is discharged to surface water. These toxicity limits are equivalent to emission limit values for chemical and physical parameters. The tests are not intended to replace assessments of the biological impacts of discharges in the natural environment. Test species may range from bacteria and algae through to invertebrates and fish. The use of systems based on luminescence measurement is useful for assessment of toxicity patterns (ISO, 1998).

When setting an emission toxicity limit, it is important to consider the effluent mixing conditions within the receiving waterbody or otherwise toxicity limits may not give adequate protection to aquatic life downstream. Information is therefore needed on the receiving waters (e.g. the minimum flow of a river) and the number of dilutions of the discharge available.

> Further information on Aquatic Toxicity Testing is available in the Agency's Wastewater Treatment Manual'Characterization of Industrial Wastewaters' (1998a).

6.5 Sampling Guidelines

As mentioned previously, a variety of devices may be used for both groundwater and leachate sampling and the techniques used for the sampling of leachate wells are similar to that used for groundwater boreholes (Section 5.6 provides further information). General sampling guidelines were previously outlined in Section 4.7.2. In addition, when sampling leachate, the following guidelines should be followed:

- It is preferable to sample from a collection point to where leachate from the landfill is pumped.
- Extreme care should be taken when sampling from leachate lagoons or manholes. Site safety precautions should be observed at all times.
- Leachate and leachate contaminated groundwater are chemically unstable in comparison with clean groundwater. Their composition is generally complex and particularly liable to change if allowed to remain in contact with air for any substantial time between collection and analysis.
- In order to obtain a representative sample of leachate from small diameter wells any stagnant water must be removed from the well. A purging trial should be undertaken to observe the behavior of field determinants (e.g. conductivity, pH, temperature) continuously or at intervals during purging. A sufficient volume (normally at least 3 well volumes) should be pumped during the trial to demonstrate genuine stabilization of the pumped water chemistry.
- Purged leachate or contaminated groundwater should be disposed of in a manner that will minimize any health risks to monitoring or other personnel, risk of cross-contamination of samples or risk to the environment. Disposal routes can include the removal of the leachate to the leachate collection system or disposal directly onto open areas of waste.
- Sampling without purging may be feasible where trials have shown that there are no significant differences between purged and non-purged samples or where there are no safe options for disposal of purge water.
- In the case of leachate wells in highly compacted or dry waste, recovery to an adequate sample volume for sampling may not occur during a practical timeframe. Such an incident should be recorded as "no sample available" as pumping a nearly dry well will result in high solids content in the sample and inaccurate, elevated concentrations of many chemical parameters.
- Where it is necessary to sample leachate from large diameter chambers, sumps or combined collection systems, it is generally impractical to purge. In such circumstances discrete grab or pumped samples should be obtained by subsurface sampling. In the case of grab samples, efforts should be made to ensure that individual subsamples are taken at differing locations and depths across and within the sump chamber. Field records and laboratory test reports should make reference to the sampling procedure used.
- Any odors from the well should be noted on a field sheet.
- Samples for chemical analysis should be transferred to appropriately labelled sample containers being careful to avoid agitation or turbulence or any air spaces or bubbles that could result in the loss of volatile organic compounds or excessive oxygenation of the samples.
- Samples for microbiological examination should be taken using sterile bailers.
- Samples for metal analysis should be filtered through a 0.45μm membrane filter and acid preserved. It is recommended that samples for metal analysis be filtered as soon as possible after sampling and preferably within 24 hours to minimize compositional changes. On-site filtration and preservation is recommended for samples where precipitation of metals may occur in transit. However, for most sample types it may be more practical to filter the sample as soon as possible on return to the laboratory. Note: acidification may cause release of hydrogen sulphide (H2S) or other harmful gases.
- Equipment used to sample leachate wells should never be used to sample groundwater boreholes as it can lead to a risk of cross-contamination.
- All reusable equipment should be thoroughly cleaned after use using a non-phosphate laboratory detergent and then fully rinsed with distilled water.

CHAPTER 7 LANDFILL GAS

7.1 Introduction

Landfill gas is generated by the decomposition of organic materials in waste deposited at the landfill. Typically, the gas is a mixture of methane (up to 65% by volume) and carbon dioxide (up to 35% by volume). It also contains many minor constituents at low concentrations (typically less than 1% volume contains 120-150 trace constituents).

The rate of gas generation at a landfill site varies throughout the life of a landfill and is dependent on several factors such as waste types, depths, moisture content, degree of compaction, landfill pH, temperature and the length of time since the waste was deposited.

The Landfill Directive requires the following:

- that appropriate measures are taken in order to control the accumulation and migration of landfill gas;
- that landfill gas should be collected from all landfills receiving biodegradable waste and the landfill gas should be treated and used. If the gas collected cannot be used to produce energy, then it should be flared; and
- that the collection, treatment and use of landfill gas should be carried on in a manner which minimizes damage to or deterioration of the environment and risk to human health

Landfill Gas Risks

Landfill gas poses various risks including:

- flammability and explosion risks;
- asphyxiation risks;
- potential health impacts due to many minor constituents present at low concentrations;
- odor impacts from trace constituents, e.g. hydrogen sulphide and mercaptans;
- environmental impacts due to global warming potential of methane and carbon dioxide; and
- vegetation dieback

It is important therefore that landfill gas is properly monitored and controlled.

Why monitor for landfill gas?

The reasons for monitoring landfill gas may be summarized as follows:

- To ensure the facility is compliant with its waste license;
- To ensure the facility is not causing environmental pollution;
- To ensure the facility is not posing a risk to human health;
- To compare actual site behavior with expected/modelled behavior;
- To assess the effectiveness of any gas control measures installed at the site; and
- To establish a reliable database of information for the landfill throughout its life.

Further details on landfill gas management systems including design details are given in the Agency's *Manual 'Landfill Site Design*' (2000).

7.2 Landfill Gas Safety

The flammability, toxicity and asphyxiate characteristics of landfill gas requires personnel involved in the monitoring, operation, construction or any other aspect of a gas management system to be adequately trained. A safe system of work with rehearsed emergency procedures should be developed and undertaken before any monitoring of landfill gas is carried out.

Stringent safety measures should be incorporated into equipment for landfill gas monitoring and all electrical equipment should comply with appropriate relevant standards.

7.3 Landfill Gas Within and Outside the Waste Body

7.3.1 Introduction

Monitoring should take place both within the waste to identify both the quantity and quality of gas generated and outside of the waste to assess whether gas is escaping in an uncontrolled manner. The methane content of landfill gas is flammable, forming potentially explosive mixtures in certain conditions, resulting in concern about its uncontrolled migration and release.

The Lower Explosive Limit (LEL) and the Upper Explosive Limit (UEL) of methane are approximately 5% v/v and 15% v/v respectively.

Landfill gas can move in any direction within the waste body and may migrate from a site. The potential for gas migration will depend on the gas quality and volume, the site engineering works, geological characteristics of the surrounding strata and on man-made pathways such as sewers, drains, mine shafts or service ducts.

The monitoring programme should commence prior to waste disposal and should continue until the biodegradation process has ceased. It is important in the case of new sites to get naturally occurring background levels of methane and carbon dioxide which may vary depending on local geology. These levels should be established prior to the commencement of landfilling at the site.

7.3.2 Monitoring Locations

Within the waste body

The Landfill Directive requires that gas monitoring be representative for each section of the landfill. It is recommended that the locations for gas monitoring within the waste body should be at a density of at least one monitoring point per cell in lined landfills and one monitoring point per hectare of filled area in unlined landfills.

Monitoring wells constructed within the waste body are for the purpose of monitoring landfill gas concentrations and fluxes within the waste. These wells should be independent of the gas collection and extraction system and used as dedicated monitoring points for the purpose of ascertaining the state of degradation within the waste body and how it responds to environmental conditions.

The monitoring of collection wells and associated manifolds is undertaken to determine the effectiveness of the gas extraction and collection system and to facilitate the balancing of the extraction and collection system. Collection well monitoring is necessary for the efficient management of an extraction system

Outside the waste body

The monitoring of boreholes outside the waste body is essential to detect any gas migrating from the waste body and to demonstrate the efficient management of gas within the site. Boreholes for monitoring gas outside the waste body may be located both on-site and off-site.

The spacing and location of gas monitoring points outside the deposited wastes should be determined on a site specific basis. A detailed exposure and risk assessment should be undertaken with potential pathways and receptors identified. Some factors which need to be taken into account when selecting monitoring locations include:

- quality and volume of gas being generated;
- geology of the site;
- type of waste;
- containment measures adopted, e.g. landfill lining or capping;
- proximity of buildings and developments to the site; and
- permeability of the waste

The spacing of the monitoring locations is unlikely to be uniform around the site. It is probable that more monitoring points would be needed near building developments, where there are changes in the site geology and where there is no containment.

It is recommended that monitoring boreholes are located a minimum of 20m from the waste body and should be installed at least to the depth of the maximum depth of waste within the waste body. Where appropriate, groundwater monitoring boreholes may also be used for gas monitoring.

Landfill gas monitoring should also be undertaken in any buildings on the site (e.g. site offices). For some sites this may take the form of a permanent monitoring system.

Pressure monitoring

Atmospheric pressure should be measured regularly in order to aid understanding of gas pressure readings within the waste body. Rapid drops in atmospheric pressure can cause the pressure of landfill gas to rise significantly above that of ambient atmospheric pressure, resulting in possible migration. The monitoring of pressures within the waste body may give an indication of the likelihood of gas migration occurring.

Inversely, a sudden rise in atmospheric pressure after a prolonged low pressure period can lead to an artificial depression of the monitored methane concentration. At some landfills very frequent recordings of barometric pressure trends (e.g. hourly intervals from the nearest meteorological station) may be necessary so that fluctuating methane concentrations can be related to barometric pressure conditions.

7.3.3 Monitoring Frequency and Parameters for Analysis

The frequency of monitoring required is site specific and should be established from the results of the investigations. The frequency will depend on a number of factors, such as:

- the age of the site;
- the type and mix of waste;
- the possible hazard or nuisance from gas escaping from the site;
- the results of previous monitoring;
- the control measures that have been installed;
- the development surrounding the site; and
- the geology of the site and its environs

Table C.4 in Appendix C summarizes typical landfill gas monitoring requirements for a non-hazardous landfill. In the case of a licensed landfill, frequencies and parameters will be governed by the waste license.

Monitoring should be increased when:

- increases in gas quantity or changes in gas quality are observed during monitoring;
- control systems are altered by landfill operations;
- capping of part, or all, of the site takes place;
- pumping of leachate ceases or leachate levels rise within the wastes; or
- buildings or services are constructed within 250 m of the boundary of the waste

Monitoring should continue until either:

a) the maximum concentration of methane from the landfill remains less than 1% by volume (20% LEL) and the concentration of carbon dioxide from the landfill remains less than 1.5% by volume measured at all monitoring points within the wastes over a 24 month period taken on at least four separate occasions, including two occasions when atmospheric pressure was falling and was below 1,000 mb; or

b) an examination of the waste using an appropriate sampling method provides a 95% level of confidence that the biodegradation process has ceased

7.3.4 Trigger Levels

Unless otherwise determined from baseline monitoring results, the trigger levels for emissions of methane and carbon dioxide in boreholes outside the waste body are shown in Table 7.3.1. These trigger levels for landfill gas emissions also apply to measurements in any service duct or manhole on, at or immediately adjacent to the landfill.

Table 7.3.1 Landfill gas trigger levels for boreholes outside of the waste body

Parameter	Trigger concentration
Methane	Greater than or equal to 1% v/v or
Carbon dioxide	Greater than or equal to 1.5% v/v

If either of these trigger levels are attained within buildings then the affected areas should be evacuated and the emergency services notified. Monitoring should be undertaken to identify the point of gas ingress and control measures should be implemented to prevent further ingress.

Methane has explosive and flammability risks and carbon dioxide is an asphyxiant.

7.3.5 Monitoring Surface Emissions

The surface methane emissions of landfill gas from a site cap and from other parts of a landfill should also be monitored from time to time. This gives a measure of the methane escaping to atmosphere and checks the integrity of the gas management system and the capping system.

A walkover survey may be undertaken using a portable flame ionization detector (FID) held as close to the surface of the landfill as possible. More detailed measurements of changes in methane concentrations above a specific small area of the landfill surface may be undertaken using a flux box. These flux boxes are most suitable for use on completed areas of a landfill site. They will produce high flux measurements if used on waste that is not capped or covered by an intermediate layer of soil or other inert material.

It has been established that on a capped landfill with active landfill gas abstraction that a limit value of 1 x

10-3 mg/m2/s of methane surface emissions or better can be achieved (Environment Agency, 2002a). Monitoring of other surface emissions such as hydrogen sulphide or non-methane volatile organic compounds (NMVOCs) should also be undertaken if required.

7.4 Landfill Gas Combustion Plants (Enclosed Flares & Utilization Plants)

7.4.1 Introduction

Methane is estimated to be 20 – 30 times more damaging (per molecule) than carbon dioxide to the global climate due to its greenhouse effect. Landfill gas should therefore, where practicable, be collected from all landfills receiving biodegradable waste and converted to energy or flared.

Methane has a high calorific value and hence can be used for power generation and process heating. Typically some 600 – 700m3 of landfill gas (containing approximately 50% methane) is required to generate 1 MW of electricity. If the gas cannot be utilized for energy, then it should be flared. Combustion disposes of the flammable constituents of landfill gas safely and also controls odor nuisance, health risks and other adverse environmental risks.

Whilst the combustion of landfill gas reduces the risk of uncontrolled landfill gas emissions and explosion, the potential health and environmental impact of emissions from flares and utilization plants also have to be taken into account. Therefore monitoring of these emissions is necessary.

It should be noted that the guidance in this document only relates to the monitoring of enclosed flares. The use of open flares is generally not allowed as they do not represent BAT and cannot be tested accurately or safely.

7.4.2 Monitoring Locations

When identifying a suitable location for the siting of a flare and/or utilization plant at a landfill, it is necessary to have an understanding of the environmental impact that the flare and/or utilization plant will have on the surroundings. Screen modelling should be carried out on expected emissions and these should be compared with relevant air quality standards. Where a potential problem exists, full modelling should be undertaken to help in selecting a location for the flare or utilization plant.

Other factors which must be considered when siting a combustion plant include explosion and fire risks, asphyxia, human health, odor nuisance, noise, heat, visual impact, ground type and operational requirements.

It is essential to monitor routinely both the inputs and outputs of the flare and/or utilization plant. All emissions from landfill gas combustion processes will be variable in terms of flow-rate and composition due to the nature of the gas source. Variations may occur due to the aging of the waste, inconsistencies within the waste composition itself as well as changing meteorological conditions.

Health and safety is of great importance when sampling emissions from combustion plants. Easily accessible, safe and functional monitoring/sampling points should be fitted on all combustion plants. The dimension of the sampling platform and the positioning of the sampling ports should be in accordance with guidelines issued for stack testing by the Source Testing Association (STA). Guidelines on hazards and risks relating to source testing are also provided by the STA (2001).

7.4.3 Monitoring Frequency and Parameters for Analysis

Table C.5 in Appendix C contains a typical monitoring regime for landfill gas flares and utilization plants. The exact parameters and emission limit values will be set in the waste license and may be dependent on the specification of the equipment.

The species and composition of emissions from the combustion of landfill gas is determined by a number of factors. These include:

- compounds present in the fuel gas;
- type and design of the equipment used;
- operation of the equipment; and

- combustion conditions, temperatures, excess air, etc.

Flares and utilization plants (such as engines) differ in the mechanism of combustion. The reaction in an engine involves a short-lived explosive reaction occurring under pressure, whereas, the combustion process in a flare occurs over a comparatively long period.

Carbon monoxide is a product of incomplete combustion of carbon and is a good indication of the combustion efficiency of the process. All flares should be fitted with continuous combustion temperature and carbon monoxide monitors and utilization plants fitted with continuous carbon monoxide monitors connected to a data logger with visible display panel at ground level.

In the case of enclosed flares, a minimum combustion temperature of 1000°C and a retention time of 0.3 seconds are recommended as an indicative standard that is likely to achieve required emission standards.

Incomplete combustion of halogenated organic compounds may occur due to a combination of low turbulence, temperature and oxygen content. These conditions may be found at the periphery of an open flare or in the cooler zones around the walls of enclosed flares. This is one of the key reasons why all flares are required to be enclosed and to operate at a minimum combustion temperature and retention time.

7.4.4 Design Certification of Flares

Design certification of enclosed flares is an approach that has been adopted in Germany where manufacturers design, build and test flares at the factory to meet the TA Luft emissions standards. The advantage of this system is that it is safe, easily automated, provides accurate data, is relatively inexpensive and allows for random spot verification. The Agency may consider the design certification approach as an alternative to emissions testing.

7.5 Sampling Guidelines

7.5.1 Introduction

There is a variety of equipment available for the detection and quantification of landfill gas. The choice of instrument will depend on the circumstances of the monitoring as shown in Table E.2 in Appendix E. The instrument to be used may be fixed where continuous monitoring is required (e.g. in a building or combustion plant) or portable where periodic monitoring is required (e.g. boreholes outside the waste).

The most important part of the instrument will be the sensor. Table E.3 in Appendix E presents the characteristics of the most common types of sensors used. In the selection of equipment, particular attention should be given to the safety features of the instrument and to its intended use.

Attention needs to be paid to the quality of monitoring being carried out and standards can vary greatly between consultants. The Source Testing Association (STA) provides information on best practice for stack sampling. Further information may be found on www.S-T-A.org. Interpretation of the results obtained from monitoring equipment requires a full understanding of the method of detection employed and of the environment which is being sampled. The wide variation in gas mixtures which can occur in and around landfills can lead to misinterpretation of readings.

7.5.2 Landfill Gas within and Outside the Waste Body

When monitoring landfill gas from boreholes or wells, the following guidelines should be followed:

- Health and safety precautions should be adhered to at all times. There should be no smoking while sampling for landfill gas. Direct inhalation of the landfill gas and entry into confined spaces should be avoided. Chemical resistant gloves should be worn to avoid contact with landfill gas condensate.

- All equipment should be operated, calibrated and serviced according to the manufacturer's instructions.
- All boreholes or wells should be fitted with sealable gas sampling valves to isolate the borehole/well from the atmosphere, to prevent air ingress and to enable equilibrium with the area to be monitored. In order to prevent atmospheric dilution of the sample the gas sampling valve should be closed at all times other than when the gas sampling equipment is attached to the monitoring structure. The borehole or well should be resealed after sampling. Monitoring boreholes should also have a security cover to ensure that the valves cannot be tampered with.
- Most portable gas monitoring instruments are susceptible to interference by water vapor or water entering the equipment. To check the borehole for flooding, it may be necessary to remove the seal and therefore open the borehole to the atmosphere. Care should be taken to ensure that liquid is not sucked into the gas sampling equipment during monitoring.
- Where groundwater boreholes are also used to monitor off-site landfill gas migration, then screw on caps and a control valve need to be fitted. Gas monitoring should be undertaken before groundwater monitoring. It should be noted that the specific construction of a groundwater monitoring borehole could sometimes render it ineffective for gas monitoring and the construction details should be assessed to determine if it is also suitable for gas monitoring.
- The atmospheric pressure should be measured during each sampling round and the details noted on the field sheet, e.g. 1001-1003 mill bar (rising). The monitoring of gas pressure in wells within the waste body may also be noted and this may give an indication of the likelihood of gas migration occurring.
- Any unusual observations should be noted while monitoring at the facility such as any vegetation die-back, any hissing sounds or bubbling occurring, description of any odors occurring and if the ground is warm.
- Leachate monitoring or abstraction wells are inappropriate for gas monitoring purposes within the waste body. If such monitoring points are used, then the results cannot be regarded as comparable with, or a substitute for specifically designed monitoring points within the waste body.
- Monitoring of bulk gases and flow rates of the gas collection wells and manifolds should be undertaken in order to achieve sufficient control over the gas extraction and treatment systems. These wells are not appropriate for the monitoring of landfill gas concentrations and fluxes within the waste body.

An example of a landfill gas monitoring form is given in Appendix B.1

Further guidance on routine monitoring of landfill gas may be found in the 'The Monitoring of Landfill Gas', IWM (1998).

7.5.3 Flares and Utilization Plants

There is a wide range of instrumentation available for monitoring landfill gas flares and utilization plants. Monitoring will usually take the form of either in-situ techniques or extractive monitoring. In-situ or in-stack techniques are where the sensing device is in the stack and the results are conveyed as an electronic signal. Extractive monitoring involves the collection of a sample of combusted gas and transport away to an analyzer.

Stack testing of flares generally cannot meet the same standardized monitoring procedures required of industrial stack testing. By using certified and experienced specialists, monitoring standards will be adhered to as closely as possible and the interpretation of sampling results will be based on a thorough understanding of the variabilities involved.

When monitoring emissions from landfill gas flares/utilization plants the following points should be noted:

- A full health and safety risk assessment should be undertaken before commencement of monitoring.
- This should identify any hazards that may be encountered and put in place potential control measures.
- Stack testing personnel or consultants should be certified under a professional competency scheme specific to landfill gas flares, where available, or alternatively should provide company certification of flare emission testing experience gained.
- Monitoring conditions are severe with high temperatures and corrosive gases present. Flares may have flames exiting at the top and as a result are extremely dangerous to personnel working near the top of the flare. Adequate personal protective equipment should be worn at all times.
- An adequate sampling platform may need to be constructed so that sampling can be undertaken safely. Ladders and small mobile platforms such as cherry-pickers should not be used to access monitoring points.
- Easily accessible, safe and functional monitoring/sampling points should be provided at all plants. Provision for these should where possible be provided at the design and construction stage. These sampling ports allow much safer and more frequent on-site testing of the flare or utilization plant.
- Sampling of emissions should take place after combustion is completed.
- Special high temperature resistant (>1,100°C) monitoring equipment is required and may have to be manufactured specifically for flare emission monitoring.
- Representative sampling points need to be determined in the ducts through which the landfill gas flows. Multi-point sampling may be necessary to obtain a more representative sample.
- In-situ probes should be fitted where continuous monitoring is required (e.g. carbon monoxide emission monitoring).
- Recognized standard methods (e.g. ISO, CEN) should be used.
- All relevant on-site sampling and laboratory analytical methods should be accredited.
- There may be variation in gas composition across the stack due to poor mixing and variable flow rates. Combustion is an unsteady process. Thus, 'single-shot' measurements may be misleading. Time averaged readings are essential. In practice measurement intervals of less than 30 minutes are of little value.
- Some flare designs operate at extremely high excess air values. This need to be accounted for when measuring and correcting data.

Table E.4 in Appendix E outlines recommended monitoring techniques for flares and utilization plants. Monitoring protocols for flares and utilization plants have also recently been developed by the UK Environment Agency (2002b, 2002c)

CHAPTER 8 ODOR

8.1 Introduction

Odor may be defined as that characteristic property of a substance which makes it perceptible to the sense of smell. The perception of odor as a nuisance will depend on a number of factors, such as the concentration of that substance in the atmosphere, the frequency of releases, the form of the release (intermittent or continuous) and the sensitivity of the individuals impacted. For each substance there is a limiting concentration in air below which its odor is not perceptible. This is generally referred to the odor threshold of that substance.

Over one hundred trace constituents have been identified in landfill gas and similarly for leachate. Unpleasant odors are usually associated with the Sulphur-containing compounds, primarily mercaptans and sulphide. These compounds also have the lowest odor threshold concentrations making them the most likely source of unpleasant odors detected in landfill gas. Organic acids and aldehydes may also be significant contributors to odors at landfills.

Odors from landfills may be caused by:

- arriving and queuing refuse vehicles;
- depositing odorous wastes (e.g. decomposing household waste or sewage sludge);
- working face;
- landfill gas emissions from temporary covered areas;
- landfill gas emissions from cracks and vents in capped cells;
- excavating old waste;
- landfill gas vented without combustion;
- gas well construction;
- leaking gas wells and collection piping;
- malfunctioning flares and utilization plants;
- leachate collection and treatment systems (e.g. uncovered lagoons or wells);
- associated landfill activities (e.g. composting); and
- odor masking agents

Landfill gas generated at landfills accepting municipal waste has a characteristic odor caused by trace chemical constituents. Gas is produced shortly after waste is landfilled. If there is a delay in capping an area and constructing a suitable landfill gas control system, then gas emissions will occur.

Generally, good landfill management practice such as daily cover, minimizing the area of the active tipping area, covering odorous wastes immediately and the provision of proper landfill gas and leachate control systems are the most effective ways of reducing odors at source, thus minimizing the need to undertake such monitoring.

Further information on landfill management may be found in the Agency's manual 'Landfill Operational Practices' (1997).

8.2 Odor Assessment

Proposed Landfill

An odor assessment study for a proposed landfill should take into consideration potential sources of odor, what actions can be taken to minimize or eliminate odor, the proximity, direction and sensitivity of likely receptors, factors such as prevailing winds and weather conditions and any other pathways which may exist.

Although odors are generally localized, they may under certain meteorological conditions travel long distances.

Existing Landfills

For existing landfills, an odor assessment study may include the following:

- olfactometry or chemical measurements of all significant odor releases and appropriate air dispersion modelling of measurements;
- on-site and off-site odor monitoring;
- complaints analysis, e.g. location of complainants, time and weather conditions to which complaints relate;
- public questionnaire on odor complaints; and
- details on the efficiency of any control and treatment systems for leachate and landfill gas

Many atmospheric conditions, such as high pressure, calm wind conditions, fog or temperature inversion, can exacerbate, prolong or increase the range of any odor present as a result of operational conditions on any site.

8.3 Frequency of Monitoring

A waste license for a landfill may require that activities be carried out in a manner such that odors do not result in significant impairment of, or significant interference with amenities or the environment beyond the facility boundary. The licensee may also be required to inspect the facility and its immediate surrounds for nuisances caused by odor and to maintain a record of those inspections.

The level of monitoring required around a facility will depend on the risk from that site. For example, sites accepting a high proportion of putrescible waste would need more odors monitoring than sites accepting inert waste. The need to monitor odors may also arise in response to complaints.

Table 8.3.1 links some commonly used descriptors of odors around landfill facilities with the most likely chemical cause.

Table 8.3.1 Odor descriptors and possible chemical cause

Odor Descriptor	Chemical cause
Rotten eggs	Hydrogen sulphide
Rotten cabbages	Methyl mercaptan – landfill gas
Gassy, pungent	Sulphur compounds – landfill gas
Faecal	Indole, skatole - leachate
Sharp, acidic, e.g. vinegar, sour milk, cheesy, sweaty feet.	Volatile organic acids - landfill gas/leachate

(Source: 'Odor Guidance –Internal Guidance for the Regulation of Odor at Waste Management Facilities, Version 3.0', Environment Agency, 2002d.)

8.4 Analysis Techniques

Techniques that are generally used for monitoring odors and their impacts include:

- Field observations

This may involve monitoring by landfill staff and/or residents. Odors can be monitored throughout the day and observations can be made of specific activities such as any odorous materials arriving, the working face, gas wells, leachate collection and treatment systems. Observations can also be made at predetermined locations such as at the facility boundary and at sensitive receptors. Any observations should be recorded along with date, time, prevailing winds, temperature, etc. All this information can help to pinpoint likely causes of odor complaints.

It should be recognized that there is the possibility that staff working at an odorous site could suffer from odor fatigue, i.e. the inability to detect relevant odors due to constant exposure to them. Monitoring should be undertaken by staff prior to them arriving onto the site.

- Olfactory methods

This technique is best used for point source sampling of potentially odorous sources such as gas vents or leachate treatment plants.

Olfactory methods involve the assessment of odor by a panel of selected persons under controlled conditions. Odor samples must be sampled and analyzed in accordance with the standard EN13725 (CEN, 2003) 'Odor concentration measurement by dynamic olfactometry'. This standard sets down rigorous procedures for determining the odor strength of a gaseous sample. It covers field sampling and laboratory analysis of air samples. Odor strength is measured in European Odor Units per cubic meter (ouE/m3). An odor that is just detectable by 50% of selected panel members is described as having an odor concentration of 1 ouE/m3. It must be noted that the relation between perceived intensity and odor concentration is not linear but logarithmic. Use of this standard means it is now possible to quantify the odor strength of releases from landfill sites and allows the perception of odor as a nuisance to be assessed.

In view of the varying background odor concentrations in ambient air, it is difficult if not impossible to reliably interpret the results of ambient olfactometric monitoring results. Ambient olfactometric measurements should not be featured routinely in odor assessment other than when verifying the extent of an identified nuisance. It is recommended that the odor assessment should be based on measurements at source with modelling to predict off-site odor impact.

- Chemical analysis

If odor levels in landfill gas can be accounted for by the chemicals in the gas, sampling and analysis of these chemicals can be used to determine odor levels in addition to direct olfactometric measurements. An attempt can be made to actually measure a multitude of odorants in the mixture, using advanced analytical methods such as GC-MS or 'electronic nose' devices. The results obtained can be compared with, where available, World Health Organization (WHO) guideline values, published odor thresholds and Occupational Exposure Limits (OELs) to allow an assessment of the odor problem at the site. Substances which may be analyzed include mercaptans, organic acids and hydrogen sulphide.

The sensitivity of the analytical methods is rarely as great as that of the human nose (e.g. the adopted odor threshold of hydrogen sulphide is as low as 0.1 µg/m3) and the capability to predict or model the actual odor perception in humans on the basis of measured parameters is poor.

Emissions from surfaces may also be determined using a flux box. Landfill surfaces are by nature heterogeneous with surface cracks and variations in cover material thickness producing wide variations in the emissions of landfill gases. Section 7.3.5 provides further information.

- Dispersion Modelling

Where the odor emission rate from a source is known by measurement or can be estimated, the odor concentration in the vicinity can be predicted by dispersion modelling. The model attempts to describe the effects of atmospheric turbulence on the emission(s) as they undergo dilution and dispersion in the surrounding environment. The effects of buildings, terrain and coastlines can be taken into account in some dispersion models. This allows the effects of specific features such as landfill phases, bunds, walls, etc. on odor dispersion to be modelled.

Air dispersion modelling is also a useful tool that can be used both as a development aid for site location and design (e.g. cell/phasing plan) and for determining the optimum location of a specific site feature, e.g. gas flare, gas engine, leachate storage lagoon and composting area.

The output from the modelling process can be compared with an odor exposure criterion (in odor units) or a guideline value for avoiding annoyance (in ppb or µg/m3). For the purpose of predicting odor impact, models and input data with the following characteristics are preferred:

- gaussian plume and new generation models, e.g. ISCST3, AERMOD and ADMS
- to represent conditions for an 'average year', hourly meteorological data for at least 3 years should be used
- one-hour average concentrations should be calculated for all hours in the meteorological data- set
- exposure to be expressed as the concentration corresponding with the 98th percentile of the distribution of hourly values
- to incorporate critical receptors as discrete receptors.
- the ability to account for the effects of buildings and topography on the plumes from point sources

Further information may be found in the Agency's R & D Report Series No. 14 'Odor Impacts and Odor Emission Control Measures for Intensive Agriculture' (2001) and in the 'IPPC Technical Guidance Note H4: Draft Horizontal Guidance for Odor: Part 1- Regulation and Permitting and Part 2 – Assessment and Control' (Environment Agency, 2002e).

CHAPTER 9 NOISE

9.1 Introduction

Noise may be defined as unwanted sound. The generation of noise at a landfill is an inevitable consequence of the activities being carried out on site. However, excessive noise may become a problem if potential noise sources are not properly monitored and controlled. Noise impacts on the environment will be influenced by a number of site specific factors relating to the site operations and the location of the landfill. The primary sources of noise at a landfill include:

- mobile plant used in the construction of the facility prior to waste acceptance;
- mobile plant used in the construction and restoration of cells;
- mobile plant used in day to day operations (e.g. compactors);
- throughput of vehicles such as refuse collection vehicles and other heavy goods vehicles (e.g. loading/unloading waste from vehicles);
- fixed plant, such as gas flares, wheel cleaners, generators, leachate treatment equipment; and
- audible bird-scaring equipment

9.2 Monitoring Locations

Proposed Landfill

Where a landfill is proposed for a green field site, a baseline noise survey should be conducted initially. This will provide useful information on existing noise levels in the vicinity of the proposed site before it is developed. Noise levels prior to the development of the proposed facility may vary considerably. For instance, sites adjacent to primary roads and built up areas will tend to have higher noise levels than sites in rural locations.

A noise impact assessment should be undertaken by the developer in order to predict the likely impacts of the proposed development on the existing noise environment. Depending on the predicted impact, appropriate mitigation measures can then be incorporated into the design and included as part of the application for a waste license.

The applicant should refer to BS 4142:1997 'Rating industrial noise affecting mixed residential and industrial areas' and BS 5228: 1997 Part 1 - 'Noise and Vibration Control on Construction and Open Sites' when assessing the potential noise impacts of a new landfill development.

Selection of Monitoring Locations

The factors to take into consideration when selecting monitoring locations for assessing noise levels are:

- proximity of the landfill to noise sensitive locations;
- existing background noise levels;
- the topography of the surrounding area; and
- the prevailing wind direction

Noise Sensitive Location

A noise sensitive location may be defined as any dwelling house, hotel or hostel, health building, educational establishment, places of worship or entertainment, or any other facility or area of high amenity which for its proper enjoyment requires the absence of noise at nuisance levels.

Activities or types of land use which could be specifically sensitive to noise pollution should be identified and noise levels at these locations measured. This provides a baseline for these locations prior to the development of the facility against which future monitoring measurements can be compared when, and if, the facility is operational. Measurements should also be made at the boundary of the proposed facility.

9.3 Frequency of Monitoring and Parameters for Analysis

During the baseline noise survey, monitoring should be undertaken during the day, at night and at weekends at the various monitoring locations. The frequency of noise monitoring for a licensed landfill will be governed by the waste license.

Noise is usually measured on the decibel (dB) scale which is a logarithmic scale of sound intensity. The most common scale used for the measurement of environmental noise is the dB(A) scale. This scale incorporates a frequency weighting (A-weighting) which differentiates between sounds of different frequency (pitch) in a similar way to the human ear. Measurements in dB(A) broadly agree with peoples assessment of loudness. A 10 dB increase in noise level will produce a perception of about a doubling of the loudness. Thus a noise measured at 50 dB(A) will sound twice as loud as one at 40 dB(A).

Some common descriptors of noise are:

- **LAeqT** - this is the equivalent continuous steady sound level in dB(A) containing the same acoustic energy as the actual fluctuating sound level over the given period T. T may be as short as 1 second when used to describe a single event, or as long as 24 hours when used to describe the noise climate at a specified location. LAeqT can be measured directly with an integrating sound level meter. It is referred to as the ambient noise which is the whole noise climate including the site specific noise under consideration
- **LA10 T** - the dB(A) level exceeded for 10% of the measurement period. Used to give an indication of the higher noise levels (or peak levels) measured.
- **LA90 T** - the dB(A) level exceeded for 90% of the measurement time. This is generally used to estimate background levels.
- **Frequency Analysis (1/3 Octave band analysis)** – this is the frequency analysis of sound such that the frequency spectrum is subdivided into bands of one third of an octave each. This technique can objectively assess the presence of prominent tonal components.
- **Narrow band analysis** – is used to identify tonal components in recorded sound where 1/3 octave band frequency cannot. The 1/3 octave band analysis may fail to detect a tone because the energy of the tone may not be sufficient (i.e. not loud enough against ambient noise) or the frequency of the tone may lie on the band edge between two 1/3 octave bands.
- **LAr T** - the equivalent continuous A-weighted sound pressure level measured over a specified time interval period and adjusted for tonal or impulsive character.
- **Impulsive noise** - this is noise of a short duration (typically less than one second), the sound pressure level of which is significantly higher than the background (e.g. reversing alarms).
- **Tonal noise** – this is noise which contains a clearly audible tone, i.e. a distinguishable, discrete or continuous note such as a whine, hiss, screech or hum. Examples of tonal noise would be noise from flares, pumps or some fans.

Due to its intermittent nature impulsive noise may pose a particular nuisance at noise sensitive locations and operators should ensure that all noise surveys conducted adequately reflect the characteristics of the noise generated. Some factors to be considered in assessing the impact of impulsive noise include the peak level and repetition of the event.

Landfill gas flares emit noise of distinctive tonal characteristics at one or two 1/3 octave band frequencies (commonly at 25Hz and 800Hz) and should be positioned in order to prevent noise disturbance, particularly at night-time.

It is always beneficial to record statistical parameters (e.g. LA90, LA10, LA1) in different types of noise climate. If such parameters are recorded then they should be reported and interpreted in the report. Where noise monitoring at a landfill is complicated by the proximity of the site and/or the monitoring points to major roadways, it may be useful to measure over very short time intervals when traffic is not present.

The methods used to measure noise should be described with reference to the equipment used, calibration procedures and duration of monitoring and time of monitoring. It is recommended that monitoring personnel obtain certification from a suitably accredited body.

All monitoring of noise should be in accordance with ISO 1996: 'Acoustics – Description and measurement of Environmental noise, Parts 1, 2 and 3' or another method approved by the Agency.

9.4 Emission Limits

Noise emission limits may apply to individual sources of noise on-site, at the site boundary of the landfill, or at the nearest noise sensitive location(s) that requires protection from disturbance. Higher limit values may be set at the boundary than at noise sensitive locations to reflect the closer relative proximity to the source of noise.

Setting a noise emission limit at a particular source of noise has the advantage of providing a control on key noisy equipment at the facility.

A boundary limit has the advantage of allowing guaranteed access to the monitoring location, observation of site activities and easier exclusion of extraneous noise. However it has the disadvantage of requiring calculation and assumptions with regard to noise reduction through distance and barriers. A limit at a sensitive location has the advantages of direct measurements without calculations but has the disadvantages of uncertain access, the possibility of poor observation of site activity and difficulty of exclusion of extraneous noise or the possibility that the site cannot in fact be measured above the residual noise.

When limits are being established for noise emissions from landfills, regard will be had to factors such as location of the activity (rural/urban, residential/industrial), ambient noise levels (LAeq), background noise levels (LA90), proximity to noise sensitive locations as well as other factors. Sensitivity to noise is usually greater at night-time than it is during the day, by about 10 dB(A).

General guidelines are that noise emissions monitored at noise sensitive locations should not: - contain any tonal component or impulsive component; and - should not exceed the LAeqT value of 55 dB(A) by daytime or the LAeqT value of 45 dB(A) by night

9.5 Noise Monitoring Equipment

Environmental noise is generally measured on a Sound Level Meter. These instruments may perform a variety of functions and are designed to be used either as portable devices or as permanent outdoor units. A number of different types of noise measurement equipment are commercially available with various levels of sophistication. The range includes instruments that are capable of measuring basic time varying sound pressure level and those that are capable of calculating statistical noise indices over time. Integrating or integrating averaging sound level meters will measure the 'A'-weighted equivalent sound level (LAeq). Statistical sound level meters will calculate the statistical noise measurement parameters such as LA90, LA10 as well as LAeq.

Many instruments also contain integral frequency filters which are used in 1/3 octave frequency analysis.

In some circumstances, tape recorders provide a useful means of recording noise or a noise event for later analysis, which is useful when the event is rare short, lived or when it is expensive to repeat a certain operation for measurement purposes. Digital audio tape (DAT) recorders have now replaced traditional tape recorders.

The sound level meter should be calibrated in the field with its specific acoustic calibrator before and after each series of measurements. All the calibration levels should be recorded. If it is vary significantly before and after the monitoring the results may have to be disregarded or treated with caution. In addition to the field calibration, an accredited laboratory should calibrate microphones and calibrators periodically in accordance with the manufacturer's instructions.

Further information on noise may be found in the Agency's Guidance Document 'Environmental Noise Survey' (2003b).

Revision of the Agency's '*Guidance Note for Noise in Relation to Scheduled Activities*' (1995) is currently being revised to encompass IPPC and waste disposal and recovery activities as set out in the Protection of the Environment Act, 2003.

CHAPTER 10 OTHER ASPECTS

10.1 Meteorological Data

The measurement of the meteorological conditions at a landfill site is an integral part of the overall monitoring programme. Precipitation, temperature, evaporation, atmospheric pressure and humidity are important influences in leachate and landfill gas generation. Water balance calculations are often used to design the optimum cell sizes for a landfill site with the intention of minimizing leachate build up within the waste body. Such calculations cannot effectively be undertaken without valid, representative data on the actual meteorological conditions experienced at the site.

Wind speed and direction can be important factors in causing litter or odor nuisance. The meteorological data can be collected from a number of sources:

- an in situ weather station at the landfill site;
- a nearby meteorological station; or
- a combination of both

Table C.6 in Appendix C outlines typical meteorological monitoring requirements for a landfill.

10.2 Dust/Particulate Matter

10.2.1 Introduction

The generation of airborne dust at landfill sites is primarily related to construction activities at the site and to the transportation and deposition of waste. The movement of dust is determined by a number of parameters including prevailing wind direction, wind speed, vehicle movement and type of waste deposited.

Dust emissions can present a soiling or visibility nuisance or may pose a hazard to human health depending on the particle size and chemical composition of the dust.

During the design stage it is important to identify sensitive receptors in the event of dust generation. Any existing dust sources such as nearby industries or quarries should be identified as well as areas of the proposed landfill such as site roads and activities such as the acceptance of particular waste types that may give rise to dust generation.

For a licensed landfill, dust monitoring requirements will be set by the waste license. Daily or weekly site inspections are generally required as a minimum. A more comprehensive monitoring programme may be required to demonstrate the effectiveness of control systems or in response to complaints by the public.

Some commonly used parameters for monitoring dust emissions include dust deposition and PM_{10}.

10.2.2 Dust deposition

The term dust deposition refers to the coarse fraction of particulates that fall out due to gravity and that cause dust annoyance. In general, particulates with diameters >50 µm tend to be deposited quickly.

The standard method used for monitoring dust deposition is VDI 2119 '*Measurement of Dustfall, Determination of Dustfall using Bergerhoff Instrument (Standard Method)*', German Engineering Institute.

A waste license typically contains a dust deposition emission limit value of 350 mg/m^2/day when the Berger off method is used.

Using the above method, samples are collected in a collecting bottle mounted on a 2m pole and protected by a bird guard. Analysis employs evaporation to dryness which produces a result for Total Deposited Dust (both dissolved and undissolved).

The monitoring period should be for 30 + 2 days unless biological growth is evident in which case shorter or more frequent analysis may be desirable. Algal growth may be hindered by sterilizing the sampling container (e.g. with dilute sodium hypochlorite) or by using a blacked-out sample container to minimize light ingress and thus minimize algal growth. Any modifications to eliminate interference due to algal growth in the gauge should be reported with the results. A typical monitoring regime may require a minimum of three monitoring periods per year, with two of the sampling periods occurring between May and September. Monitoring may be required at the facility boundary, near sensitive receptors and potential sources.

Ideally the gauges should be positioned at a minimum of four locations surrounding the site of interest. It is preferable to monitor upwind and downwind of the prevailing wind. The gauges should be positioned away from interfering objects such as trees to minimize the risk of interference from birds, falling leaves, etc.

Directional dust deposition gauges can be used alongside the Berger off gauge if the source of the dust is in dispute. A relevant wind rose for each sampling period also provides additional information on wind direction.

10.2.3 PM_{10}

PM_{10} may be defined as particles with a diameter of less than 10 µm which can be inhaled beyond the larynx. These fine particles may present a health hazard. The requirement to monitor PM_{10} will be site specific. The frequency of monitoring will be dependent on the size of the site, the wastes accepted at the site and any history of dust problems at the site. Monitoring may be required at the facility boundary, upwind and downwind of potential sources and near sensitive receptors.

The standard method for the measurement of PM_{10} is EN12341 (CEN, 1998) 'Determination of the PM_{10} fraction of suspended particulate matter. Reference Method and field test procedure to demonstrate reference equivalence to measurement methods'.

A typical trigger level in a waste license is PM10 > 50 µg/m^3 for a daily sample measured at any location on the boundary of the facility. This trigger level is a 24-hour average and therefore the monitoring interval must be over a 24-hour period.

PM_{10} sampling equipment generally consists of an automatic pump sampler which draws air in through a fine filter. The sampler is set up at each monitoring point for a 24-hour period and should be located away from road traffic or other non-site specific PM_{10} sources. The internal filters collect the fine particulates contained in the ambient air. After sampling, the filters are gravimetrically analyzed in a laboratory.

10.3 Topography & Stability

10.3.1 Introduction

Monitoring of topography provides data on the landfill body and is a specific requirement of the

Landfill Directive. Monitoring of landfill settlement and investigating the structure and composition of the landfill body is required.

Stability monitoring ensures that the emplacement of waste takes place in such a way as to ensure stability of the mass of waste and associated structures particularly in respect of avoidance of slippages.

10.3.2 Topographical Surveys

The information gained through topographical monitoring can provide the following:

- a definitive drawing which indicates the extent of landfill activities at a given date,
- a record of construction activities at the site and the location of key elements of environmental control infrastructure,
- information to calculate the void space remaining in a landfill, and
- information to determine whether the desirable level of compaction is being achieved

The following points should be borne in mind when undertaking topographical surveys:

- The survey drawing should be based on one or more temporary benchmarks at the facility. These in turn should be related to local permanent Ordnance Survey benchmarks. Temporary benchmarks should be selected on the criteria that they are unlikely to ever be affected by site development works, waste settlement, that they are accessible and that they will be able to provide effective reference points from which subsequent surveys should be carried out.
- The drawing should be of a consistent scale to any final contour/restoration drawing referred to in the waste license.
- The drawing should be consistent in its methods of presentation to earlier drawings (captioning, methods of portraying site contours, etc.).
- The drawing should have a unique identification number, be dated, captioned and any revision clearly identified.

Settlement

Settlement within landfills is due primarily to compaction and volume changes during the waste decomposition process and a reduction in void spaces due to the placement of the waste. The amount of settlement is difficult to predict and will depend on a number of site specific factors such as moisture content, waste composition and waste density.

Settlement values of up to 25% can be expected for municipal waste landfills with most settlement occurring over the first five years. The settlement process may cause damage to the cap, any components of the leachate collection system constructed within the waste body and gas collection and drainage systems.

Regular monitoring to observe settling behavior should be carried out throughout the life of a landfill and if necessary, corrective measures should be put in place. The assessment of settlement should be undertaken by an appropriately qualified person (e.g. Chartered Civil Engineer). It should be carried out at intervals not exceeding twelve months.

10.3.3 Stability

The monitoring of stability is important in assessing the structural integrity of a landfill. Slope failure may pose a potential hazard to the environment and to human health and therefore the slopes of landfilled waste should be monitored at regular intervals to ensure they remain within acceptable limits. Landfill stability should be assessed annually by an appropriately qualified person (e.g. Chartered Civil Engineer).

Slope stability should be analyzed using conventional limit state analysis. These include Fellenius method and Bishops method. Computer programs (e.g. Slope) are usually used to analyze the data.

Further information on stability and settlement is available in the Agency's manual '*Landfill Site Design*' (2000).

10.4 Ecology

It is important that the operation of a landfill site does not have a significant adverse impact on ecosystems. A baseline assessment of the ecology surrounding the site and the identification of any significant species or habitats should be undertaken as part of the waste license application process. Any designated areas such as Special Protection Areas (SPAs) or Special Areas of Conservation (SACs) should be identified. The advice of the appropriate authority should be sought. The implications that the development of the landfill will have on the biological diversity and the ecology of the area should be addressed.

Ecological monitoring of a particular species or habitat may also be required as part of the waste license. An appropriately qualified professional ecologist should be employed to undertake any studies and standard survey techniques should be employed where possible.

Further information is available in the Agency's Manual – '*Investigations for Landfills*' (1995). A good overview of Ireland's biodiversity is provided in 'Biodiversity in Ireland – A Review of Habitats and Species' (Lucey & Doris, 2001).

10.5 Archaeology

The operation of a landfill should not have a significant adverse impact on the archaeological importance of a site. The potential impact of a landfill would be to disturb and in some instances to cover archaeological remains.

Before the development of any undisturbed area, the advice of the appropriate authority should be sought. A desk study should be undertaken to establish the proximity and relative archaeological importance of any sites. A check should also be carried out by walking the site and noting any item of potential archaeological significance.

Further information is available in the Agency's Manual '*Investigations for landfills*' (1995)

CHAPTER 11 REPORTING OF MONITORING

11.1 Routine Reporting

Routine monitoring reports submitted to the Agency should be set out in a format that allows for the ready assessment of the data. All monitoring reports should contain the following information:

- A cover letter detailing the waste license registers number, the licensee name and the period to which the contents relate.
- An interpretation of all monitoring data.
- Any exceedance of an emission limit value or trigger level should be highlighted and actions taken as a result outlined.
- The monitoring point reference number and details.
- A drawing showing all the monitoring locations.
- Sample date, analysis date, and analytical method together with its detection limits.
- The parameter, measurement unit and where contained in the license, the emission limit value. The measurement uncertainty should also be estimated and reported with the result.
- For continuous monitoring, the average, minimum and maximum result in addition to percentage compliance should be calculated for each parameter. Results should, if possible, be shown in graphical format.

11.2 Annual Environmental Report

Under the waste license, a landfill operator is required to submit an Annual Environmental Report (AER) to the Agency. The purpose of the AER is to give a concise overview of the activities undertaken and the operational and monitoring performance of the facility in the year being reported on. The AER should be produced on a calendar year basis unless otherwise stated in the license. This is so that figures presented in the document may be used to update the National Waste Database or provide information for EPER (European Pollutant Emissions Register) reporting.

The following information should be included in the AER:

- **Summary report on emissions:** the licensee should provide a brief outline on the emissions monitoring carried out during the year and the trends of the results should be given. An up to date drawing of monitoring points should be included.
- **Summary of results and interpretation of environmental monitoring:** this information may be presented as a series of graphs of the key parameters with an interpretation of the trends from the past year and a discussion on predicted future trends. For example, key parameters in groundwater may be pH, TOC, ammonia and conductivity. An example of a graphical presentation of groundwater results over a year is shown in Figure 11.1.
- **Surface water:** trends in key parameters (e.g. pH, BOD, COD, suspended solids, ammonia) should be compared between upgrading and downgradient monitoring locations. Any change in the Q-value of the surface water should be highlighted.
- **Groundwater:** estimated annual and cumulative quantity of indirect emissions to groundwater may be calculated. Guidance is provided in the Agency's manual 'Landfill Site Design' (2000).
- **Leachate:** the volume of leachate produced and volume of leachate transported/discharged off-site should be calculated. An annual water balance calculation and interpretation should be

included. This should include a comparison of predicted leachate versus actual leachate generated during the reporting period.

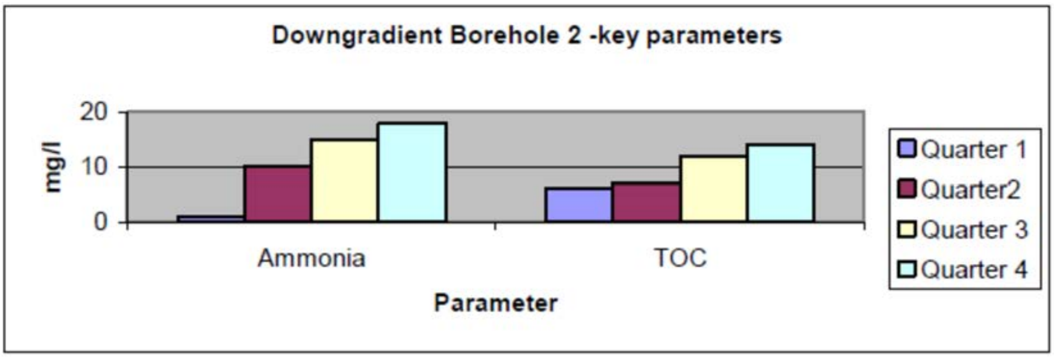


Figure 11.2.1 Graphical presentation of results at a groundwater borehole

- **Landfill gas:** the estimated annual and cumulative quantities of landfill gas emitted from the facility should be calculated by use of models such as the US EPA's LandGEM or GasSim (Environment Agency, 2002f). Information from pumping trials or from flares may be included here. Guidance is provided in the Agency's manual 'Landfill Site Design' (2000). The amount of landfill gas flared and quantities of electricity or heat generated (if applicable) and the amount of flare or engine downtime should be included.
- **Topography:** site survey showing existing levels of the facility and the areas in which it is proposed to fill in the next year should be provided. A comparison with the previous years estimated levels should be made. The remaining capacity of the facility and the year in which the final capacity is expected to be reached should be calculated.

CHAPTER 12 GLOSSARY

Aerobic: A condition in which elementary oxygen is available and utilized in the free form by bacteria

Aftercare: Any measures are necessary to be taken in relation to the facility for the purposes of preventing environmental pollution following the cessation of the activity in question at a facility.

Anaerobic: A condition in which oxygen is not available in the form of dissolved oxygen or nitrate/nitrite.

Annually: At approximately twelve monthly intervals

Aquifer: A formation (e.g. body of rock, gravel or sand stratum) that is capable of storing significant quantities of water and through which groundwater moves.

Baseline monitoring: Monitoring in and around the location of a proposed facility so as to establish background environmental conditions prior to any development of the proposed facility

Benthic: Bottom dwelling Benthic organisms may crawl, burrow or remain attached to a substrate

Biodegradable waste: Any waste that is capable of undergoing anaerobic or aerobic decomposition, such as food and garden waste, paper and paperboard

Biotic index: An index derived from observations of the responses to water quality of indicator species or higher taxa designed primarily to indicate organic pollution

Borehole: A shaft installed outside a waste area for the monitoring of and/or extraction of landfill gas/groundwater. Established by placing a casing and well screen into the boring. If installed within the waste area, it is called a well

Bunding/berm: A dike or mound usually of clay or other inert material used to define limits of cells or phases or roadways; or to screen the operation of a landfill from adjacent properties; reducing noise, visibility, dust and litter impacts.

Capping: The covering of a landfill, usually with low permeability material (landfill cap)

Condensate: The liquid which forms within gas pipework due to the condensation of water vapor from landfill gas

Detection Limit: That concentration of the determinant for which there is a 95% probability of detection when a single analytical result is obtained, detection being defined as obtaining a result which is significantly greater (p=0.05) than zero. Also referred to as Limit of Detection

Direct discharge: Introduction into groundwater of List I or II substances without percolation through the ground or subsoil

Downgradient: The direction towards which groundwater or surface water flows

Emission: Meaning assigned by the EPA Act of 1992

Flare unit: Device used for the combustion of landfill gas thereby converting its methane content to carbon dioxide.

Gas wells: Wells installed during filling or retrofitted later within the waste area for the monitoring of and/or removal of landfill gas either actively through an extraction system or passively by venting

Greenhouse effect: Accumulation of gases in the upper atmosphere which absorbs heat re-radiated from the earth's surface, resulting in an increase in global temperature

Groundwater: Groundwater is that part of the subsurface water which is in the saturated zone

Hazardous landfill: Landfill that accepts only hazardous waste that fulfils criteria set out in the Agency's draft manual 'Waste Acceptance' and that set out in Article 6 of Council Directive 99/31/EC on the landfill of waste

Hydrogeology: The study of the interrelationships of the geology of soils and rocks with groundwater

Indirect discharge: Introduction into groundwater of List I or II substances after percolation through the ground or subsoil

Inert landfill: Landfill that accepts only inert waste that fulfils the criteria set out in the Agency's draft manual 'Waste Acceptance'.

Lagoon: Land area used to contain liquid, e.g. leachate collected from landfill.

Landfill: Waste disposal facility used for the deposit of waste on to or into land.

Landfill gas (LFG): Gases generated from the landfilled waste.

Leachate: Any liquid percolating through the deposited waste and emitted from or contained within a landfill as defined in Section 5(1) of the WMA.

Leachate well: Well installed within the waste area for the monitoring and/or extraction of leachate as opposed to borehole which is the term used when located outside the waste deposition area.

List I/II substances: Substances referred to in the EU Directives on Dangerous Substances (76/464/EEC) and Groundwater (80/68/EC).

Lower explosive limit (LEL): Lowest percentage concentration by volume of a mixture of flammable gas with air which will propagate a flame at 25°C and atmospheric pressure.

Macroinvertebrate: Larger invertebrate animals visible to the eye. Usually defined as those that are retained by a net or sieve of mesh size 0.6mm

Minimum Reporting Value: This is the lowest concentration of a substance that can be determined with a known degree of confidence. It is matrix dependent and not necessarily equivalent to the Limit of Detection of the analytical system but is generally a multiple of that value which reflects the robustness and reproducibility of the test method as applied to the specific matrix. Also it referred to as the Limit of Quantitation or Practical Reporting Limit.

Noise Sensitive Location (NSL): Any dwelling-house, hotel or hostel, health building, educational establishment, place of worship or entertainment, or any other facility or area of high amenity which for its proper enjoyment requires the absence of noise at nuisance levels.

Quarterly: At approximately three monthly intervals

Receiving Water: A body of water, flowing or otherwise, such as a stream, river, lake, estuary or sea, into which water or wastewater is discharged.

Restoration: Works carried on a landfill site to allow planned after use.

Substrata: River bed or bottom on or in which invertebrates live.

Taxa: Named taxonomic groups. Usually it is family or species level in biotic indices.

Trigger level: Parameter value specified in the license, the achievement or exceedance of which requires certain actions to be taken by the licensee.

Upper explosive limit (UEL): Highest percentage concentration by volume of a mixture of flammable gas with air which will propagate a flame at 25°C and atmospheric pressure

Void space: Space available to deposit waste.

Water balance: Calculation to estimate a volume of liquid generated. In the case of landfills, water balance normally refers to leachate generation volumes.

CHAPTER 13 SAMPLING PROTOCOLS (APPENDIX A)

A protocol is a set of instructions that must be executed in performing a specific task. They are designed to give credibility to data by ensuring that the same procedures are followed each time a task is performed. Protocols for analytical techniques are generally well documented. However, protocols for sampling are often less well documented. Procedures detailed within such protocols will be task specific since they depend on the type of medium being sampled, the proposed method of sampling, the equipment used, the intended use of the sample and the data recording procedures. For example, protocols for groundwater sampling may include:

- sampling of groundwater from boreholes by depth sampler;
- sampling of groundwater from boreholes by pumping;
- sampling of groundwater from nested boreholes by pumping;
- sampling of groundwater from boreholes fitted with a permanent pump;
- multilevel groundwater samples from a borehole; or
- sampling of groundwater by depth sampler for volatile organic analysis

The validity and reliability of the analytical results generated will depend largely on the quality of the samples obtained and on the procedures carried out to maintain the integrity of the samples before their analysis. Operators are therefore encouraged to develop or adapt protocols for each relevant aspect of their monitoring programme to ensure that a consistent and logical approach is taken to sampling. Guidelines on the information to be contained in a typical sampling protocol are given in Table 13.A.1.

Table 13 A.1 Design of a Sampling Protocol

<table>
<tr><td colspan="2" align="right">Page 1 of</td></tr>
<tr><td colspan="2">Sampling Protocol For: (groundwater/surface water/leachate/landfill gas)</td></tr>
<tr><td>Compiled By:</td><td>Authorized By:</td></tr>
<tr><td>Protocol Number:</td><td>Version Number:</td></tr>
<tr><td>Issue Date:</td><td>Supersedes Version:</td></tr>
<tr><td colspan="2">Reason for update:</td></tr>
<tr><td colspan="2">Background
This should briefly outline the following:
the location of the site;
The purpose of the sampling exercise (e.g. to check compliance with license conditions); and the type of sample to be obtained (e.g. surface water sample for the assessment of water quality).</td></tr>
<tr><td colspan="2">Responsibilities
This should outline the responsibilities of the designated quality assurance officer in relation to the protocol. Such responsibilities may include:
• overseeing all technical aspects of the sampling exercise;
• undertaking periodic checks and audits to ensure the sampling procedures have been carried out in accordance with the protocol requirements; and
• authorizing deviations from the protocol</td></tr>
<tr><td colspan="2">Materials
Instrumentation and Equipment:
This would list all equipment required to obtain a valid and representative sample of the medium being investigated and may also include equipment for field analysis of particular parameters. For example, in groundwater sampling the equipment required may include bailers or discrete depth samplers, purging devices, dip meters and instruments for chemical analysis of conductivity, dissolved oxygen, pH and temperature.
Ancillary Material:
This would list the supplementary equipment and materials required and would typically include:
• sample containers (appropriate for the type of sample required and including any preservative if required);
• sample bags, tags and labels;
• field record sheets;
• chain of custody documentation;
• indelible markers;
• site maps showing monitoring points; and
• health & safety accessories (first aid kit, safety clothing)</td></tr>
</table>

Methods

This section should outline stepwise the procedures to be followed in the sampling exercise. Within the text, references should be made, where appropriate, to methods developed in-house or to recognized standard methods. For example, one of the steps in a groundwater sampling protocol will require the purging of the borehole before sampling. However, it may not be necessary to detail in each protocol the set of instructions to be followed for purging, but instead to refer to recognized standard procedures.

The methods section should also outline procedures for on-site chemical analyses and for the labelling, tagging, transport of samples and cleaning of equipment.

Sample Plan

The sampling plan should outline:

- the number and location (including grid references) of the monitoring points to be sampled;
- the frequency of sampling of each monitoring point;
- the depths from which the samples are to be obtained;
- the number and type of samples required (e.g. for chemical or biological analysis); and
- QA/QC sample requirements.

Records

The records maintained at the site should be sufficient to demonstrate that the sampling protocol has been strictly adhered to. This section should outline the records to be maintained and the field sheets to be completed during the sampling exercise. Such records would include:

- date & time of sampling;
- name of sampling personnel;
- weather conditions;
- amount of sample obtained;
- tag numbers and description of samples;
- precise location of monitoring point;
- details of preservatives used;
- analytical results obtained from field determinations;
- completion of appropriate standard forms;
- deviations from the protocol; and
- difficulties encountered during sampling

CHAPTER 14 STANDARD FORMS (APPENDIX B)

This appendix provides examples of suggested forms which operators are encouraged to use in order to standardize monitoring and reporting formats. Although actual formats may vary, the report should contain the key components as shown in the suggested forms. The documents included are:

- Example of a Landfill Gas Monitoring Form,
- Example of a Chain of Custody Document,
- Example of a Sample Analysis Report Form, and
- Example of a Rivers Ecological Assessment Field sheet.

14.1 B.1 Example of a Landfill Gas Monitoring Form

LANDFILL GAS MONITORING FORM		
Facility Name: Waste License no.:	Facility Address:	
Licensee:		
Date of licensing:	Date of sampling:	Time of sampling:
Instrument used:	Date Next Full Calibration: Last Field Calibration: (include date and gases)	
Monitoring Personnel:	Weather:	Barometric pressure: (e.g. 1001-1003 mbar rising) Mean temperature:

Results 1						
Sample Station Number	CH_4 (%v/v)	CO_2 (% v/v)	O_2 (% v/v)	CO ppm	H_2S ppm	Comments
e.g. GS1	0.0	0.5	20.7			Perimeter borehole.
e.g. GS2	59.6	34.8	0.0			Borehole within body of waste.
General Comments						

Note:
1. Monitoring for other gases such as hydrogen (H2) may be required also.

14.2 B.2 Example of a Chain of Custody Form

Chain of custody form				
Facility Name			Waste License no.	
Facility Address			Grid Reference	
Operator/Site Manager				
Telephone		Fax		
Sample Ref. No.	Sample Type	Sample Description	Sampled by	Date
Potential Hazards Associated with Sample:				
TRANSPORTATION Samples Dispatched by: Signature Date/Time			RECEIVING LABORATORY Laboratory Name & Address:	
Received by: Signature Date/Time			Samples Received by: Signature Date/Time	
Received by: Signature Date/Time			Condition of Samples:	

14.3 B.3 Example of a Sample Analysis Report Form

SAMPLE ANALYSIS REPORT FORM	
Facility Name:	Waste License No.:
Report to:	Date of report:
Sampling Location & grid reference: Sampling Date: Sampled by:	Sample Type (e.g. groundwater/surface water/leachate) Weather: Other Remarks:
Received at (laboratory): Date: By: (Signature) Time:	

Sample Reference Number:		Date of analysis:

Parameter	Units	Results	ELV (if relevant)	Limit of Detection	Analytical Technique/Method	Accreditation
e.g. Ammonia (as N)	mg/l	0.058		<0.001	Colorimetry or method reference	Y

Comments: e.g. sampling method such as grab for surface water, bailer/pump for groundwater e.g. details of any pre-treatment of samples should be included here such as filtration, acid preservation, etc.
Report Compiled by: Signature: Date: Position:
Report Certified by: Signature: Date: Position:

14.4 B.4 Example of a Rivers Ecological Assessment Field sheet

Facility Name:		Waste License No.	Date & Time of Sampling:	Weather:
River:		Sample Station No.: Grid Ref.:	Sampling Personnel:	
DO %		Modifications: Canalized – Widened – Bank Erosion – Arterial Drainage Dominant Types: Substratum Condition: Bedrock Calcareous – Compacted – Loose Boulder (>128mm) Degree of Siltation: Cobble (32-128mm) Clean - Slight - Moderate – Heavy Fine Gravel (2-8mm) Gravel (8-32mm) Sand (0.25-2mm) Cattle Access: u/s – d/s Silt (<0.25mm) Litter: NO - P - M – A 1		Sampled in: Cascades Riffles Glides Pools Deeps Margins Vegetation
DO mg/l				
Temp				
Conductivity				
pH				
Bank Width				
Wet Width				
Avg Depth		Photo: Video:		
Staff Gauge				
Velocity: Torrential Fast Moderate Slow Very Slow	Colored:	Macrophysics (A - M - P - NO) Submerged Emergent Bankside		Shading H - M - L– N2
	None			Tree Species:
	Slightly			
	Highly			
Clarity:		Filamentous Algae: A - M - P – NO Gelatinous Complexes A - M - P – NO Other: Sewage Fungus: A - M - P – NO		Main Land Use upstream Pasture Bog Forestry Urban Tillage Other:
Very Clear Clear Slightly Turbid Highly Turbid				
Discharge:				
Flood				
Normal	V. Low			
Low	Dry	Overall Macroinvertebrate Abundance and Diversity		Sample in Minutes:
Recent Flood		Density High Average Low	Diversity High Average Low / No. Taxa	Pond Net x Stone Wash x Weed Sweep x Sample Retained Y - N
Fish species: (where known)				
		Macroinvertebrate Composition - Taxa		
Protected species: (where known)		Excessive (>75%)	Dominant (51-75)	Numerous (21-50)
Common (6-20)			Few (1-5)	
Remarks:				
Q-Value:			Previous Qs:	
Access Point:				

Notes:
NO-P-M-A indicates: Not observed – Present – Moderate – Abundant.
H-M-L-N indicates: High-Medium-Low-None.

CHAPTER 15 MINIMUM MONITORING REQUIREMENTS (APPENDIX C)

Table 15.C.1 Minimum baseline monitoring requirements for a Non-Hazardous landfill

Monitoring Medium	Parameters	Monitoring Points	Frequency of Monitoring
Surface water	Flow/level and composition. See Table C.2 for further details.	At least two monitoring points in each watercourse – one upstream and one downstream of the proposed landfill.	Quarterly intervals over a one year period (pre-operational).
	Biological assessment.	At least two monitoring points in the main watercourse adjacent to the landfill – one upstream and one downstream of the proposed landfill.	At least once between June & September.
	Sediment assessment.	Site specific.	Site specific.
Groundwater	Level and composition. See Table C.2 for further details.	Minimum of three boreholes, one upgrading and two downgradient of the proposed landfill.	Quarterly intervals over a one year period (pre-operational).
Landfill Gas	Gas composition (methane, carbon dioxide, oxygen).	Three perimeter boreholes.	Two readings over a year prior to waste deposition to establish background gas concentrations.
Meteorological Data	See Table C.6.	Historical data from nearby meteorological station.	Sufficient data required to be able to predict leachate generation and to undertake air dispersion modelling of e.g. odor or emissions from flare/utilization plant.
Other Aspects	Noise, dust, PM_{10} and odors.	Sensitive receptors. Potential sources. Perimeter locations.	Site specific.
	Topography, ecology, archaeology.	Assessment of facility and surrounding locality needed.	Site specific.

Table 15.C.2 Parameters for monitoring of groundwater, surface water & leachate

Monitoring Parameter 1	Surface Water Baseline (pre-operational)	Groundwater Baseline 2 (pre-operational)	Leachate Characterization (when site is operational)
Fluid Level	○	○	○
Flow rate 3	○		
Temperature	○	○	○
Dissolved oxygen	○		
pH	○	○	○
Electrical conductivity 4	○	○	○
Total suspended solids	○		
Total dissolved solids		○	
Ammonia (as N)	○	○	○
Total oxidized nitrogen (as N)	○	○	○
Total organic carbon		○	
Biochemical oxygen demand	○		○
Chemical oxygen demand	○		○
Metals 5	○	○	○
Total alkalinity (as $CaCO_3$)	○	○	
Sulphide	○	○	○
Chloride	○	○	○
Moly date Reactive Phosphorus 6	○	○	○
Cyanide (Total)	○	○	○
Fluoride	○	○	○
Trace organic substances 7	○	○	○
Faecal & Total Coliforms 8		○	
Biological assessment 9	○		

Notes:
1. Tables D.1 and D.2 recommend guideline minimum reporting values for parameters.
2. For landfills accepting biodegradable wastes, it is recommended that trigger levels are set for ammonia, TOC and chloride as a minimum. Section 5.5 contains further details.
3. Range of flow measurements required, i.e. high and low flow.
4. Where saline influences are suspected, a salinity measurement should also be taken.
5. Metals for analysis should include: calcium, magnesium, sodium, potassium, iron, manganese, cadmium, chromium (total), copper, nickel, lead, zinc, arsenic, boron and mercury.
6. Total Phosphorus should be measured in leachate samples where colorimetric interference is likely.
7. Table D.2 recommends trace organic substances that should be included in the determination. Surface water should be analyzed for the pesticides and solvents listed in the Water Quality (Dangerous Substances) Regulations (S.I. No. 12 of 2001).
8. Required for drinking water supplies within 500m of the landfill.
9. Site specific and twice between June and September.

Table 15.C.3 Typical leachate monitoring requirements for Non-Hazardous landfill

Parameter	Monitoring Points	Monitoring Frequency (operational and aftercare)
Leachate levels	For lined landfills, at the leachate collection point and at two other points per cell. For unlined landfills, three points per five hectares of filled area. Leachate lagoon.	As required by waste license.
Leachate composition See Table C.2 for details.	Sampling point representative of the landfill body. Leachate lagoon. Treated leachate before discharge.	As required by waste license.
Leachate discharge volume	Treated leachate discharge point.	As required by waste license.

Table 15.C.4 Typical landfill gas monitoring requirements for a Non-Hazardous landfill

Monitoring Points	Parameter	Monitoring Frequency (operational and aftercare)
Perimeter boreholes (outside the waste body)1, site office/buildings	Methane, carbon dioxide, oxygen2, atmospheric pressure3, temperature.	As required by license.
Boreholes/Vents/Wells 4 (within the waste mass)	Methane, carbon dioxide, oxygen2, atmospheric pressure3, temperature.	As required by waste license.
Collection wells and associated manifolds	Bulk gas concentration, flow-rate.	As required by waste license.
Surface emissions	Methane, flow-rate.	As required by waste license.
Inputs and outputs of each flare/utilization plant	See Table C.5 for details.	See Table C.5 for details.

Notes:
1. Number and location depends on the site risk assessment.
2. Other gases, e.g. H2S, CO and H2 as required.
3. Falling atmospheric pressure may cause increased migration of gas out of the waste body.
4. The locations for gas monitoring within the waste body should be at a density of at least one monitoring point per cell in lined landfills and one monitoring point per hectare of filled area in unlined landfills.

Table 15.C.5 Typical Landfill Gas Flare and Utilization Plant Monitoring Regime

Parameter	Flare Monitoring Frequency	Utilization Plant Monitoring Frequency
Inlet		
Gas flow rate	Continuous	Continuous
Methane (CH_4) % v/v	Continuous	Continuous
Carbon dioxide (CO_2) % v/v	Continuous	Weekly
Oxygen (O_2) % v/v	Continuous	Weekly
Total Sulphur 1	Annually	Annually
Total Chlorine 1	Annually	Annually
Total Fluorine 1	Annually	Annually
Process Parameters		
Combustion temperature	Continuous	Not applicable
Retention time	Annually	Not applicable
Outlet		
Carbon monoxide (CO_2)	Continuous	Continuous
Nitrogen oxides (NO_x)	Annually	Annually
Sulphur dioxide (SO_2)	Annually	Annually
Total VOCs as carbon	Annually	Annually
Total non-methane VOCs	Not applicable	Annually
Particulates	Not applicable	Annually
Hydrochloric acid (HCl)	Annually	Annually
Hydrogen fluoride (HF)	Annually	Annually
Other parameters, e.g. heavy metals, halogenated organic compounds.	Site specific	Site specific

Notes:
1. If a high concentration of these substances is present in the gas (Cl > 160 mg/m3, F > 25 mg/m3, S >1400 mg/m3), purification treatment may be required in order to fulfill emission standards.
2. The presence of CO in the flue gases is indicative of incomplete combustion.

Table 15.C.6 Minimum meteorological monitoring requirements

Parameter 1	Operational phase	Aftercare phase
Volume of precipitation	Daily	Daily, added to monthly values
Temperature min/max, 14.00h CET 2	Daily	Monthly average
Direction and force of prevailing wind	Daily	Not required
Evaporation	Daily	Daily, added to monthly values
Atmospheric pressure	Daily	Monthly average
Atmospheric humidity, 14.00h CET 2	Daily	Monthly average

Notes:
1. Data to be collected from an in situ weather station at the landfill site or from a nearby meteorological station.
2. CET is Central European Time and is specified in the Landfill Directive.

CHAPTER 16 MINIMUM REPORTING VALUES (APPENDIX D)

In general, the term 'clean' waters refer to surface waters, groundwater and drinking waters whereas the term 'dirty' waters refers to leachates or similar matrices. All analysis should be carried out by a competent laboratory using standard or internationally accepted procedures capable of achieving, where practicable, the Minimum Reporting Value (MRV) for the matrix. The MRVs represent acceptable criteria for the sensitivity of test methods. Where procedures routinely employed are capable of producing measurements of greater resolution, then these should be reported in preference.

Table 16.D.1 Guideline Minimum Reporting Values

Determinant 1	Units	Recommended Analytical method	MRV 'clean'	MRV 'dirty'
Temperature 2	°C	Thermometry	± 1	± 1
pH 2	pH units	Electrometer	± 0.2	± 0.2
Electrical conductivity 3	µS/cm	Electrometer	10	50
Dissolved oxygen 2	mg/l	Electrometer	± 0.1	± 5
Dissolved oxygen 2	% saturation	Electrometer	± 1	± 5
Total suspended solids	mg/l	Gravimetric	5	10
Total dissolved solids	mg/l	Gravimetric	10	20
Ammonia (as N)	mg/l	Ion selective electrode/Colorimetry	0.05	1
Total oxidized nitrogen (as N) 4	mg/l	Colorimetry/Ion chromatography/Ion selective electrode	1	1
Total organic carbon 5	mg/l	TOC Analyzer	2	10
Biochemical oxygen demand 6	mg/l	Electrometer or Titrimetric	2	10
Chemical oxygen demand	mg/l	Digestion/Colorimetry	10	20
Calcium 7	mg/l	Atomic spectroscopy/Ion chromatography	1	10
Magnesium 7	mg/l	Atomic spectroscopy/Ion chromatography	1	10
Sodium 7	mg/l	Atomic spectroscopy/Ion chromatography	1	10
Potassium 7	mg/l	Atomic spectroscopy/Ion chromatography	1	10
Iron 7	mg/l	Atomic spectroscopy/Colorimetry	0.05	0.2
Manganese 7	mg/l	Atomic spectroscopy/Colorimetry	0.02	0.05
Cadmium 7	mg/l	Atomic spectroscopy/Colorimetry	0.0005	0.005
Chromium (Total) 7	mg/l	Atomic spectroscopy/Colorimetry	0.005	0.05
Copper 7	mg/l	Atomic spectroscopy/Colorimetry	0.005	0.05
Lead 7	mg/l	Atomic spectroscopy/Colorimetry	0.005	0.05

Determinant 1	Units	Recommended Analytical method	MRV 'clean'	MRV 'dirty'
Nickel 7	mg/l	Atomic spectroscopy/Colorimetry	0.005	0.05
zinc 7	mg/l	Atomic spectroscopy/Colorimetry	0.008	0.1
Arsenic 7	mg/l	Atomic spectroscopy	0.005	0.05
Boron 7	mg/l	Atomic spectroscopy/Colorimetry	0.2	2
Mercury 7	mg/l	Atomic spectroscopy	0.0001	0.001
Cyanide (Total)	mg/l	Colorimetry/Ion chromatography/Ion selective electrode after distillation	0.01	0.05
Total alkalinity (as CaCO3)	mg/l	Potentiometric or Acidimetric titration	5	50
Sulphide	mg/l	Ion chromatography/Turbidimetry	20	50
Chloride	mg/l	Colorimetry/Ion chromatography/Ion selective electrode	2	25
Fluoride	mg/l	Ion chromatography/Ion selective electrode	0.1	1
Phosphorus 8	mg/l	Atomic spectroscopy/Colorimetry	0.02	0.2
Trace organic substances	µg/l	See Table D.2	-	-
Dissolved methane	µg/l	Sensor/GCMS/GCFID	5	5
Total & Faecal coliforms 9	No./100ml	Membrane filtration, MPN or ColilertTM, dilution as required	<1	10

Notes:
1. The Water Quality (Dangerous Substances) Regulations (S.I. No. 12 of 2001) lists water quality standards for the following metals: arsenic, chromium, copper, cyanide, fluoride, lead, nickel and zinc as well as selected pesticides and solvents.
2. This is the typical instrumentation resolution required rather than reporting value.
3. The reference temperature at which the conductivity is measured should be specified.
4. Total oxidized nitrogen may be expressed as the sum of nitrate (NO3) and nitrite (NO2) analyses.
5. For waters high in inorganic carbon the preferred method for determination of TOC is measurement of an acid-purged sample where TOC is reported as Non-Purgeable Organic Carbon.
6. Carbonaceous BOD analysis may be required in certain situations, e.g. when analyzing treated leachates. This is done by addition of a nitrification inhibitor and if undertaken, then should be specified in the sample analysis report form. Unless otherwise specified, BOD data should relate to non-inhibited measurements.
7. It is recommended that metal analysis on groundwater and leachate samples is undertaken on samples that have been filtered through a 0.45µm membrane filter and acid preserved.
8. Soluble molybdate reactive phosphorus (MRP) should be analyzed in 'clean' waters and total phosphorus in 'dirty' waters where practicable. Total phosphorus is desirable where colorimetric interference in the measurement of MRP is likely.
9. Faecal Coliforms should be confirmed as E. coli.

In general, the term 'clean' waters refer to surface waters, groundwater and drinking waters whereas the term 'dirty' waters refers to leachates or similar matrices. All analysis should be carried out by a competent laboratory using standard or internationally accepted procedures capable of achieving, where practicable, the Minimum Reporting Values for the matrix. These represent acceptable criteria for the sensitivity of test methods. Where procedures routinely employed are capable of producing measurements of greater resolution, then these should be reported in preference.

Table 16.D.2 Recommended core determinants for trace organics analysis & guideline

Determinant 1 (include representative compounds from the following groups)	MRV 'clean' μg/l	MRV 'dirty' μg/l
VOCs		
e.g. trichloroethylene, tetrachloroethylene, 1,2-dichloroethane, 1,2- dichlorobenzene, toluene, xylenes, hexachlorobutadiene, trichlorobenzene, dichloromethane, chlorobenzene, benzene.	1.0 2, 3	1.0 2
SEMI-VOCs		
Organochlorine pesticides e.g. aldrin, γ-HCH (Lindane), dieldrin, endosulfan, trifluralin, hexachlorobenzene.	0.1 2, 3	1.0 2
Triazine herbicides e.g. atrazine, simazine.	0.1 2, 3	1.0 2
Organophosphorus pesticides e.g. dichlorvos.	0.1 2, 3	1.0 2
Herbicides e.g. dichlorprop, mecoprop, bromoxynil.	0.1 2, 3	1.0 2
Phenols e.g. 2-chlorophenol, pentachlorophenol, 2,4,6-trichlorophenol.	0.1 2, 3	1.0 2
Organotin compounds e.g. tributyltin	Note 4.	Note 4.
Polycyclic Aromatic Hydrocarbons (PAHs) e.g. benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(g,h,i)perylene, indeno(1,2,3-cd)pyrene, napthalene .	0.1 2, 3	1.0 2

Notes:

1. Inclusion of the above substance groups reflects legislation current at the time of preparation of this document. Studies being undertaken on behalf of the Department of the Environment and Local Government are expected to provide further guidance on priority substance monitoring. The above groupings are not exhaustive and this listing may be subject to change to reflect new information and/or legislation. The Water Quality (Dangerous Substances) Regulations (S.I. No. 12 of 2001) lists the following pesticides and solvents: atrazine, dichloromethane, simazine, toluene, tributyltin and xylenes.
2. Samples should be analyzed by appropriate recognized standard methods such as US EPA, ISO, CEN, NSAI or equivalent which are capable of achieving the required degree of analytical performance.
3. Lower minimum reporting values may be necessary in some circumstances, e.g. where compounds are detected in drinking waters or where a trigger level is set for a particular substance.
4. This parameter only relates to tidal waters. Analytical techniques capable of meeting the requirements of relevant legislation should be used. Monitoring for biological effects such as reproductive impairment in gastropods may also be necessary.

CHAPTER 17 SAMPLING EQUIPMENT & ANALYTICAL TECHNIQUES (APPENDIX E)

Table 17.E.1 Groundwater & Leachate sampling equipment

Equipment	Advantages	Disadvantages
Bailers	• Low cost • Simple to operate and reliable • Readily portable • External power source not required • Can be constructed in a wide variety of diameters and materials • Dedicated or disposable options • Suitable for VOC sampling	• Aeration of sample possible if operated too vigorously or when transferring water to the sample bottle • Can cause turbidity in sample medium • Possibility of cross contamination from the bailing cable • Labor intensive when used for purging • Can only sample top of water column
Discrete Depth Samplers	• Samples at specific levels in boreholes. • Low cost – can be dedicated • Easy to operate and portable	• Low abstraction rate makes purging slow • Causes agitation if operated too vigorously
Inertial pumps	• Low cost and can be used as a dedicated pump • Can be used for purging and sampling • Can be used in silty/sandy water • Can operate to c. 60m depth • Lightweight and portable mechanical unit available	• Potential mixing of water column • May cause disturbance of accumulated sediments • Causes agitation of sample.
Suction lift pumps (including peristaltic)	• Suitable for sampling most inorganic compounds • Relatively inexpensive and portable • Pump is at surface – dedicated tubing can be left in hole • Inertial pumps can be used as priming mechanism to avoid cross-contamination	• Only suitable for boreholes <9 m depth • Unsuitable for VOC determinations • Can cause degassing of samples • Possible contamination of samples from priming fluid • Causes pressure changes and agitation
Bladder Pumps/Gas driven pumps	• Easy to operate and reliable • Portable and easily cleaned • Can operate at very low flow rates • Suitable for sampling all major organic and inorganic parameters • Can operate to any depth	• Low discharge rate unsuitable for purging • Expensive • Gas source required • Large gas volumes and long cycles are necessary when pumping from deep wells
Diffusion samplers	• Only suitable for VOC • No purging required	• Dedicated • Expensive
Submersible pumps	• Flow rate variable, suitable for purging and sampling • Efficient for purging deep boreholes • Easy to operate and reliable	• Heat generated by pump may cause changes in chemical composition of sample • Possible pressure changes/agitation of sample

Equipment	Advantages	Disadvantages
Multilevel samplers	• Can take samples from several discretely isolated zones within a single borehole • Useful in determining flow patterns and contaminant distribution	• Expensive and requires specialist knowledge • Installation difficult and if poorly done may lead to cross-contamination

Table 17.E.2 The relationship between measured gas parameters & monitoring purpose

Purpose	Monitoring Location	Measured Parameters	Instrument Type(s)
Personal protection	Atmosphere around a person working in a confined space	Flammable gas concentration, oxygen deficiency. Other gases (e.g. H2S) concentration if necessary.	Pocket size device with acoustic, optic or vibrating alarm
Building or development protection	Confined spaces, rooms, etc.	Flammable gas concentration, oxygen deficiency. Other gases (e.g. H2S) concentration if necessary.	Fixed or transportable with acoustic or optic alarm with or without telemetry OR Portable instrument for surveys
Monitoring for gas during a surface survey	Ground surface, services, manholes, search bar holes	Flammable gas (methane), carbon dioxide and oxygen concentration. Pressure, temperature, flow.	Portable
Monitoring for gas outside the waste	Gas monitoring borehole or probe	As above.	Portable OR Fixed for continuous monitoring with telemetry (optional)
Monitoring the gas in the waste or within a gas collection system	Gas or leachate extraction well, Knock-Out-Pot (gas dewatering plant), gas collection pipes	As above. Carbon monoxide in case of suspected underground fires.	As above
Monitoring in a gas thermal destruction unit	Gas flare	Flammable gas (methane), carbon dioxide and oxygen concentration. Pressure, temperature and flow.	As above
Monitoring in a gas utilization plant	Power station, kiln, boiler, etc.	As above and calorific value, moisture.	As above
Detailed gas analysis	Sample of gas	Gas composition, concentration of its components, moisture.	Fixed or transportable laboratory instruments (e.g. GC-MS)

(Source: *'Monitoring of Landfill Gas'*, IWM, 1998)

Table 17.E.3 Characteristics of various gas sensors

Sensor type	Gas	Advantages	Disadvantages
Infrared	CH4 Other hydrocarbons, CO2	Fast response and simple to use Can be used to measure specific gases in gas mixtures and cannot be 'poisoned' Wide detection range (ppmv – 100%) Less prone to cross-interference with other gases than other sensors Can be incorporated into intrinsically safe instruments Gas sample passes unchanged through the sensor	Prone to zero drift Pressure sensitive Temperature sensitive Moisture sensitive Majority instruments sensitive to hydrocarbon bond only, not specifically to CH_4 – in presence of specific organic compounds can cause interference Optics sensitive to contamination (condensate, particulates).
Flame ionization	CH_4 Flammable gases Vapors	Highly sensitive (usual range (0.1 - 10,000ppmv) Fast response	Will not work in O_2 deficient environment Accuracy is affected by presence of other gases like CO_2, H_2, minor constituents of landfill gas, water vapor 'Blind test' – respond to any flammable gas Limited detection range Gas sample destroyed
Electrochemical	O_2, H_2S and CO_2.	Low cost Usual detection range 0-25% v/v, against various gases	Limited shelf-life and requires frequent calibration Can lose sensitivity due to moisture, corrosion and poisoning Poor performance against cross-contamination
Paramagnetic	O_2	Accurate and robust No interference from majority of other gases	Prone to drift and gas contaminants Expensive Respond to partial pressure and not concentration
Catalytic oxidation (Pallister)	CH_4 Flammable gases and vapors	Fast response Low detection range (0.1–100% LEL) Respond to any flammable gas	Accuracy affected by presence of other flammable gases Readings inaccurate in O_2 deficient atmosphere (<12% v/v) Prone to aging, poisoning and moisture Not possible to notice sensor deterioration Gas sample destroyed during measurement
Thermal conductivity	CH_4 Flammable gases and vapors	Fast response to any flammable gas Full detection range (0 – 100% v/v) Independent on oxygen fuel Can be combined with other detectors	Accuracy affected by presence of other flammable gases, CO2 and other gases with the same thermal conductivity Sensitivity too poor for use in safety checks Errors at low concentrations

Sensor type	Gas	Advantages	Disadvantages
Semiconductor	Mainly toxic gases	Good selectivity for some toxic gases (e.g. H_2S) Less susceptible to poisoning High sensitivity to low concentration of gases Long-term stability	Lack of selectivity to combustible gases Not specific to any one material Accuracy and response depend upon humidity
Chemical (indicator tubes)	CO_2, CO, H_2S, water vapor, other gases	Simple in use and inexpensive	Crude identification of specific landfill gas constituents and prone to interference effects
Photo–ionization detector	Most organic gases	Very sensitive	Susceptible to cross – contamination and expensive

(Source: *'Monitoring of Landfill Gas'*, IWM, 1998)

Table 17.E.4 Monitoring methods & techniques for flares & utilization plans

Parameter	Analysis method / technique 1
Temperature	Thermocouple/temperature probe/data logger
Flow	Pitot tube
Methane	Infrared/flame ionization/thermal conductivity
Carbon dioxide	Infrared/thermal conductivity
Oxygen	Non-dispersive infrared (NDIR)/paramagnetic/electrochemical/thermal conductivity
Total Sulphur/total chlorine/total fluorine	Ion chromatography/ion selective electrode
Sulphur dioxide	NDIR/non-dispersive ultraviolet/electrochemical/chemical absorption
Nitrogen oxides	NDIR/chemiluminescence/electrochemical/chemical absorption
Carbon monoxide	NDIR/infrared/electrochemical/data logger
Particulates	Isokinetic & gravimetric
VOCs	Adsorption/desorption & GC-FID/GC-MS
Hydrochloric acid, hydrogen fluoride & acid gases	Impugner & ion chromatography
Heavy metals	Isokinetic & ICP-AES

Note:
1. All equipment used for monitoring flares and utilization plants must be capable of withstanding high temperatures and may have to be specifically manufactured or altered to be fit for the purpose.