ضمایم

ضمیمه ۱.۴

گزارش بررسیهای پایش در ماهشهر

Acronyms and abbreviations

ASTM	American Society for Testing and Materials
BGLB	Brilliant Green Lactose Bile
BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
CSR	Corporate Social Responsibility
DBP_S	Disinfection Byproducts
DO	Dissolved Oxygen
DOE	Department of Environment
DST	Daylight Saving Time
EC	Electrical conductivity
EPA	Environmental Protection Agency
GPS	Global Position System
HSE	Health, Safety and Environment
JBIC	Japan Bank for International Cooperation
JICA	Japan International Corporation Agency
JOCV	Japan Overseas Cooperation Volunteers
JTU	Jackson Turbidity Units
LST	Lauryl Tryptose
MOP	Ministry of Petroleum
MPN	Most Problem Numbers
NIOC	National Iranian Oil Company
NOM	Natural Organic Matter
NPC	National Petroleum Company
NTU	Nephelometric Turbidity Units
PETZONE	Petrochemical Special Zone
pH	Potential of Hydrogen
PMO	Ports and Maritimes Organization
PSEZ	Petrochemical Special Economic Zone
RIPI	Research Institute of Petroleum Industry
TDS	Total Dissolved Solid
TKN	Total Kjeldahl Nitrogen
TOC	Total Organic Carbon
TPH	Total Petroleum Hydrocarbon
TSS	Total Suspended Solid
WHO	World Health Organization
RO	Reverse Osmosis
NM	Nautical Mile

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1 Objectives

The aim of this task is to convey the environmental baseline study (EBS) and to grasp the characteristics of seawater and sediment quality, which will be used in the environmental assessment and future planning. This data will be used to distinguish if the construction or operational criteria are required to be changed to avoid the environmental impact. It will also be used as a basis to judge which environmental effect on seawater and sediment quality shall be assessed.

The expected outputs from this study are as follows:

- To identify the extent and quality of s e a water and sediments within the study area that may potentially be affected by the petrochemical facilities.
- To determine the presence and nature of any potential contaminants present within sea water and sediments in areas likely to be affected by development activities.
- To provide an idea for developing appropriate management/mitigation measures to deal with potentially significant effects on water quality and sediment quality likely to arise as a result of the development.
- To understand the present environmental situation in the ambient sea area (seawater and sediment).
- To establish efficient and effective environmental monitoring program for MOP and environmental management bodies in Mahshahr.
- To establish clear objectives of the environmental monitoring programs in petrochemicals zones in order to raise public awareness.
- To compare and analyze compliance with seawater and sediment quality guidelines.

2 Outline of the Survey

2.1 Overview of the Target Area

Persian Gulf is bordered by Oman and the United Arab Emirates on the south, Qatar, Bahrain and Saudi Arabia on the west, Kuwait and Iraq on the north and Iran along the entire east coast. The gulf sits on top of the largest hydrocarbon reserve in the world, which makes this area extremely important for oil production and one of the most important strategic waterways in the world. Maximum depth is 90 m, whereas the narrowest point is only 56 km wide (See Figure 2.1.1).

The Persian Gulf is considered among the highest anthropogenically impacted regions in the world. Heavy-metal contamination in the coastal and marine environments is becoming an increasingly serious threat to both the naturally stressed marine ecosystems and humans that rely on marine resources for food, industry and recreation through a variety of sources and activities including sewage and industrial effluents, brine discharge, coastal modifications and oil pollution.

Another peculiar characteristic of the Persian Gulf marine environment is the presence of coral reef colonies and plant species that thrive in areas which mark tidal movements. The mangrove forest in the Persian Gulf, which is a continuation of the forests in Southeast Asia and the Indian Ocean, is also very important from the ecological viewpoint.

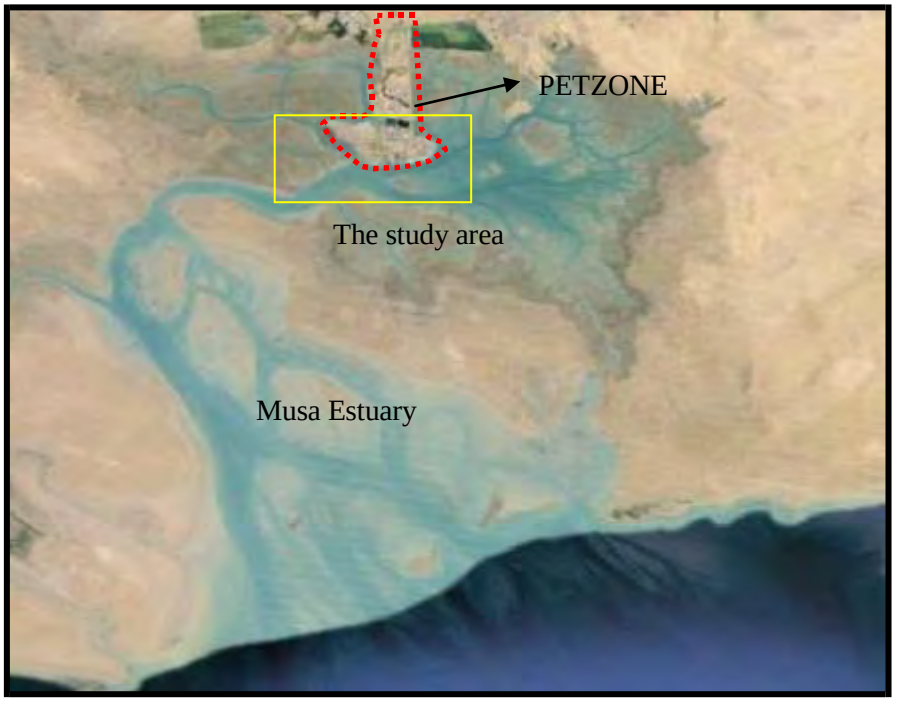
The coral reefs are crucial in controlling the water flow and they hold various kinds of fish, particularly the smaller species. The mangrove species, *Avicennia marina*, which is peculiar to the Persian Gulf and the Gulf of Oman, are among the sea resources that provide ideal living environments for crustaceans such as shrimps and also for other marine life.

Source: www.worldatlas.com

Figure 2.1.1 Outline of Persian Gulf

Musa estuary is a complex of tidal channels in the North West part of the Persian Gulf (Mahshahr) and it is consisted of several estuaries, creeks and a main canal (See Figure 2.1.2). The second largest port of Iran (Imam Khomeini Port) is situated in the north of Musa

estuary, and it's related to the Persian Gulf through a 60 km length canal. There are several sources of anthropogenic pollutants including petrochemical industries, oil transportations and agricultural activities, which produce and release large concentrations of contaminants such as heavy metal into the sea water. Like many other estuaries, Musa Estuary is an important place for fisheries and aquaculture activities. Considerable amount of fish and shrimp are caught from this estuary annually, which is introduced to the markets. The presence of high concentrations of contaminants in the aquatic environment could result in bio-accumulation and bio-magnification by marine organisms and increase the risk of toxicity in the people who consumed contaminated seafood.



Source: Google Earth

Figure 2.1.2 Musa Estuary and the Study Area

2.2 Survey Location

Prior to conducting the study, sampling locations were determined by carrying out the field reconnaissance at the Musa Estuary, considering the pollutant sources (petrochemical effluents, the locations of discharge outlets, etc.) and sensitive area (Mangrove forest) which plays a vital role for aquatic organisms especially for the conservation of biota and fishing area and many other respects. And eight (8) sampling points were selected for survey seawater and sediment quality (See Table 2.2.1). Figure 2.2.1 shows the locations of eight (8) sampling points, consisting of seven (7) target points and one (1) as a control point in Mahshar.

Table 2.2.1 Sampling locations

Sampling Point	Latitude (N)	Longitude (E)	Depth (m)	Note
MS-1	30° 27' 20.00"	49° 06' 06.10"	1.5	Monitoring point
MS-2	30° 27' 26.09"	49° 06' 33.19"	>5	
MS-3	30° 26' 56.30"	49° 07' 02.20"	>5	
MS-4	30° 26' 07.40"	49° 07' 08.60"	1.8	
MS-5	30° 25' 16.50"	49° 06' 15.70"	>20	
MS-6	30° 25' 07.00"	49° 05' 00.60"	>30	
MS-7	30° 24' 58.90"	49° 03' 06.70"	>30	
MS-8	30° 23' 25.08"	49° 00' 29.52"	>40	Control point

Source of image: Google Earth Others: Study team

Figure 2.2.1 Survey Locations

2.3 Survey Schedule

Table 2.3.1 shows the survey schedule. The frequency of sampling is basically once (1) per month for the basic parameters and total number of seven (7) samplings were conducted during the project. Out of seven samplings, two (2) times are the sampling for heavy metals in water and for sediment quality.

Every survey was conducted at the timing of ebb tide in the spring tide, which is considered that the discharged water from PETZONE spreads widely and the influence from the area would be well understood.

Table 2.3.1 Survey Schedule

		2013						
		April	May	June	July	August	September	October
		1392						
			Ordibehesht	Khordad	Tir	Mordad	Shahrivar	Mehr	Aban
Sea water	Genral items		■		■		■	■	
	Heavy metals		■			■	■		
Sediment			■				■		
Survey date (in Gregorian calendar)			27 28	11 12 14	25 26		14 15	27 28	21 22	19 20	
Timeing of spring tide			28	12	25		9	23	22	21	

Source:Study team

Due to restrictions of the holy month of Ramazan (July sampling), sampling date in July was postponed to beginning of the August.

2.4 Survey Items and Methodology

Survey items, layers, frequency are summarized in Table 2.4.1. Instruments which were used for field observation are shown in Table 2.4.3. Analytical method of each parameter and the detection limit are listed in Table 2.4.2 and equipment used for chemical analysis is presented in Table 2.4.4.chemical analysis is shown in Table 2.4.4.

Table 2.4.1 Survey Items, Frequency, Number of samples

Item	Frequency, Layer
1. Field observation	
Time, Air temperature, Depth, Water color, Transparency, Odor, Tidal Condition and Current	8 locations ×7 times
2. Seawater	
(1) General Items	
Water temperature	8 locations ×7 times× every 1 m
Salinity	8 locations ×7 times× every 1 m
Conductivity	8 locations ×7 times× every 1 m
pH	8 locations ×7 times × 3 layers
Turbidity	8 locations ×7 times × 3 layers
Suspended solid	8 locations ×7 times × 3 layers
Dissolved Oxygen	8 locations ×7 times × 3 layers
COD	8 locations ×7 times × 3 layers
Total Organic Carbon (TOC)	8 locations ×7 times × 3 layers
Oil Contents	8 locations ×7 times × 3 layers
Coliform Bacteria	8 locations ×7 times × 3 layers
Total Nitrogen	8 locations ×7 times × 3 layers
Total Phosphorus	8 locations ×7 times × 3 layers
(2) Heavy Metals, etc.	
Aluminum (Al)	8 locations ×2 times × 3 layers
Arsenic (As)	8 locations ×2 times × 3 layers
Cadmium (Cd)	8 locations ×2 times × 3 layers
Cyanide (CN)	8 locations ×2 times × 3 layers
Chromium (Cr^{+6})	8 locations ×2 times × 3 layers
Cobalt (Co)	8 locations ×2 times × 3 layers
Copper (Cu)	8 locations ×2 times × 3 layers
Iron (Fe)	8 locations ×2 times × 3 layers
Methyl Mercury (Hg)	8 locations ×2 times × 3 layers
Mercury (Hg)	8 locations ×2 times × 3 layers
Manganese (Mn)	8 locations ×2 times × 3 layers
Magnesium (Mg)	8 locations ×2 times × 3 layers
Nickel (Ni)	8 locations ×2 times × 3 layers
Lead (Pb)	8 locations ×2 times × 3 layers
Zinc (Zn)	8 locations ×2 times × 3 layers
Phenols	8 locations ×2 times × 3 layers

Item	Frequency, Layer
3. Sediment	
Specific Gravity	8 locations × 2 times
Moisture Content	8 locations × 2 times
Grain Size	8 locations × 2 times
Total Organic Carbon (TOC)	8 locations × 2 times
Total Petroleum Hydrocarbon	8 locations × 2 times
Aluminum (Al)	8 locations × 2 times
Arsenic (As)	8 locations × 2 times
Cadmium (Cd)	8 locations × 2 times
Cyanide (CN)	8 locations × 2 times
Chromium (total)	8 locations × 2 times
Chromium (Cr^{+6})	8 locations × 2 times
Cobalt (Co)	8 locations × 2 times
Copper (Cu)	8 locations × 2 times
Iron (Fe)	8 locations × 2 times
Methyl Mercury (Hg)	8 locations × 2 times
Mercury (Hg)	8 locations × 2 times
Manganese (Mn)	8 locations × 2 times
Magnesium (Mg)	8 locations × 2 times
Nickel (Ni)	8 locations × 2 times
Lead (Pb)	8 locations × 2 times
Zinc (Zn)	8 locations × 2 times
Total Sulfur (T-S)	8 locations × 2 times

Table 2.4.2 Instruments Used for Field Observation

Item	Method, Instrument	Note
Location	GPS, GARMIN, 12 CX, Made in USA	
Air temperature	Temperature sensor, Multi analyzer	
Wind	Visual observation	Beufort grade
Wave	Visual observation	Beufort grade
Depth	Examine with anchoring, Ship echo sounder	
Current	Visual observation	
Watercolor	Visual observation	Muncel color code
Sediment color	Visual observation	Muncel color code
Transparency	Secchi disk	

Table 2.4.3 Analytical Methodology and Detection Limit

Category	Parameter	Analytical Methodology	Detection limit
Water quality (General parameter)	Turbidity	ASTM D1889	0.1 NTU
	Suspended solid	Standard Method 2540 D	0.1 mg/l
	COD	Standard Method 5220 B	
	TOC	Standard Method 5310 B	1 mg/l
	Oil contents	ASTM D7066	0.2 mg/l
	Coliform bacteria	Standard method9215B	2 MPN index/100
	Total nitrogen	Standard Method 419D, 4500B,	0.2 mg/l as N
	Total phosphorous	ASTM D515	0.2 mg/l as P
Water quality (Heavy metal)	Aluminum (Al)	St. Methods 3111E	0.1 mg/L
	Arsenic (As)	St. Methods 3112	1 µg/l
	Cadmium (Cd)	St. Methods 3111C	1 µg/l
	Cyanide (CN)	ASTM D2036	5 µg/l
	Chromium (Cr)	St. Methods 3111C	0.1 µg/l
	Cobalt (Co)	St. Methods 3111C	0.1 µg/l
	Copper (Cu)	St. Methods 3111C	0.1 µg/l
	Iron (Fe)	St. Methods 3111C	0.01 mg/l
	Methyl Mercury (Hg)	Home-made method	5 µg/l
	Mercury (Hg)	St. Methods 3112	1 µg/l
	Manganese (Mn)	St. Methods 3111C	0.1 µg/l
	Magnesium (Mg)	St. Methods 2340C	0.05 mg/l
	Nickel (Ni)	St. Methods 3111C	0.1 µg/l
	Lead (Pb)	St. Methods 3111C	0.1 µg/l
	Zinc (Zn)	St. Methods 3111C	0.01 mg/l
	Phenols	ASTM D1783	1 µg/l
Sediment quality	Specific Gravity	ISO 7202	---
	Moisture Content	ISO 11465	---
	Total Organic Carbon (TOC)	Based on the manual of TOC analyzer	0.1 Mass %
	Total Petroleum Hydrocarbon (TPH)	ASTM D 5368, D 5369, D7066	0.7 µg/g
	Aluminum (Al)	ASTM D 3974, St. Methods	25 µg/g
	Arsenic (As)	ASTM D 3974, St. Methods 3112	0.025 µg/g
	Cadmium (Cd)	ASTM D 3974, St. Methods	2 µg/g
	Cyanide (CN)	ASTM D2036	0.1 µg/g
	Chromium (total)	ASTM D 3974, St. Methods	2 µg/g
	Chromium (Cr+6)	ASTM D 3974, St. Methods	---
	Cobalt (Co)	ASTM D 3974, St. Methods	2 µg/g
	Copper (Cu)	ASTM D 3974, St. Methods	2 µg/g
	Iron (Fe)	ASTM D 3974, St. Methods	2 µg/g
	Methyl Mercury (Hg)	JRC technical reports EUR 25830	0.01 µg/g
	Mercury (Hg)	US EPA 3200, St. Methods 3112	0.025 µg/g
	Manganese (Mn)	ASTM D 3974, St. Methods	2 µg/g
	Magnesium (Mg)	ASTM D 3974, St. Methods	2 µg/g
	Nickel (Ni)	ASTM D 3974, St. Methods	2 µg/g
	Lead (Pb)	ASTM D 3974, St. Methods	2 µg/g
	Zinc (Zn)	ASTM D 3974, St. Methods	2 µg/g
	Total Sulfur (T-S)	Based on sulfur analyzer's manual	---

Table 2.4.4 Equipment Used for Chemical Analysis

Equipment	Equipment Model
Atomic Absorption Spectroscopy	Perkin Elmer AAS-2380 & AAnalyst 700
UV-Vis spectrometer	PG instrument, T 80+
Water purification system	
TOC analyzer	Rosemount analytical, Dohrmann DC-190

3 Results of the Survey

3.1 Survey in April 2013

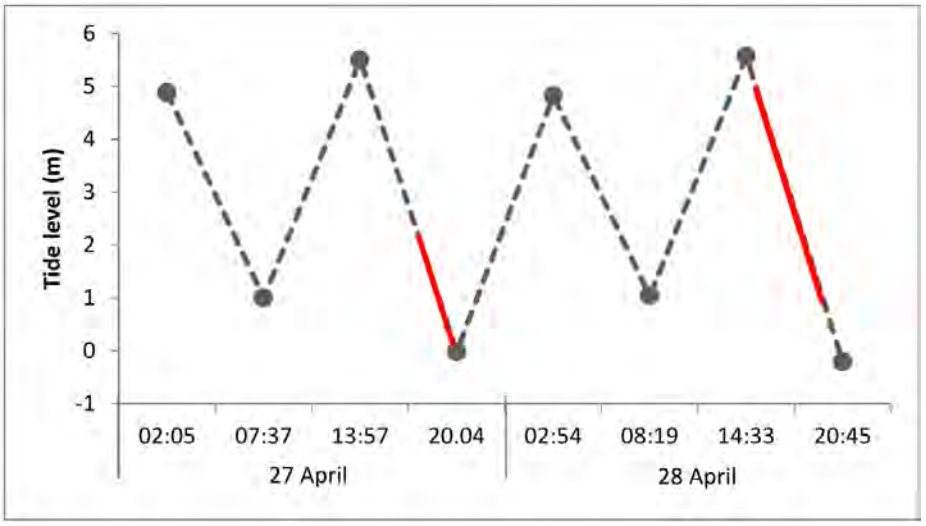
3.1.1 Survey Timing

shows the tiof table of the survey and Figure 3.1.1 shows the tide timing at the survey, respectively.

Table 3.1.1 Time Table of the Survey (April, 2013)

Date	Time	Site	Note
Saturday, 27 April 2013	16 to 20	MS-1 to MS-6	Water sampling & In-situ monitoring
Sunday, 28 April 2013	15 to 19	MS-7 & MS-8	

Source: Study team



Source: Tide table (http://www.iranhydrography.org/default.asp)

Red line shows the timing of the survey

Figure 3.1.1 Tide Timing at the Survey (April, 2013)

3.1.2 Result of the Survey

Summary of the survey results is presented in Table 3.1.2 and raw data is stored in Annex A.data is stored in Annex A.

Table 3.1.2 Summary of the Survey Result

Survey date: Apr. 27-28, 2013

Category	Parameter	Unit	Environmental standard (*1)	Apr		
				Min	Max	Ave
Water quality (Field measurement)	Water temperature	°C	(*2)	23.9	26.5	24.8
	Salinity	-	(*3)	41.00	44.30	43.17
	Conductivity	mS/cm		64.2	67.0	66.0
	pH	-	6.5-9.0	8.12	8.79	8.24
	DO	mg/L	> 3 (*4)	7.45	7.86	7.65
Water quality (Analysis: general parameters)	Turbidity	NTU		9	166	105
	Suspended solid	mg/L	(*5)	2	112	55
	COD	mg/L as O2	5	8	16	14
	TOC	mg/L as C		1.6	1.9	1.8
	Oil contents	mg/L	(*6)	< 0.2	< 0.2	< 0.2
	Coliform bacteria (*10)	MPN Index/100ml	500 (*7)	<2	<2	<2
	Total nitrogen	mg/L as N	0.4 (*8)	0.67	4.20	2.70
	Total phosphorous	mg/L as P	0.045 (*9)	<0.2	<0.2	<0.2

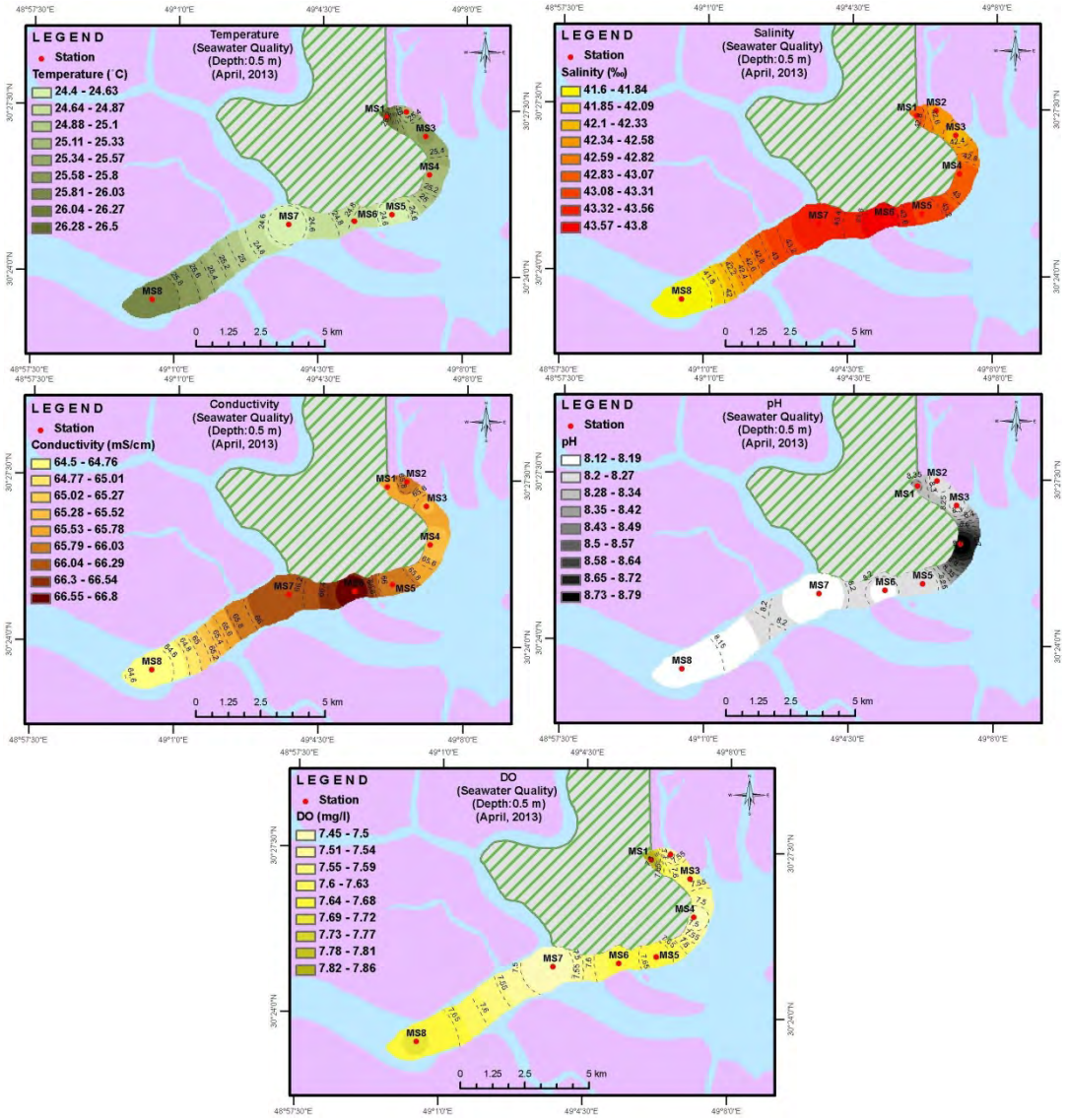
Source: Study team
Note: Red letter means excess of the standard/criteria value
*1: Standard for Ambient Water in Persian Gulf and Oman Sea (draft), Class 6: Industrial zone or Port, DOE.
*2 Water temperature: ±3 of natural temperature of receptive source
*3 Salinity: It should be no more than 10 percent of minimum natural salinity of the region.
*4 DO: 40% of Saturation
*5 Suspended Solid: Its increase should not be more than its daily, monthly, annual average considering standard deviation.
*6 Oil contents: There should be no oil layer, foam visible on its surface.
*7 Coliform bacteria: Fecal coliform should be less than 100 CFU/100ml.
*8 Total nitrogen: The value of Nitrate-nitrogen is used in this table.
*9 Total phosphorous: The value of Phosphate-phosphorus is used in this table.
*10 Total coliform was analyzed in Apr., May, Jun. and Aug-1, while fecal coliform analyzed in Aug-2, Sep. and Oct.

3.1.3 Discussion

a) Field measurement

Horizontal distribution of the field measurement parameters (in-situ parameters) is shown in Figure 3.1.2.

The seawater temperature ranges from 23.9–26.5°C with an average of 24.7 °C. The electrical conductivity (EC) varies from 64.2–67.0 mS/cm (average, 65.95 mS/cm). The minimum, maximum and average of salinity in the seawater samples are 41.00, 44.30 and 43.15, respectively. The highest values of conductivity and salinity shows in MS-2 and MS-5, respectively. The range and average of pH are 8.12–8.79 and 8.26. The dissolved oxygen (DO) varies between 7.45–7.86 mg/l with an average of 7.65 mg/l. Vertical profiles of in-situ parameters are shown in Annex D.



Source: Study team

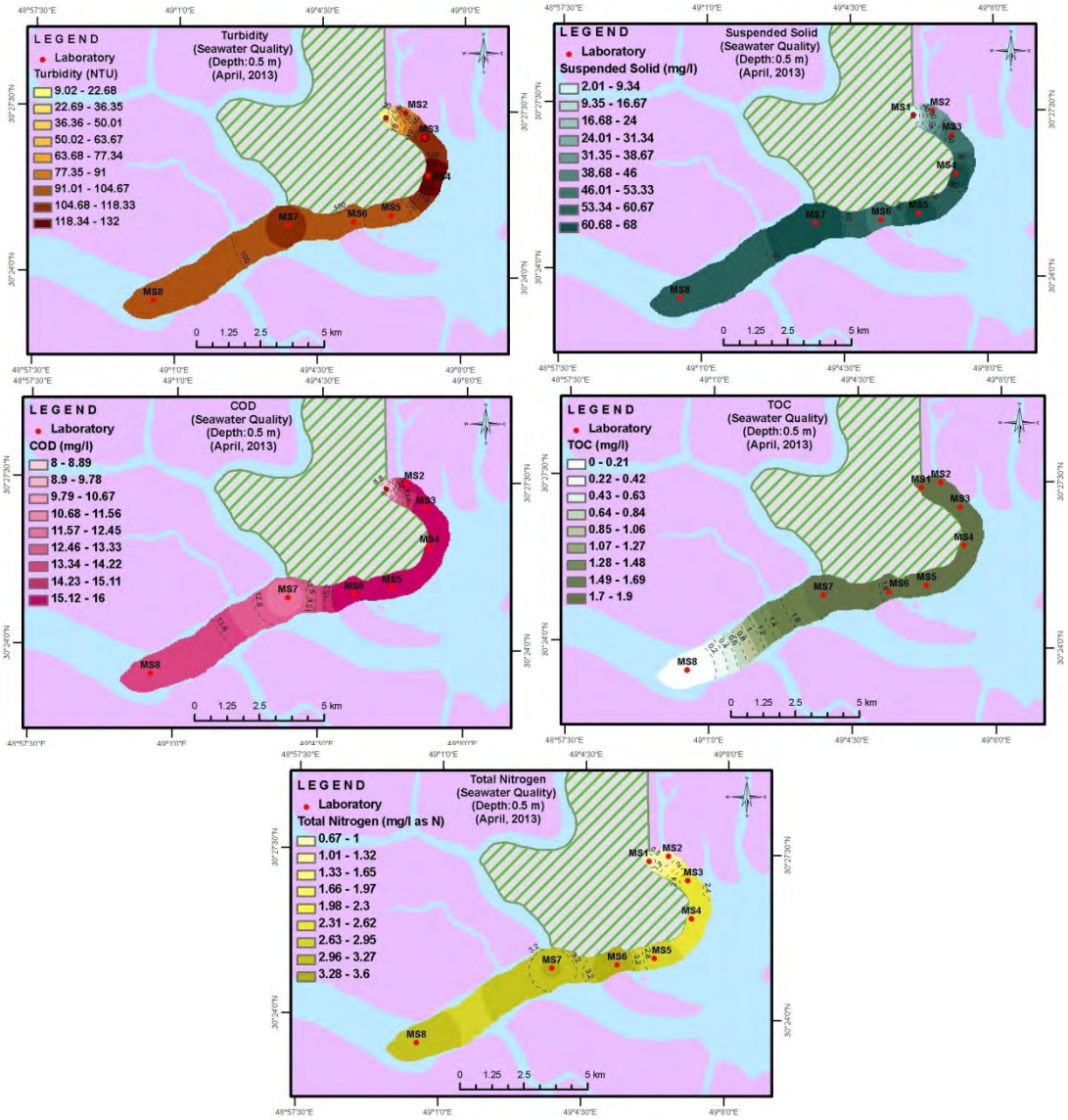
Figure 3.1.2 Horizontal Distribution of In-situ Parameters

b) Laboratory analysis

Horizontal distribution of the parameters of laboratory analysis (laboratory parameters) is shown in Figure 3.1.3.

Turbidity in MS-3 and MS-8 is higher than the other stations. Distribution of suspended solid is similar to the one of turbidity, MS-3 and MS-8 are higher than other sampling points. Chemical oxygen demand (COD) ranges between 8 and 16 mg/l with the average of 14.33 mg/l. Total organic carbon (TOC) values are similar to COD values and the variation of TOC are very low. Total nitrogen shows highest in MS-5 (2m below surface). It might be related to the discharge from PETZONE.

Vertical profiles of laboratory parameters are shown in Annex D.



Source: Study team

Figure 3.1.3 Horizontal Distribution of the Laboratory Parameters

3.2 Survey in May 2013

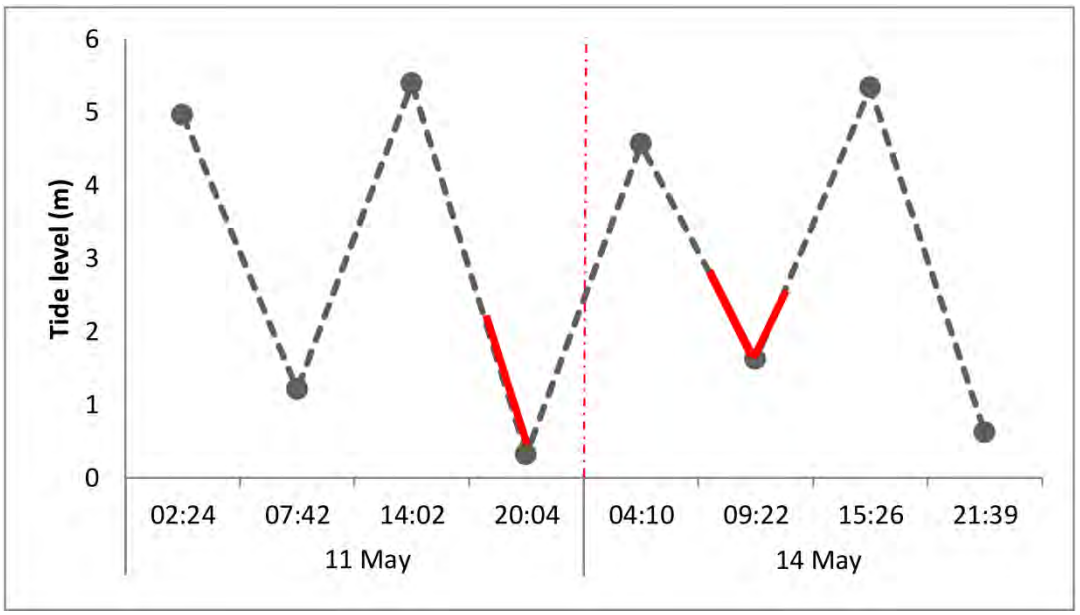
3.2.1 Survey Timing

Table 3.2.1 shows the timetable of the survey and Figure 3.2.1 shows the tide timing of the survey, respectively.

Table 3.2.1 Time Table of the Survey (May, 2013)

Date	Time	Site	Note
Saturday, 11 May 2013	16 to 19	MS-1 to MS-4	Water, sediment sampling & in-situ monitoring
Sunday, 12 May 2013	7 to 11	MS-5 to MS-6	
Tuesday, 14 May 2013	7 to 11	MS-7 to MS-8	

Source: Study team



Source: Tide table (http://www.iranhydrography.org/default.asp)

he red line shows the timing of the survey

Figure 3.2.1 Tide Timing at the Survey (May, 2013)

3.2.2 Result of the Survey

Summary of the survey results is shown in Table 3.2.2 and raw data is stored in Annex A.

Table 3.2.2 Summary of the Survey Result

Survey date: May 11-12, 14, 2013

Category	Parameter	Unit	Environmental standard (*1)	May		
				Min	Max	Ave
Water quality (Field measurement)	Water temperature	°C	(*2)	26.6	31.9	27.8
	Salinity	-	(*3)	41.70	43.10	42.72
	Conductivity	mS/cm		67.7	74.4	69.6
	pH	-	6.5-9.0	8.14	8.27	8.20
	DO	mg/L	> 3 (*4)	6.53	7.69	7.27
Water quality (Analysis: general parameters)	Turbidity	NTU		22	157	83
	Suspended solid	mg/L	(*5)	20	168	78
	COD	mg/L as O2	5	8	18	15
	TOC	mg/L as C		1.7	2.1	1.9
	Oil contents	mg/L	(*6)	< 0.2	< 0.2	< 0.2
	Coliform bacteria (*10)	MPN Index/100ml	500 (*7)	<2	<2	<2
	Total nitrogen	mg/L as N	0.4 (*8)	0.68	0.88	0.83
	Total phosphorous	mg/L as P	0.045 (*9)	<0.2	<0.2	<0.2
Water quality (Analysis: heavy metals)	Aluminum (Al)	mg/L		<0.1	<0.1	<0.1
	Arsenic (As)	micro-g/L	50	<1	<1	<1
	Cadmium (Cd)	micro-g/L	10	<0.1	<0.1	<0.1
	Cyanide (CN)	micro-g/L		<5	<5	<5
	Chromium (Cr)	micro-g/L	50	<0.1	0.5	0.3
	Cobalt (Co)	micro-g/L		0.1	1.5	0.6
	Copper (Cu)	micro-g/L	50	<0.1	0.5	0.3
	Iron (Fe)	mg/L	0.3	0.01	0.03	0.02
	Methyl Mercury (Hg)	micro-g/L	0.2	-	-	-
	Mercury (Hg)	micro-g/L	0.5	<1	<1	<1
	Manganese (Mn)	micro-g/L	100	<0.1	<0.1	<0.1
	Magnesium (Mg)	mg/L		1681	1717	1693
	Nickel (Ni)	micro-g/L	50	2	4.3	2.7
	Lead (Pb)	micro-g/L	40	0.30	1.20	0.68
	Zinc (Zn)	mg/L	100	<0.01	<0.01	<0.01
	Phenols	micro-g/L	0.05	<1	<1	<1
Sediment quality (Analysis)	Specific Gravity	g/cm3		1.1	1.6	1.4
	Moisture Content	Mass%		0.31	0.85	0.66
	Total Organic Carbon (TOC)	Mass%		0.18	0.54	0.34
	Total Petroleum Hydrocarbon	micro-g/g.dw	550	41	158	111
	Aluminum (Al)	mg/g.dw		3.2	11.6	9.7
	Arsenic (As)	micro-g/g.dw	20	0.1	2.1	1.3

Category	Parameter	Unit	Environmental standard (*1)	May		
				Min	Max	Ave
	Cadmium (Cd)	micro-g/g.dw	1.5	3.2	4.2	3.8
	Cyanide (CN)	micro-g/g.dw		<0.1	<0.1	<0.1
	Chromium (total)	micro-g/g.dw	80	13.9	38.2	30.9
	Chromium (Cr+6)	micro-g/g.dw		-	-	-
	Cobalt (Co)	micro-g/g.dw		12.5	37.7	22.3
	Copper (Cu)	micro-g/g.dw	65	3.2	26.4	16.1
	Iron (Fe)	mg/g.dw		6.8	22.4	16.1
	Methyl Mercury (Hg)	micro-g/g.dw		-	-	-
	Mercury (Hg)	micro-g/g.dw	0.15	<0.05	0.2	0.1
	Manganese (Mn)	micro-g/g.dw		239	510	434
	Magnesium (Mg)	mg/g.dw		19.1	54.6	44.6
	Nickel (Ni)	micro-g/g.dw	21	31	187	105
	Lead (Pb)	micro-g/g.dw	50	25.6	29.7	28.4
	Zinc (Zn)	micro-g/g.dw	200	46	118	86
	Total Sulfur (T-S)	mg/g		0.03	2.70	0.99
	Grain size			-	-	-
	Sand (>0.04mm & <1mm)	%		6.0	86.0	20.3
	Silt (>0.002mm & <0.04mm)	%		5.0	47.0	38.0
	Clay (>0.0002mm & <0.002mm)	%		9.0	51.0	41.8

Source: Study team

Note: Red letter means excess of the standard/criteria value

*1: Standard for Ambient Water in Persian Gulf and Oman Sea (draft), Class 6: Industrial zone or Port, DOE.
*2 Water temperature: ±3 of natural temperature of receptive source
*3 Salinity: It should be no more than 10 percent of minimum natural salinity of the region.
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*6 Oil contents: There should be no oil layer, foam visible on its surface.
*7 Coliform bacteria: Fecal coliform should be less than 100 CFU/100ml.
*8 Total nitrogen: The value of Nitrate-nitrogen is used in this table.
*9 Total phosphorous: The value of Phosphate-phosphorus is used in this table.
*10 Total coliform was analyzed in Apr., May, Jun. and Aug-1, while fecal coliform analyzed in Aug-2, Sep. and Oct.

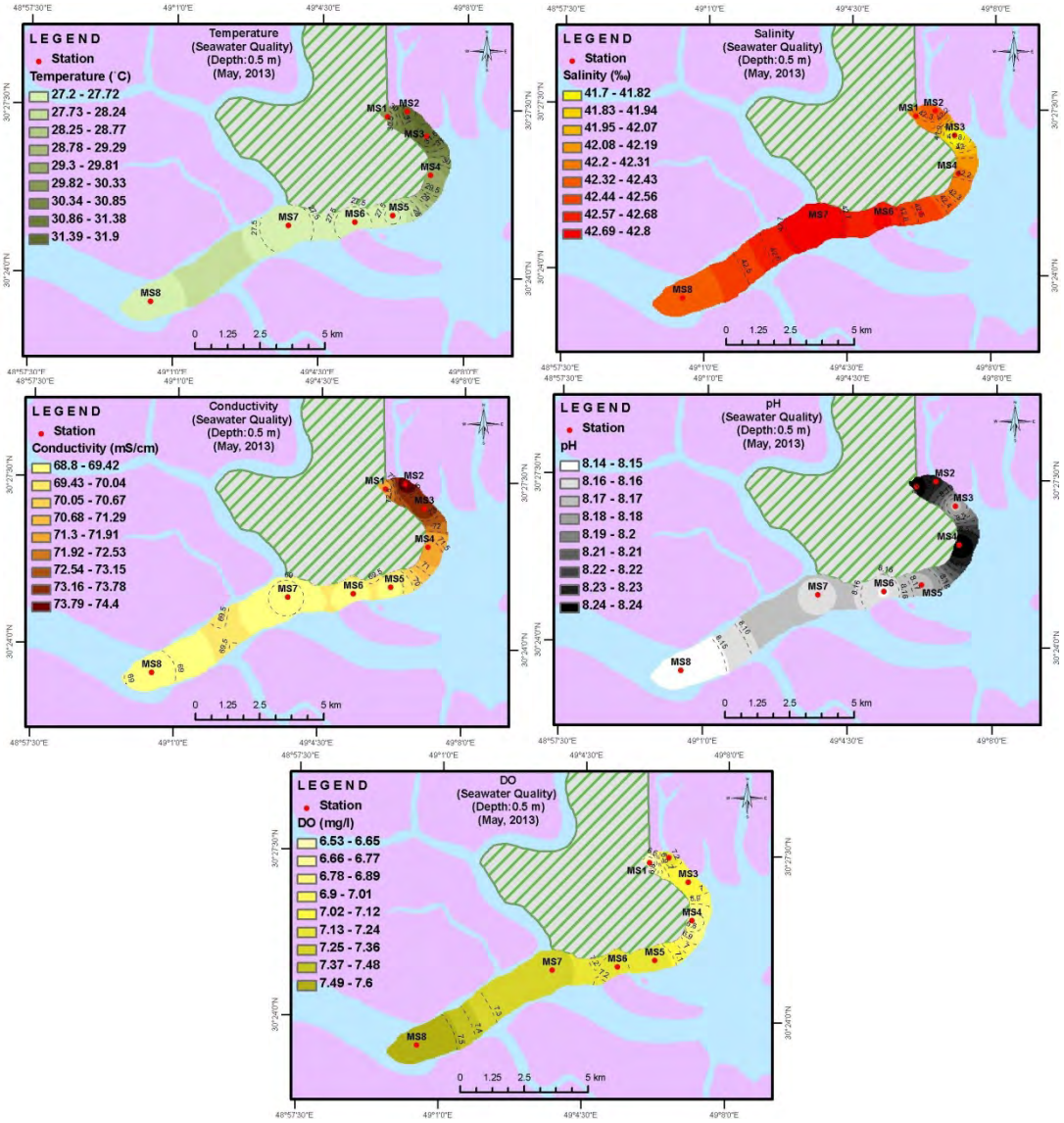
3.2.3 Discussion

a) Field measurement

Horizontal distribution of the field measurement parameters (in-situ parameters) are shown in Figure 3.2.2.

The water temperature ranges from 26.6–31.9 °C with an average of 27.82 °C. The high values of temperature are seen at stations from MS-1 to MS-4. The pH shows minor variations from 8.14

to 8.27, with the average value of 8.20. The ranges of DO in samples are between 6.53 and 7.69 mg/l with the average of 7.23 mg/l. The lowest DO concentration shows in MS-1, probably indicates that discharge of industrial effluents to the estuary. The minimum, maximum and average of EC values are 67.7, 74.4 and 69.64 mS/cm, respectively. The high conductivity is observed from MS-1 to MS-4. Salinity value in the study area indicates the Persian Gulf ranges (41.7-43.1, with an average of 42.7). Vertical profiles of in-situ parameters are presented in Annex D.

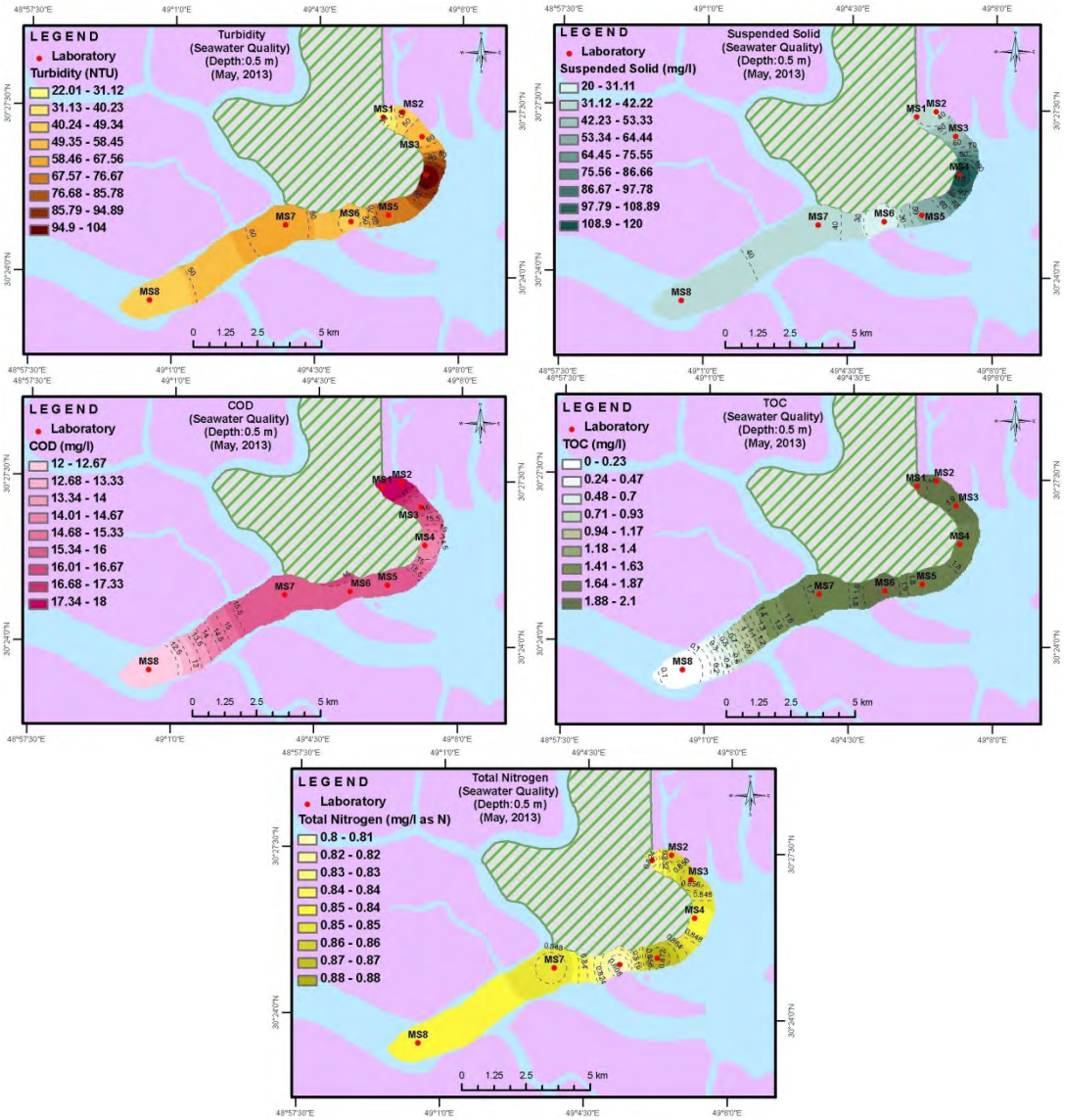


Source: Study team

Figure 3.2.2 Horizontal Distribution of In-situ Parameters

b) Laboratory analysis

Horizontal distribution of the laboratory analysis parameters (laboratory parameters) is shown in Figure 3.2.3.Turbidity in MS-2 (2m below surface) and MS-3 (2m below surface) is more than other stations. It appears that the water turbulence at the near bottom surface is the main factor. Suspended solid in MS-2 (2m below surface) and MS-3 (2m below surface) is turbid much more than other stations. The variation of COD is between 8 and 18 mg/l with the average of 14.7 mg/l. The maximum of TOC is recorded in MS-2 and TOC values show minor variation between stations. The variation of total nitrogen is very low in the area and the average value is 0.83 mg/l as N. Vertical profiles of laboratory parameters are presented in Annex D.



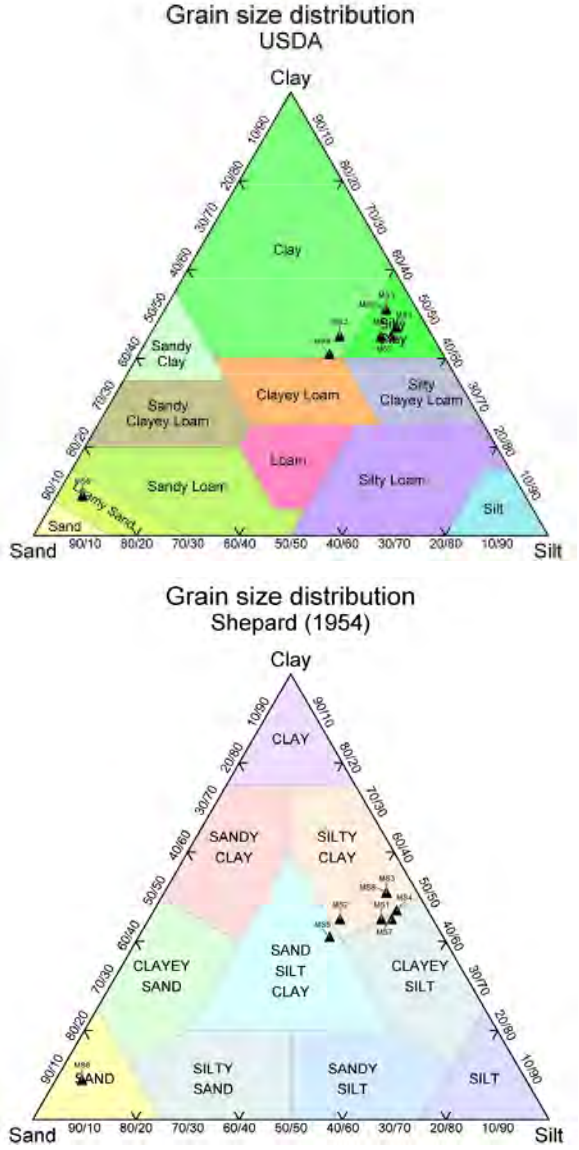
Source: Study team

Figure 3.2.3 Horizontal Distribution of Laboratory Parameters

c) Sediment texture

Surface sediments mainly consist of fine materials in the study area (see Figure 3.2.4). According to the USDA classification (Schoeneberger et al., 2002), texture of sediment samples is categorized into Clay (MS-2 and MS-5) and Silty-Clay (MS-1, MS-3, MS-4, MS-7 and MS-8). Particle size distribution shows significantly different in MS-6 that classified as the Loamy-Sand texture.

According to the Shepard classification (Shepard, 1954), the texture of the surface sediment in the survey area is categorized into Silty-Clay (MS-2, MS-3 and MS-8), Clayey-Silt (MS-1, MS-4 and MS-7), Sand-Silt-Caly (MS-5) and Sand (MS-6).



Source: Schoeneberger et al., 2002 and Shepard, 1954

Figure 3.2.4 Classification of Sediments

d) Heavy metals

Summary of the survey results is presented in Table 3.2.2 and raw data is stored in Annex A.data is stored in Annex A.

The result shows that Arsenic (As) in all seawater samples are less than 1 µg/l, while the concentration of As in sediment varies from 0.1 to 2.1 µg/g. The highest concentration is recorded in MS-8, (2.1µg/g), and the second highest station is MS-4 with 1.7µg/g arsenic. The least value of As observed in MS-5 (0.1µg/g). MS-1 and MS-2 show the same concentration and the other sampling points nearly show similar values (See Figure 3.2.6).

Cadmium (Cd) is not detected in seawater samples, but average of cadmium in sediment is 3.8 µg/g (See Figure 3.2.6). MS-6 shows the least concentration of Cd, 3.2 µg/g, and MS-1 shows the maximum concentration, 4.2 µg/g. The order of concentration of Cd in other stations is as follows:
MS-2 (4.0 µg/g)> MS-3 (3.8 µg/g)>MS-4 (3.8 µg/g)>MS-5 (3.4 µg/g)> MS-7(3.9 µg/g)> MS-8 (3.7 µg/g)

Chromium (Cr) level in sediment is much higher than seawater samples. Cr in seawater samples shows between 0.1 – 0.5 µg/l with the highest concentration in MS-1 and MS-2 at 2m below surface and the lowest concentration in MS-7 and MS-8 at 2m below surface, and 10m below surface of MS-5 and MS-6 (less than 0.1 µg/l). The average concentration of Cr in sediment is 30.9 µg/g, with a maximum in MS-5, 38.2 µg/g and minimum in MS-6, 13.9 µg/g. Cr values for other stations are: MS-1, 35.4 µg/g, MS-2, 34.5 µg/g, MS-3, 34.4 µg/g, MS-4, 32.5 µg/g, MS-7, 31.0 µg/g and MS-8, 27.1 µg/g (See Figure 3.2.6).

Cobalt (Co) concentration in sediment and seawater samples are much different. Co in seawater varies between 0.1 – 1.5 µg/l. MS-1 shows the maximum level of Co, 1.5 µg/l, and the minimum is observed in MS-8 at 10m below the surface, 0.1 µg/l. The level of cobalt decreases from MS-1 to MS-8 (See Figure 3.2.5). The average concentration of Co in sediment is 22.3 µg/g, with a maximum in MS-1, 37.7 µg/g and minimum in MS-6, 12.5 µg/g. Co values for other stations are: MS-2, 18.9 µg/g, MS-3, 22.0 µg/g, MS-4, 23.9 µg/g, MS-5, 18.9 µg/g, MS-7, 23.1 µg/g, and MS-8, 21.6 µg/g (See Figure 3.2.6).

Copper (Cu) in seawater ranges 0.1- 0.5 µg/l. MS-8 at 10m below the surface shows the minimum level of Cu, 0.1 µg/l, and MS-1, MS-2 (2m below surface) and MS-5 (all depths)

show maximum concentration, 0.5µg/l (See Figure 3.2.5). The average concentration of Cu in sediment is 16.1 µg/g , with a maximum in MS-1, 26.4 µg/g, and the minimum in MS-6 , 3.2 µg/g. Cu values in other stations are: MS-2, 18.0 µg/g, MS-3 and MS-4, 19.1 µg/g, MS-5, 12.6 µg/g, MS-7, 17.4 µg/g and MS-8, 13.3 µg/g (See Figure 3.2.6).

The concentration of Iron (Fe) in seawater and sediment varies with a big difference. Fe level ranges from 0.01 to 0.03 mg/l in seawater samples (See Figure 3.2.5), while sediments show average 16.1 mg/g. The maximum concentration of iron is observed in MS-1, 22.4 mg/g. MS-6 shows the lowest level of Fe, 6.8 mg/g. Fe values in other stations are: MS-2, 16.9 mg/g, MS-3, 17.5 mg/g, MS-4, 17.3 mg/g, MS-5, 15.7 mg/g, MS-7, 17.2 mg/g and MS-8, 14.7 mg/g (See Figure 3.2.6).

Nickel (Ni) in seawater ranges 2.0- 4.3 µg/l. MS-6 at 2m below surface shows the maximum level of Ni, 4.3 µg/l, while 2.3µg/l in 0.5m below the surface and 2.9 µg/l in 10m below surface, respectively. On the other hand, stations MS-8 show the minimum level of Ni at 10m below surface, 2.0 µg/l. MS-2 and MS-7 show the second greatest Ni concentration, average 3.3 µg/l (See Figure 3.2.5). The average concentration of Ni in sediment is 105 µg/g with a maximum in MS-1, 187 µg/g, and minimum in MS-6, 31 µg/g. Ni values in other stations are: MS-2, 102 µg/g, MS-3, 108 µg/g, MS-4, 106 µg/g, MS-5, 95 µg/g, MS-7, 112 µg/g and MS-8, 97 µg/g (See Figure 3.2.6).

Lead (Pb) in seawater ranges between 0.1 to 1.2 µg/l. MS-7 and MS-8 in 10m below surface show the minimum level of Pb, less than 0.1 µg/l, and MS-2 (2m below surface) and MS-7 (0.5m below surface) show the maximum concentration, 1.2 µg/l. The second greatest concentration is observed in MS-4, 1.1 µg/l (See Figure 3.2.5). The average concentration of Pb in sediment is 28.4 µg/g, with a maximum in MS-6, 29.7 µg/g and minimum in MS-5, 25.6 µg/g. Pb values in other stations are: MS-1, 27.8 µg/g, MS-2 and MS-3, 29.1 µg/g, MS-4, 29.6 µg/g, MS-7, 28.4 µg/g and MS-8, 28.0 µg/g (See Figure 3.2.6).

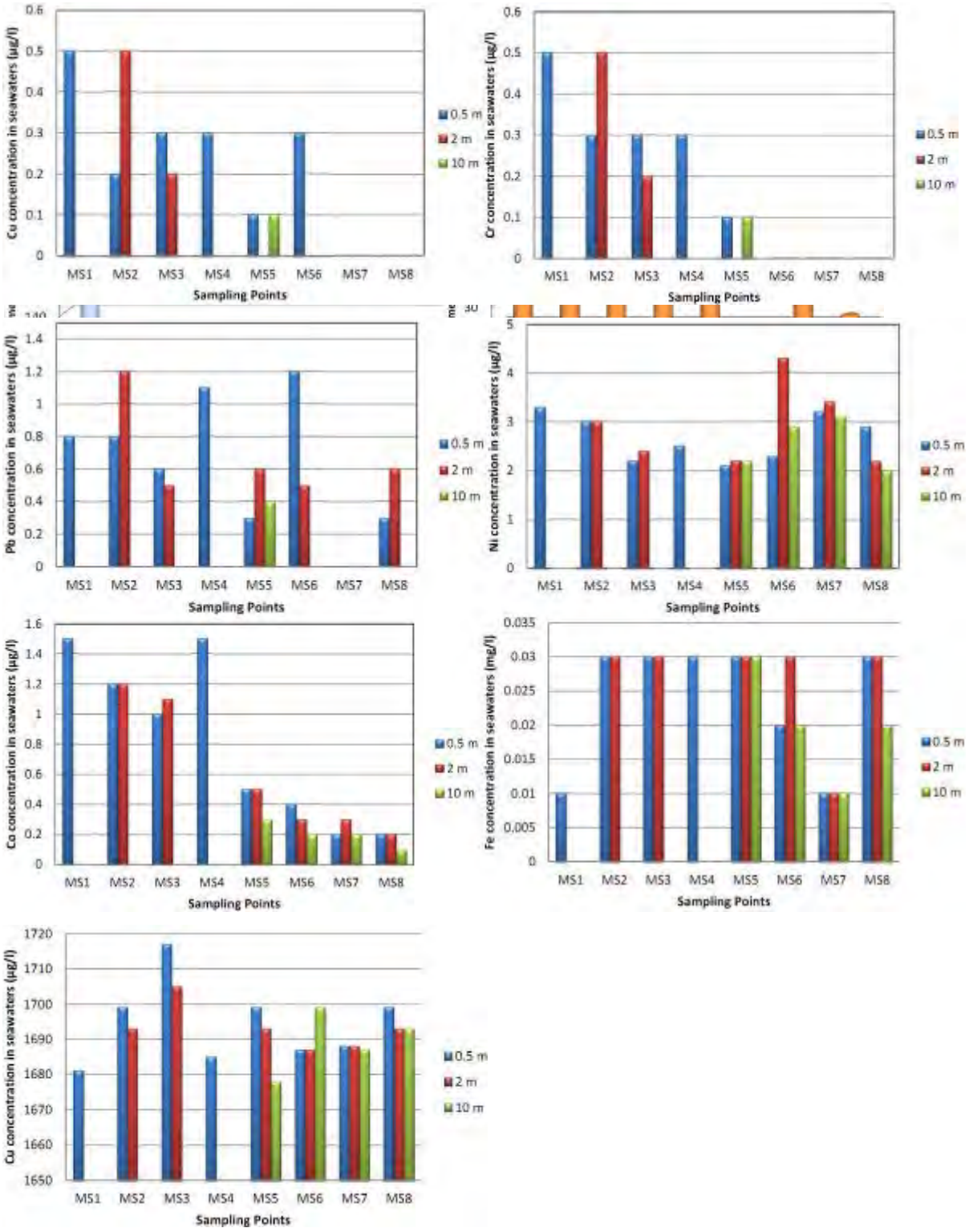
The result showed that Zinc (Zn) in all seawater samples is less than 0.01 mg/l , while the concentration of Zn in sediment varies. The average concentration of Zn in sediment is 86.0 µg/g, with a maximum in MS-1, 118 µg/g, and minimum in MS-6, 46.0 µg/g. Zn values in other stations are: MS-2, 109 µg/g, MS-3, 103 µg/g, MS-4, 115 µg/g, MS-5, 63.0 µg/g, MS-7, 70.0 µg/g and MS-8, 64.0 µg/g (See Figure 3.2.6).

Seawater samples are free of Manganese (Mn), less than 0.1 µg/l. While sediments show a much higher concentration of Mn. The average concentration of Mn in sediment is 434 µg/g with a maximum in MS-7, 510 µg/g, and minimum in MS-6, 239 µg/g. Mn values in other stations are: MS-1, 458 µg/g, MS-2, 451 µg/g, MS-3, 463 µg/g, MS-4, 454 µg/g, MS-5, 443 µg/g and MS-8, 457 µg/g (See Figure 3.2.6).

Methyl Mercury (Me-Hg) and Mercury (Hg) in seawater samples are less than 1 µg/l. Also, Me-Hg in sediment samples is less than 0.01 µg/g, except MS-1 with 0.16 µg/g. While Hg in sediment is not detected in MS-5, MS-6, MS-7 and MS-8, MS-1 to MS-4 show different concentration of Hg. Maximum Hg is observed in MS-1, 0.16 µg/g, and minimum Hg is in MS-2 and MS-4, 0.07 µg/g. Hg concentration in MS-3 is 0.15 µg/g (See Figure 3.2.6).

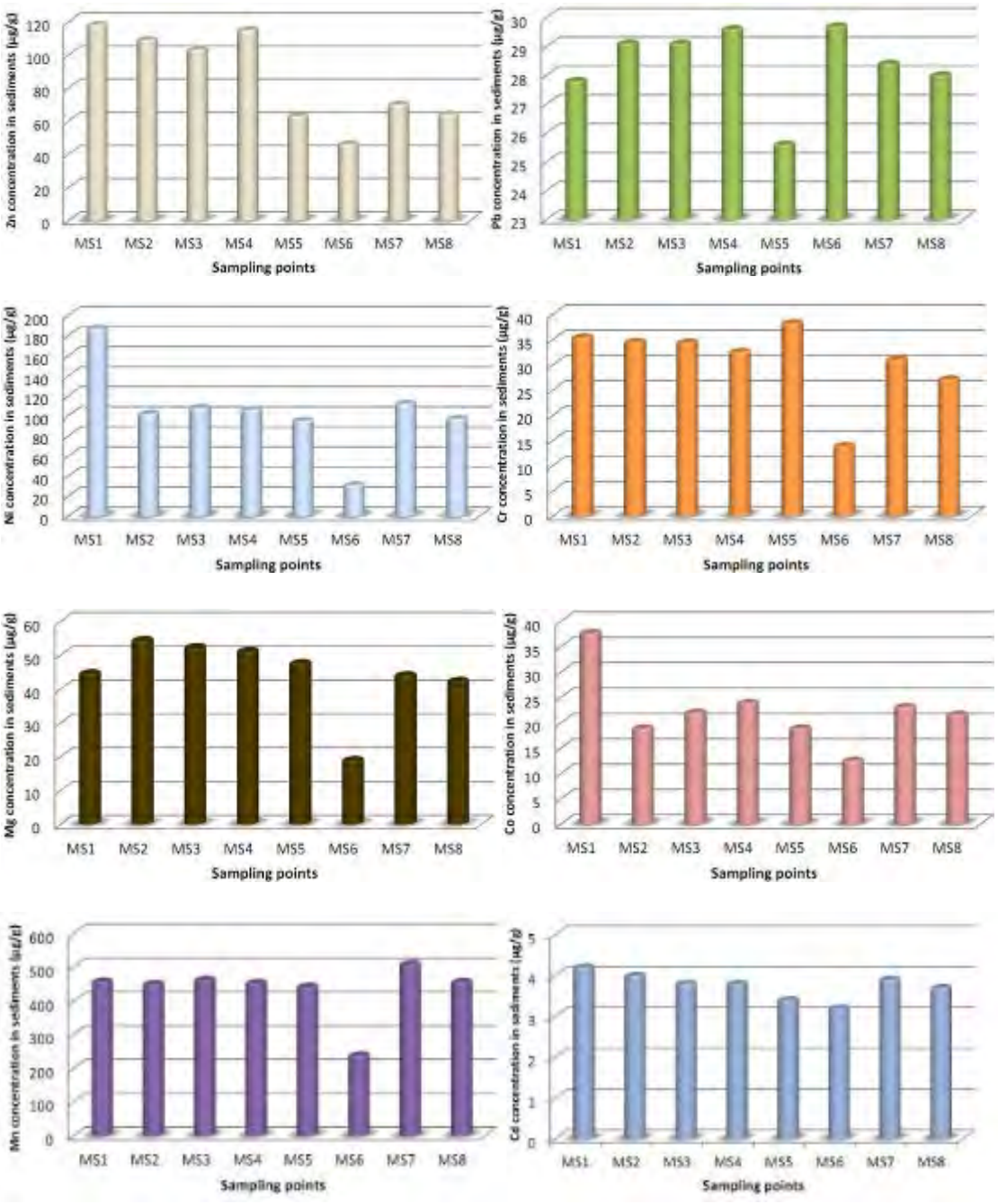
The concentration of Aluminum (Al) in seawater and sediment samples is not on the same scale because of erratic changes in concentration values in sediment. Seawater samples show less than 0.1mg/l Al, while sediments show average 9.7 mg/g. Maximum concentration of Al is observed in MS-4, 11.6 mg/g. MS-6 shows the lowest level of Al, 3.2 mg/g. All values in other stations are: MS-1, 11.2 mg/g, MS-2, 11.0 mg/g, MS-3, 11.3 mg/g, MS-5, 9.8 mg/g , MS-7, 10.1 mg/g and MS-8, 9.0 mg/g (See Figure 3.2.6).

Magnesium (Mg) concentration in seawater samples ranges from 1717 to 1681 mg/l. MS-1 show minimum level of Mg, 1681 mg/l and MS-3 at 0.5 m below surface show the maximum concentration of Mg, 1717 mg/l. 2m below surface at MS-3 shows 1705 mg/l. The concentration of Mg in other station are: MS-2 at 0.5m below surface, 1699mg/l, at 2m below surface, 1693mg/l, MS-4, 1685 mg/l, MS-5 at 0.5m below surface, 1699mg/l, at 2m below surface, 1693mg/l, at 10m below surface, 1687mg/l, MS-6 at 0.5m and 2m below surface, 1687mg/l, at 10m below surface, 1699 mg/l, MS-7 at 0.5m and 2m below surface, 1688mg/l, at 10m below surface, 1687 mg/l and MS-8 at 0.5m below surface, 1699mg/l, at 2m and 10m below surface, 1693mg/l (See Figure 3.2.5). The average concentration of Mg in sediment is 44.6 mg/g. Maximum level of Mg is observed in MS-2, 54.6 mg/g, and MS-6 show the minimum concentration, 19.1 mg/g. Other stations show various concentrations of Mg; MS-1, 44.8 mg/g , MS-3, 52.5 mg/g , MS-4, 51.4 mg/g, MS-5, 47.8mg/g, MS-7, 44.2 mg/g and MS-8, 42.5 mg/g (See Figure 3.2.6).



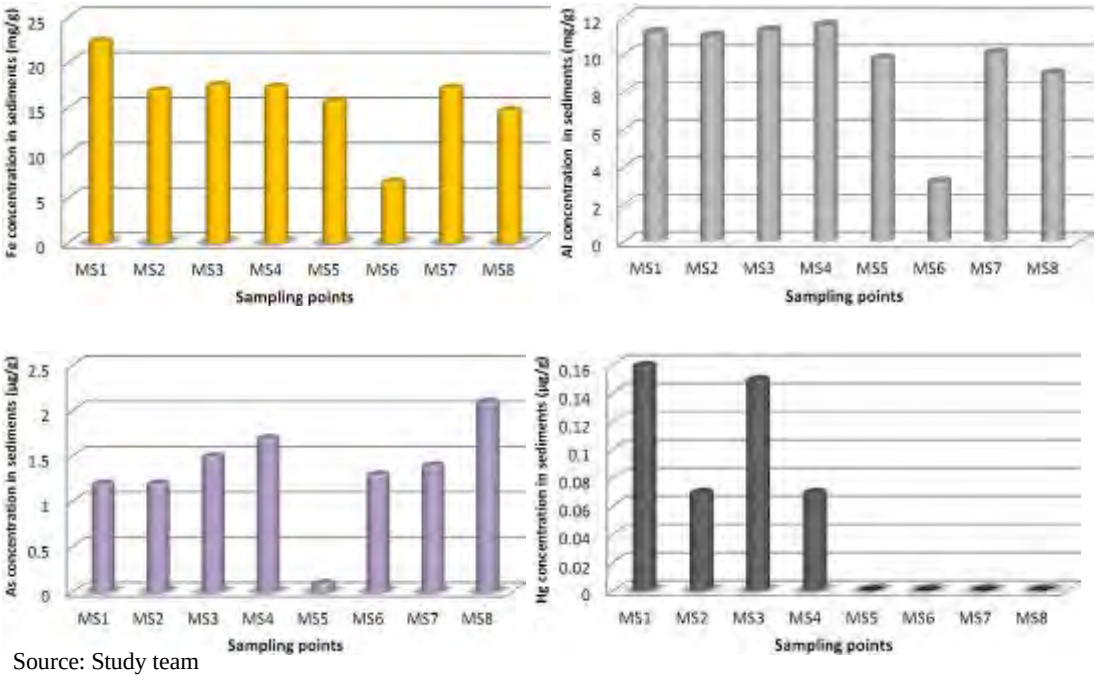
Source: Study team

Figure 3.2.5 Heavy Metal Concentrations in Seawater Samples



Source: Study team

Figure 3.2.6 (1) Heavy Metal Concentrations in Sediment Samples



Source: Study team

Figure 3.2.6 (2) Heavy Metal Concentrations in Sediment Samples

The average concentrations of trace elements and heavy metals in the study area (May 2013) and their concentration in seawater in south Persian Gulf countries including Bahrain, UAE, Oman, Saudi Arabia and also average concentration of trace elements in natural seawaters (Kabata-Pendias and Pendias, 1999) are shown in Table 3.2.3. The maximum concentrations of Cu and Zn, Fe, Hg and Pb, and Cd are recorded in UAE, Saudi Arabia, Bahrain and Oman, respectively. Each element shows minor variation in concentrations (with the exception of Pb, Co and Ni), with low standard deviations.

By comparing with the natural seawaters (Kabata-Pendias and Pendias, 1999), the average concentrations of Co, Cu, Fe, Ni and Pb are higher than the average concentrations of trace elements in natural seawaters (See Figure 3.2.7). 100% of the total of seawater samples at all depths for Co, Fe and Ni, 67% for Pb, 28% for Cu, and 11% for Cr exceed the average concentration of natural seawaters (See Figure 3.2.8). Thus, Co, Fe, Ni, Pb, Cu and Cr are the major pollutants in the study area may pose health risk of aquatic life and the residents in the area and the water receiving areas.

Table 3.2.3 Comparison of Heavy Metals Concentration in Seawater between the Study Area and Other Persian Gulf Countries

Parameter	Unit	Study Result			Bahrain[A]	UAE A	Oman A	Saudi Arabia[A]	CCME[B]	Mahshahr[C]	Seawater[D]
		Min	Max	Mean							
Al	mg/	<0.	<0.	<0.1	---	---	---	---	---	---	0.002
As	µ/L	<1	<1	<1	---	---	---	---	12.5	<5	7
Cd	µ/L	<0.	<0.	<0.1	11-16	<2-12	30	0.31-	0.12	<10	0.1
Cr	µ/L	<0.	0.5	0.29	---	---	---	---	56 as	<10	0.3
Co	µ/L	0.1	1.5	0.61	---	---	---	---	---	<10	0.01
Cu	µ/L	<0.	0.5	0.28	20-30	80-	130	0.9-	---	<10	0.2
Fe	mg/	0.0	0.0	0.02	---	---	---	0.01-	---	0.038-	0.001
Hg	µ/L	<1	<1	<1	10-25	9-20	7	---	0.016	<2	0.02
Mn	µ/L	<0.	<0.	<0.1	---	---	---	---	---	---	0.2
Ni	µ/L	2.0	4.3	2.73	---	---	---	0.52-	---	<20	0.5
Pb	µ/L	0.3	1.2	0.68	20-	30-60	30	0.01-	---	<20	0.03
Zn	mg/	<0.	<0.	<0.0	0.06-	0.002-	0.4	0.005-	---	---	0.002

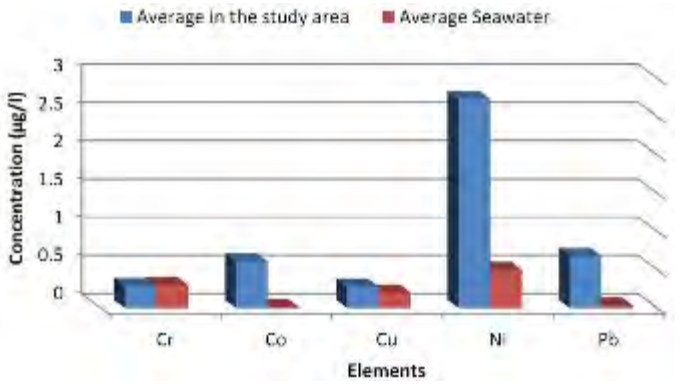
Source:

A: Heavy metal concentrations of seawater in south of Persian Gulf (Marine Pollution Bul., 1997).

B: Canadian Council of Ministers of the Environment 1999.

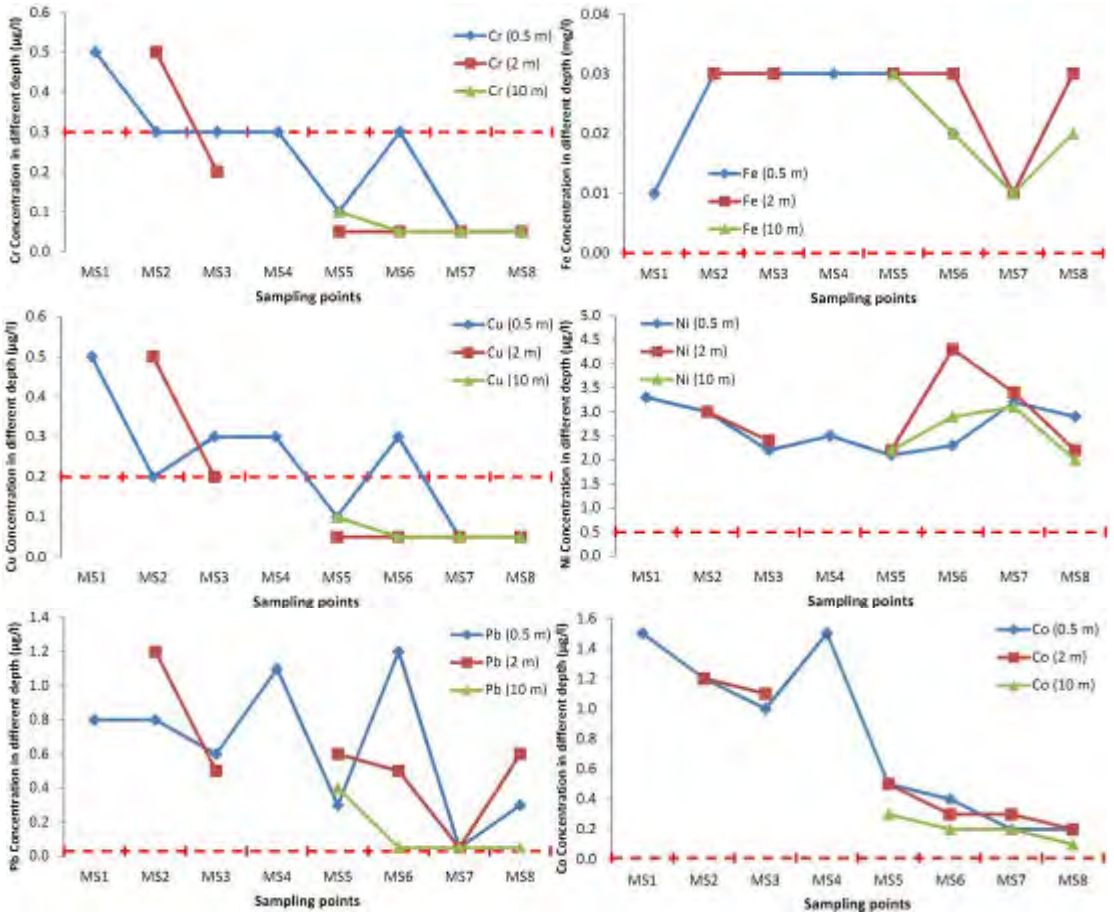
C: Heavy metal concentrations in sediment of PETZONE, 2008.

D: Mean concentrations of trace elements in natural seawater (Kabata-Pendias and Pendias, 1999)



Source: Kabata-Pendias and Pendias, 1999

Figure 3.2.7 Average Concentration of Cr, Co, Cu, Ni and Pb in the Study Area and Natural Seawater



Source: The study team and Kabata-Pendias and Pendias, 1999

The red dash line shows the average concentration in natural sea water.

Figure 3.2.8 Heavy Metal Concentration in Each Survey Point

The water quality guidelines for protection of aquatic life (CCME[1]) specifies only As, Cd, Cr^{3+} and Hg. The concentrations of these elements in the study area are lower than CCME standard.

The range and average concentrations of trace and heavy metals in the surface sediment expressed on a dry-weight are summarized in Table 3.2.2. This leads to the following ranking based on the concentrations:

Al>Fe>Mn>Ni>Zn>Cr>Pb>Co>Cu>Cd>As>Hg

The average concentrations of trace elements and heavy metals in sediment samples of the study area (May 2013) and their concentration in sediment of south Persian Gulf countries (ROPME, 1998-2000) including Bahrain, UAE, Oman, Saudi Arabia, Qatar, Kuwait and also mean concentrations of trace elements in continental crust (Mason and Moore, 1995; Reimann and Caritat, 1998) are presented in Table 3.2.4 and Figure 3.2.9. The maximum concentrations of

[1] CCME: Canadian Council of Ministers of the Environment

Cd, Co, Cr and Zn are recorded in Kuwait, Ni in Oman, Pb in Bahrain, and Al, Fe and Cu in continental crust. As and Hg concentrations are not measured in ROPME project, whereas in this study, Hg concentration is higher than average of continental crust.

Table 3.2.4 Comparison of Heavy Metal Concentration in Sediment between the Study Area and Other Persian Gulf Countries

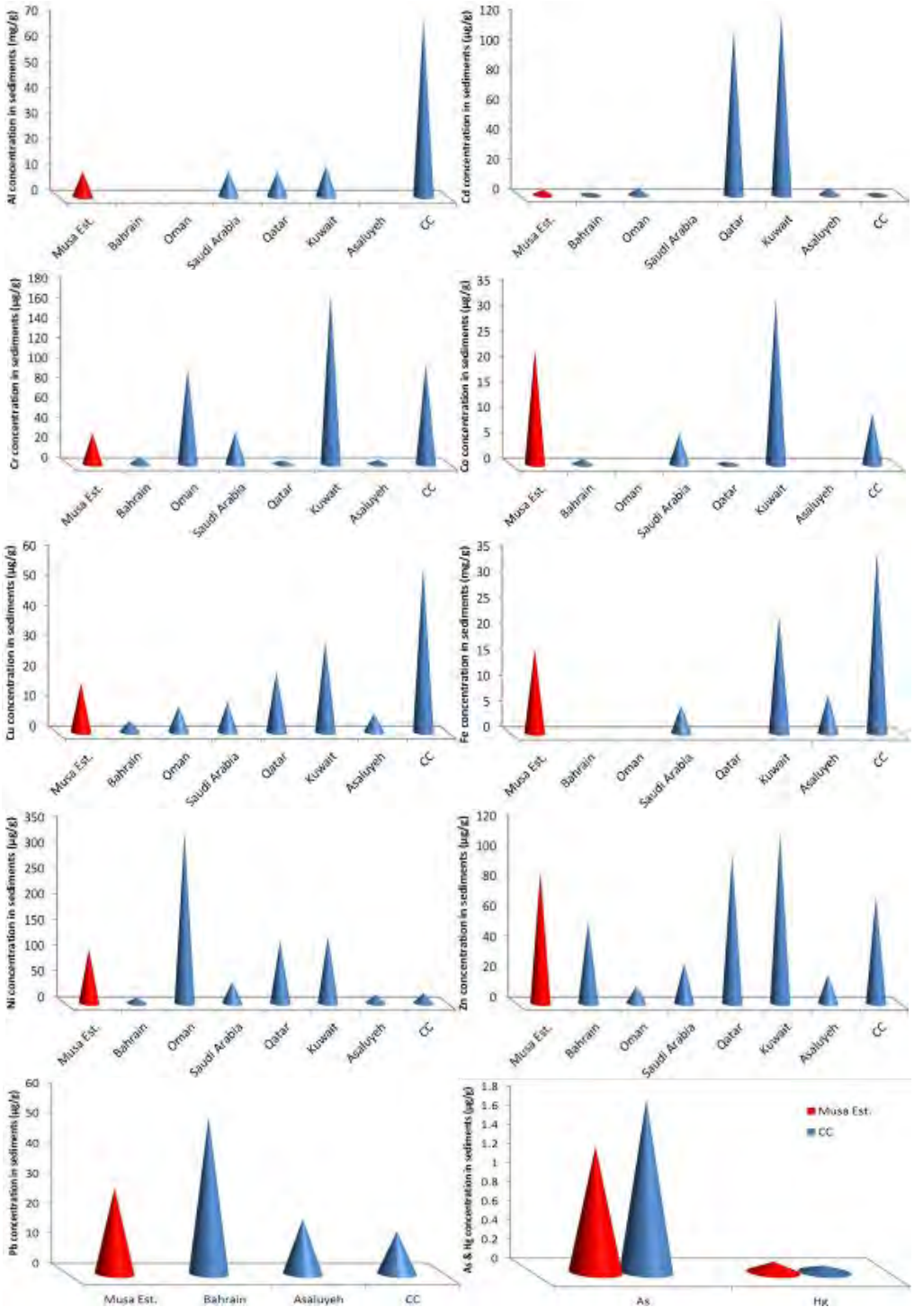
Parameters	Unit	Study Result			Bahrain[A]	Oman[A]	Saudi Arabia[A]	Qatar[A]	Kuwait	Asaluyeh[A]	Continental Crust[B]	Mahshahr[C]
		Min	Max	Mean								
Al	mg/g.	3.20	11.6	9.65	---	---	10[A]	9.8[A]	12[A]	---	69	---
As	µg/g.	0.10	2.10	1.31	---	---	---	---	---	---	1.8	3.6-
Cd	µg/g.	3.20	4.20	3.75	0.1[A]	4.82	---	110[A]	120	5.1[A]	0.1	<1
Cr	µg/g.	13.9	38.2	30.8	7 D	95.4	32.3	3.8 D	170[D]	4.3[A]	100	69-
Co	µg/g.	12.5	37.7	22.3	1.2 D	---	6 D	0.5 D	32.2	---	10	11-
Cu	µg/g.	3.20	26.4	16.1	3.9 D	8.7[A]	9.9 D	20[A]	30	6.1[A]	55	22-
Fe	mg/g.	6.80	22.4	16.0	---	---	5.3 D	---	22.6	7.3[A]	35	23-
Hg	µg/g.	<0.0	0.16	0.11	---	---	---	---	---	---	0.07	0.05-
Mn	µg/g.	239.	510.	434.	---	---	---	---	---	---	900	---
Ni	µg/g.	31.0	187.	104.	10.9	329.5	41.6	120[A]	130	17[A]	20	70-
Pb	µg/g.	25.6	29.7	28.4	52[A]	---	---	---	---	18.1	14	11-
Zn	µg/g.	46.0	118.	86.0	54[A]	11.3	26.3	98[A]	112	19.3	70	50-

Source:

A: Heavy metal concentrations of sediment of Persian Gulf (ROPME, 1998-2000).

B: Mason and Moore, 1995; Reimann and Caritat, 1998.

C & D: Heavy metal concentrations in sediment of PETZONE, 2008.

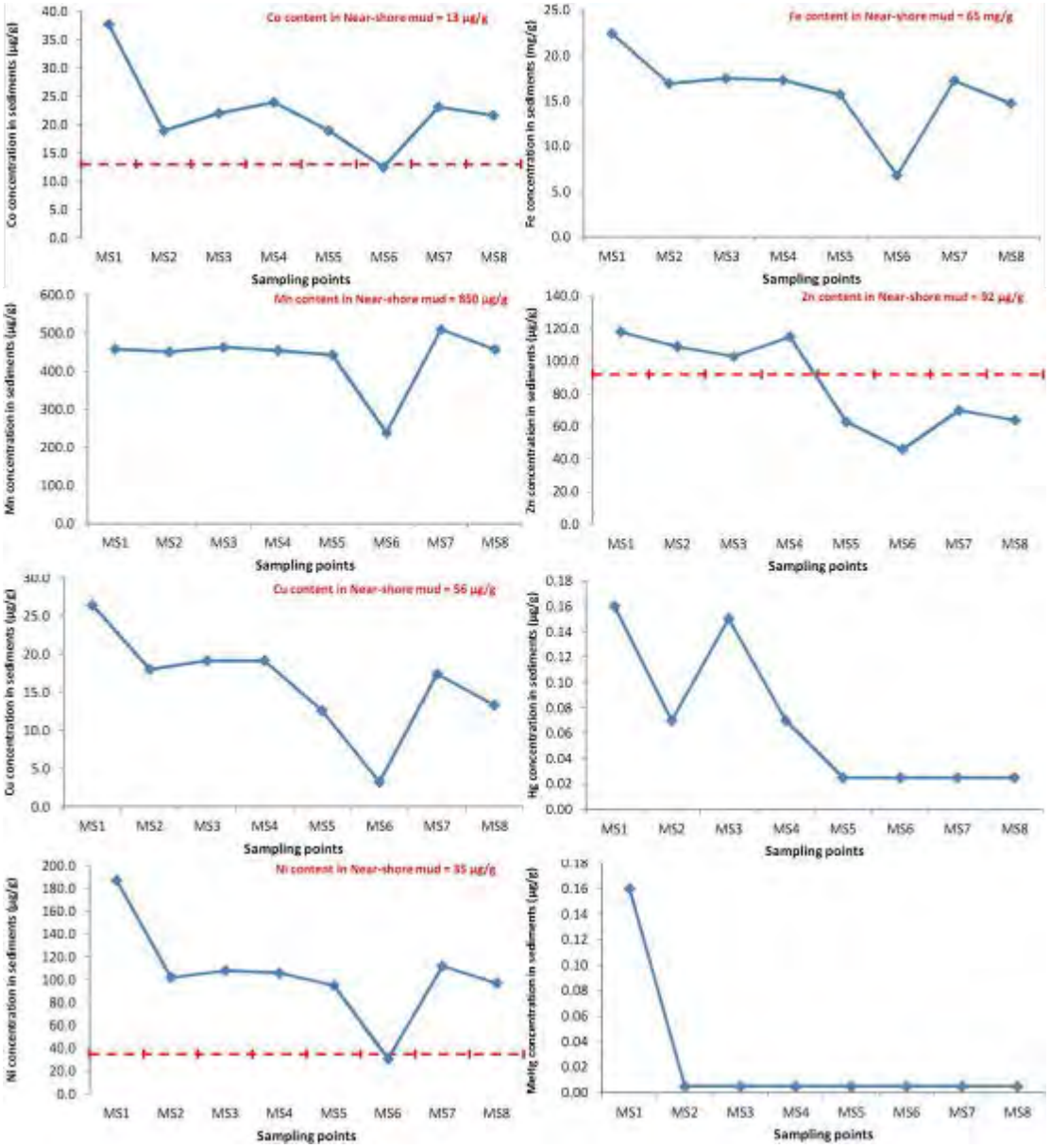


Source: ROPME, 1998-2000, Mason and Moore, 1995, Reimann and Caritat, 1998

Figure 3.2.9 Comparison of Heavy metal Concentration in Sediment between Different Study

In order to observe the accumulation pattern of elements in sediment, the metal concentrations in each sampling points are shown in Figure 3.2.10. The patterns of Mn, Cu, Ni, Fe, Al, Cd and Cr variation in sediment are similar and comparable, whereas Co, Zn, Hg, Me-Hg, As and Pb show different patterns.

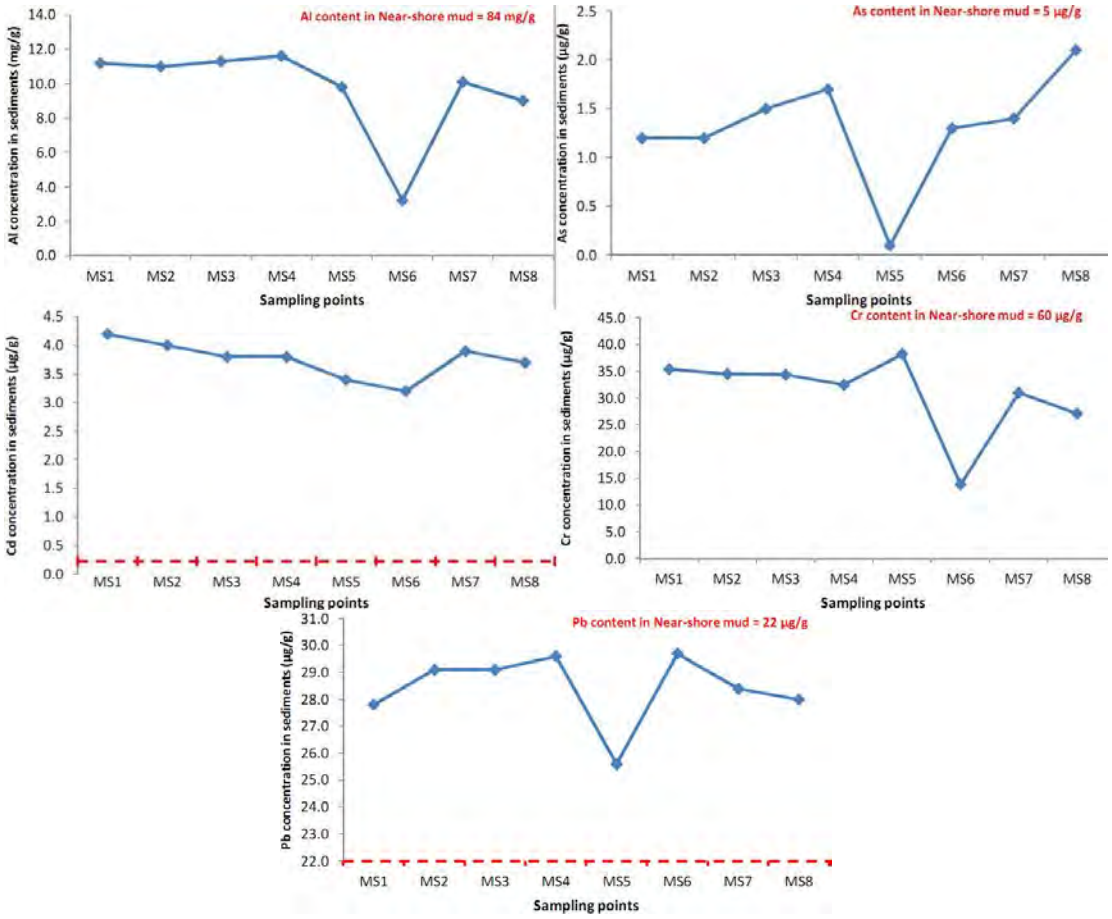
Horizontal distributions of heavy metals in seawater and sediment are shown in Figure 3.2.11and Figure 3.2.12 respectively.



Source: Study team, ROPME, 1998-2000, Mason and Moore, 1995, Reimann and Caritat, 1998

The red dash line shows the average concentration in continental crust.

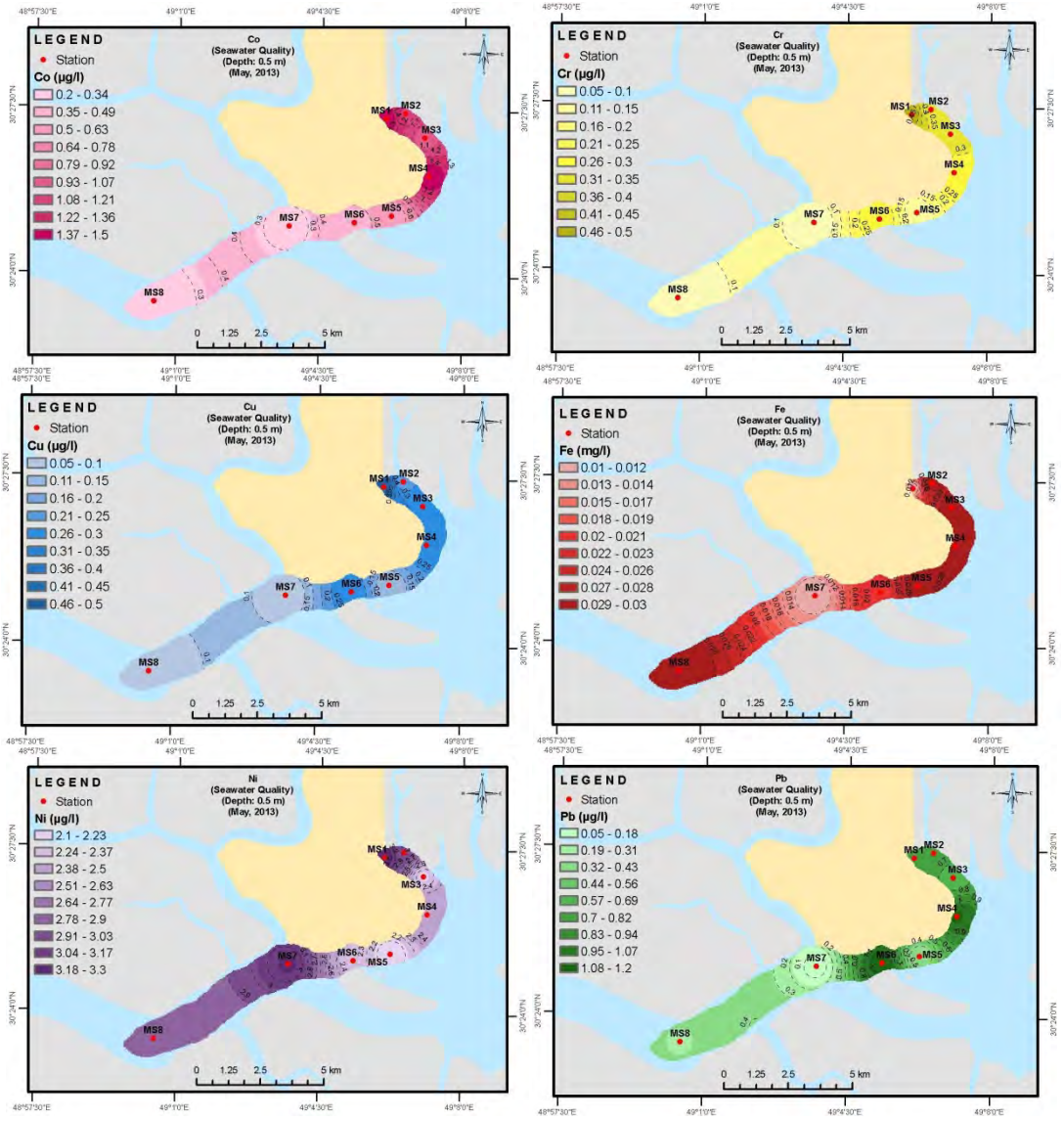
Figure 3.2.10 (1) Trace and Heavy Metal Concentration in Each Sampling Point



Source: Study team , ROPME, 1998-2000, Mason and Moore, 1995, Reimann and Caritat, 1998

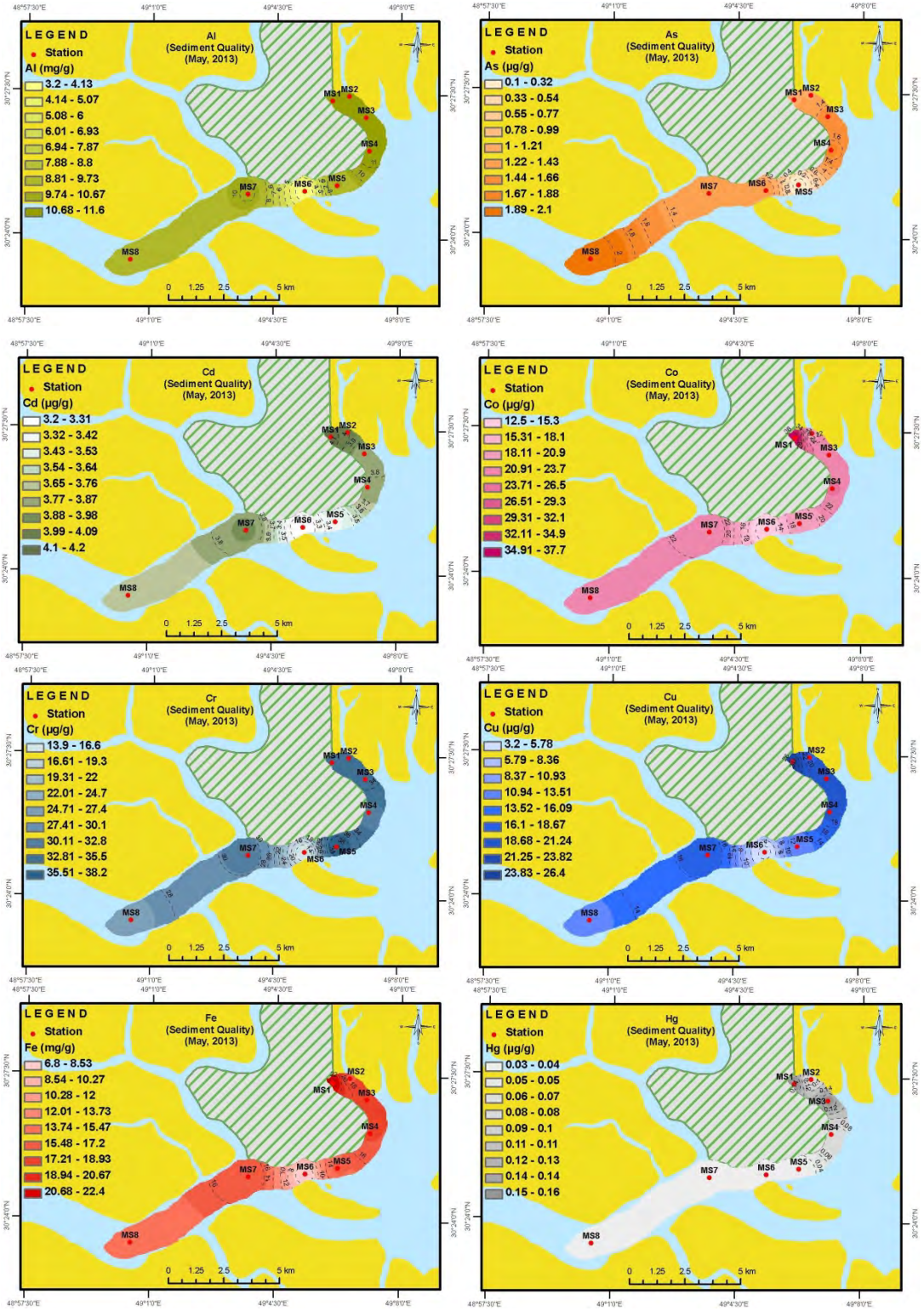
The Red dash line shows the average concentration in continental crust.

Figure 3.2.10 (2) Trace and Heavy Metal Concentration in Each Sampling Point



Source: Study team

Figure 3.2.11 Horizontal Distribution of Heavy Metal Concentration in Seawater (0.5 m).



Source: Study team

Figure 3.2.12 Horizontal Distribution of Heavy Metal Concentration in Sediment

In order to detect the pollution level in sediment of the study area (PETZONE) and to detect the impact to aquatic life and especially benthic organisms, the concentrations of elements

detected in this study were compared with the Effects Range Low (ERL) and the Effects Range Medium (ERM) values by NOAA Marine Sediment Quality Guideline and the Threshold Effect Level (TEL) and the Probable Effect Level (PEL) by the Canadian Interim Marine Sediment Quality Guideline (ISQG, CCME, 2002) (See Table 3.2.5). The TEL is the level below which adverse effects rarely occurred and the PEL is the level above which adverse effects frequently occurred.

In this study, the maximum and the average concentration of As, Cr, Pb and Zn in sediment do not exceed the sediment quality guidelines (ISQG/TEL) and pose no environmental concerns.
Cu concentrations in sediment in three sampling points exceed the ISQG/TEL. Relatively higher Cu levels in some stations (MS-1, MS-3 and MS-4) might be originated from discharges of wastewater in Mahshahr petrochemical zone.
Sediment quality guideline and the TEL do not specify the Mn concentration, but the concentration of Mn in two sampling stations (MS3 and MS7) is higher than the ERL that should be taken into consideration.
However the concentrations of Hg in all sediment samples are lower than the ERM and the ERL, while two sampling points (MS1 and MS3) are higher than ISQG/TEL.
The concentrations of Ni and Cd in all sediments are higher than the TEL and the ERL. Moreover, the Ni concentration in seven sampling points is greater than the ERM that can be harmful to benthic organisms. Nickel has a high natural background in this mineral-rich region. A part of the high level of Ni in the sediment might be originated from natural mineralization of ophiolitic rocks (De Mora et al., 2004). High nickel concentrations in sediment samples and lower concentration of Cr and Co in sediment indicate that there is some other source of nickel in the study area. Concentrations of cobalt in five sampling stations were higher than freshwater sediments (20 µg/g; Canadian Technical Report. 2004).
Comparing the element concentration in eight sampling stations, it is understood those are relatively higher than in similar areas. Maximum levels of Co, Ni, Cu, Fe, Hg, Zn, Cd and Me-Hg are observed at MS-1. Maximum levels of Al, Cr, Pb, Mn and As are observed in MS-4, MS-5, MS-6, MS-7 and MS-8 sampling points, respectively. In this comparison, elevated levels do not indicate whether there are potential toxicological concerns associated with these levels for Al, Fe, As, Cr, Cu, Hg, Pb and Zn.

Table 3.2.5 Comparison of Sediment Concentration between the Survey Result and the Guideline Values by NOAA and ISQGs Marine Sediment Quality Guideline

Elements	Average in this study	ISQG/TE	ERL	ERM	PEL	Near-shore
Al (mg/g)	9.65	---	---	---	---	84
As (µg/g)	1.31	7.24	8.2	70	41.6	5
Cd (µg/g)	3.75	0.7	1.2	9.6	4.2	---
Cr (µg/g)	30.88	52	81	370	160	60
Co (µg/g)	22.33	---	---	---	---	13
Cu (µg/g)	16.14	18.7	34	270	108	56
Fe (mg/g)	16.06	---	---	---	---	65
Hg (µg/g)	0.11	0.13	---	---	0.7	---
Mn (µg/g)	434.38	---	460	1100	---	850
Ni (µg/g)	104.75	< 20	21	52	>50	35
Pb (µg/g)	28.41	30.2	47	220	112	22
Zn (µg/g)	86.00	124	---	---	271	92

Source: NOAA Marine Sediment Quality Guideline
Canadian Interim Marine Sediment Quality Guideline (ISQG, CCME, 2002)
Note: * Average concentration of trace elements in near-shore muds (Martin and Whitfield 1983)
ERL: Effects Range Low
ERM: Effects Range Medium
TEL: Threshold Effect Level
PEL: Probable Effect Level
SQG: Sediment Quality Guidelines (CCME, 2002)

3.3 Survey in June 2013

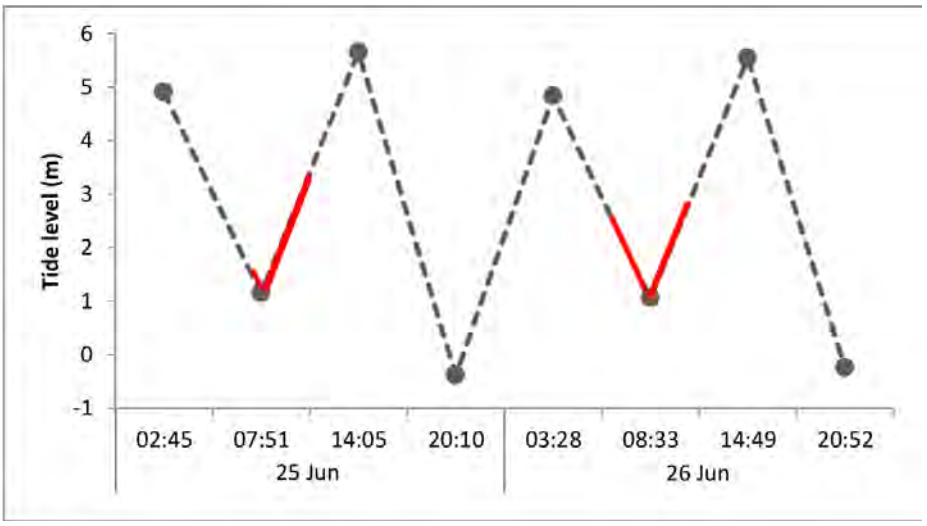
3.3.1 Survey Timing

Table 3.3.1shows the timetable of the survey and Figure 3.3.1 shows the tide timing of the survey, respectively.

Table 3.3.1 Time Table of the Survey (Jun., 2013)

Date	Time	Site	Note
Tuesday, 25 June 2013	7 to 11	MS-4 to MS-4	Water sampling & in-situ monitoring
Wednesday, 26 June 2013	7 to 12	MS-5 to MS-8	

Source: Study team



Source: Tide table (http://www.iranhydrography.org/default.asp)

Red line shows the timing of the survey

Figure 3.3.1 Tide Timing at the Survey (June, 2013)

3.3.2 Result of the Survey

Summary of the survey results is shown in Table 3.3.2 and raw data is stored in Annex A.

Table 3.3.2 Summary of the Survey Result

Survey date: Jun. 25-26, 2013

Category	Parameter	Unit	Environmental standard (*1)	Jun		
				Min	Max	Ave
Water quality (Field measurement)	Water temperature	°C	(*2)	28.5	30.9	29.2
	Salinity	-	(*3)	42.90	44.60	43.95
	Conductivity	mS/cm		71.6	73.6	72.9
	pH	-	6.5-9.0	8.37	8.46	8.42
	DO	mg/L	> 3 (*4)	6.49	7.58	7.31
Water quality (Analysis: general parameters)	Turbidity	NTU		25	231	127
	Suspended solid	mg/L	(*5)	20	240	121
	COD	mg/L as O2	5	12	24	14
	TOC	mg/L as C		1.7	3.6	2.1
	Oil contents	mg/L	(*6)	< 0.2	< 0.2	< 0.2
	Coliform bacteria (*10)	MPN Index/100ml	500 (*7)	<2	<2	<2
	Total nitrogen	mg/L as N	0.4 (*8)	0.36	0.93	0.67
	Total phosphorous	mg/L as P	0.045 (*9)	<0.2	<0.2	<0.2

Source: Study team

Note: Red letter means excess of the standard/criteria value

*1: Standard for Ambient Water in Persian Gulf and Oman Sea (draft), Class 6: Industrial zone or Port, DOE.
*2 Water temperature: ±3 of natural temperature of receptive source

*3 Salinity: It should be no more than 10 percent of minimum natural salinity of the region.
*4 DO: 40% of Saturation
*5 Suspended Solid: Its increase should not be more than its daily, monthly, annual average considering standard deviation.
*6 Oil contents: There should be no oil layer, foam visible on its surface.
*7 Coliform bacteria: Fecal coliform should be less than 100 CFU/100ml.
*8 Total nitrogen: The value of Nitrate-nitrogen is used in this table.
*9 Total phosphorous: The value of Phosphate-phosphorus is used in this table.
*10 Total coliform was analyzed in Apr., May, Jun. and Aug-1, while fecal coliform analyzed in Aug-2, Sep. and Oct.

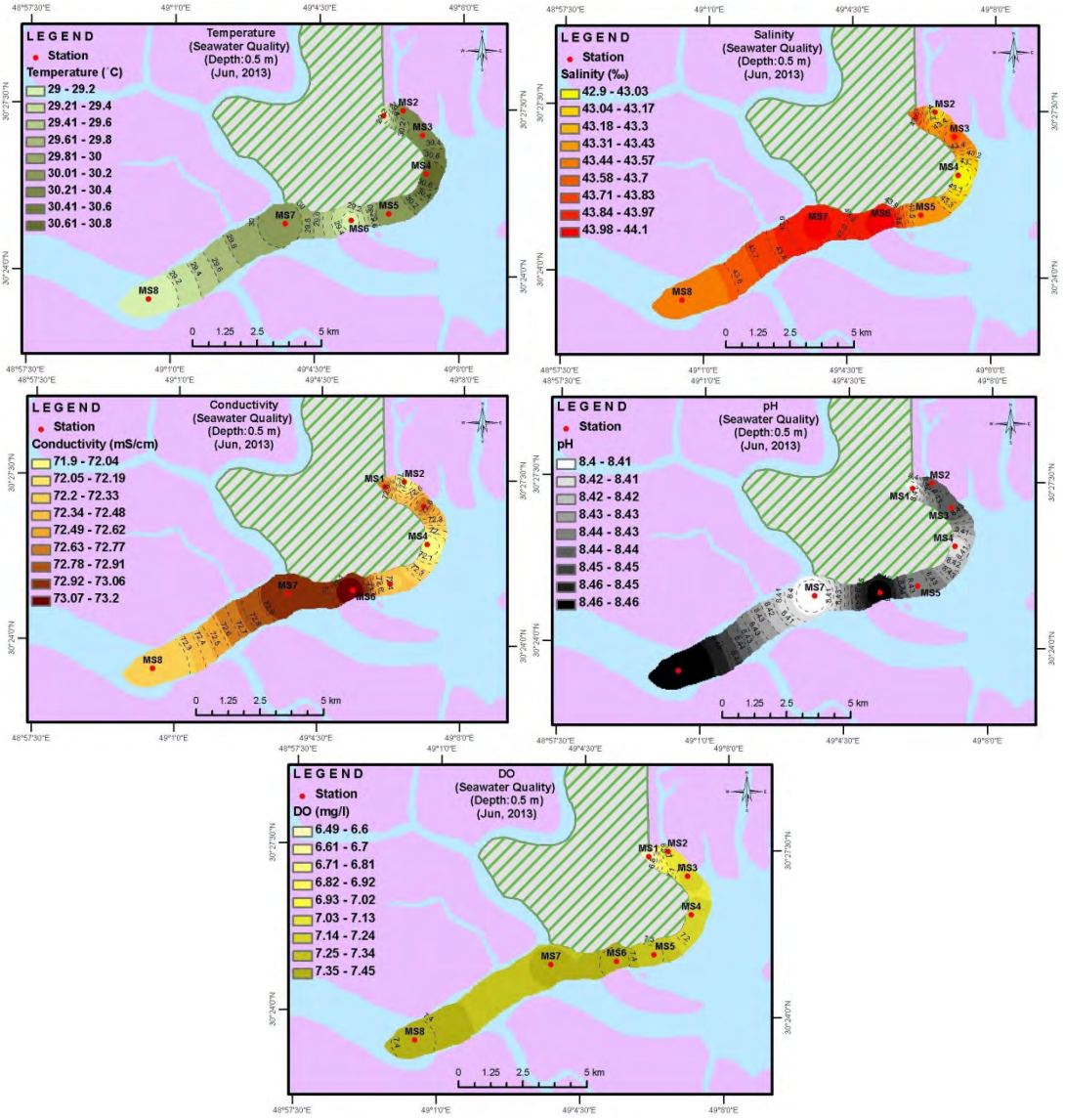
3.3.3 Discussion

a) Field measurement

Horizontal distribution of the field measurement parameters (in-situ parameters) are shown in Figure 3.3.2.

The water temperature ranges from 28.5–30.9 ^{OC} with an average of 29.26 ^{o}C. The pH of seawater samples varies between 8.37 and 8.46 with an average of 8.42 during this period. The variation of EC and salinity are minor, ranging between 71.6 and 73.6 mS/cm (average=72.89 mS/cm), and 42.9 and 44.6 (average=43.94), respectively. Dissolved oxygen ranges 6.49–7.58 mg/l. The lowest DO shows at MS-1, suggesting the possibility of influence from discharge of industrial effluents in the study area.

Vertical profiles for in-situ parameters are shown in Annex D.



Source: Study team

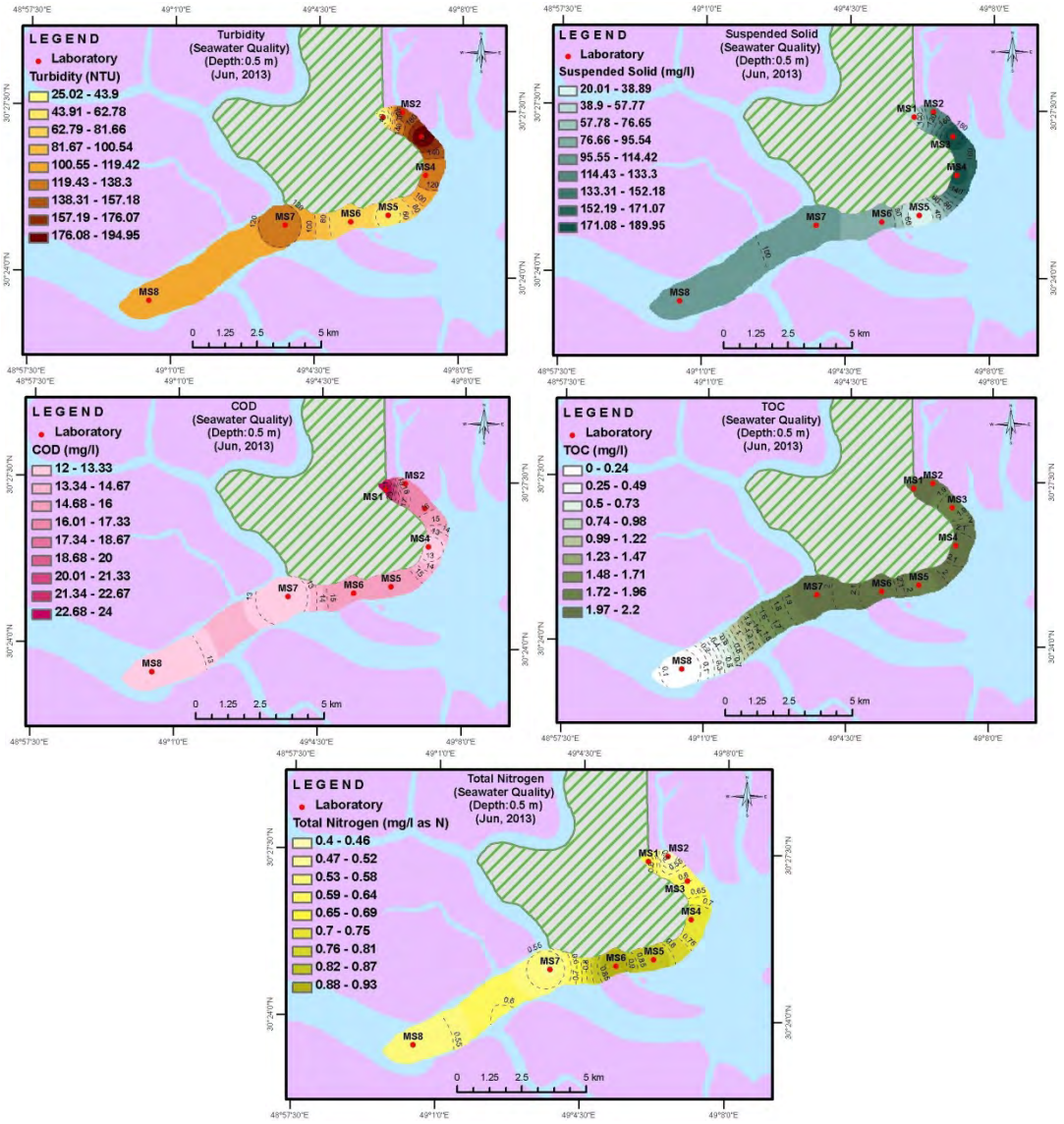
Figure 3.3.2 Horizontal Distribution of In-situ Parameters

b) Laboratory analysis

Horizontal distribution of the parameters of laboratory analysis is shown in Figure 3.1.3.

Turbidity in MS-2, MS-3 and MS-8 (10m below surface) is high, compared to the other sampling points. Suspended solid in MS-2 is the highest and the average of Suspended solid is 121 mg/l. COD in MS-1 shows the highest value (24 mg/l) and the other stations show relatively similar values. TOC values are precisely similar to COD parameters and the maximum of TOC is observed in MS-1. Total nitrogen ranges from 0.36 to 0.93 mg/l and MS-6 (0.5m below surface) shows the maximum value.

Vertical profiles of laboratory parameters are presented in Annex D.



Source: Study team

Figure 3.3.3 Horizontal Distribution of the Laboratory Parameters

3.4 Survey in August (1st trial) 2013

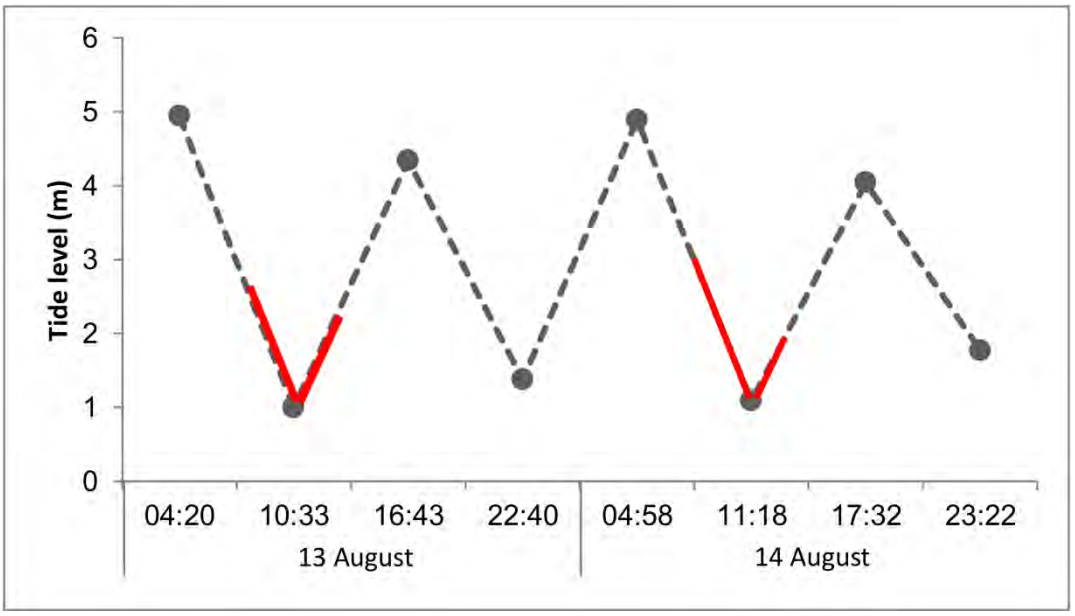
3.4.1 Survey Timing

Table 3.4.1 shows the timetable of the survey and Figure 3.4.1 shows the tide timing of the survey, respectively.

Table 3.4.1 Time Table of the Survey (August-1, 2013)

Date	Time	Site	Note
Tuesday, 13 August 2013	8 to 12	MS-1 to MS-4	Water sampling & in-situ monitoring
Wednesday, 14 August 2013	9 to 13	MS-5 to MS-8	

Source: Study team



Source: Tide table (http://www.iranhydrography.org/default.asp)

Red line shows the timing of the survey

Figure 3.4.1 Tide Timing at the Survey (August-1, 2013)

3.4.2 Result of the Survey

Summary of the survey results is shown in Table 3.4.2 and raw data is stored in Annex A.

Table 3.4.2 Summary of the Survey Result

Survey date: Aug. 13-14, 2013

Category	Parameter	Unit	Environmental standard (*1)	Aug-1		
				Min	Max	Ave
Water quality (Field measurement)	Water temperature	^{o}C	(*2)	30.6	32.9	31.4
	Salinity	-	(*3)	45.20	47.40	46.27
	Conductivity	mS/cm		77.5	83.5	80.6
	pH	-	6.5-9.0	5.67	8.46	8.23
	DO	mg/L	> 3 (*4)	5.47	6.44	6.02
Water quality (Analysis: general parameters)	Turbidity	NTU		14	222	86
	Suspended solid	mg/L	(*5)	30	270	105
	COD	mg/L as O2	5	7	24	12
	TOC	mg/L as C		1.9	8.6	2.7
	Oil contents	mg/L	(*6)	< 0.2	< 0.2	< 0.2
	Coliform bacteria (*10)	MPN Index/100ml	500 (*7)	7	920	129
	Total nitrogen	mg/L as N	0.4 (*8)	0.52	1.24	0.84
	Total phosphorous	mg/L as P	0.045 (*9)	<0.2	<0.2	<0.2

Source: Study team

Note: Red letter means excess of the standard/criteria value

*1: Standard for Ambient Water in Persian Gulf and Oman Sea (draft), Class 6: Industrial zone or Port, DOE.
*2 Water temperature: ±3 of natural temperature of receptive source
*3 Salinity: It should be no more than 10 percent of minimum natural salinity of the region.
*4 DO: 40% of Saturation
*5 Suspended Solid: Its increase should not be more than its daily, monthly, annual average considering standard deviation.
*6 Oil contents: There should be no oil layer, foam visible on its surface.
*7 Coliform bacteria: Fecal coliform should be less than 100 CFU/100ml.
*8 Total nitrogen: The value of Nitrate-nitrogen is used in this table.
*9 Total phosphorous: The value of Phosphate-phosphorus is used in this table.
*10 Total coliform was analyzed in Apr., May, Jun. and Aug-1, while fecal coliform analyzed in Aug-2, Sep. and Oct.

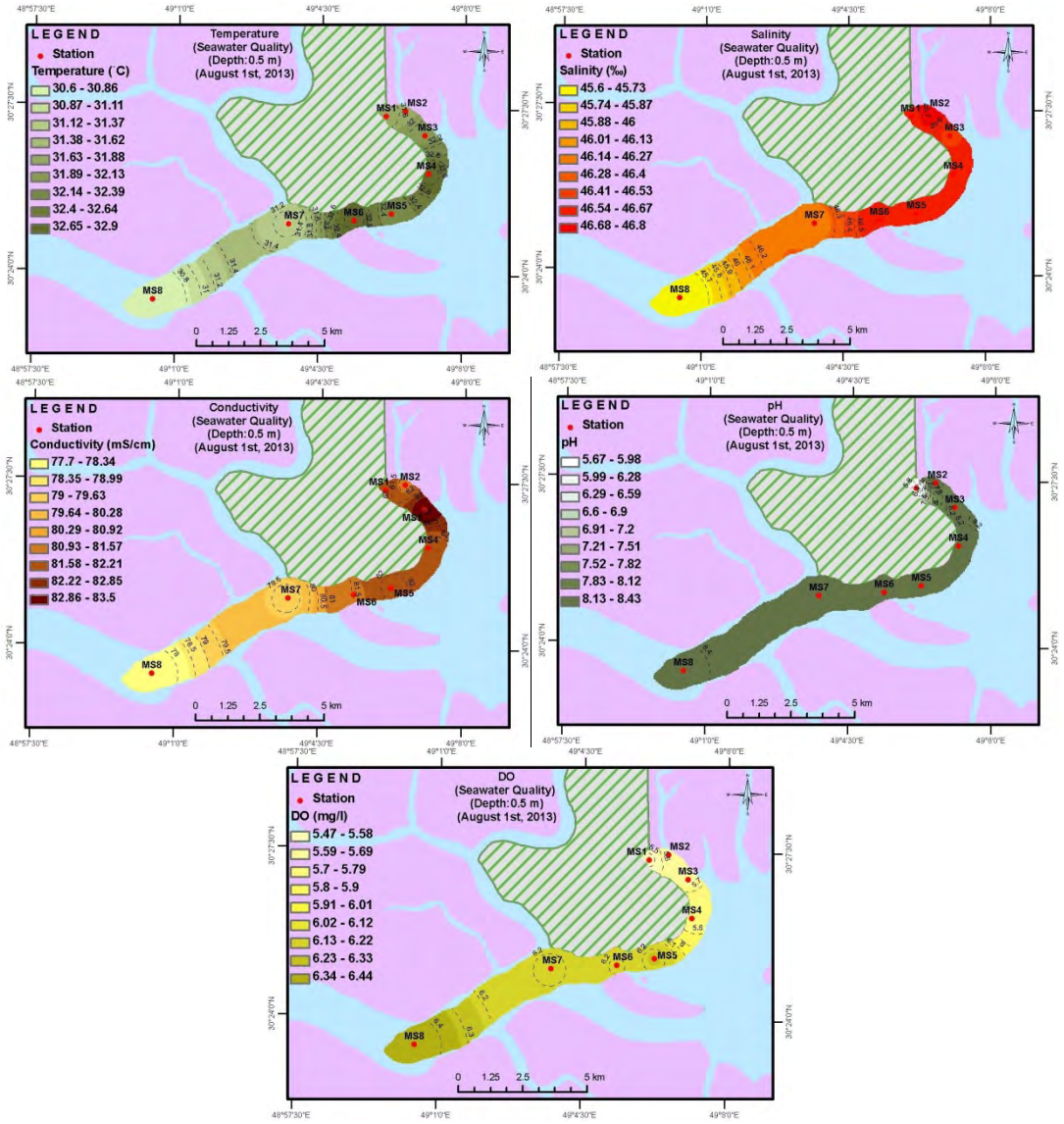
3.4.3 Discussion

a) Field measurement

Horizontal distribution of the field measurement parameters (in-situ parameters) are shown in Figure 3.4.2.

Seawater samples of different stations show relatively homogeneous values of temperature, varying between 30.60 and 32.90 ^{o}C with an average of 31.55 ^{o}C. The pH values in seven stations are very homogeneous and present a narrow range of variation (between 8.31 and 8.46), but it is 5.67 in MS-1 indicate that possibly discharge of PETZONE effluents. Values of EC vary between 77.5 and 83.5 mS/cm. The average of EC is 80.77 mS/cm which it is higher than EC in other sampling periods. The salinity shows a low range of variation from 45.20 to 47.40

with an average of 46.33. The ranges of DO in seawater samples are between 5.47 and 6.44 mg/l with the average of 6.09 mg/l. The lowest DO concentration is in MS-1, probably indicates that discharge of industrial effluents in the study area. The average of DO values is smaller than other sampling periods. Vertical profiles of in-situ parameters are illustrated in Annex D.



Source: Study team

Figure 3.4.2 Horizontal Distribution of In-situ Parameters

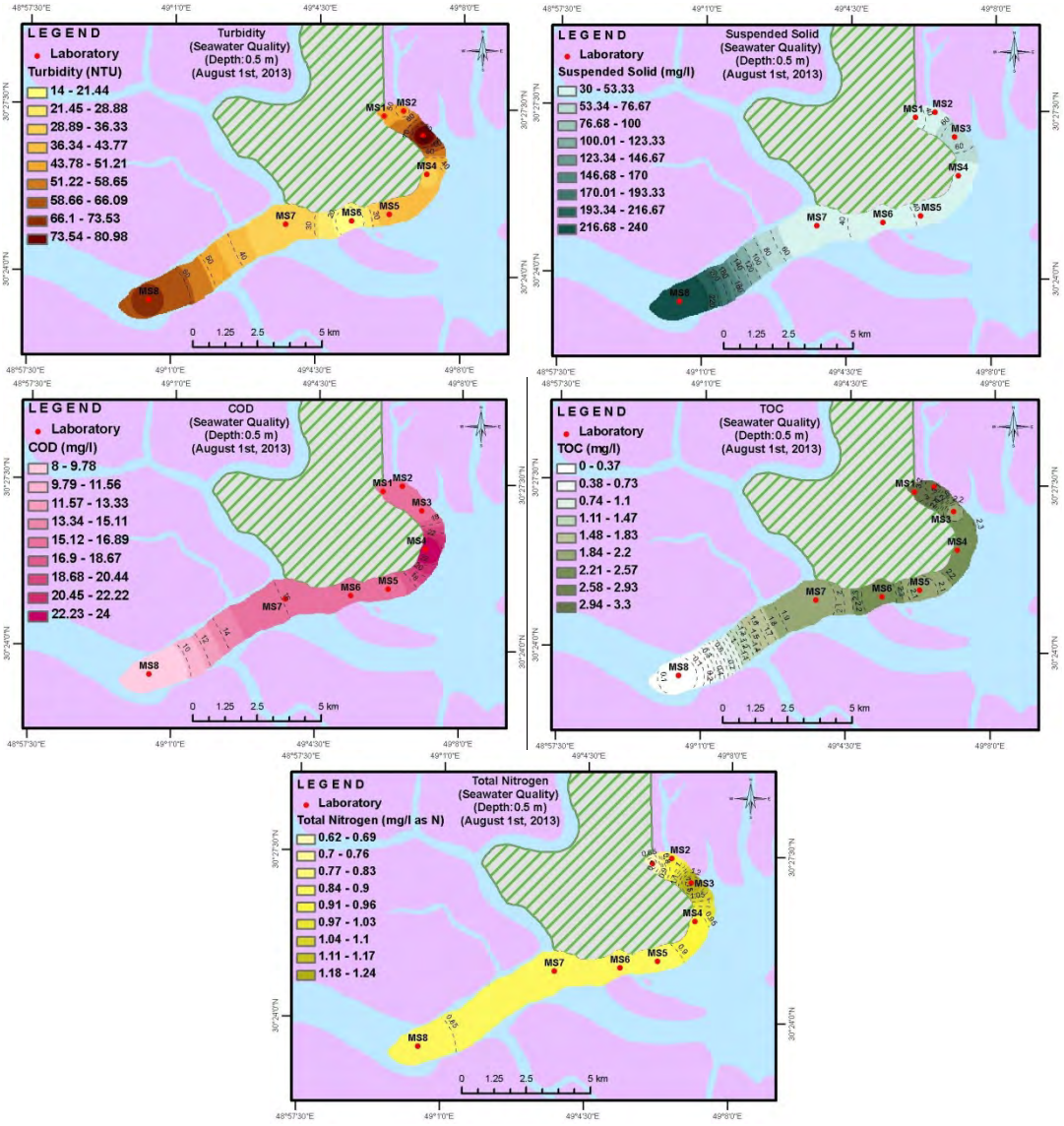
b) Laboratory analysis

Horizontal distribution of the parameters of laboratory analysis is shown in Figure 3.4.3.

The highest turbidity is recorded in MS-2 (2m below surface) and MS-3 (2m below surface). Suspended solid parameter is high in MS-5 (2m below surface) and MS-3 (2m below surface),

MS-8 (0.5m below surface) and MS-2 (2m below surface). COD in MS-4 shows the highest value (24 mg/l). TOC concentration in MS-1 (8.6 mg/l) is higher than the other stations. Total nitrogen concentration varies from 0.52 to 1.24 mg/l, the highest value (1.24 mg/l) is observed in MS-3 (0.5 m).

Vertical profiles of laboratory parameters are presented in Annex D.



Source: Study team

Figure 3.4.3 Horizontal Distribution of the Laboratory Parameters

3.5 Survey in August (2nd trial) 2013

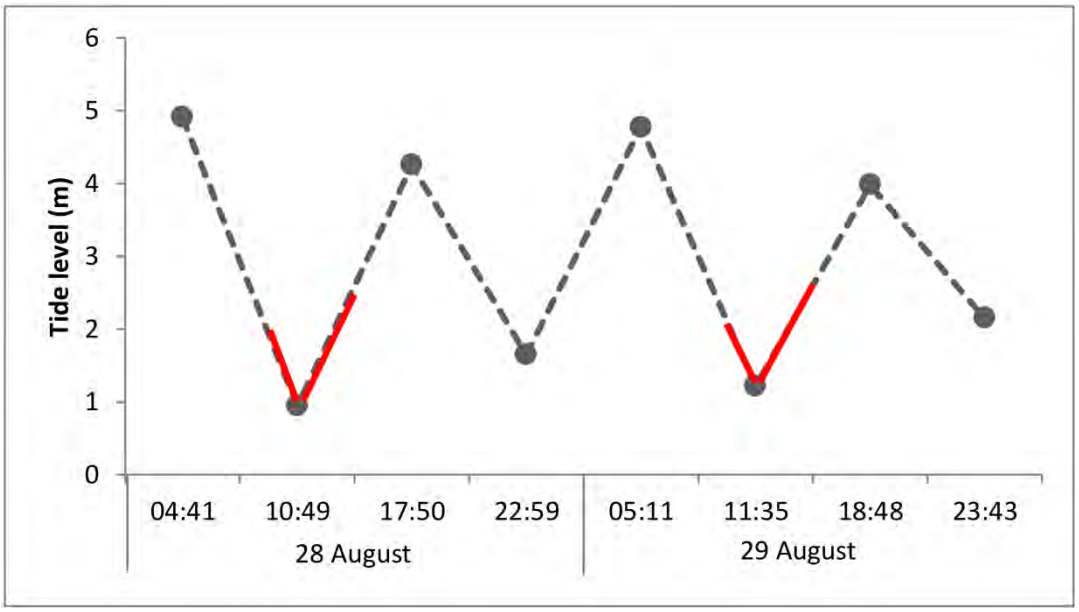
3.5.1 Survey Timing

Table 3.5.1 shows the tiof table of the survey and Figure 3.5.1 shows the tide timing at the survey, respectively.

Table 3.5.1 Time Table of the Survey (August-2, 2013)

Date	Time	Site	Note
Wednesday, 28 August 2013	9 to 13	MS-1 to MS-4	Water, sediment sampling & in-situ monitoring
Thursday, 29 August 2013	9 to 15	MS-5 to MS-8	

Source: Study team



Source: Tide table (http://www.iranhydrography.org/default.asp)

The red line shows the timing of the survey

Figure 3.5.1 Tide Timing at the Survey (August-2, 2013)

3.5.2 Result of the Survey

Summary of the survey results is shown in Table 3.5.2 and raw data is stored in Annex A.

Table 3.5.2 Summary of the Survey Result

Survey date: Aug. 28-29, 2013

Category	Parameter	Unit	Environmental standard (*1)	Aug-2		
				Min	Max	Ave
Water quality (Field measurement)	Water temperature	°C	(*2)	28.4	32.2	30.5
	Salinity	-	(*3)	34.90	46.30	43.62
	Conductivity	mS/cm		60.4	84.0	74.7
	pH	-	6.5-9.0	8.25	8.54	8.35
	DO	mg/L	> 3 (*4)	5.58	6.54	6.29
Water quality (Analysis: general parameters)	Turbidity	NTU		20	125	41
	Suspended solid	mg/L	(*5)	20	140	45
	COD	mg/L as O2	5	8	24	13
	TOC	mg/L as C		1.6	2.9	2.3
	Oil contents	mg/L	(*6)	< 0.2	< 0.2	< 0.2
	Coliform bacteria (*10)	MPN Index/100ml	500 (*7)	<2	384	112
	Total nitrogen	mg/L as N	0.4 (*8)	0.65	1.30	0.84
	Total phosphorous	mg/L as P	0.045 (*9)	<0.2	<0.2	<0.2
Water quality (Analysis: heavy metals)	Aluminum (Al)	mg/L		<0.1	<0.1	<0.1
	Arsenic (As)	micro-g/L	50	<1	<1	<1
	Cadmium (Cd)	micro-g/L	10	<0.1	<0.1	<0.1
	Cyanide (CN)	micro-g/L		<5	<5	<5
	Chromium (Cr)	micro-g/L	50	<0.1	0.1	<0.1
	Cobalt (Co)	micro-g/L		<0.1	<0.1	<0.1
	Copper (Cu)	micro-g/L	50	<0.1	2.5	1.4
	Iron (Fe)	mg/L	0.3	<0.1	0.01	0.01
	Methyl Mercury (Hg)	micro-g/L	0.2	-	-	-
	Mercury (Hg)	micro-g/L	0.5	<1	<1	<1
	Manganese (Mn)	micro-g/L	100	<0.1	0.44	0.44
	Magnesium (Mg)	mg/L		1869	1954	1910
	Nickel (Ni)	micro-g/L	50	0.8	3.1	1.7
	Lead (Pb)	micro-g/L	40	0.1	1.5	0.4
	Zinc (Zn)	mg/L	100	<0.01	<0.01	<0.01
	Phenols	micro-g/L	0.05	<1	<1	<1
Sediment quality (Analysis)	Specific Gravity	g/cm3		1.0	1.3	1.2
	Moisture Content	Mass%		39.00	73.90	53.55
	Total Organic Carbon (TOC)	Mass%		0.30	0.57	0.42
	Total Petroleum Hydrocarbon	micro-g/g.dw	550	33	155	77
	Aluminum (Al)	mg/g.dw		6.7	10.0	8.2
	Arsenic (As)	micro-g/g.dw	20	1.5	2.3	1.7
	Cadmium (Cd)	micro-g/g.dw	1.5	1.2	2.1	1.6
	Cyanide (CN)	micro-g/g.dw		<0.1	<0.1	<0.1
	Chromium (total)	micro-g/g.dw	80	20.8	33.0	27.3
	Chromium (Cr+6)	micro-g/g.dw		-	-	-

Category	Parameter	Unit	Environmental standard (*1)	Aug-2		
				Min	Max	Ave
	Cobalt (Co)	micro-g/g.dw		16.6	20.5	19.1
	Copper (Cu)	micro-g/g.dw	65	12.9	18.7	15.5
	Iron (Fe)	mg/g.dw		12.3	18.0	14.9
	Methyl Mercury (Hg)	micro-g/g.dw		<0.01	0.06	<0.06
	Mercury (Hg)	micro-g/g.dw	0.15	<0.05	1.90	0.66
	Manganese (Mn)	micro-g/g.dw		271	372	329
	Magnesium (Mg)	mg/g.dw		11.0	21.6	18.2
	Nickel (Ni)	micro-g/g.dw	21	3.1	80.1	56.4
	Lead (Pb)	micro-g/g.dw	50	21.1	26.7	22.9
	Zinc (Zn)	micro-g/g.dw	200	36.4	69.4	52.4
	Total Sulfur (T-S)	mg/g		1.3	8.0	2.5
	Grain size					
	Sand (>0.04mm & <1mm)	%		4.0	38.0	21.8
	Silt (>0.002mm & <0.04mm)	%		27.0	53.0	39.8
	Clay (>0.0002mm & <0.002mm)	%		23.0	51.0	38.5

Source: Study team

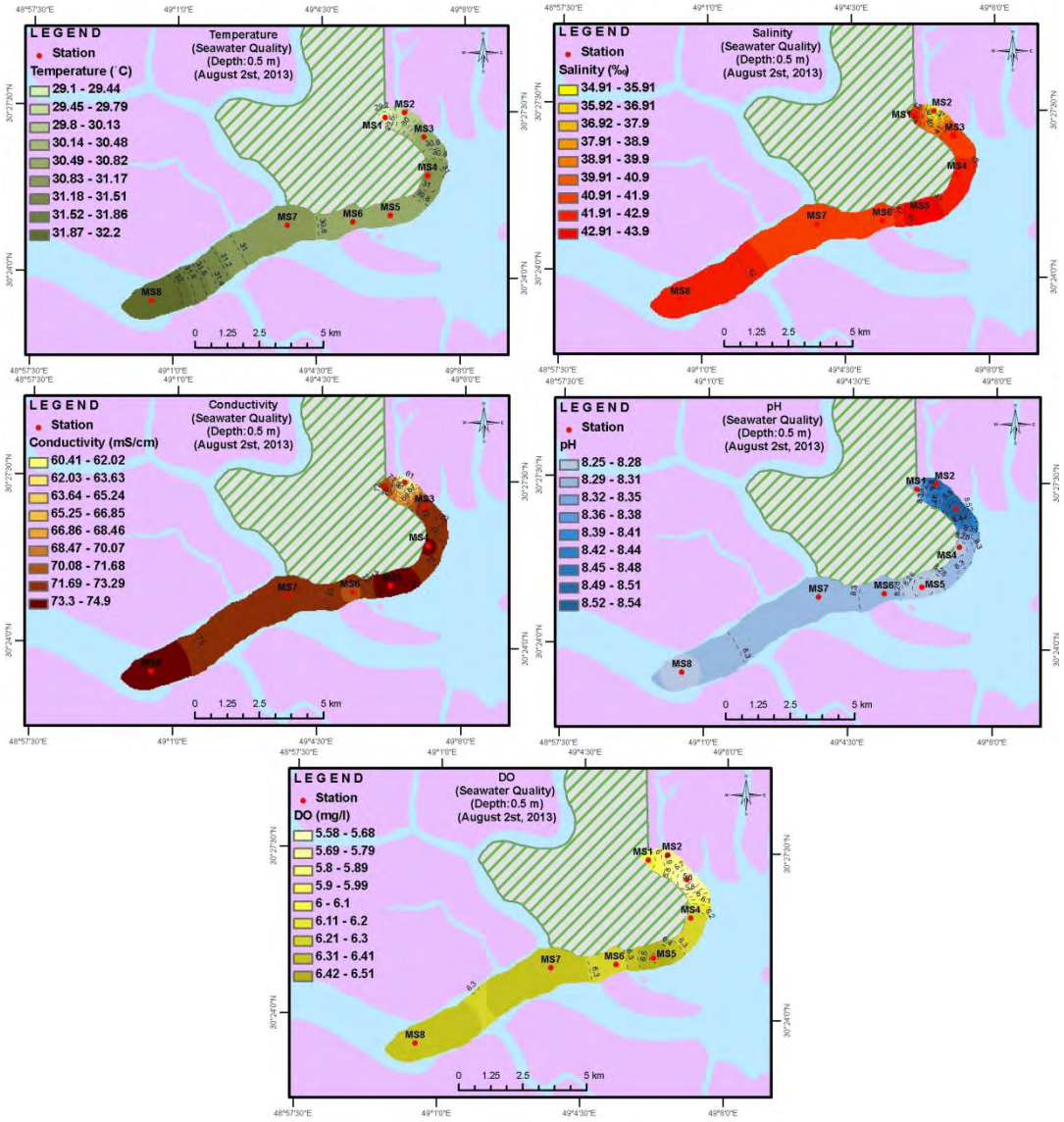
Note: Red letter means excess of the standard/criteria value

*1: Standard for Ambient Water in Persian Gulf and Oman Sea (draft), Class 6: Industrial zone or Port, DOE.
*2 Water temperature: ±3 of natural temperature of receptive source
*3 Salinity: It should be no more than 10 percent of minimum natural salinity of the region.
*4 DO: 40% of Saturation
*5 Suspended Solid: Its increase should not be more than its daily, monthly, annual average considering standard deviation.
*6 Oil contents: There should be no oil layer, foam visible on its surface.
*7 Coliform bacteria: Fecal coliform should be less than 100 CFU/100ml.
*8 Total nitrogen: The value of Nitrate-nitrogen is used in this table.
*9 Total phosphorous: The value of Phosphate-phosphorus is used in this table.
*10 Total coliform was analyzed in Apr., May, Jun. and Aug-1, while fecal coliform analyzed in Aug-2, Sep. and Oct.

3.5.3 Discussion

a) Field measurement

Horizontal distribution of the field measurement parameters (in-situ parameters) are shown in Figure 3.5.2.The water temperature ranges from 28.4–32.2 ^{o}C with an average of 30.5 ^{o}C. The pH varies from 8.25 to 8.54 with an average value 8.35, indicating the alkaline nature of seawater. The EC values range from 60.4 to 84 ms/cm with an average of 74.51 mS/cm. Salinity values range from 34.9 to 46.3 with an average value of 43.49. The dissolved oxygen varies between 5.58–6.54 mg/l with an average 6.33 mg/l. Vertical profile of in-situ parameters are presented in Annex D.



Source: Study team

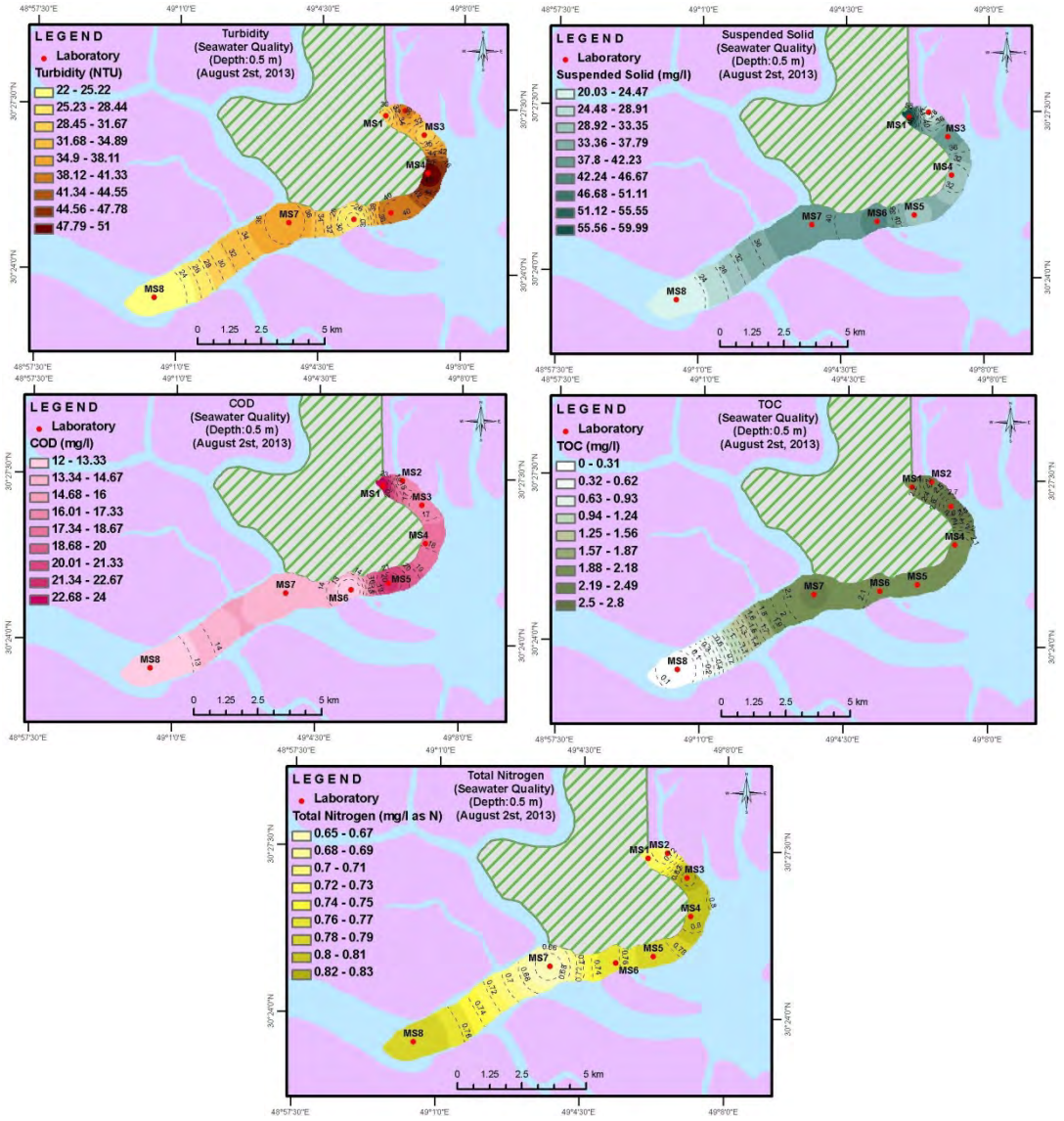
Figure 3.5.2 Horizontal Distribution of In-situ Parameters

b) Laboratory analysis

Horizontal distribution of the parameters of laboratory analysis is shown in Figure 3.5.3.

Turbidity in MS-2 (2m below surface) is the highest value and the other stations are very low and close together. Suspended solid in MS-2 (2m below surface) shows the highest value and the others are similar together. COD ranges from 8 to 24 mg/l and the maximum COD is recorded in MS-1 (0.5m below surface) and MS-5 (5m below surface). TOC ranges from 2 to 2.9 mg/l. Total nitrogen varies between 0.65 and 1.3 mg/l and the highest value is observed in MS-8 (10m below surface).

Vertical profiles of laboratory parameters are shown in Annex D.

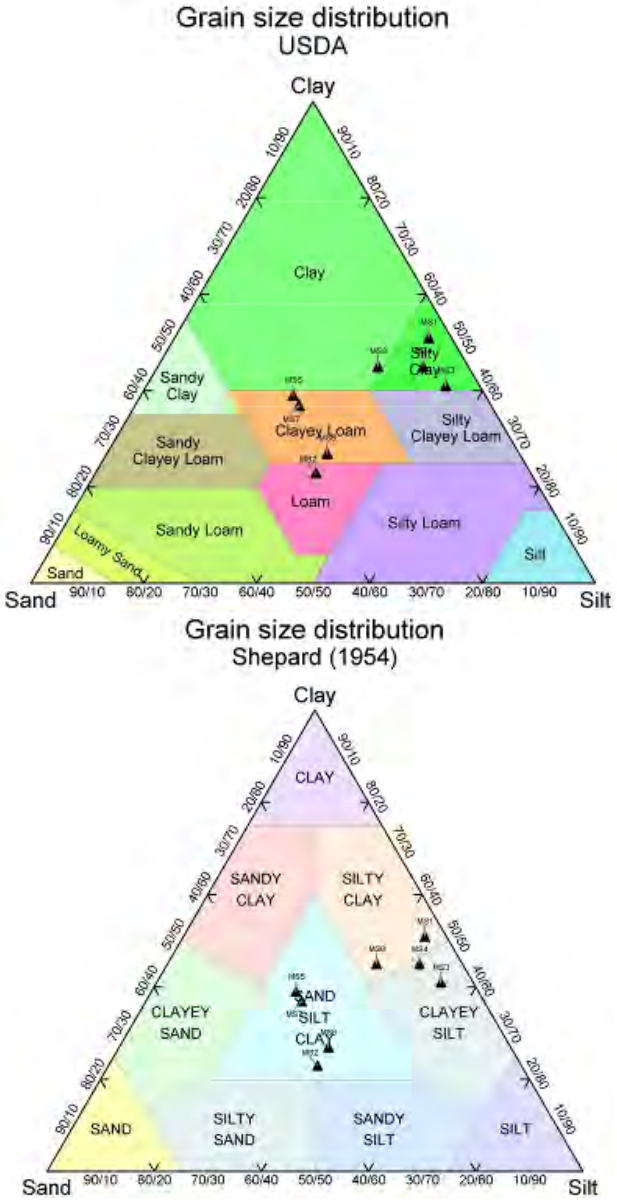


Source: Study team

Figure 3.5.3 Horizontal Distribution of Laboratory Parameters

c) Sediment texture

Particle size distribution in sediment samples shows minor differences. Sediment samples have fairly evenly distributed proportions of sand (2-0.05 mm), silt (0.05-0.002mm) and clay (<0.002 mm). According to the USDA classification scheme (Schoeneberger et al., 2002), the sediment samples are categorized as Loam (MS-2), Calyey-Loam (MS-5, MS-6 and MS-7), Clay (MS-8) and Silty-Clay (MS-1, MS-3 and MS-4) classes. According to the Shepard diagram (Shepard, 1954), sediment textures in the study area are classified as Silty-Clay (MS-1 and MS-8), Clayey-Silt (MS-3 and MS-4) and Sand-Silt-Clay (MS-2, MS-5, MS-6 and MS-7) classes (See Figure 3.5.4).



Source: Schoeneberger et al., 2002 and Shepard, 1954

Figure 3.5.4 Classification of Sediments

d) Heavy metals

Summary of the survey results is presented in Table 3.5.2 and raw data is stored in Annex A.

The result shows that Arsenic (As) in all seawater samples is less than 1 µg/l, while sediments contain various concentrations of arsenic from 1.5-2.3 µg/g. The highest concentration is observed in MS-8, 2.3 µg/g, and the second greatest is in MS-5 with 1.8 µg/g As. The lowest concentration is observed in MS-1, MS-2 and MS-4, 1.5 µg/g. MS-3 and MS-6 show the same

concentration, 1.6 µg/g, and MS-6 and MS-7 show 1.8 and 1.7 µg/g arsenic, respectively (See Figure 3.5.6).

Seawater samples show free of Cadmium (Cd), but average 1.6µg/g of cadmium is detected in sediment. MS-7 show the least concentration of cadmium, 1.2 µg/g, and MS-1 shows the maximum concentration, 2.1 µg/g. The values in other stations are: MS-2, 2.0 µg/g, MS-3, 1.7 µg/g, MS-4, 1.6 µg/g, MS-5, 1.5 µg/g , MS-6, 1.4 µg/g and MS-8, 1.5 µg/g (See Figure 3.5.6).

Chromium (Cr) level in sediment is much higher than in seawater samples. Cr in seawater samples is less than 0.1 µg/l. The average concentration of Cr in sediment is 27.3 µg/g, with a maximum in MS-3, 33.0 µg/g and minimum in MS-5, 20.8 µg/g. Cr values in other stations are: MS-1, 32.3 µg/g, MS-2, 22.9 µg/g , MS-4, 28.1 µg/g, MS-6, 25.9 µg/g , MS-7, 24.0 µg/g and MS-8, 31.5 µg/g (See Figure 3.5.6).

Cobalt (Co) concentration in sediment and sea water samples are much different. Co in sea water is less than 0.1 µg/l. The average concentration of Co in sediment is 19.1 µg/g, with the maximum in MS-3, 20.5 µg/g, and the minimum in MS-5, 16.6 µg/g. Co values in other stations are: MS-1, 20.1 µg/g, MS-2, 19.8 µg/g, MS-4, 19.6 µg/g, MS-6, 17.2 µg/g, MS-7, 18.8 µg/g , and MS-8, 20.1 µg/g (See Figure 3.5.6).

Copper (Cu) in seawater ranges 0.1- 2.2 µg/l. MS-3 at 0.5m below surface, MS-4 and MS-6 at 2m below surface and MS-8 at 0.5m below surface shows the minimum concentration of Cu, less than 0.1 µg/l, and MS-2 at 0.5m below surface shows the maximum concentration, 2.2 µg/l. The concentration in other seawater samples are: MS-1, 2.5 µg/l, MS-2 at 2m below surface, 0.1 µg/l, MS-3 at 2m below surface, 1.6 µg/l, MS-5 at 0.5m below surface, 0.1 µg/l, at 2m below surface: 1.4 µg/l, at 10m below surface, 0.94 µg/l, MS-6 at 0.5m below surface, 1.8 µg/l, at 10m below surface, 0.89 µg/l, MS-7 at 0.5m below surface, 1.4 µg/l, at 2m below surface, 0.1 µg/l, at 10m below surface, 0.1 µg/l and MS-8 at 2m below surface, 0.1 µg/l, at 10m below surface, 0.3 µg/l (See Figure 3.5.6). The average concentration of Cu in sediment is 15.5 µg/g, with a maximum in MS-8, 18.7 µg/g and minimum in MS-2, 13.0 µg/g. Cu values in other stations are: MS-1, 17.2 µg/g, MS-3 and MS-4, 18.5 µg/g, MS-4, 16.6 µg/g , MS-5, 12.9 µg/g, MS-6, 13.2 µg/g and MS-7, 14.0 µg/g (See Figure 3.5.6).

The concentration of Iron (Fe) in water and sediment shows the same level because of erratic changes in concentration values in sediment. Fe level in seawater samples is less than 0.1 mg/l,

while, concentration in sediment shows average 14.9 mg/g. Maximum concentration is observed in MS-8, 18.0 mg/g. MS-5 shows the lowest level of Fe, 12.3 mg/g. Fe values in other stations are: MS-1, 16.1 mg/g, MS-2, 12.9 mg/g, MS-3, 16.3 mg/g, MS-4, 15.7 mg/g, MS-6, 14.3 mg/g and MS-7, 13.4 mg/g (See Figure 3.5.6).

Nickel (Ni) in seawater ranges 0.8- 3.1 µg/l. MS-3 at 2m below surface shows the maximum level of Ni, 3.1 µg/l, while it is 1.7 µg/l at 0.5m below surface. On the other hand, MS-8 shows the minimum level of Ni at 10m below surface, 0.8 µg/l, but at 0.5m and 10m below surface show 1.6 and 2.0 µg/l, respectively. The concentration of Ni in other station are: MS-1, 1.8 µg/l, MS-2 at 0.5 and 2m below surface, 1.4 µg/l, MS-3 at 0.5m below surface, 1.7 µg/l, MS-4, 1.5 µg/l, MS-5 at 0.5m below surface, 1.6 µg/l, at 2m below surface, 1.8 µg/l, at 10m below surface, 1.7 µg/l, MS-6 at 0.5m below surface, 2.3 µg/l, at 2m below surface, 2.0 µg/l, at 10m below surface, 1.8 µg/l and MS-7 at 0.5m below surface, 2.0 µg/l, at 2m below surface, 1.0 µg/l at 10m below surface, 1.9 µg/l (See Figure 3.5.5).
The average concentration of Ni in sediment is 62.7 µg/g, with a maximum in MS-3, 80.2 µg/g and minimum in stations MS-2 and MS-7, 53 µg/g. Ni values in other stations are: MS-1, 72.7 µg/g, MS-4, 69.8 µg/g, MS-5, 55.2 µg/g, MS-7, 59.2 µg/g and MS-8, 58.2 µg/g (See Figure 3.5.6).

Lead (Pb) in seawater ranges between 0.1 to 1.5 µg/l. Stations MS-1, MS-2, MS-3 at 0.5m below surface, MS-6 at 2m below surface and MS-8 at 10m below surface show the minimum concentration of Pb, less than 0.1 µg/l and MS-4 show maximum concentration, 1.5 µg/l. The concentration of Pb in other stations are: MS-3 at 2m below surface, 0.1 µg/l, MS-5 at 0.5 and 10m below surface, 0.2 µg/l, at 2m below surface, 0.5 µg/l, MS-6 at 0.5m below surface, 0.3 µg/l, at 10m below surface, 0.1 µg/l, MS-7 at 0.5m below surface, 0.1 µg/l, at 2m below surface, 0.5 µg/l, at 10m below surface, 0.2 µg/l, MS-8 at 0.5m below surface, 0.3 µg/l, at 2m below surface, 0.5 µg/l (See Figure 3.5.5).
The average concentration of Pb in sediment is 22.9 µg/g, with a maximum in MS-8, 26.7 µg/g and the minimum in MS-7, 21.1 µg/g. Pb values in other stations are: stations MS-1and MS-4, 22.0 µg/g, MS-2, 22.3 µg/g, MS-3, 25.3 µg/g , MS-5, 22.2 µg/g and MS-6, 21.3 µg/g (See Figure 3.5.6).

The result showed that Zinc (Zn) in all seawater samples is less than 0.01 mg/l, while the concentration of Zn in sediment varies. The average concentration of Zn in sediment is 52.4 µg/g, with the maximum in MS-8, 69.4 µg/g, and the minimum in MS-7, 36.4 µg/g. Pb values in other

stations are: MS-1, 61.8 µg/g, MS-2, 47.1µg/g, MS-3, 68.7 µg/g , MS-4, 52.6 µg/g, MS-5, 42.2 µg/g and MS-6, 41.2 µg/g (See Figure 3.5.6).

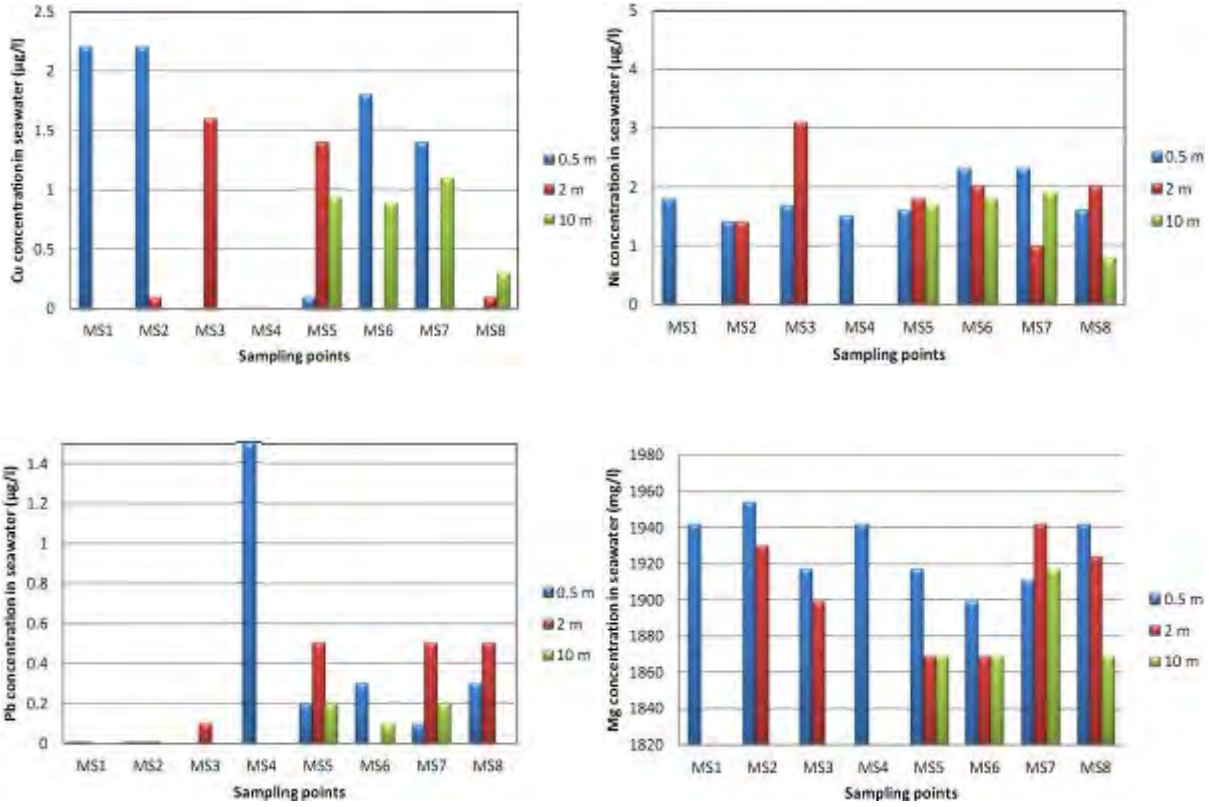
Seawater samples are free of Manganese (Mn), less than 0.1 µg/l, except MS-8 at 2m below surface with 0.44 µg/l Mn. However, concentrations in sediment show much higher concentration of Mn. The average concentration of Mn in sediment is 329 µg/g, with a maximum in MS-1, 372 µg/g and minimum in MS-5, 271 µg/g. Mn values in other stations are: MS-2, 354 µg/g, MS-3, 347 µg/g, MS-4, 355 µg/g, MS-6, 324 µg/g, MS-7, 308 µg/g and MS-8, 298 µg/g (See Figure 3.5.6).

Methyl mercury (Me-Hg) and Mercury (Hg) in sea water samples are less than 1 µg/l. Also, Me-Hg in sediment samples are less than 0.01 µg/g. While Hg is not detected in MS-5, MS-6 and MS-7, MS-1, 2, 3, 4 and MS-8 show different concentrations of Hg. The maximum Hg is detected in MS-1, 0.7 µg/g and the minimum Hg is observed in MS-8, 0.1 µg/g. Hg concentration in MS-2 , MS-3, MS-4 are 0.26, 1.9 and 0.34 µg/g, respectively (See Figure 3.5.6).

The concentration of Aluminum (Al) in seawater and sediment samples is not the same level because of erratic changes in concentration values in sediment. Sea water samples show less than 0.1mg/l Al, while average concentration of Al in sediment is 8.2 mg/g. The maximum concentration of Al is detected in MS-3, 10 mg/g. MS-5 shows the lowest level of Al, 6.7 mg/g. Al values in other stations are: MS-1, 9.2 mg/g, MS-2, 6.9 mg/g, MS-4, 9.0 mg/g, MS-6, 8.2 mg/g, MS-7, 7.1 mg/g and MS-8, 8.6 mg/g (See Figure 3.5.6).

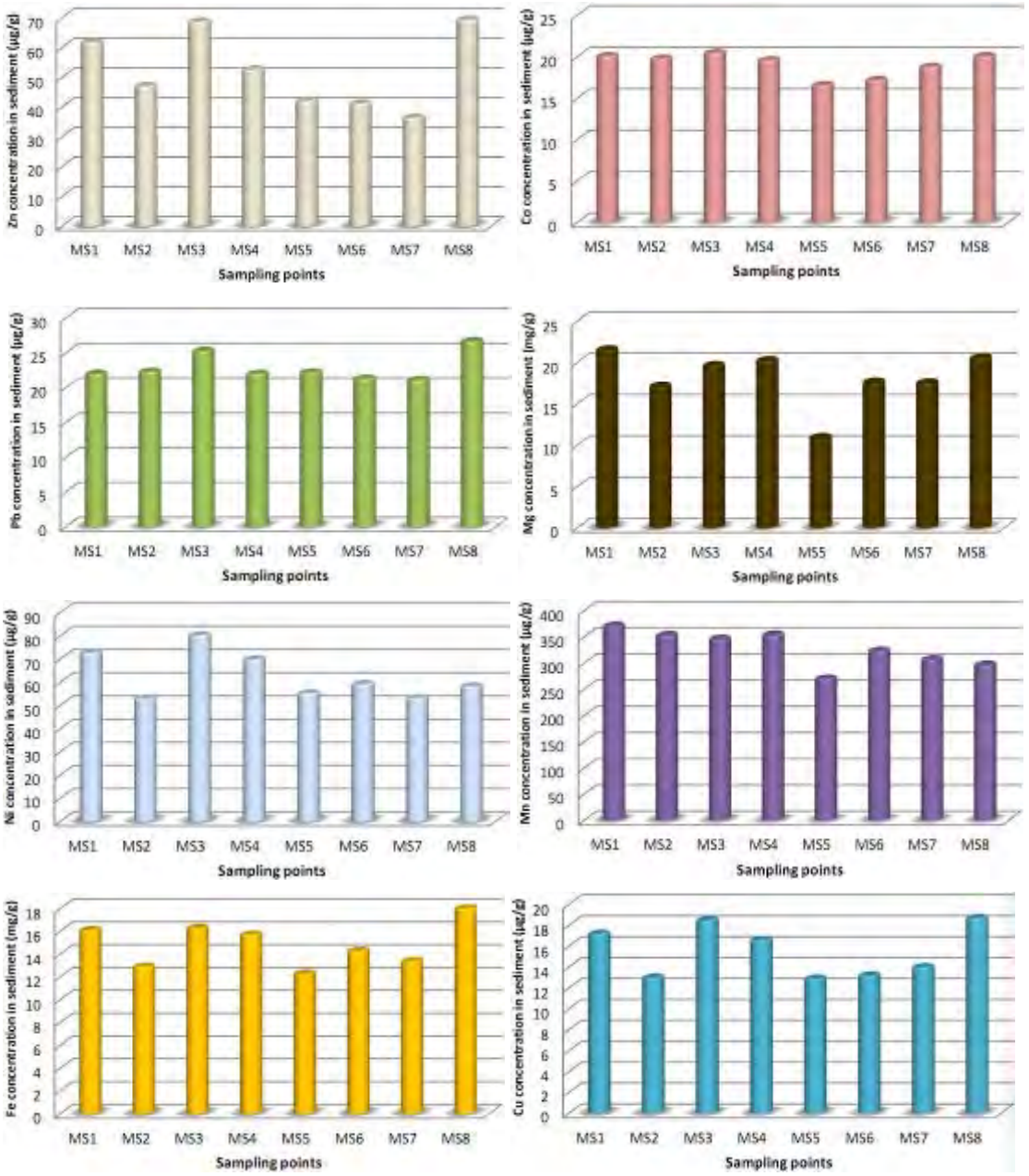
Magnesium (Mg) concentration in sea water samples differs from 1869 to 1954 mg/l. MS-2 at 0.5m below surface shows the maximum level of Mg, 1954 mg/l, although it shows 1930 mg/l at 2m below surface. MS-8 at 10 m below surface shows the lowest concentration of Mg, 1869 mg/l. This station shows 1942 and 1929 mg/l Mg at 0.5 m and 2 m below surface, respectively. The concentration of Mg in other station is: MS-1, 1942mg/l, MS-3 at 0.5m below surface, 1917mg/l, at 2m below surface, 1899mg/l, MS-4, 1942 mg/l , MS-5 at 0.5m below surface, 1917mg/l, at 2m and 10m below surface, 1869mg/l, MS-6 at 0.5m below surface, 1899mg/l, at 2m and 10m below surface, 1869 mg/l, MS-7 at 0.5m below surface, 1911mg/l , at 2m below surface, 1942mg/l at 10m below surface, 1917mg/l (See Figure 3.5.5).
The average concentration of Mg in sediment is 18.2 mg/g. Maximum level of Mg is observed in MS-1, 21.6 mg/g, and MS-5 shows the minimum concentration, 11.0 mg/g. Other station

shows various concentrations of Mg; MS-2, 17.2 mg/g , MS-3, 19.7 mg/g , MS-4, 20.3 mg/g, MS-6, 17.7 mg/g, MS-7, 17.6 mg/g and MS-8, 20.6 mg/g (See Figure 3.5.6).



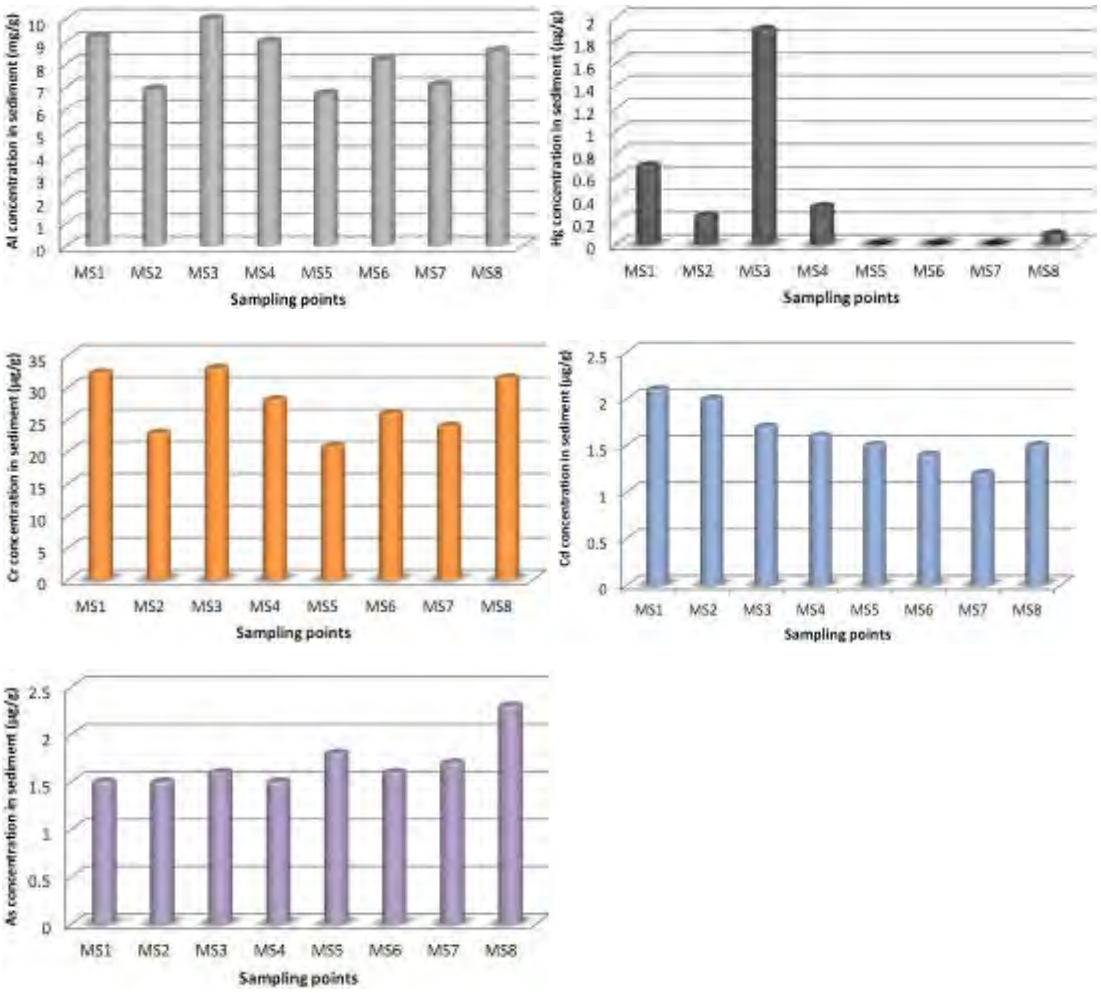
Source: Study team

Figure 3.5.5 Heavy Metal Concentrations in Seawater Samples



Source: Study team

Figure 3.5.6 (1) Heavy Metal Concentrations in Sediment Samples



Source: Study team

Figure 3.5.6 (2) Heavy Metal Concentrations in Sediment Samples

The average concentration of trace elements and heavy metals in the study area and their concentrations in seawater of south Persian Gulf countries including Bahrain, UAE, Oman, Saudi Arabia and also average concentrations of trace elements in natural seawaters (Kabata-Pendias and Pendias, 1999) are presented in Table 3.5.3. Each element displays a minor variation in concentrations (with the exception of Pb, Cu and Ni), reflecting by the low standard deviations. By comparing the natural seawaters (Kabata-Pendias and Pendias, 1999), the average concentration of Cu, Ni and Pb are higher than the average concentrations of trace elements in natural seawaters (See Figure 3.5.7). 100% of the total of seawater samples at all depths of Ni, 67% of Pb, and 55% of Cu exceed the averaged concentrations in natural seawaters (See Figure 3.5.8). Thus, Ni, Pb and Cu are the major pollutants in the study area and may pose health risk of aquatic life and also the residents in the region and the water receiving areas.

Table 3.5.3 Comparison of Heavy Metals Concentration in Seawater between the Study Area and Other Persian Gulf Countries

Parameter	Unit	Survey Result			Bahrain[A]	UAE A	Oman A	Saudi Arabia[A]	CCME[B]	Mahshahr[C]	Seawater[D]
		Min	Max	Mean							
Al	mg/	<0.	<0.	<0.	---	---	---	---	---	---	0.002
As	µ/L	<1	<1	<1	---	---	---	---	12.5	<5	7
Cd	µ/L	<0.	<0.	<0.	11-16	<2-12	30	0.31-	0.12	<10	0.1
Cr	µ/L	<0.	<0.	<0.	---	---	---	---	56 as	<10	0.3
Co	µ/L	<0.	<0.	<0.	---	---	---	---	---	<10	0.01
Cu	µ/L	<0.	1.8	0.8	20-30	80-	130	0.9-	---	<10	0.2
Fe	mg/	<0.	<0.	<0.	---	---	---	0.01-	---	0.038-	0.001
Hg	µ/L	<1	<1	<1	10-25	9-20	7	---	0.016	<2	0.02
Mn	µ/L	<0.	<0.	<0.	---	---	---	---	---	---	0.2
Ni	µ/L	0.8	2.3	1.7	---	---	---	0.52-	---	<20	0.5
Pb	µ/L	0.1	0.5	0.2	20-	30-60	30	0.01-	---	<20	0.03
Zn	mg/	<0.	<0.	<0.	0.06-	0.002-	0.4	0.005-	---	---	0.002

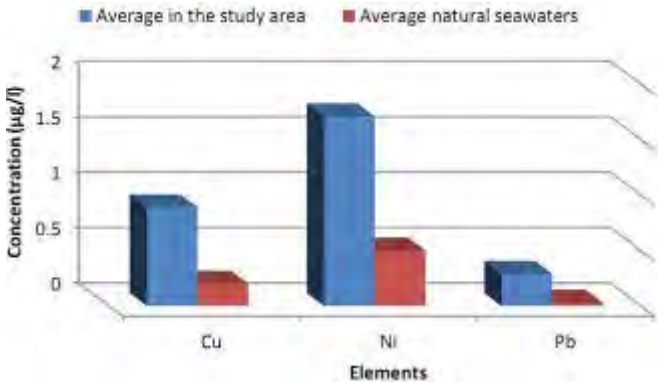
Source:

A: Heavy metal concentrations of seawater in south of Persian Gulf (Marine Pollution Bul., 1997).

B: Canadian Council of Ministers of the Environment 1999.

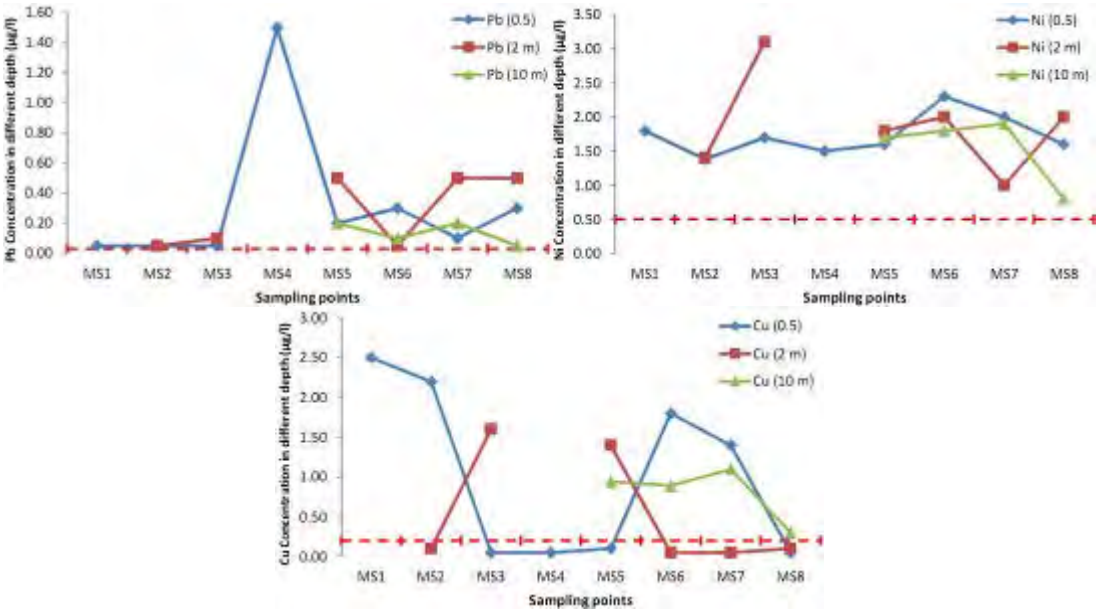
C: Heavy metal concentrations in sediment of PETZONE, 2008.

D: Mean concentrations of trace elements in natural seawater (Kabata-Pendias and Pendias, 1999)



Source: Kabata-Pendias and Pendias, 1999

Figure 3.5.7 Average Concentration of Cr, Co, Cu, Ni and Pb in the Study Area and Natural Seawater



Source: The study team and Kabata-Pendias and Pendias, 1999

The Red dash line shows the average concentration in natural sea water.

Figure 3.5.8 Heavy Metal Concentration in Each Survey Point

The water quality guidelines for protection of aquatic life (CCME[2]) specifies only As, Cd, Cr^{3+} and Hg. The concentrations of these elements are lower than CCME standard.

The range and average concentrations of trace and heavy metals in the surface sediment expressed on a dry-weight are summarized in Table 3.5.2. This leads to the following ranking based on the concentrations:

Al>Fe>Mn>Ni>Zn>Cr>Pb>Co>Cu>As>Cd>Hg

The average concentrations of heavy metals in sediment samples of the study area and their concentration in sediment of south Persian Gulf countries (ROPME, 1998-2000) including Bahrain, UAE, Oman, Saudi Arabia, Qatar, Kuwait and also mean concentrations of trace elements in continental crust (Mason and Moore, 1995; Reimann and Caritat, 1998) are shown in Table 3.5.4 and Figure 3.5.9. The maximum concentrations of Cd, Co, Cr and Zn are recorded in Kuwait, Ni in Oman, Pb in Bahrain, and Al, Fe and Cu in continental crust. As and Hg concentrations were not measured in ROPME project, whereas in this study Hg concentration is higher than average of continental crust.

[2] Canadian Council of Ministers of the Environment

Table 3.5.4 Comparison of Heavy Metal Concentration in Sediment between the Study Area and Other Persian Gulf Countries

Parameters	Unit	Survey Result			Bahrain[A]	Oman[A]	Saudi Arab	Qatar[A]	Kuwait[A]	Asaluyeh A	Continental	Mahshahr[C]
		Min	Max	Mean								
Al	mg/g.	6.70	10.0	8.10	---	---	10[A]	9.8[A]	12[A]	---	69	---
As	µg/g.	1.50	2.30	1.69	---	---	---	---	---	---	1.8	3.6-
Cd	µg/g.	1.20	2.10	1.63	0.1[A]	4.82	---	110	120	5.1[A]	0.1	<1
Cr	µg/g.	20.8	33.0	27.3	7 D	95.4	32.3	3.8 D	170	4.3[A]	100	69-
Co	µg/g.	16.6	20.5	18.9	1.2 D	---	6 D	0.5 D	32.2	---	10	11-
Cu	µg/g.	12.9	18.7	15.5	3.9 D	8.7[A]	9.9 D	20[A]	30	6.1[A]	55	22-
Fe	mg/g.	12.3	18.0	14.9	---	---	5.3 D	---	22.6	7.3[A]	35	23-
Hg	µg/g.	<0.0	1.90	0.39	---	---	---	---	---	---	0.07	0.05-
Mn	µg/g.	271.	372.	327.	---	---	---	---	---	---	900	---
Ni	µg/g.	53.0	80.1	63.4	10.9	329.	41.6	120	130	17[A]	20	70-
Pb	µg/g.	21.1	26.7	23.0	52[A]	---	---	---	---	18.1	14	11-
Zn	µg/g.	36.4	69.4	52.5	54[A]	11.3	26.3	98[A]	112	19.3	70	50-

Source:

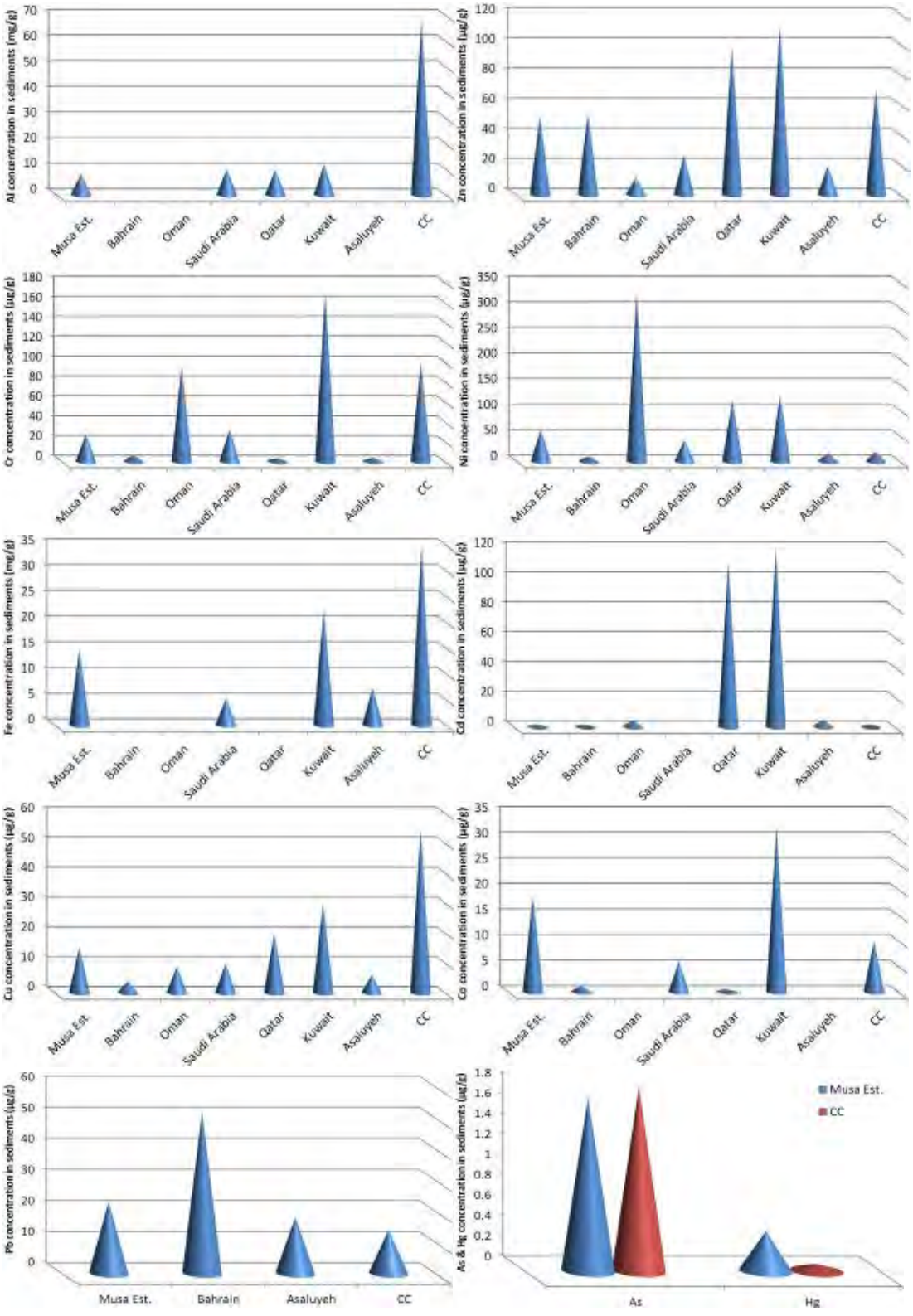
A: Heavy metal concentrations of sediment of Persian Gulf (ROPME, 1998-2000).

B: Mason and Moore, 1995; Reimann and Caritat, 1998.

C & D: Heavy metal concentrations in sediment of PETZONE, 2008.

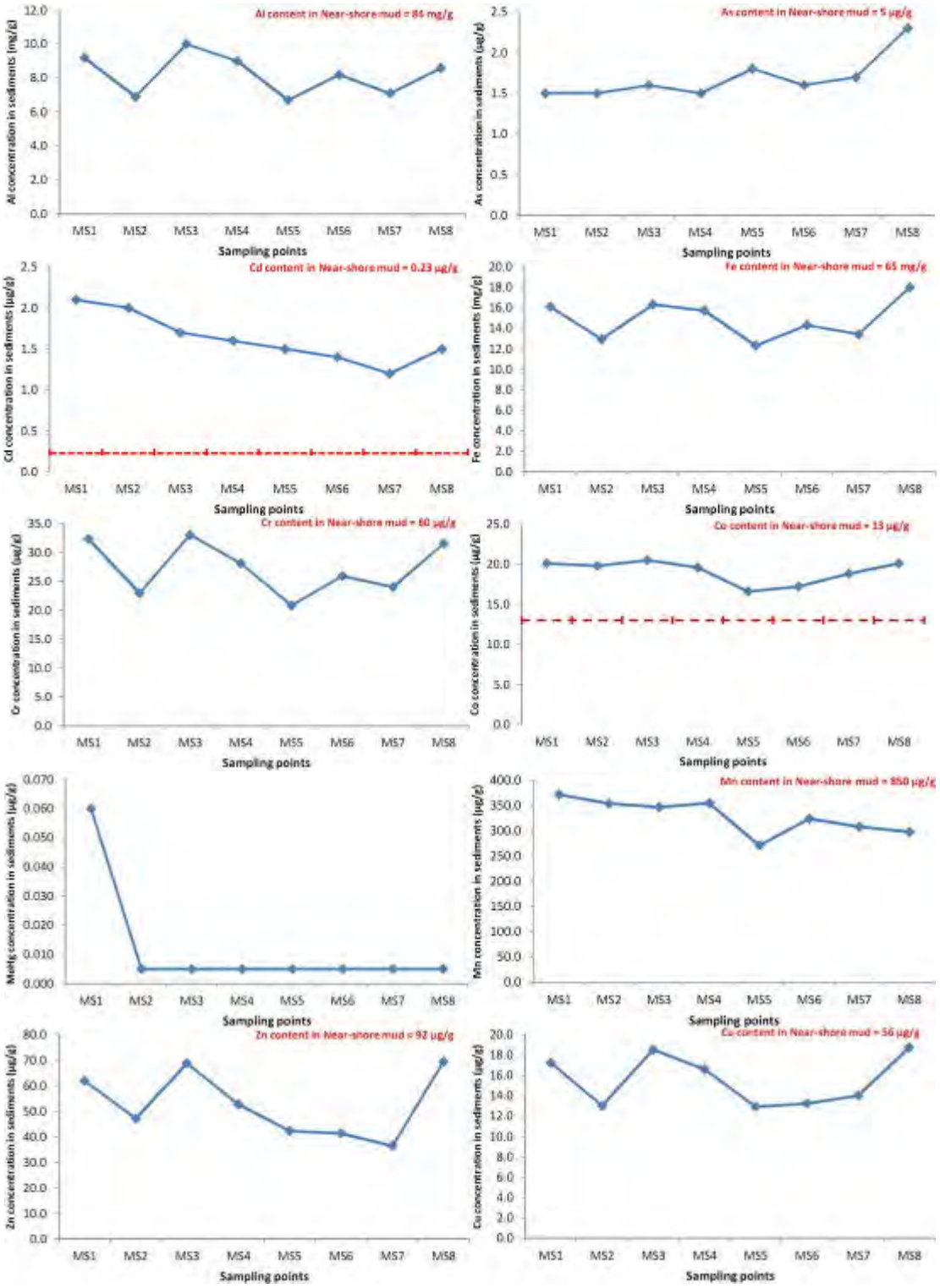
In order to detect the accumulation pattern of elements in sediment, the metal concentrations are plotted versus sampling points in Figure 3.5.10. The patterns of Zn, Cu, Ni, Fe, Al and Cr variation in sediment are similar and comparable, whereas Co, Mn, Hg, MeHg, As, Cd and Pb in sediment samples show different patterns.

Horizontal distributions of heavy metals in seawater and sediment are shown in Figure 3.5.11 and Figure 3.5.12 respectively.



Source: ROPME, 1998-2000, Mason and Moore, 1995, Reimann and Caritat, 1998

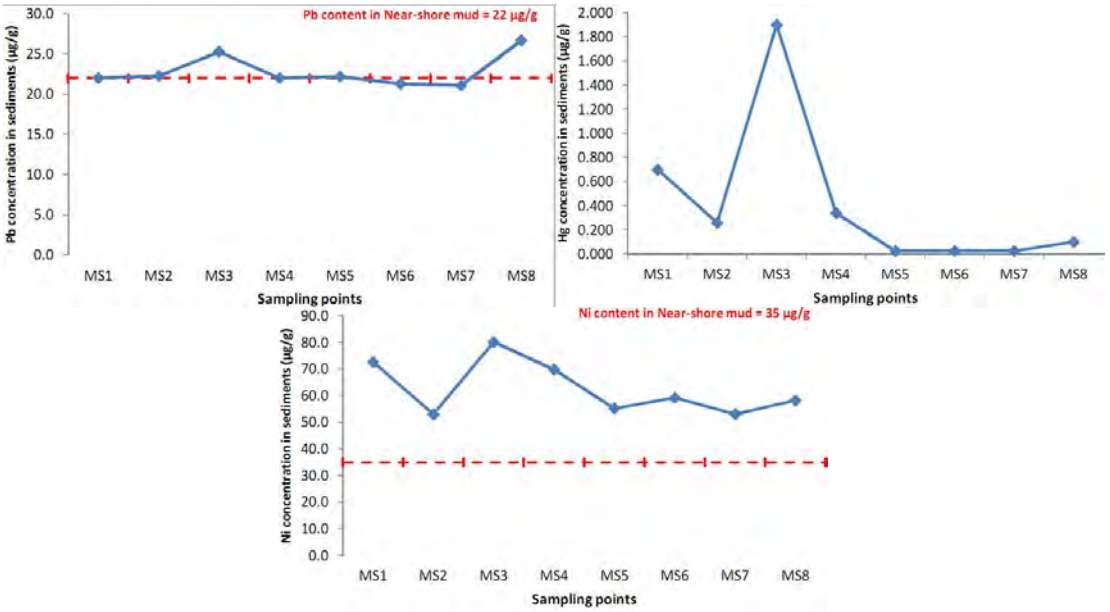
Figure 3.5.9 Comparison of Heavy metal Concentration in Sediment between Different Study



Source: Study team, ROPME, 1998-2000, Mason and Moore, 1995, Reimann and Caritat, 1998

The Red dash line shows the average concentration in continental crust.

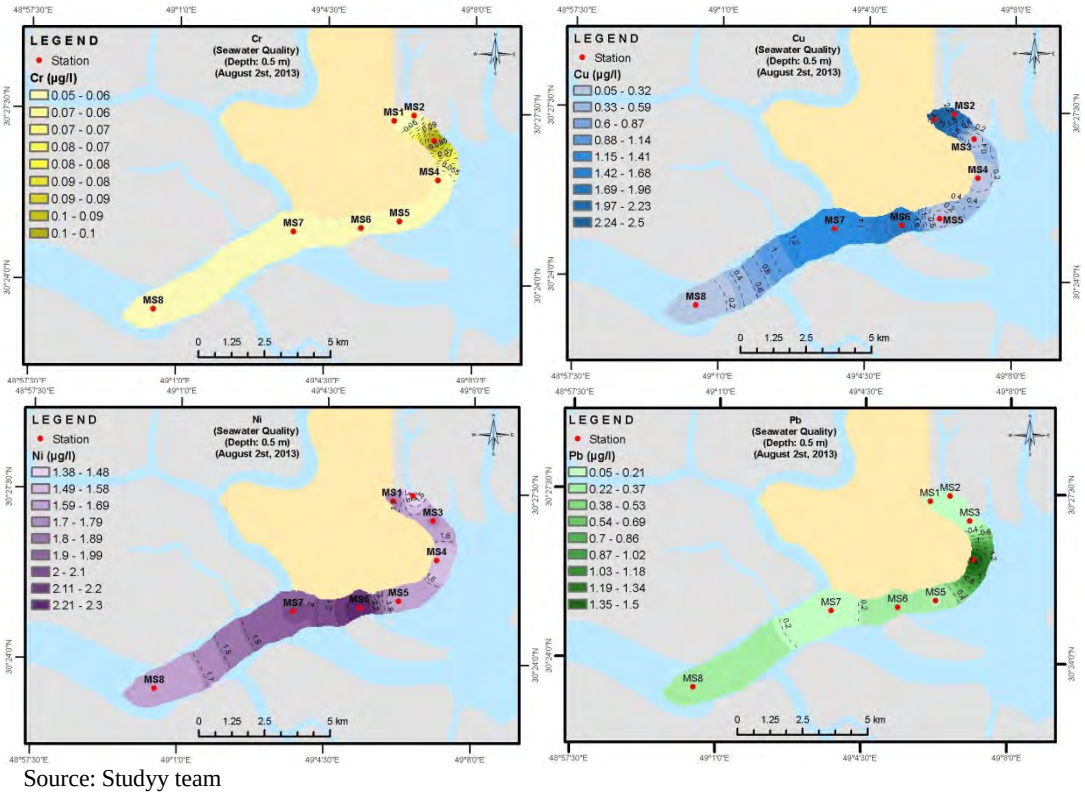
Figure 3.5.10 (1) Trace and Heavy Metal Concentration in Each Sampling Point



Source: Study team, ROPME, 1998-2000, Mason and Moore, 1995, Reimann and Caritat, 1998

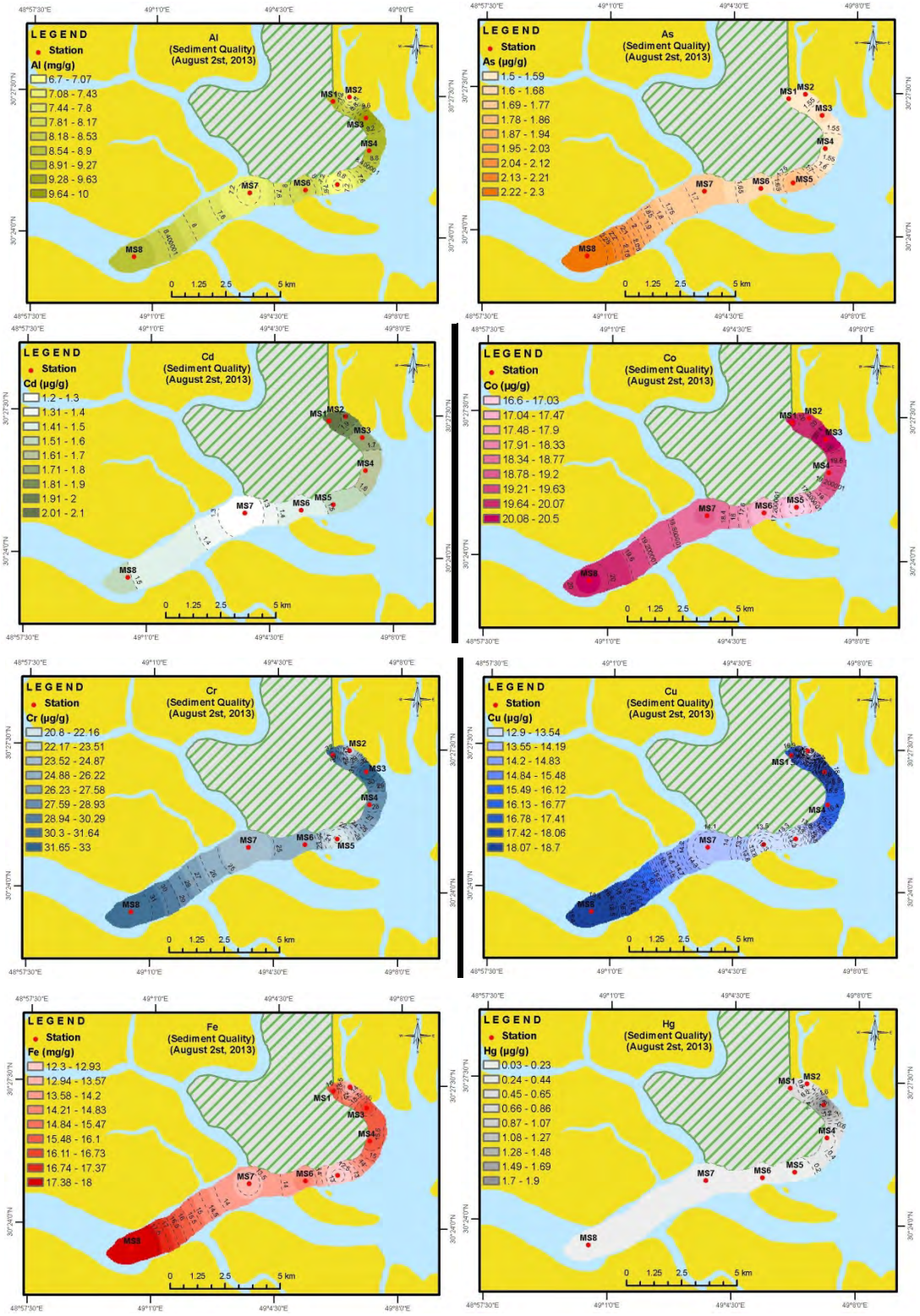
The Red dash line shows the average concentration in continental crust.

Figure 3.5.10 (2) Trace and Heavy Metal Concentration in Each Sampling Point



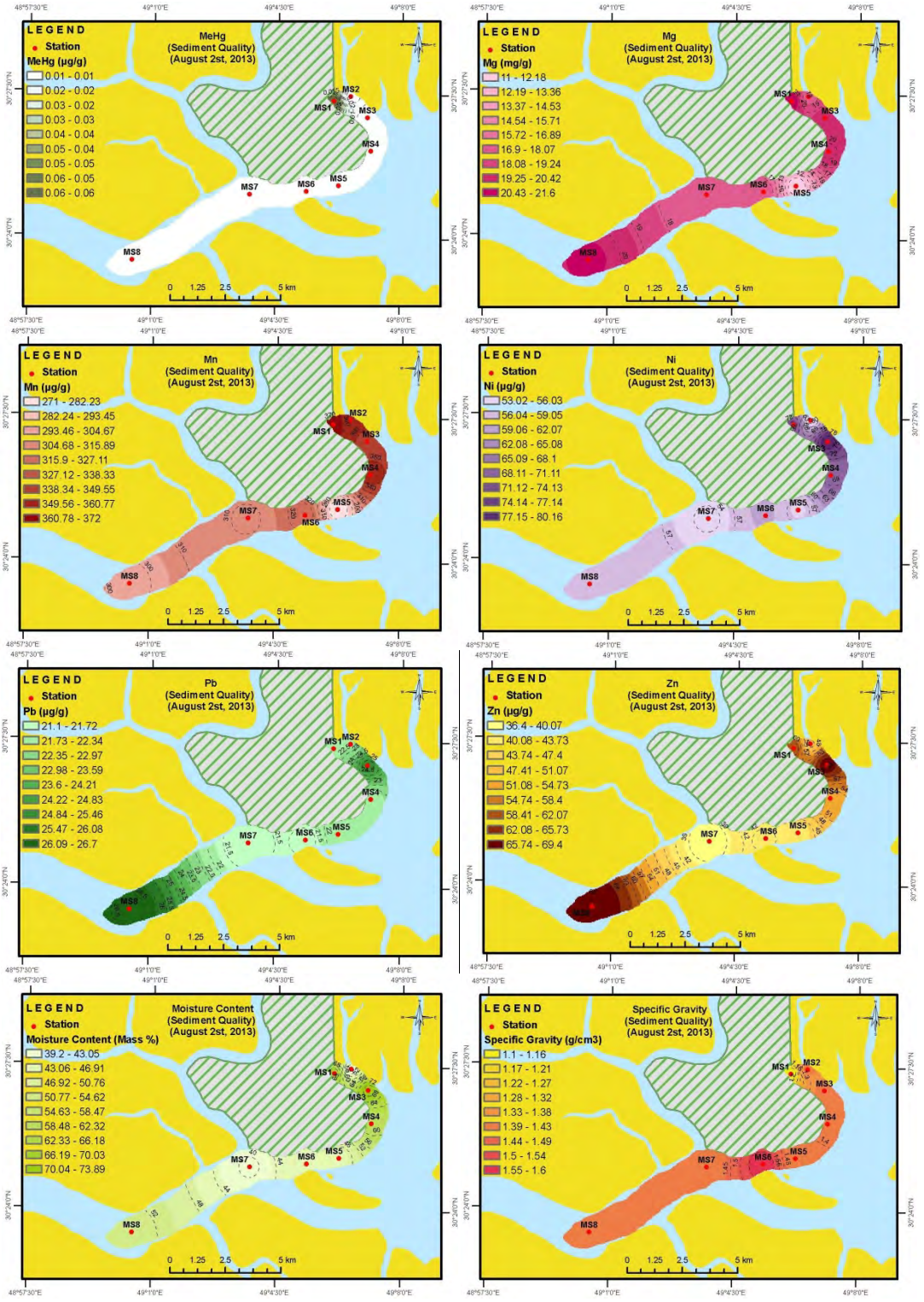
Source: Studyy team

Figure 3.5.11 Horizontal Distribution of Heavy Metal Concentration in Seawater.



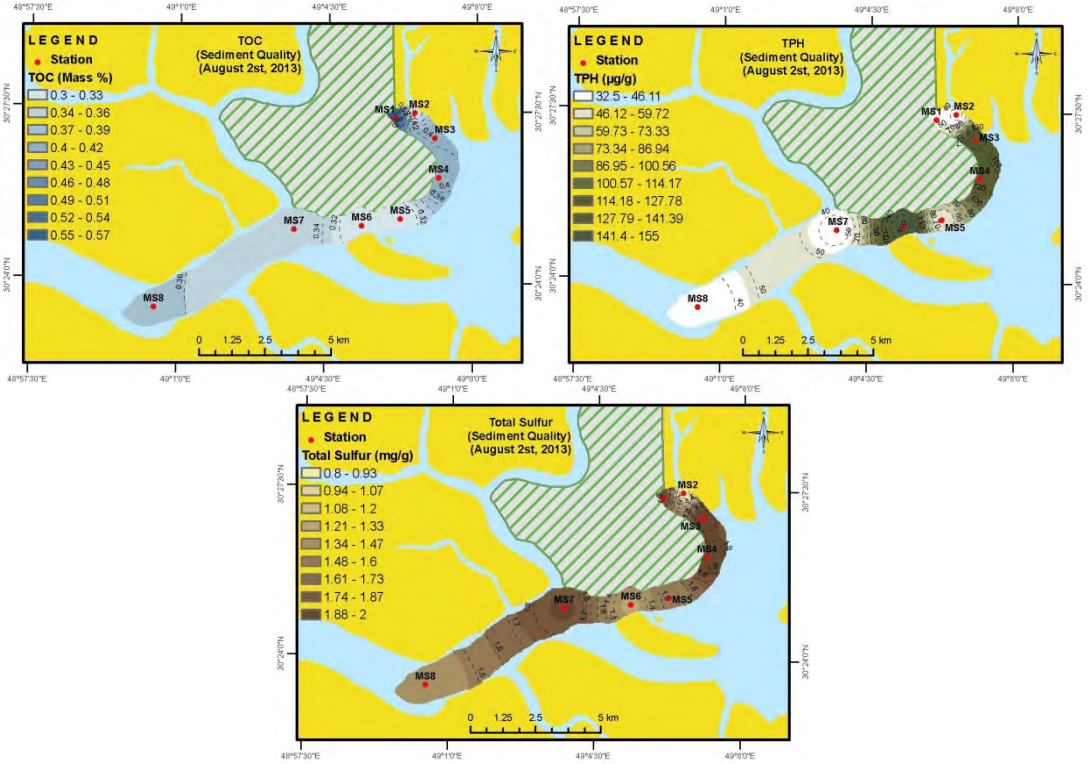
Source: Study team

Figure 3.5.12 (1) Horizontal Distribution of Heavy Metal Concentration in Sediment



Source: Study team

Figure 3.5.12 (2) Horizontal Distribution of Heavy Metal Concentration in Sediment



Source: Study team

Figure 3.5.12 (3) Horizontal Distribution of Heavy Metal Concentration in Sediment

In order to detect the pollution level in sediment in the study area (PETZONE) and to detect the impact to benthic organisms, the concentrations of trace elements detected in this study are compared with the Effects Range Low (ERL) and the Effects Range Medium (ERM) values by NOAA Marine Sediment Quality Guideline and the Threshold Effect Level (TEL) and the Probable Effect Level (PEL) by the Canadian Interim Marine Sediment Quality Guideline (ISQG, CCME, 2002) (See Table 3.5.5). The Threshold Effect Level (TEL) is the level below which adverse effects rarely occurs and the Probable Effect Level (PEL) is the level above which adverse effects frequently occurs.

In this sampling period, the maximum and average concentration of As, Cr, Cu, Pb and Zn in sediment do not exceed the sediment quality guidelines (ISQG/TEL) and pose no environmental concerns. Cu concentration of sediments in two sampling points (MS-3 and MS-8) are close to the ISQG/TEL.

Sediment quality guideline and TEL are not determined for Mn, but the concentration of Mn in all of the sampling stations is lower than ERL.

The concentration of Hg in all the sediment samples is lower than PEL, while in four sampling points (MS-1, MS-2, MS-3 and MS-4) are higher than ISQG/TEL.

The concentrations of Ni and Cd in all sediments are higher than TEL and ERL. Moreover, Ni concentrations in all of sampling stations are higher than ERM that can be harmful to benthic organisms. Nickel has a high natural background in this mineral-rich region. A part of the high level of Ni in the sediments could be the result of natural mineralization of ophiolitic rocks (De Mora et al., 2004). High nickel concentrations in sediment samples and lower concentration of Cr and Co in sediment indicate that there is another source for nickel in the study region.

Concentrations of cobalt in three sampling stations (MS-1, MS-3 and MS-8) are higher than freshwater sediments (20 µg/g; Canadian Technical Report. 2004). Comparing the element concentration in eight sampling stations demonstrate that relatively elevated concentrations of some elements occurred in similar areas.

Maximum levels of Cd and MeHg are detected at the MS-1 sampling point, Al, Cr, Pb, Hg and Ni at the MS-3 sampling point, and As, Fe, Cu and Pb at the MS-8 sampling point.

Maximum detected levels of Co (20.1µg/g) are observed in MS-1 and MS-8.

In this comparison, elevated levels do not indicate whether there are potential toxicological concerns associated with these levels for Al, Fe, As, Cr, Cu, Hg, Pb and Zn.

Table 3.5.5 Comparison of Sediment Concentration between the Survey Result and the Guideline Values by NOAA and ISQGs Marine Sediment Quality Guideline

Elements	Average in this study	ISQG	ERL	ERM	PEL	Nearshore muds
Al (mg/g)	8.10	---	---	---	---	84
As (µg/g)	1.69	7.24	8.2	70	41.6	5
Cd (µg/g)	1.63	0.7	1.2	9.6	4.2	---
Cr (µg/g)	27.31	52	81	370	160	60
Co (µg/g)	18.98	---	---	---	---	13
Cu (µg/g)	15.57	18.7	34	270	108	56
Fe (mg/g)	14.93	---	---	---	---	65
Hg (µg/g)	0.39	0.13	---	---	0.7	---
Mn (µg/g)	327.20	---	460	1100	---	850
Ni (µg/g)	63.45	< 20	21	52	>50	35
Pb (µg/g)	23.07	30.2	47	220	112	22
Zn (µg/g)	52.52	124	---	---	271	92

Source: NOAA Marine Sediment Quality Guideline
Canadian Interim Marine Sediment Quality Guideline (ISQG, CCME, 2002)
Note: * Average concentration of trace elements in near-shore muds (Martin and Whitfield 1983)
ERL: Effects Range Low
ERM: Effects Range Medium
TEL: Threshold Effect Level
PEL: Probable Effect Level
SQG: Sediment Quality Guidelines (CCME, 2002)

3.6 Survey in September 2013

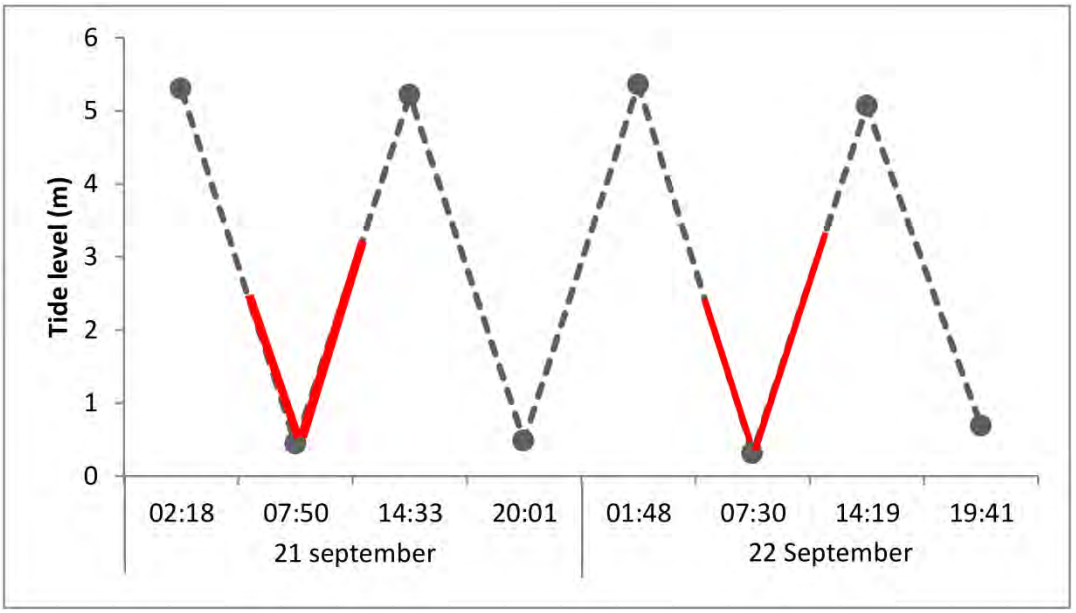
3.6.1 Survey Timing

Table 3.6.1 shows the timetable of the survey and Figure 3.6.1 shows the tide timing of the survey, respectively.

Table 3.6.1 Time Table of the Survey (September, 2013)

Date	Time	Site	Note
Saturday, 21 September 2013	6 to 11	MS-1 to MS-4	Water sampling & in- situ monitoring
Sunday, 22 September 2013	6 to 12	MS-5 to MS-8	

Source: Study team



Source: Tide table (http://www.iranhydrography.org/default.asp)

Red line shows the timing of the survey

Figure 3.6.1 Tide Timing at the Survey (September, 2013)

3.6.2 Result of the Survey

Summary of the survey results is shown in Table 3.6.2band raw data is stored in Annex A.

Table 3.6.2 Summary of the Survey Result

Survey date: Sep. 21-22, 2013

Category	Parameter	Unit	Environmental standard (*1)	Sep		
				Min	Max	Ave
Water quality (Field measurement)	Water temperature	°C	(*2)	29.8	31.3	30.2
	Salinity	-	(*3)	40.60	44.70	43.16
	Conductivity	mS/cm		69.5	76.0	73.6
	pH	-	6.5-9.0	8.44	8.61	8.52
	DO	mg/L	> 3 (*4)	5.90	6.61	6.49
Water quality (Analysis: general parameters)	Turbidity	NTU		31	176	100
	Suspended solid	mg/L	(*5)	10	240	97
	COD	mg/L as O2	5	12	48	17
	TOC	mg/L as C		1.9	3.8	2.5
	Oil contents	mg/L	(*6)	< 0.2	< 0.2	< 0.2
	Coliform bacteria (*10)	MPN Index/100ml	500 (*7)	<2	71	23.2
	Total nitrogen	mg/L as N	0.4 (*8)	0.56	0.88	0.67
	Total phosphorous	mg/L as P	0.045 (*9)	<0.2	<0.2	<0.2

Source: Study team

Note: Red letter means excess of the standard/criteria value

*1: Standard for Ambient Water in Persian Gulf and Oman Sea (draft), Class 6: Industrial zone or Port, DOE.
*2 Water temperature: ±3 of natural temperature of receptive source
*3 Salinity: It should be no more than 10 percent of minimum natural salinity of the region.
*4 DO: 40% of Saturation
*5 Suspended Solid: Its increase should not be more than its daily, monthly, annual average considering standard deviation.
*6 Oil contents: There should be no oil layer, foam visible on its surface.
*7 Coliform bacteria: Fecal coliform should be less than 100 CFU/100ml.
*8 Total nitrogen: The value of Nitrate-nitrogen is used in this table.
*9 Total phosphorous: The value of Phosphate-phosphorus is used in this table.
*10 Total coliform was analyzed in Apr., May, Jun. and Aug-1, while fecal coliform analyzed in Aug-2, Sep. and Oct.

3.6.3 Discussion

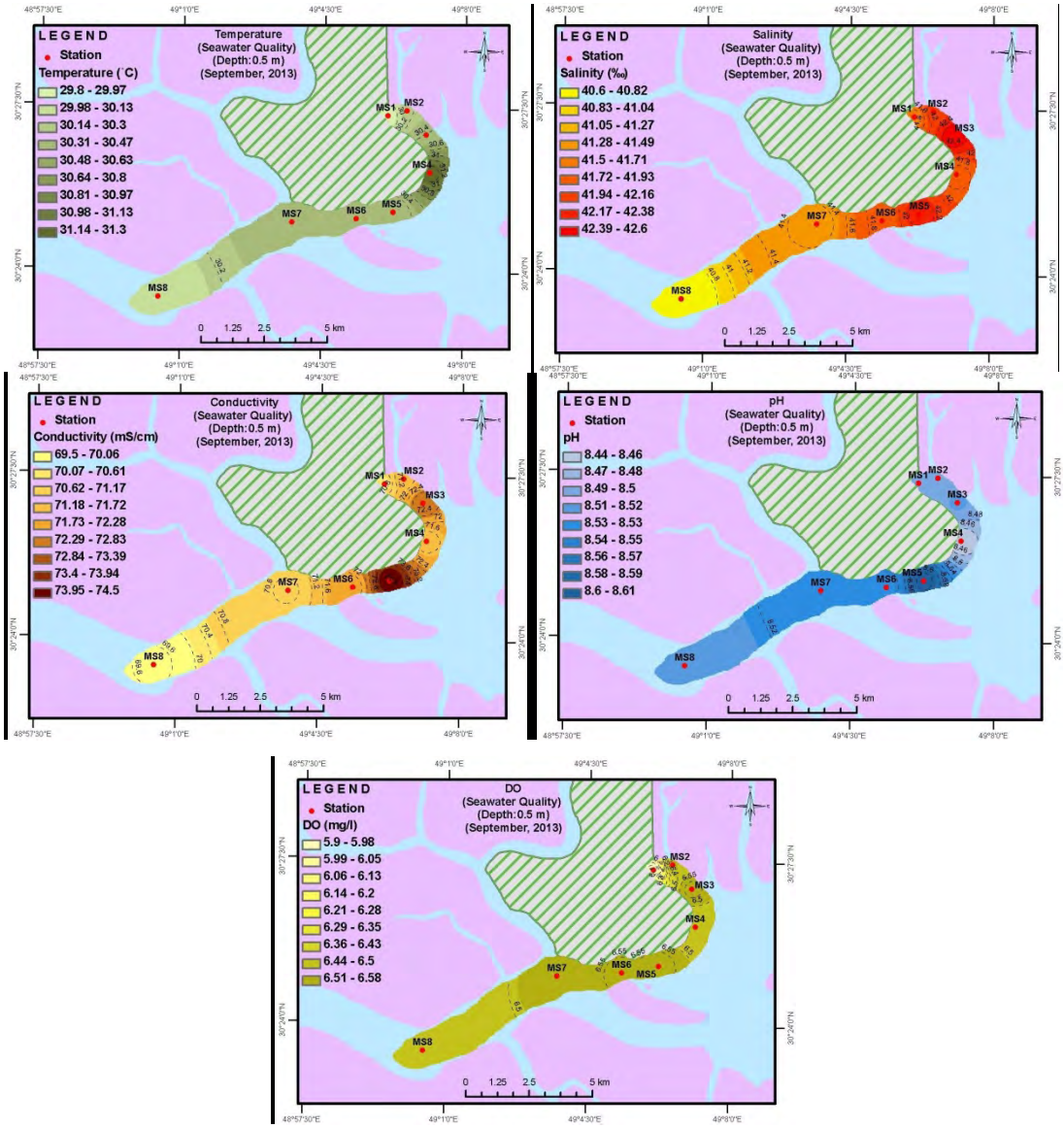
a) Field measurement

Horizontal distribution of the field measurement parameters (in-situ parameters) are shown in Figure 3.3.2.

The water temperature ranges from 29.8 to 31.3 °C (average: 30.22 °C). The pH varies from 8.44 to 8.61 with an average value 8.53, which indicate that seawater is alkaline in nature. The

DO concentration varies between 5.80–6.63 mg/l with an average 6.49 mg/l. The EC in the study area varies from 69.5 to 76 mS/cm with an average of 73.62 mS/cm. Salinity varies between 40.6 and 44.7 with an average value of 43.18.

Vertical profiles for in-situ parameters are shown in Annex D.



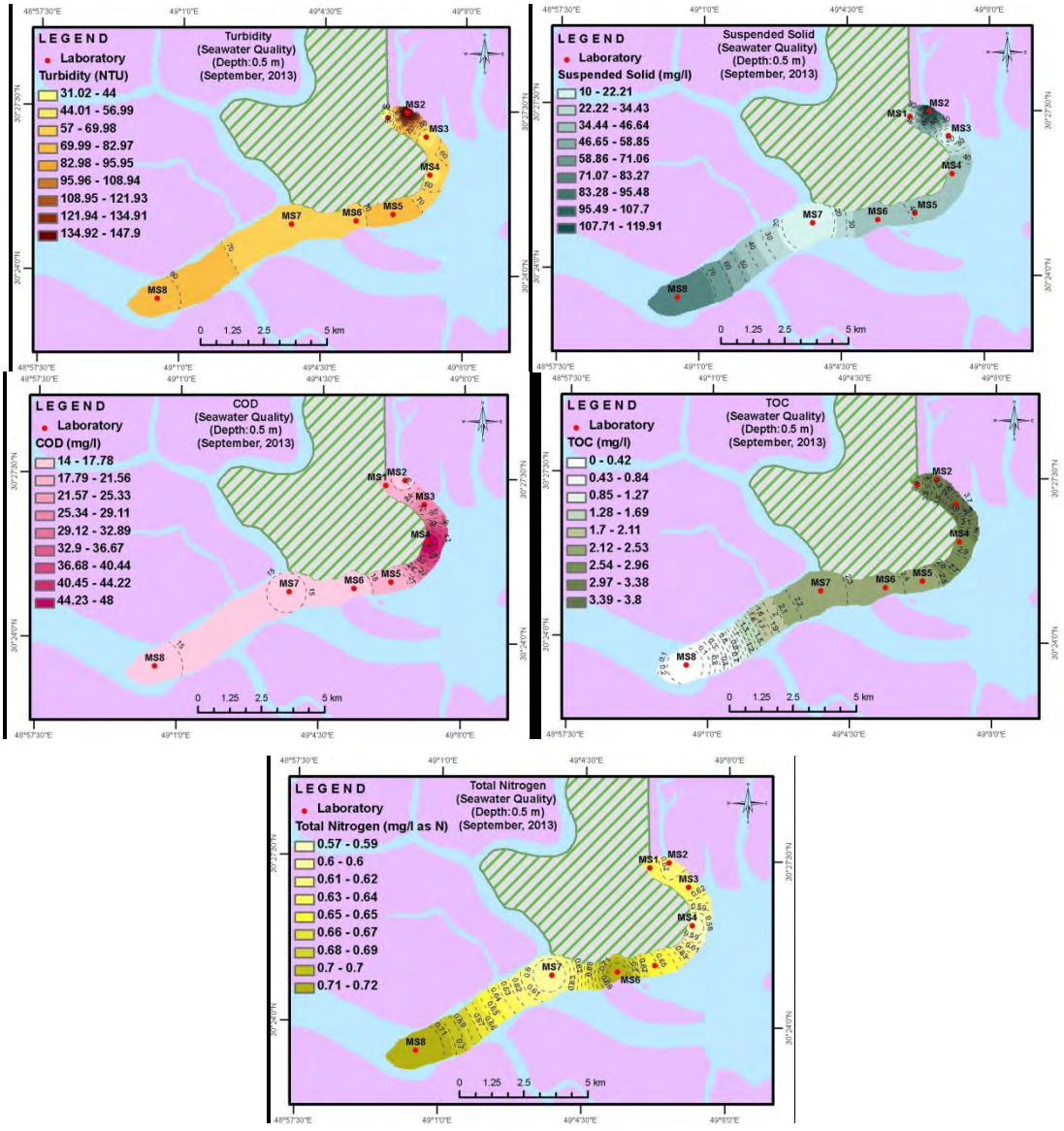
Source: Study team

Figure 3.6.2 (1) Horizontal Distribution of In-situ Parameters

b) Laboratory analysis

Horizontal distribution of the parameters of laboratory analysis is shown in Figure 3.6.3. Turbidity varies between 31 and 190 mg/l and MS-3 (2m below surface) shows the highest

value. Suspended solid varies between 10 and 240 mg/l and MS-8 (10m below surface) shows the maximum concentration. COD in MS-4 (0.5m below surface) shows the highest value and the others are relatively similar. TOC varies between 1.9 and 3.8 mg/l and MS-4 (0.5m below surface) shows the highest value. Total nitrogen concentration varied from 0.58 to 0.88 mg/l. The highest nitrogen concentration is observed in MS-5 (2m below surface). Vertical profiles of laboratory parameters are shown in Annex D.



Source: Study team

Figure 3.6.3 Horizontal Distribution of the Laboratory Parameters

3.7 Survey in October 2013

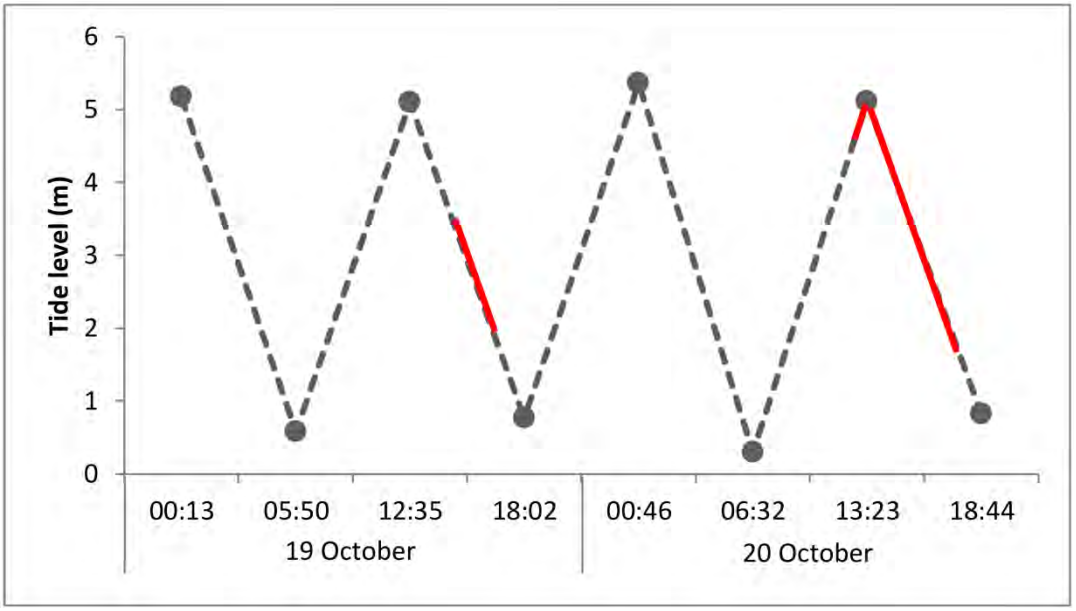
3.7.1 Survey Timing

Table 3.7.1 shows the time table of the survey and Figure 3.7.1 shows the tide timing at the survey, respectively.

Table 3.7.1 Time Table of the Survey (October, 2013)

Date	Time	Site	Note
Saturday, 19 October 2013	2 to 4	MS-1 to MS-4	Water sampling & in- situ monitoring
Sunday, 20 October 2013	1 to 5	MS-5 to MS-8	

Source: Study team



Source: Tide table (http://www.iranhydrography.org/default.asp)

Red line shows the timing of the survey

Figure 3.7.1 Tide Timing at the Survey (October, 2013)

3.7.2 Result of the Survey

Summary of the survey results are shown in Table 3.7.2 and raw data is stored in Annex A.

Table 3.7.2 Summary of the Survey Result

Survey date: Oct. 19-20, 2013

Category	Parameter	Unit	Environmental standard (*1)	Oct		
				Min	Max	Ave
Water quality (Field measurement)	Water temperature	°C	(*2)	24.8	25.5	25.1
	Salinity	-	(*3)	35.60	50.30	42.00
	Conductivity	mS/cm		56.1	76.8	65.1
	pH	-	6.5-9.0	6.34	8.66	8.34
	DO	mg/L	> 3 (*4)	6.98	7.67	7.33
Water quality (Analysis: general parameters)	Turbidity	NTU		19	96	67
	Suspended solid	mg/L	(*5)	70	200	103
	COD	mg/L as O2	5	10	25	17
	TOC	mg/L as C		2.2	3.5	2.7
	Oil contents	mg/L	(*6)	< 0.2	< 0.2	< 0.2
	Coliform bacteria (*10)	MPN Index/100ml	500 (*7)	< 2	23	11
	Total nitrogen	mg/L as N	0.4 (*8)	0.53	0.84	0.64
	Total phosphorous	mg/L as P	0.045 (*9)	<0.2	<0.2	<0.2

Source: Study team

Note: Red letter means excess of the standard/criteria value

*1: Standard for Ambient Water in Persian Gulf and Oman Sea (draft), Class 6: Industrial zone or Port, DOE.
*2 Water temperature: ±3 of natural temperature of receptive source
*3 Salinity: It should be no more than 10 percent of minimum natural salinity of the region.
*4 DO: 40% of Saturation
*5 Suspended Solid: Its increase should not be more than its daily, monthly, annual average considering standard deviation.
*6 Oil contents: There should be no oil layer, foam visible on its surface.
*7 Coliform bacteria: Fecal coliform should be less than 100 CFU/100ml.
*8 Total nitrogen: The value of Nitrate-nitrogen is used in this table.
*9 Total phosphorous: The value of Phosphate-phosphorus is used in this table.
*10 Total coliform was analyzed in Apr., May, Jun. and Aug-1, while fecal coliform analyzed in Aug-2, Sep. and Oct.

3.7.3 Discussion

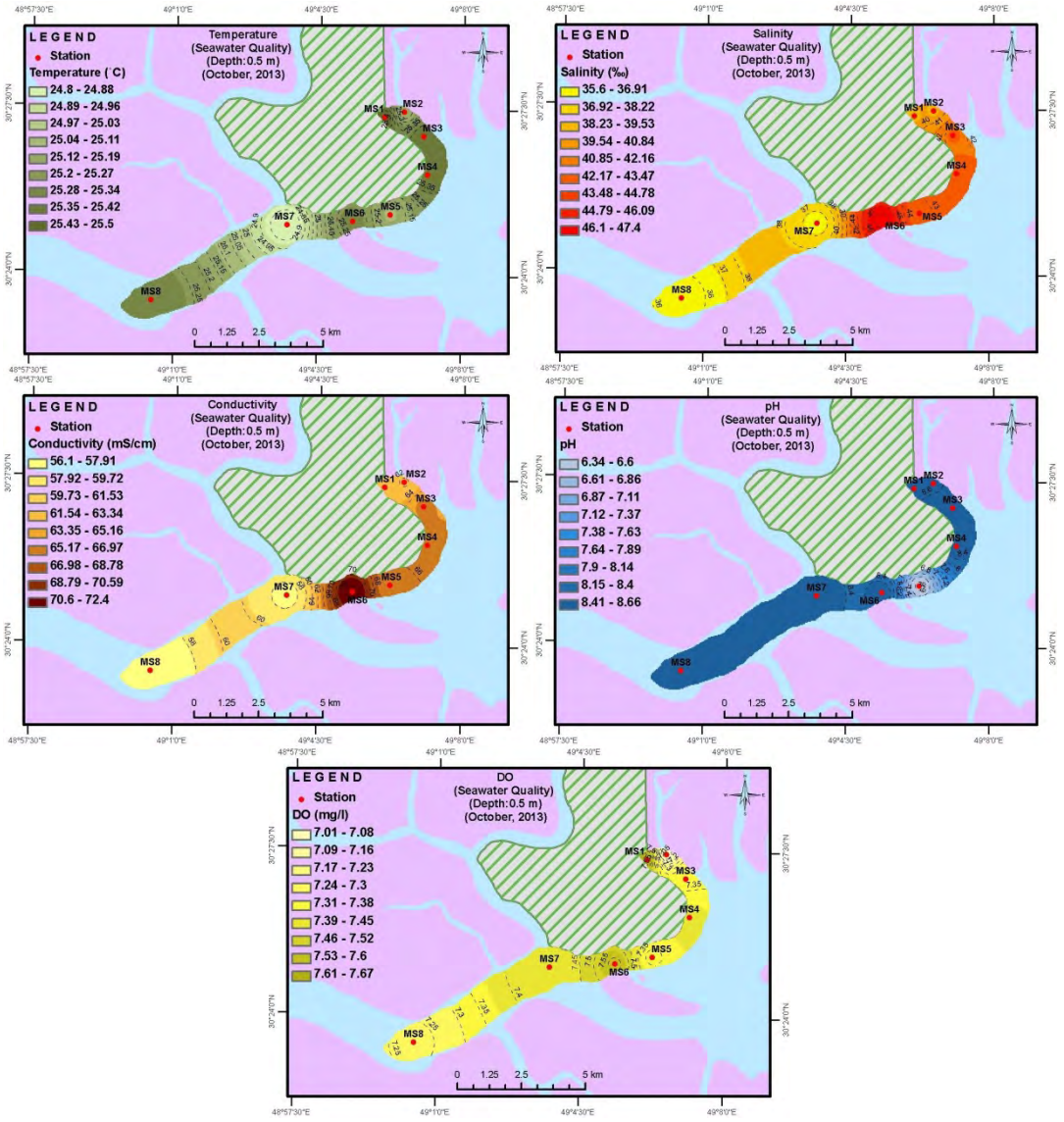
a) Field measurement

Horizontal distribution of the field measurement parameters (in-situ parameters) are shown in Figure 3.7.2.

The water temperature ranges from 24.8–25.5 °C with an average of 25.1 °C. The pH values vary from 6.34 to 8.66 with an average value 8.40, indicating the alkaline nature of seawater.

The EC values range from 56.1 to 76.8 mS/cm with an average of 65.1 mS/cm. Salinity ranges from 35.6 to 50.3 with an average value of 42.1. The dissolved oxygen varies between 6.98–7.67 mg/l with an average 7.32 mg/l.

Vertical profiles of in-situ parameters are illustrated in Annex D.



Source: Study team

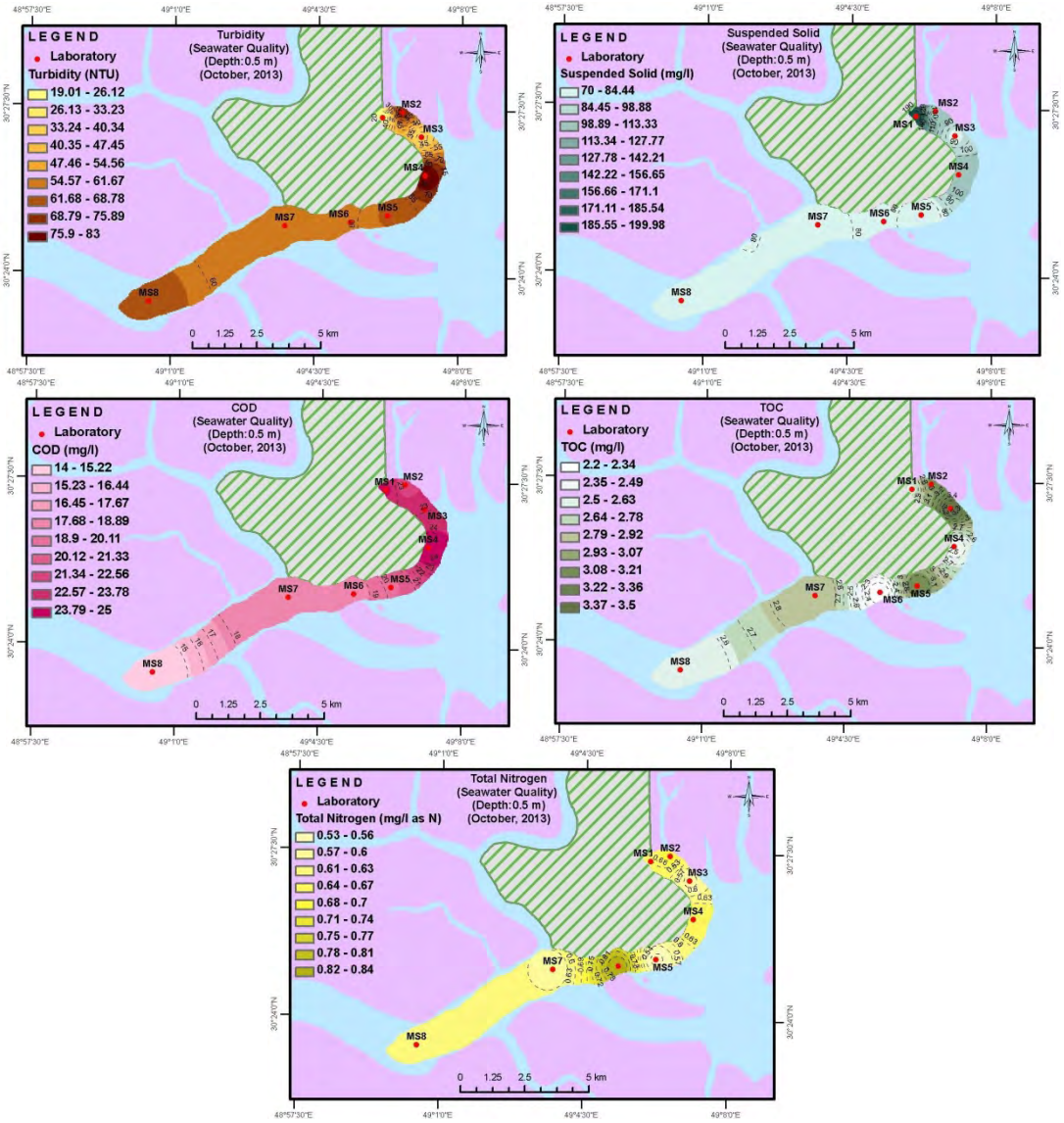
Figure 3.7.2 Horizontal Distribution of In-situ Parameters

b) Laboratory analysis

Horizontal distribution of the parameters of laboratory analysis is shown in Figure 3.7.3.

Turbidity in seawater samples varies between 19 and 96 mg/l and MS-2 (2m below surface) shows the highest value. Suspended solid varies between 70 and 200 mg/l with the maximum concentration in MS-7 (2m below surface). COD in MS-4 (0.5m below surface) shows the highest value and the others are relatively similar. TOC in MS-3 (0.5m below surface) shows the highest value (3.5 mg/l) and in other stations it varies between 2.2 and 3.5 mg/l. Total nitrogen concentration varies from 0.53 to 0.84 mg/l. The highest nitrogen concentration is observed in MS-6 (0.5m below surface).

Vertical profiles of laboratory parameters are shown in Annex D.



Source: Study team

Figure 3.7.3 Horizontal Distribution of the Laboratory Parameters

4 Time Series Variation

Time series of minimum, maximum and average of monthly monitoring parameters is shown in Figure 3.7.1.

Red line in each graph shows the standard value of the Standard for Ambient Water in Persian Gulf and Oman Sea (draft), Class 6: Industrial zone or Port, prepared by DOE.

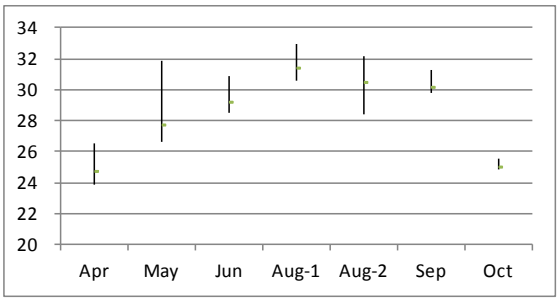
Water temperature is the highest in August, while DO shows the lowest in August. This is considered because of higher demand of oxygen consumption by the decomposition process of organic matters in the water due to high water temperature.

Fluctuation of pH is occasionally high leading excess of the standard value, suggesting some impacts of discharges from the PETZONE.

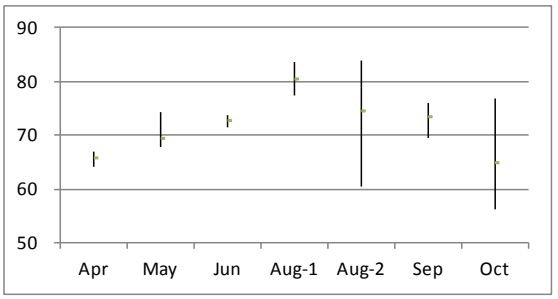
T-N and COD steadily exceed the standard value and the temporal trend of COD and TOC shows an increase of nutrient level in the area, suggesting the nutrient load from PETZONE might be increasing.

Horizontal distribution of COD in each month is shown in Figure 3.7.2 and horizontal distribution of major parameters in May and August is shown in Figure 3.7.3. The figures of horizontal distribution of COD and Lead in water quality and Cadmium, Mercury, Nickel and Total Petroleum Hydrocarbon (TPH) in sediment quality show a tendency that each value is high at upper stream in the watercourse of surrounded area of the PETZONE and low at downstream, suggesting the impact form the PETZONE.

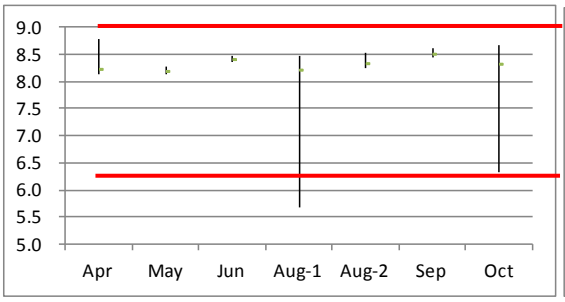
Therefore continuous monitoring is considered important to assess the temporal change of the impact from the PETZONE to the surrounded area and to evaluate the effect of planned improvements of the facilities in the PETZONE.



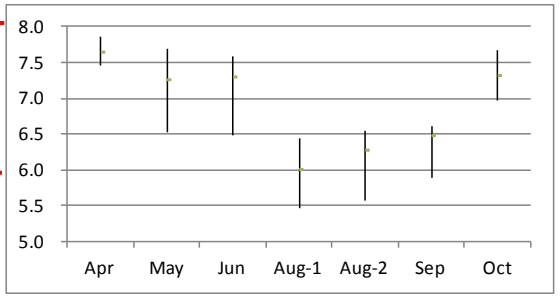
Water Temperature (Unit: ^{o}C)



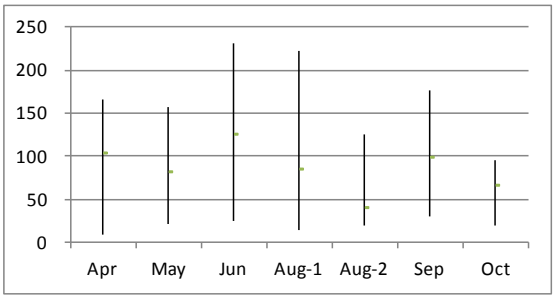
Conductivity (Unit:mS/cm)



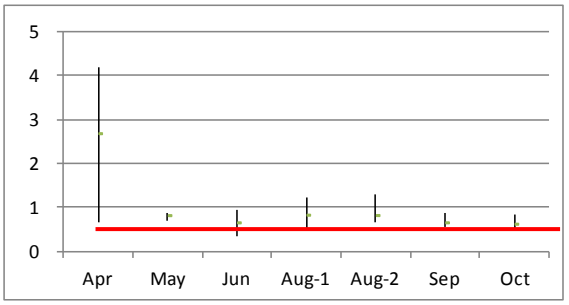
pH (Unit: -)



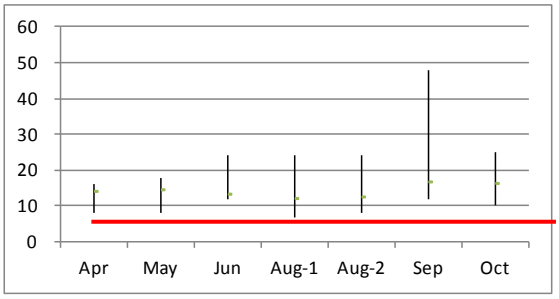
DO (Unit: mg/L)



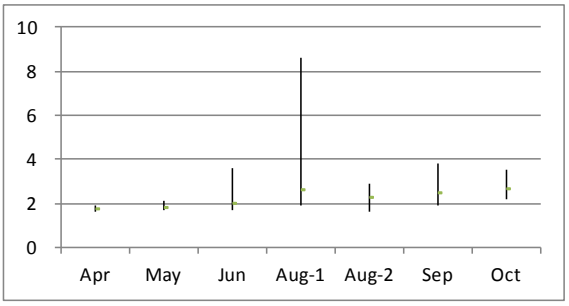
Turbidity (Unit: NTU)



T-N (Unit: mg/L)



COD (Unit: mg/L)

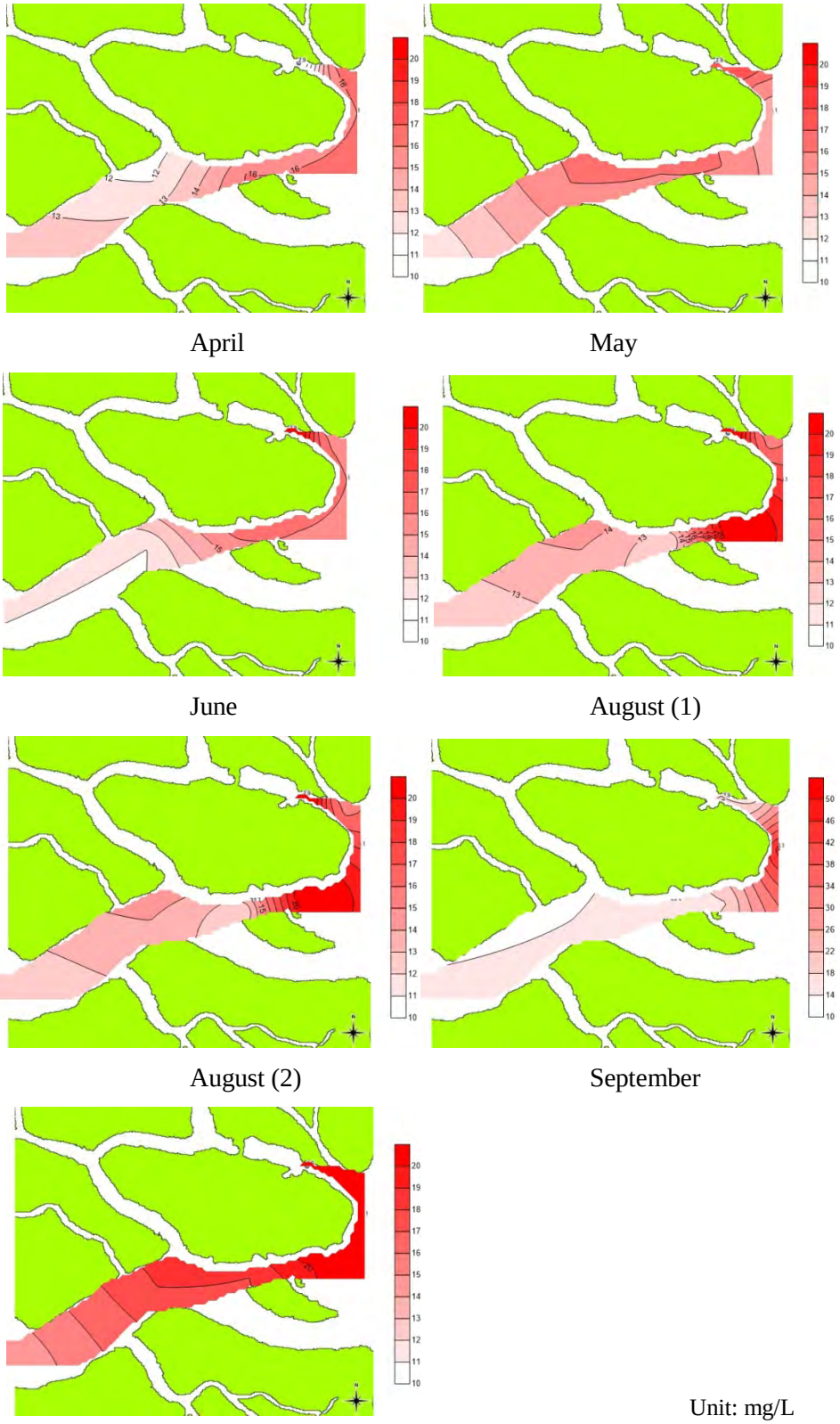


TOC (Unit: mg/L)

Source: Study team

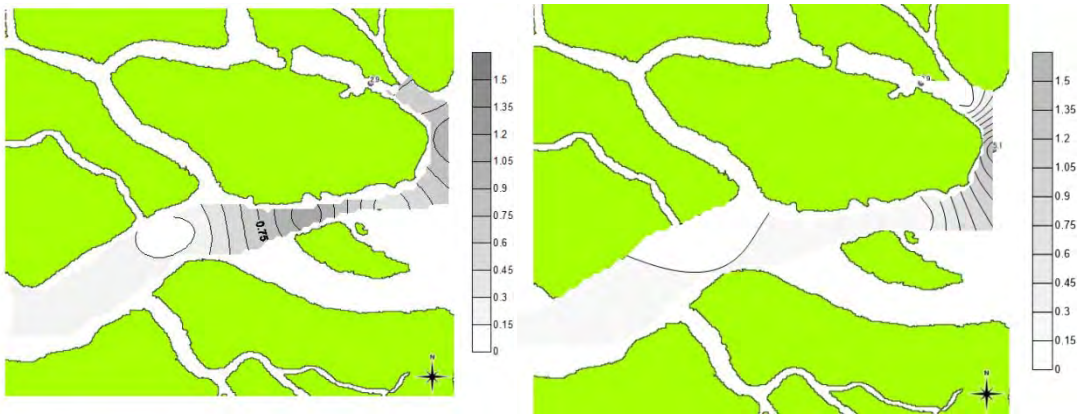
The red line in each graph indicates the standard value of the Standard for Ambient Water in Persian Gulf and Oman Sea (draft), Class 6: Industrial zone or Port, DOE

Figure 3.7.1 Time Series of Minimum, Maximum and Average of the Monthly Monitoring Parameters, 2013

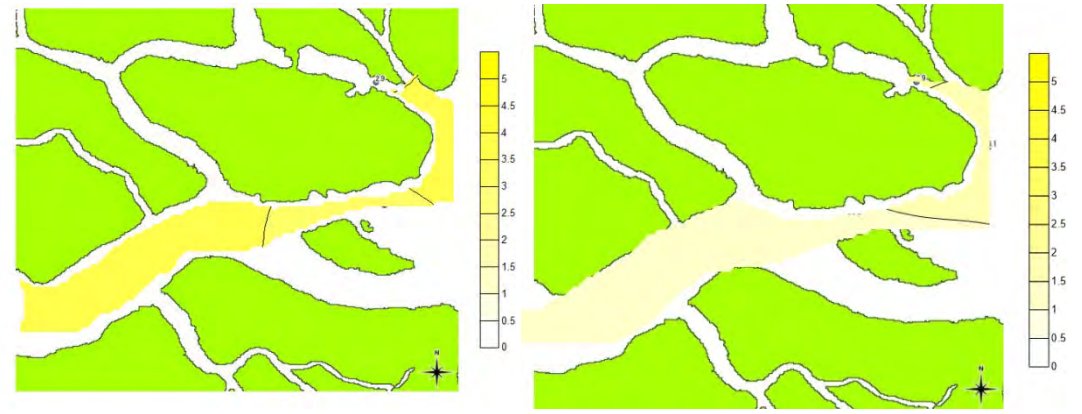


Source: Study team

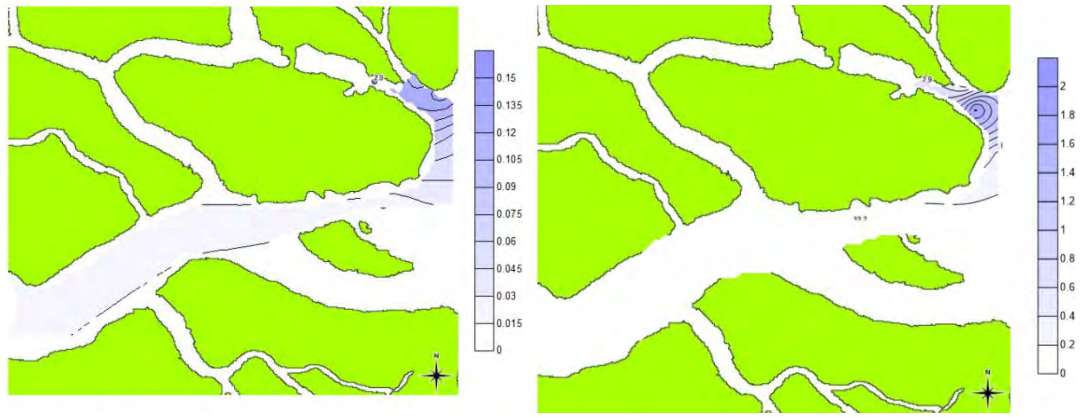
Figure 3.7.2 Horizontal Distribution of COD in each month, 2013



Lead (Water quality, May) Lead (Water quality, August)



Cadmium (Sediment quality, May) Cadmium (Sediment quality, August)



Mercury (Sediment quality, May) Mercury (Sediment quality, August)

Source: Study team
Unit of water quality: micro-g/L
Unit of sediment quality: micro-g/g.dw

Figure 3.7.3 Horizontal Distribution of Major Parameters (May and August, 2013)

5 Findings from the Survey

Followings from the series of survey are summarized as findings:

- Semidiurnal tide is dominant in this area and the deference of tide level between the high-tide and the low-tide reaches 5m.
- This great difference of the tide level causes high-speed tidal current and results in the active vertical mixing of the water mass. Vertical distribution of water temperature and salinity (0-10m below surface) shows that the difference of the value at 0.5m below surface and 10m below surface is significantly smaller, suggesting that vertical mixing is great.
- No clear evidence of the high concentration of increased oil & grease in water and total petroleum hydrocarbons (TPHs) in sediment was identified. It means oil contamination in this country is small.
- pH value in MS-1 shows the lowest (5.67) in the 4th sampling (13 August 2013). This might be considered the effluent discharge from PETZONE changed the pH to acidic conditions.
- T-N and COD steadily exceed the draft standard value by DOE and the temporal trend of COD and TOC shows increase of nutrient level in the area, suggesting the nutrient load from PETZONE might be increasing.
- Since the sampling point MS-1 tends to show higher COD concentration than other sampling points, effluent discharge, whose outlet is close to MS-1, might be one of the sources of entrance of different of chemicals to seawater.
- Although Mercury (Hg) is not detected in seawater, Hg in sediment is detected at several survey points and its concentration exceeds the guideline value. Therefore, it should be followed up in the further survey.
- The concentrations of Co, Pb and Cu elements in seawater are higher than natural seawater values and the concentrations of Co, Pb and Cd elements in sediment are relatively high. These are the major pollutants in the study area and may pose risk for aquatic life and also the residents in the region and the water receiving areas.
- The concentration of Ni in both seawater and sediments is very high and it is necessary to pay attention about this increment of concentration.
- Since harmful substances such as Mercury and Chromium in water, and Arsenic, Cadmium and Mercury in sediment are detected, although those concentrations are low, and the possibility of increase of nutrient level is considered, continuous monitoring in sea area is necessary.

6 Recommendation for the Future Plan

The study should be designed to confirm or refute the presence of pollutants, to determine the spatial extent of chemical contamination (both in surface and in deeper sediments), to identify chemical gradients (which can be used to identify possible sources of contamination), and to identify the location of sediment hot spots. Data from toxicity tests (including whole- sediment and pore-water tests), benthic invertebrate community assessments, and fish community assessments can provide important information for evaluating the effects of contaminated seawater and sediments on aquatic organisms. In addition, bioaccumulation assessments can be used to assess the potential effects of pollutants that tend to bioaccumulation in the food web and, in so doing, pose risks to aquatic-dependent wildlife and/or human health. The results of sediment toxicity tests can be used to assess the bioavailability of contaminants in the field/collected seawater/sediments. The responses of organisms exposed to field collected sediments are often compared to the response of organisms exposed to a control and/or reference sediment. While whole seawater/sediment chemistry, seawater/sediment toxicity, and benthic invertebrate community structure play important role in this investigation, in this way, it is possible to identify the contaminants at the site. For instance, identification and determination of volatile organic compounds are very important for investigation. While the results of chemical analyses of environmental samples provide important information for assessing the risks that contaminated seawater/sediments pose to human health and environmental receptors, other types of data should also be collected during investigation to confirm the results of such assessments and to provide multiple lines of evidence for assessing risks to ecological receptors.

General approaches to conduct bioaccumulation assessments include:

- It is recommended to measure Tributyltin (TBT) in seawater and sediment. TBT chemical is very toxic and harmful to aquatic organisms and fishes. It is used for anti-algae and antifouling in ships and boat painting,
- Trihalomethanes (THMs) identifications and determinations in seawater is very essential especially near petrochemical effluents zones,
- Bioassey tests and toxicity tests are highly recommended,
- Since Chlorophyll a is a very important test for marine waters, it is recommended to perform the test in the future survey,
- Sequential extraction analysis to predict heavy metal bioavailability in sediment, and
- Elements such as V, Mo and Rare Earth Elements (REE) are recommended to include in the future tests for source identification and estimation of pollution degree, and ratio calculation for some elements (Ni/V).

It is suggested that to consider a sampling point as a background station for determination of anthropogenic and natural or geogenic contamination.

6.1 Environmental Monitoring

Environmental monitoring can be defined as the systematic sampling of air, water, soil, and biota in order to observe and study the environment, as well as to derive knowledge from this process.

Monitoring can be conducted for a number of purposes, including establishing environmental "baselines, trends, and cumulative effects" to test environmental modeling processes, to educate the public about environmental conditions, to inform policy design and decision-making, to ensure compliance with environmental regulations, to assess the effects of anthropogenic influences, or to prepare an inventory of natural resources.

6.2 Monitoring System

Monitoring is the systematic collection and analysis of information as a project progresses. It is aimed at improving the efficiency and effectiveness of a project or organization. It is based on targets set and activities planned during the planning phases of work. It helps to keep the work on track, and can let management know when things are going wrong. If it is conducted properly, it will be a valuable tool for good management, and it provides a useful base for evaluation. It enables you to determine whether the resources you have available are sufficient and are being well used, whether the capacity you have is sufficient and appropriate, and whether you are doing what you planned to do.

There are various products for system monitoring offer the widest range of possibilities:

- Wireless or internet based,
- Compact or complex,
- Concise or elaborate.

Online monitoring systems for air pollution and water and wastewater recently have been subjected in the world widely. In this project, multi analyzer for in-situ analysis such as EC, pH, T, etc. are widely used. In the future, new and modern instruments for in-situ analysis will be applied. Laboratories, which are involved in analysis of pollutants , also must be equipped with advanced analytical instruments such as high resolution GC/MS, LC/MS, GC/ECD (for halogenated compounds) and etc.

6.3 Structure of the Monitoring Team

For this monitoring survey, around ten (10) people shall be engaged in sampling, extraction, analysis and data collection and data interpretation.

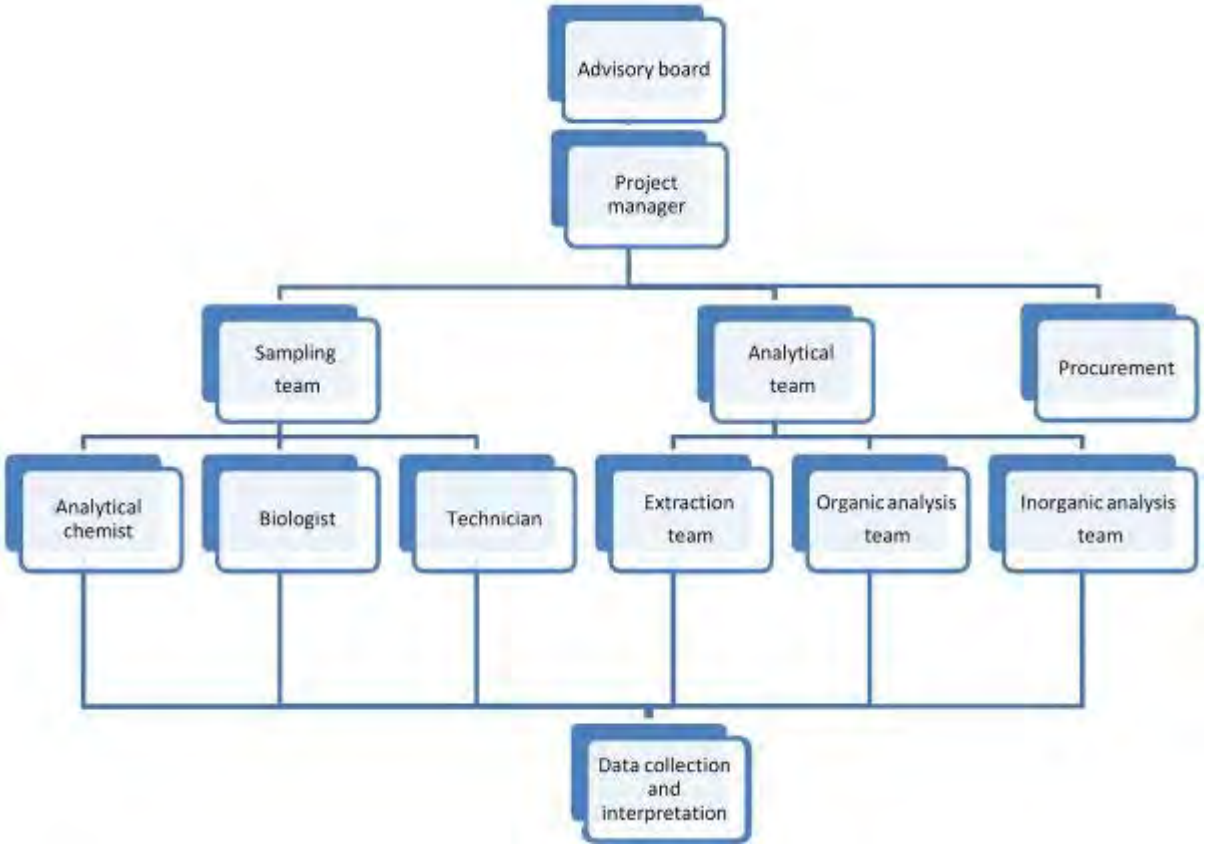


Figure 5.3.1 Proposed Organizational Chart for Monitoring

Reference

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ANNEX

Annex A Survey result

[April 2013]

	MS-1					MS-2					MS-3					MS-4				
Date	27 Apr., 2013					27 Apr., 2013					27 Apr., 2013					27 Apr., 2013				
Time	16:00					16:20					18:00					18:45				
Longitude	30° 27' 19.9"N					30° 27' 26.4"N					30° 26' 56.2"N					30° 26' 07.5"N				
Latitude	49° 06' 05.0"N					49° 06' 33.3"N					49° 07' 02.5"N					49° 07' 08.7"N				
Air temperature(ºC)	28.0					25.6					25.6					25.6				
Wind[1]	S, 2					S, 2					S, 2					S, 2				
Wave (cm)	10					20					10					No wave				
Depth (m)	0.8					5.0					5.0					1.6				
Current (Direction, knot)	No current					S, 2					S, 2					S, 0.5				
Water color[2]	5GY6/10 (strong yellow green)					5.5Y7/5 (dull yellow)					5.5Y7/5 (dull yellow)					5.5Y7/5 (dull yellow)				
Transparency (m)	0.20					0.20					0.20					0.18				
Below water surf	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)
0.5	26.5	43.00	65.7	8.36	7.86	25.1	42.40	65.9	8.21	7.49	25.6	42.20	65.5	8.23	7.55	25.3	42.91	65.4	8.79	7.47
1						25.2	42.95	66.3	---	---	25.2	42.50	65.6	---	---	25.3	42.80	65.7	8.43	7.70
2						25.7	42.70	67.0	8.21	7.57	25.5	42.60	66.0	8.24	7.56					
3						25.4	42.63	66.2	---	---										
4						25.4	42.80	66.2	---	---										
5																				
6																				
7																				
8																				
9																				
10																				
Remarks																				

Note:
1 Beufort grade
2 Muncel color code

	MS-5					MS-6					MS-7					MS-8				
Date	27 Apr., 2013					28 Apr., 2013					28 Apr., 2013					28 Apr., 2013				
Time	19:15					19:45					18:25					15:45				
Longitude	30° 25' 16.6"N					30° 25' 07.2"N					30° 25' 02.2"N					30° 23' 24.1"N				
Latitude	49° 06' 15.2"N					49° 05' 20.5"N					49° 03' 44.6"N					49° 00' 27.6"N				
Air temperature(ºC)	25.2					24.5					23.8					32.0				
Wind[1]	No wind					S, 1					S, 2					S, 1				
Wave (cm)	No wave					No wave					No wave					No wave				
Depth (m)	>10					>40					>30					>40				
Current (Direction, knot)	No current					W, 2					W, 1					W, 0.5				
Water color[2]	5.5Y7/5 (dull yellow)					5.5Y7/5 (dull yellow)					5.5Y7/5 (dull yellow)					5.5Y7/5 (dull yellow)				
Transparency (m)	0.20					0.17					0.20					0.20				
Below water surf	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)
0.5	24.4	43.30	65.8	8.20	7.68	24.8	43.80	66.8	8.18	7.64	24.5	43.40	66.2	8.17	7.45	25.9	41.60	64.5	8.12	7.68
1	24.5	44.30	66.3	---	---	24.6	44.00	66.5	---	---	24.4	43.30	66.1	---	---	25.0	41.60	64.2	---	---
2	24.1	43.70	65.8	8.20	7.75	24.2	44.10	66.4	8.20	7.81	24.9	43.10	66.2	8.18	7.57	26.5	41.00	66.0	8.12	7.82
3	24.2	43.74	65.6	---	---	24.3	44.20	66.5	---	---	24.4	43.30	66.2	---	---	26.4	41.20	65.3	---	---
4	24.3	43.80	65.5	---	---	24.2	44.15	66.5	---	---	24.5	43.20	66.1	---	---	26.3	41.20	66.0	---	---
5	24.2	43.90	66.4	---	---	24.5	44.00	66.8	---	---	24.6	43.40	66.2	---	---	24.7	42.20	64.7	---	---
6	24.0	44.15	66.3	---	---	24.2	44.20	66.5	---	---	24.7	43.51	66.3	---	---	24.6	42.40	64.8	---	---
7	24.1	44.00	66.4	---	---	24.7	43.90	67.0	---	---	24.8	43.50	66.6	---	---	24.2	42.50	64.5	---	---
8	24.0	43.80	66.3	---	---	24.5	44.10	66.7	---	---	24.6	43.50	66.3	---	---	24.3	42.40	64.5	---	---
9	23.9	43.90	66.4	---	---	24.5	44.15	66.9	---	---	24.7	43.50	66.4	---	---	24.1	42.70	64.6	---	---
10	23.9	43.80	65.9	8.22	7.78	24.5	43.90	66.8	8.18	7.70	24.7	43.30	66.3	8.16	7.52	24.9	41.90	64.6	8.17	7.84
Remarks																				

Note:
1 Beufort grade
2 Muncel color code

Category	Parameter	Unit	MS-1			MS-2			MS-3			MS-4		
			0.5m	2m	10m	0.5m	2m	10m	0.5m	2m	10m	0.5m	2m	10m
Water quality (General parameter)	Turbidity	NTU	9	-	-	89	92	-	120	156	-	132	-	-
	Suspended Solids	mg/L	2	-	-	36	44	-	52	76	-	64	-	-
	COD	mg/L as O2	8	-	-	16	16	-	16	16	-	16	-	-
	TOC	mg/L as C	1.9	-	-	1.9	1.8	-	1.9	1.8	-	1.8	-	-
	Oil contents	mg/L	< 0.2	-	-	< 0.2	< 0.2	-	< 0.2	< 0.2	-	< 0.2	-	-
	Coliform bacteria	MPN Index/100ml	ND	-	-	ND		-	ND	ND	-	ND	-	-
	Total nitrogen	mg/L as N	0.67	-	-	1.10	2.90	-	2.60	2.60	-	2.60	-	-
	Total phosphorous	mg/L as P	< 0.2	-	-	< 0.2	< 0.2	-	< 0.2	< 0.2	-	< 0.2	-	-

Category	Parameter	Unit	MS-5			MS-6			MS-7			MS-8		
			0.5m	2m	10m	0.5m	2m	10m	0.5m	2m	10m	0.5m	2m	10m
Water quality (General parameter)	Turbidity	NTU	95	107	103	101	109	113	107	85	116	95	92	166
	Suspended Solids	mg/L	64	44	60	52	32	64	68	32	68	60	56	112
	COD	mg/L as O2	16	16	16	16	14	16	12	14	12	14	12	12
	TOC	mg/L as C	1.9	1.8	1.9	1.9	1.9	1.8	1.8	1.7	1.7	1.7	1.6	1.6
	Oil contents	mg/L	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
	Coliform bacteria	MPN Index/100ml	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Total nitrogen	mg/L as N	2.70	4.20	2.90	3.60	2.10	3.40	3.30	2.90	3.00	3.00	2.50	2.50
	Total phosphorous	mg/L as P	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2

[May, 2013]

	MS-1					MS-2					MS-3					MS-4				
Date	11 May, 2013					11 May, 20132					11 May, 2013					11 May, 2013				
Time	16:00					16:30					17:15					18:15				
Longitude	30° 27' 19.9"N					30° 27' 26.4"N					30° 26' 56.2"N					30° 26' 07.5"N				
Latitude	49° 06' 05.0"N					49° 06' 33.3"N					49° 07' 02.5"N					49° 07' 08.7"N				
Air temperature(ºC)	35.7					36.3					35.5					34.8				
Wind[1]	S, 1					S, 1					SW, 1					SW, 1				
Wave (cm)	No wave					No wave					No wave					No wave				
Depth (m)	1.6					2.8					5.0					3.0				
Current (Direction, knot)	No current					S, 1					S, 2					S, 0.5				
Water color[2]	10GY4.5/7 (strong yellowing green)					5GY5/8 (deep yellow green)					5GY6/4 (leaf)					5GY6/4 (leaf)				
Sediment color[2]	N4.5 (dark medium gray)					5.5Y4/4 (olive)					2.5Y4/4 (brownish olive)					2.5Y4/4 (brownish olive)				
Transparency (m)	0.40					0.25					0.22					0.17				
Below water surface (m)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)
0.5	29.8	42.30	71.5	8.24	6.53	31.7	42.40	74.4	8.22	7.21	31.9	41.70	73.5	8.17	7.10	29.7	42.20	71.4	8.24	6.75
1						31.1	42.10	74.2	---	---	31.6	41.90	73.6	---	---	29.8	42.30	71.5	---	---
2						30.7	41.70	74.1	8.15	7.04	31.4	42.10	73.5	8.20	6.86					
3																				
4																				
5																				
6																				
7																				
8																				
9																				
10																				
Remarks																				

Note:
1 Beufort grade
2 Muncel color code

	MS-5					MS-6					MS-7					MS-8				
Date	12 May, 2013					12 May, 2013					14 May, 2013					14 May, 2013				
Time	7:00					8:00					7:55					8:45				
Longitude	30° 25' 16.6"N					30° 25' 07.2"N					30° 25' 02.2"N					30° 23' 24.1"N				
Latitude	49° 06' 15.2"N					49° 05' 20.5"N					49° 03' 44.6"N					49° 00' 27.6"N				
Air temperature(ºC)	29.7					29.6					28.1					30.2				
Wind[1]	No wind					W,1					No wind					W, 2				
Wave (cm)	No wave					No wave					No wave					No wave				
Depth (m)	35.0					51.0					52.0					45.0				
Current (Direction, knot)	SW, 0.5					E, 1					W, 0.5					E, 0.25				
Water color[2]	5GY6/4 (leaf)					10GY4.5/7 (strong yellowish green)					5GY6/4 (leaf)					10GY4.5/7 (strong yellowish green)				
Sediment color[2]	5.5Y4/4 (olive)					9YR4/4 (yellowish brown)										5.5Y4/4 (olive)				
Transparency (m)	0.26					0.33					0.24					0.27				
Below water surface (m)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)
0.5	27.4	42.50	69.2	8.17	7.17	27.6	42.70	69.2	8.15	7.22	27.2	42.80	68.8	8.16	7.29	27.6	42.40	68.9	8.14	7.60
1	26.9	43.10	68.9	---	---	27.3	43.00	69.2	---	---	27.1	42.90	68.8	---	---	27.0	42.50	68.7	---	---
2	27.0	43.10	69.0	8.27	7.45	27.3	43.00	69.2	8.20	7.51	28.9	42.50	70.8	8.20	7.43	27.1	42.90	68.5	8.19	7.59
3	26.9	43.10	68.8	---	---	27.2	43.10	69.2	---	---	27.2	42.90	69.0	---	---	26.7	42.90	68.3	---	---
4	27.0	43.10	69.0	---	---	27.2	43.00	69.1	---	---	27.2	42.90	68.6	---	---	26.7	42.80	68.2	---	---
5	26.9	43.10	68.9	---	---	27.5	42.80	69.2	---	---	27.3	42.80	68.9	---	---	26.8	42.60	68.1	---	---
6	27.0	43.10	68.9	---	---	27.3	42.90	69.2	---	---	27.3	42.70	69.1	---	---	26.6	42.70	67.7	---	---
7	26.9	43.10	68.9	---	---	27.3	43.00	69.2	---	---	27.6	42.40	68.9	---	---	26.6	42.60	67.9	---	---
8	26.9	43.10	68.9	---	---	27.1	42.90	68.9	---	---	27.2	42.90	68.8	---	---	26.8	42.70	68.1	---	---
9	26.9	43.10	68.9	---	---	27.1	42.90	69.9	---	---	26.9	42.90	68.9	---	---	26.8	42.70	67.9	---	---
10	26.9	43.10	69.0	8.26	7.57	27.2	42.90	69.0	8.22	7.50	28.0	42.70	69.7	8.22	7.34	26.8	42.70	68.1	8.24	7.69
Remarks											The direction of water has just changed, so the mixing of water in several layers may occur. The temperature profile is not logical. Sampling position for sediment was moved to 30°24'20.0"N, 49°03'04.7"E due to diffficulty of sampling of sediment.					Due to the difficulty of sampling sediment, the location was changed to 30° 23' 54.5''N, 49° 00' 35.6''E with the depth of 14.8 m.				

Note:
1 Beufort grade
2 Muncel color code

Category	Parameter	Unit	MS-1			MS-2			MS-3			MS-4		
			0.5m	2m	10m	0.5m	2m	10m	0.5m	2m	10m	0.5m	2m	10m
Water quality (General parameter)	Turbidity	NTU	22	-	-	46	137	-	56	157		104		
	Suspended Solids	mg/L	40	-	-	30	168	-	52	164		120		
	COD	mg/L as O2	18	-	-	18	18	-	16	14		14		
	TOC	mg/L as C	2.0	-	-	2.1	2.1	-	1.9	1.9		1.9		
	Oil contents	mg/L	< 0.2	-	-	< 0.2	< 0.2	-	< 0.2	< 0.2		< 0.2		
	Coliform bacteria	MPN Index/100ml	<2	-	-	<2	<2	-	<2	<2		<2		
	Total nitrogen	mg/L as N	0.82	-	-	0.86	0.87	-	0.86	0.83		0.84		
	Total phosphorous	mg/L as P	< 0.2	-	-	< 0.2	< 0.2	-	< 0.2	< 0.2		< 0.2		
Water quaity (Heavy metal)	Aluminum (Al)	mg/L	<0.1			<0.1	<0.1		<0.1	<0.1		<0.1		
	Arsenic (As)	micro-g/L	<1			<1	<1		<1	<1		<1		
	Cadmium (Cd)	micro-g/L	<0.1			<0.1	<0.1		<0.1	<0.1		<0.1		
	Cyanide (CN)	micro-g/L	<5			<5	<5		<5	<5		<5		
	Chromium (Cr)	micro-g/L	0.5			0.3	0.5		0.3	0.2		0.3		
	Cobalt (Co)	micro-g/L	1.5			1.2	1.2		1.0	1.1		1.5		
	Copper (Cu)	micro-g/L	0.5			0.2	0.5		0.3	0.2		0.3		
	Iron (Fe)	mg/L	0.01			0.03	0.03		0.03	0.03		0.03		
	Methyl Mercury (Hg)	micro-g/L	-			---	-		-			-		
	Mercury (Hg)	micro-g/L	<1			<1	<1		<1	<1		<1		
	Manganese (Mn)	micro-g/L	<0.1			<0.1	<0.1		<0.1	<0.1		<0.1		
	Magnesium (Mg)	mg/L	1681			1699	1693		1717	1705		1685		
	Nickel (Ni)	micro-g/L	3.3			3.0	3.0		2.2	2.4		2.5		
	Lead (Pb)	micro-g/L	0.80			0.80	1.20		0.60	0.50		1.10		
	Zinc (Zn)	mg/L	<0.01			<0.01	<0.01		<0.01	<0.01		<0.01		
	Phenols	micro-g/L	<1			<1	<1		<1	<1		<1		

Category	Parameter	Unit	MS-5			MS-6			MS-7			MS-8		
			0.5m	2m	10m	0.5m	2m	10m	0.5m	2m	10m	0.5m	2m	10m
Water quality (General parameter)	Turbidity	NTU	75	88	71	47	71	115	63	113	114	46	82	87
	Suspended Solids	mg/L	54	72	72	20	54	96	42	86	110	32	87	100
	COD	mg/L as O2	16	16	14	16	16	14	16	16	16	12	8	8
	TOC	mg/L as C	1.8	1.9	1.8	1.7	1.8	1.9	2.0	1.7	1.8	1.7	1.8	1.7
	Oil contents	mg/L	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
	Coliform bacteria	MPN Index/100ml	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
	Total nitrogen	mg/L as N	0.88	0.88	0.88	0.80	0.85	0.77	0.85	0.83	0.86	0.84	0.68	0.81
	Total phosphorous	mg/L as P	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Water quaity (Heavy metal)	Aluminum (Al)	mg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	Arsenic (As)	micro-g/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Cadmium (Cd)	micro-g/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	Cyanide (CN)	micro-g/L	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
	Chromium (Cr)	micro-g/L	0.1	<0.1	0.1	0.3	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	Cobalt (Co)	micro-g/L	0.5	0.5	0.3	0.4	0.3	0.2	0.2	0.3	0.2	0.2	0.2	0.1
	Copper (Cu)	micro-g/L	0.1	<0.1	0.1	0.3	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	Iron (Fe)	mg/L	0.03	0.03	0.03	0.02	0.03	0.02	0.01	0.01	0.01	0.03	0.03	0.02
	Methyl Mercury (Hg)	micro-g/L	-	-	-	-	-	-	-	-	-	---	---	---
	Mercury (Hg)	micro-g/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Manganese (Mn)	micro-g/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	Magnesium (Mg)	mg/L	1699	1693	1687	1687	1687	1699	1688	1688	1687	1699	1693	1693
	Nickel (Ni)	micro-g/L	2.1	2.2	2.2	2.3	4.3	2.9	3.2	3.4	3.1	2.9	2.2	2.0
	Lead (Pb)	micro-g/L	0.30	0.60	0.40	1.20	0.50	<0.1	<0.1	<0.1	<0.1	0.30	0.60	<0.1
	Zinc (Zn)	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Phenols	micro-g/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1

Category	Parameter	Unit	MS-1			MS-2			MS-3			MS-4		
			0.5m	2m	10m	0.5m	2m	10m	0.5m	2m	10m	0.5m	2m	10m
Sediment quality	Specific Gravity	g/cm3	1.10			1.40			1.40			1.40		
	Moisture Content	Mass%	77.0			54.0			77.0			85.0		
	Total Organic Carbon (TOC)	Mass%	0.54			0.30			0.36			0.41		
	Total Petroleum Hydrocarbon	micro-g/g.dw	158			126			129			158		
	Aluminum (Al)	mg/g.dw	11.2			11.0			11.3			11.6		
	Arsenic (As)	micro-g/g.dw	1.2			1.2			1.5			1.7		
	Cadmium (Cd)	micro-g/g.dw	4.2			4.0			3.8			3.8		
	Cyanide (CN)	micro-g/g.dw	<0.1			<0.1			<0.1			<0.1		
	Chromium (total)	micro-g/g.dw	35.4			34.5			34.4			32.5		
	Chromium (Cr+6)	micro-g/g.dw	-			-			-			-		
	Cobalt (Co)	micro-g/g.dw	37.7			18.9			22.0			23.9		
	Copper (Cu)	micro-g/g.dw	26.4			18.0			19.1			19.1		
	Iron (Fe)	mg/g.dw	22.4			16.9			17.5			17.3		
	Methyl Mercury (Hg)	micro-g/g.dw	-			-			-			-		
	Mercury (Hg)	micro-g/g.dw	0.16			0.07			0.15			0.07		
	Manganese (Mn)	micro-g/g.dw	458			451			463			454		
	Magnesium (Mg)	mg/g.dw	44.8			54.6			52.5			51.4		
	Nickel (Ni)	micro-g/g.dw	187			102			108			106		
	Lead (Pb)	micro-g/g.dw	27.8			29.1			29.1			29.6		
	Zinc (Zn)	micro-g/g.dw	118			109			103			115		
	Total Sulfur (T-S)	mg/g	2.70			1.50			1.90			1.60		
	Grain size		-			-			-			-		
	Sand (>0.04mm & <1mm)	%	10.0			18.0			6.0			6.0		
	Silt (>0.002mm & <0.04mm)	%	45.0			37.0			43.0			47.0		
	Clay (>0.0002mm & <0.002mm)	%	45.0			45.0			51.0			47.0		

Category	Parameter	Unit	MS-5			MS-6			MS-7			MS-8		
			0.5m	2m	10m	0.5m	2m	10m	0.5m	2m	10m	0.5m	2m	10m
Sediment quality	Specific Gravity	g/cm3		1.40			1.60			1.40			1.40	
	Moisture Content	Mass%		69.0			31.0			70.0			62.0	
	Total Organic Carbon (TOC)	Mass%		0.30			0.18			0.33			0.29	
	Total Petroleum Hydrocarbon	micro-g/g.dw		94			105			80			41	
	Aluminum (Al)	mg/g.dw		9.8			3.2			10.1			9.0	
	Arsenic (As)	micro-g/g.dw		0.1			1.3			1.4			2.1	
	Cadmium (Cd)	micro-g/g.dw		3.4			3.2			3.9			3.7	
	Cyanide (CN)	micro-g/g.dw		<0.1			<0.1			<0.1			<0.1	
	Chromium (total)	micro-g/g.dw		38.2			13.9			31.0			27.1	
	Chromium (Cr+6)	micro-g/g.dw		-			-			-			-	
	Cobalt (Co)	micro-g/g.dw		18.9			12.5			23.1			21.6	
	Copper (Cu)	micro-g/g.dw		12.6			3.2			17.4			13.3	
	Iron (Fe)	mg/g.dw		15.7			6.8			17.2			14.7	
	Methyl Mercury (Hg)	micro-g/g.dw		-			-			-			-	
	Mercury (Hg)	micro-g/g.dw		<0.05			<0.05			<0.05			<0.05	
	Manganese (Mn)	micro-g/g.dw		443			239			510			457	
	Magnesium (Mg)	mg/g.dw		47.8			19.1			44.2			42.5	
	Nickel (Ni)	micro-g/g.dw		95			31			112			97	
	Lead (Pb)	micro-g/g.dw		25.6			29.7			28.4			28.0	
	Zinc (Zn)	micro-g/g.dw		63			46			70			64	
	Total Sulfur (T-S)	mg/g		0.09			0.04			0.09			0.03	
	Grain size			-			-			-			-	
	Sand (>0.04mm & <1mm)	%		22.0			86.0			8.0			6.0	
	Silt (>0.002mm & <0.04mm)	%		37.0			5.0			47.0			43.0	
	Clay (>0.0002mm & <0.002mm)	%		41.0			9.0			45.0			51.0	

[June, 2013]

	MS-1					MS-2					MS-3					MS-4				
Date	25 Jun., 2013					25 Jun., 2013					25 Jun., 2013					25 Jun., 2013				
Time	7:45					8:30					9:20					10:10				
Longitude	30° 27' 19.9"N					30° 27' 26.4"N					30° 26' 56.2"N					30° 26' 07.5"N				
Latitude	49° 06' 05.0"N					49° 06' 33.3"N					49° 07' 02.5"N					49° 07' 08.7"N				
Air temperature(ºC)	32.3					35.8					36.8					39.2				
Wind[1]	W, 1					W, 1					W, 1					W, 1				
Wave (cm)																				
Depth (m)	0.9					5.0					<3.0					1.5				
Current (Direction, knot)																				
Water color[2]	5GY6/10 (strong yellow green)					5.5Y7/5 (dull yellow)					5GY5/8 (deep yellow green)					5GY6/10 (strong yellow green)				
Transparency (m)	0.22					0.18					0.22					0.18				
Below water surface (m)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)
0.5	29.0	43.70	72.7	8.40	6.49	30.4	43.00	71.9	8.44	7.13	30.4	43.60	72.7	8.44	7.16	30.8	42.90	71.9	8.41	7.14
1						28.9	43.10	71.6	---	---	29.2	43.20	72.2	---	---	30.2	43.00	72.7	8.40	7.31
2						29.9	43.90	72.9	8.43	7.39	29.9	43.70	72.8	8.43	7.40					
3						29.0	44.00	73.0	---	---										
4						29.0	44.00	73.0	---	---										
5																				
6																				
7																				
8																				
9																				
10																				
Remarks																				

Note:
1 Beufort grade
2 Muncel color code

	MS-5					MS-6					MS-7					MS-8				
Date	26 Jun., 2013					26 Jun., 2013					26 Jun., 2013					26 Jun., 2013				
Time	7:30					8:50					9:50					10:55				
Longitude	30° 25' 16.6"N					30° 25' 07.2"N					30° 25' 02.2"N					30° 23' 24.1"N				
Latitude	49° 06' 15.2"N					49° 05' 20.5"N					49° 03' 44.6"N					49° 00' 27.6"N				
Air temperature(ºC)	35.3					36.9					39.6					42.3				
Wind[1]	W, 1					N, 1					W, 2					W, 1				
Wave (cm)																				
Depth (m)	>10					>50					>50					>40				
Current (Direction, knot)																				
Water color[2]	5GY6/10 (strong yellow green)					5GY5/8 (deep yellow green)					5GY5/8 (deep yellow green)					5GY6/4 (leaf)				
Transparency (m)	0.22					0.22					0.20					0.20				
Below water surface (m)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)
0.5	30.2	43.30	72.3	8.43	7.31	29.1	44.10	73.2	8.46	7.45	30.1	44.00	73.0	8.40	7.36	29.1	43.50	72.2	8.46	7.41
1	29.2	43.40	72.5	---	---	29.0	44.00	73.0	---	---	29.0	44.10	73.2	---	---	28.9	43.60	72.3	---	---
2	30.6	43.10	72.6	8.37	7.27	29.8	44.30	73.2	8.45	7.40	29.7	44.20	73.3	8.44		29.6	43.60	72.3	8.45	7.53
3	29.1	43.70	72.8	---	---	28.9	44.30	73.4	---	---	29.0	44.30	73.4	---	---	28.7	43.70	72.2	---	---
4	29.1	43.90	73.0	---	---	28.9	44.40	73.5	---	---	28.9	44.30	73.4	---	---	28.5	43.80	72.1	---	---
5	29.0	44.00	73.1	---	---	28.9	44.20	73.5	---	---	28.9	44.40	73.5	---	---	28.5	43.90	72.2	---	---
6	29.0	44.10	73.2	---	---	28.9	44.10	73.5	---	---	28.9	44.30	73.4	---	---	28.5	43.90	72.1	---	---
7	29.0	44.10	73.2	---	---	28.9	44.50	73.6	---	---	28.9	44.40	73.5	---	---	28.5	44.00	72.3	---	---
8	28.9	44.20	73.3	---	---	28.9	44.40	73.6	---	---	28.9	44.40	73.5	---	---	28.5	44.10	72.4	---	---
9	28.9	44.20	73.2	---	---	28.9	44.50	73.5	---	---	28.9	44.40	73.5	---	---	28.5	44.10	72.4	---	---
10	29.5	44.10	73.0	8.39	7.58	30.3	44.60	73.6	8.40	7.42	30.9	44.40	73.6	8.43	7.42	29.2	44.30	72.5	8.39	7.40
Remarks																				

Note:
1 Beufort grade
2 Muncel color code

Category	Parameter	Unit	MS-1			MS-2			MS-3			MS-4		
			0.5m	2m	10m	0.5m	2m	10m	0.5m	2m	10m	0.5m	2m	10m
Water (General parameter)	Turbidity	NTU	25	-	-	159	231	-	195	224	-	124	-	-
	Suspended Solids	mg/L	40	-	-	120	240	-	190	210	-	180	-	-
	COD	mg/L as O2	24	-	-	16	12	-	16	12	-	12	-	-
	TOC	mg/L as C	3.6	-	-	2.0	1.9	-	2.0	1.8	-	1.8	-	-
	Oil contents	mg/L	< 0.2	-	-	< 0.2	< 0.2	-	< 0.2	< 0.2	-	< 0.2	-	-
	Coliform bacteria	MPN Index/100ml	7	-	-	15	-	-	3	-	-	3	-	-
	Total nitrogen	mg/L as N	0.68	-	-	0.40	0.49	-	0.60	0.78	-	0.75	-	-
	Total phosphorous	mg/L as P	< 0.2	-	-	< 0.2	< 0.2	-	< 0.2	< 0.2	-	< 0.2	-	-

Category	Parameter	Unit	MS-5			MS-6			MS-7			MS-8		
			0.5m	2m	10m	0.5m	2m	10m	0.5m	2m	10m	0.5m	2m	10m
Water (General parameter)	Turbidity	NTU	51	55	128	66	127	148	128	89	124	103	78	225
	Suspended Solids	mg/L	20	70	100	90	90	150	100	70	120	110	60	210
	COD	mg/L as O2	16	12	12	16	12	12	12	12	12	12	12	12
	TOC	mg/L as C	2.2	2.1	1.7	1.9	2.1	1.8	2.2	2.0	2.0	2.0	1.9	1.9
	Oil contents	mg/L	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
	Coliform bacteria	MPN Index/100ml	11	-	-	9	-	-	3	-	-	15	-	-
	Total nitrogen	mg/L as N	0.84	0.82	0.82	0.93	0.63	0.87	0.51	0.36	0.86	0.52	0.67	0.53
	Total phosphorous	mg/L as P	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2

[August-1, 2013]

	MS-1					MS-2					MS-3					MS-4				
Date	13 Aug., 2013					13 Aug., 2013					13 Aug., 2013					13 Aug., 2013				
Time	9:30					10:10					10:40					11:20				
Longitude	30° 27' 19.9"N					30° 27' 26.4"N					30° 26' 56.2"N					30° 26' 07.5"N				
Latitude	49° 06' 05.0"N					49° 06' 33.3"N					49° 07' 02.5"N					49° 07' 08.7"N				
Air temperature(ºC)	39.5					40.6					44.8					44.5				
Wind[1]	-, 0					-, 0					-, 0					-, 0				
Wave (cm)	-					-					-					-				
Depth (m)	1.5					2.5					6.0					2.5				
Current (Direction, knot)	-					-					-					-				
Water color[2]	5GY 5/8 (deep yellow green)					5GY 6/4 (leaf)					5GY6/4 (leaf)					5GY6/4 (leaf)				
Transparency (m)	0.25					0.25					0.22					0.30				
Below water surface (m)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)
0.5	31.7	46.60	82.1	5.67	5.47	31.8	46.80	81.3	8.37	5.64	32.1	46.50	83.5	8.33	5.68	32.9	46.60	81.7	8.34	5.76
1						32.3	47.30	82.3	8.37	5.67	32.9	47.30	82.2	8.38	5.69	32.8	46.50	81.6	8.35	5.77
2						32.3	47.30	82.4	8.36	5.65	32.9	47.40	83.2	8.35	5.68	32.9	46.60	81.7	8.35	5.77
3											32.8	47.30	83.4	8.35	5.69					
4											32.9	47.30	83.2	8.34	5.69					
5											32.9	47.40	83.2	8.34	5.69					
6																				
7																				
8																				
9																				
10																				
Remarks																				

Note:
1 Beufort grade
2 Muncel color code

	MS-5					MS-6					MS-7					MS-8				
Date	14 Aug., 2013					14 Aug., 2013					14 Aug., 2013					14 Aug., 2013				
Time	10:00					10:40					11:20					12•20				
Longitude	30° 25' 16.6"N					30° 25' 07.2"N					30° 25' 02.2"N					30° 23' 24.1"N				
Latitude	49° 06' 15.2"N					49° 05' 20.5"N					49° 03' 44.6"N					49° 00' 27.6"N				
Air temperature(ºC)	40.6					42.5					44.8					46.9				
Wind[1]	-, 0					-, 0					S, 1					N, 1				
Wave (cm)	-					-					-					-				
Depth (m)	>10					>40					>30					>40				
Current (Direction, knot)	-					-					-					-				
Water color[2]	5GY6/4 (leaf)					5G5/4 (dull green)					5GY5/8 (deep yellow green)					5GY5/8 (deep yellow green)				
Transparency (m)	0.40					0.22					0.28					0.32				
Below water surface (m)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)
0.5	32.3	46.60	82.1	8.31	6.24	32.9	46.60	81.5	8.35	6.21	31.1	46.20	79.3	8.38	6.22	30.6	45.60	77.7	8.43	6.44
1	31.8	46.70	82.3	8.37	6.14	32.0	46.50	81.4	8.35	6.23	31.5	46.00	79.6	8.37	6.24	30.6	45.50	77.5	8.42	6.43
2	31.7	46.50	82.2	8.34	6.12	31.8	46.60	81.5	8.34	6.18	30.8	46.20	79.7	8.38	6.24	30.6	45.50	77.8	8.43	6.42
3	31.6	46.40	82.2	8.32	6.12	31.7	46.60	81.4	8.34	6.15	30.7	45.70	79.3	8.40	6.23	30.6	45.50	78.4	8.43	6.42
4	31.6	46.40	82.1	8.32	6.11	31.7	46.50	81.4	8.35	6.14	31.0	46.10	80.3	8.39	6.22	30.6	45.40	77.7	8.42	6.41
5	31.6	46.40	82.1	8.34	6.07	31.6	46.60	81.5	8.34	6.14	30.9	46.10	79.4	8.39	6.22	30.6	45.40	78.2	8.42	6.40
6	31.6	46.50	82.2	8.34	6.07	31.6	46.60	81.5	8.35	6.14	30.6	46.10	79.6	8.40	6.21	30.6	45.40	77.8	8.41	6.40
7	31.6	46.40	82.3	8.36	6.05	31.6	46.50	81.4	8.35	6.13	30.9	46.10	79.8	8.40	6.20	30.6	45.40	78.0	8.41	6.39
8	31.4	46.40	82.3	8.37	6.04	31.5	46.60	81.4	8.35	6.14	31.0	46.00	79.8	8.41	6.19	30.6	45.40	78.1	8.39	6.38
9	31.5	46.60	82.3	8.36	6.02	31.5	46.60	81.3	8.34	6.10	31.0	46.20	79.4	8.42	6.18	30.7	45.30	78.0	8.35	6.38
10	31.4	46.80	82.2	8.37	6.02	31.5	46.50	81.3	8.34	6.08	30.8	46.00	79.7	8.40	6.17	30.9	45.20	77.5	8.46	6.37
Remarks																				

Note:
1 Beufort grade
2 Muncel color code

Category	Parameter	Unit	MS-1			MS-2			MS-3			MS-4		
			0.5m	2m	10m	0.5m	2m	10m	0.5m	2m	10m	0.5m	2m	10m
Water (General parameter)	Turbidity	NTU	50			49	213	-	81	222	-	33	-	-
	Suspended Solids	mg/L	30			50	200	-	70	240	-	50	-	-
	COD	mg/L as O2	16			16	8	-	16	16	-	24	-	-
	TOC	mg/L as C	8.6			3.2	2.8	-	3.3	2.1	-	2.1	-	-
	Oil contents	mg/L	< 0.2			< 0.2	< 0.2	-	< 0.2	< 0.2	-	< 0.2	-	-
	Coliform bacteria	MPN Index/100ml	920			26	-	-	21	-	-	28	-	-
	Total nitrogen	mg/L as N	0.62			0.93	1.02	-	1.24	1.04	-	0.94	-	-
	Total phosphorous	mg/L as P	< 0.2			< 0.2	< 0.2	-	< 0.2	< 0.2	-	< 0.2	-	-

Category	Parameter	Unit	MS-5			MS-6			MS-7			MS-8		
			0.5m	2m	10m	0.5m	2m	10m	0.5m	2m	10m	0.5m	2m	10m
Water (General parameter)	Turbidity	NTU	40	107	126	14	65	95	33	67	97	67	74	118
	Suspended Solids	mg/L	40	270	140	30	63	83	40	60	90	240	160	30
	COD	mg/L as O2	16	16	8	16	7	7	16	8	8	8	8	8
	TOC	mg/L as C	2.2	2.1	2.0	2.0	2.2	2.5	2.4	2.2	2.3	1.9	2.1	2.0
	Oil contents	mg/L	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
	Coliform bacteria	MPN Index/100ml	11	-	-	11	-	-	7	-	-	11	-	-
	Total nitrogen	mg/L as N	0.87	0.90	0.89	0.86	0.56	0.54	0.89	0.86	0.52	0.84	0.82	0.85
	Total phosphorous	mg/L as P	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2

[August-2, 2013]

	MS-1					MS-2					MS-3					MS-4				
Date	28 August, 2013					28 August, 2013					28 August, 2013					28 August, 2013				
Time	13:00					13:30					12:00					11:15				
Longitude	30° 27' 19.9"N					30° 27' 26.4"N					30° 26' 56.2"N					30° 26' 07.5"N				
Latitude	49° 06' 05.0"N					49° 06' 33.3"N					49° 07' 02.5"N					49° 07' 08.7"N				
Air temperature(ºC)	45.0					45.8					36.5					35.5				
Wind[1]	N, 4					N, 1					N, 2					N, 2				
Wave (cm)	50					50					50					50				
Depth (m)	1.0					2.0					3.0					2.0				
Current (Direction, knot)	S					-					S					E				
Water color[2]	5GY 5/8 (deep yellow green)					5GY 5/8 (deep yellow green)					5GY 5/8 (deep yellow green)					5GY 6/10 (strong yellow green)				
Sediment color[2]																				
Transparency (m)	0.20					0.27					0.20					0.20				
Below water surface (m)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)
0.5	29.1	42.60	72.2	8.30	6.04	29.8	34.90	60.4	8.49	5.87	30.6	42.00	72.7	8.54	5.58	31.2	42.40	73.5	8.27	6.28
1	29.0	43.40	70.8	8.32	5.90	28.9	43.00	72.1	8.41	5.94	30.3	42.70	72.8	8.38	5.86	31.4	43.10	73.7	8.30	6.29
2						28.4	44.10	72.3	8.39	6.07	29.8	43.70	73.6	8.36	6.48	31.5	43.70	73.7	8.32	6.19
3																				
4																				
5																				
6																				
7																				
8																				
9																				
10																				
Remarks																				

Note:
1 Beufort grade
2 Muncel color code

	MS-5					MS-6					MS-7					MS-8				
Date	29 August, 2013					29 August, 2013					29 August, 2013					29 August, 2013				
Time	10:30					10:00					11:15					11:45				
Longitude	30° 25' 16.6"N					30° 25' 07.2"N					30° 25' 02.2"N					30° 23' 24.1"N				
Latitude	49° 06' 15.2"N					49° 05' 20.5"N					49° 03' 44.6"N					49° 00' 27.6"N				
Air temperature(ºC)	31.0					31.0					49.0					49.0				
Wind[1]	N, 1					N, 1					N, 1					N, 1				
Wave (cm)	-, 0					50					50					50				
Depth (m)	25.0					25.0					30.0					> 40.0				
Current (Direction, knot)	S					S					S					-				
Water color[2]	5GY 5/8 (deep yellow green)					5GY 5/8 (deep yellow green)					5GY 5/8 (deep yellow green)					5GY 5/8 (deep yellow green)				
Sediment color[2]																				
Transparency (m)	0.40					0.45					0.38					0.47				
Below water surface (m)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)
0.5	30.6	43.90	74.9	8.25	6.51	30.7	41.50	71.5	8.29	6.28	31.0	41.90	72.5	8.31	6.39	32.2	42.40	73.7	8.28	6.34
1	30.4	43.90	74.9	8.28	6.53	30.6	42.20	72.5	8.31	6.35	30.8	42.40	73.3	8.34	6.39	31.0	42.60	73.7	8.31	6.41
2	30.6	43.90	75.6	8.31	6.54	30.5	42.70	73.2	8.32	6.38	30.7	43.10	73.9	8.35	6.40	31.0	42.90	74.2	8.33	6.40
3	30.6	45.20	76.8	8.32	6.53	30.5	42.90	73.5	8.33	6.41	30.5	43.60	74.5	8.36	6.39	31.0	43.30	74.7	8.33	6.41
4	30.6	45.50	77.3	8.33	6.49	30.5	43.30	74.1	8.34	6.42	30.5	43.80	74.9	8.36	6.38	31.0	43.50	75.1	8.34	6.42
5	30.4	45.80	77.8	8.33	6.48	30.4	43.60	74.5	8.34	6.42	30.5	44.00	75.1	8.36	6.38	30.9	43.70	75.3	8.34	6.42
6	30.6	45.90	77.9	8.34	6.46	30.4	43.80	74.7	8.35	6.42	30.4	44.10	75.3	8.37	6.38	30.9	43.80	75.4	8.35	6.42
7	30.5	46.10	78.1	8.34	6.45	30.4	43.80	74.8	8.35	6.43	30.3	44.30	75.5	8.37	6.37	30.8	43.90	75.5	8.35	6.42
8	30.5	46.20	78.3	8.35	6.45	30.4	43.90	74.9	8.36	6.44	30.3	44.40	75.6	8.37	6.37	30.9	43.90	75.6	8.36	6.42
9	30.5	46.30	78.4	8.35	6.44	30.4	44.00	75.0	8.36	6.42	30.3	44.50	75.7	8.37	6.36	30.9	44.00	75.7	8.36	6.42
10	30.5	46.20	84.0	8.35	6.44	30.4	44.10	75.1	8.36	6.42	30.3	44.50	75.8	8.37	6.35	30.8	44.10	75.8	8.36	6.42
Remarks											Sampling position for sediment was moved to 30°24'20.0"N, 49°03'04.7"E due to diffficulty of sampling of sediment.					Due to the difficulty of sampling sediment, the location was changed to 30° 23' 54.5''N, 49° 00' 35.6''E with the depth of 14.8 m.				

Note:
1 Beufort grade
2 Muncel color code

Category	Parameter	Unit	MS-1			MS-2			MS-3			MS-4		
			0.5m	2m	10m	0.5m	2m	10m	0.5m	2m	10m	0.5m	2m	10m
Water quality (General parameter)	Turbidity	NTU	29	-	-	40	125	-	30	23	-	51	41	-
	Suspended Solids	mg/L	60	-	-	20	140	-	40	34	-	30	32	-
	COD	mg/L as O2	24	-	-	16	12	-	16	12	-	18	22	-
	TOC	mg/L as C	2.9	-	-	2.1	2.1	-	2.4	1.6	-	2.8	2.0	-
	Oil contents	mg/L	< 0.2	-	-	< 0.2	< 0.2	-	< 0.2	< 0.2	-	< 0.2	< 0.2	-
	Coliform bacteria*1	MPN Index/100ml	384	-	-	39	-	-	13	-	-	10	-	-
	Total nitrogen	mg/L as N	0.72	-	-	0.70	0.80	-	0.83	1.20	-	0.81	0.78	-
	Total phosphorous	mg/L as P	< 0.2	-	-	< 0.2	< 0.2	-	< 0.2	< 0.2	-	< 0.2	< 0.2	-
Water quaity (Heavy metal)	Aluminum (Al)	mg/L	<0.1	-	-	<0.1	<0.1	-	<0.1	<0.1	-	<0.1	-	-
	Arsenic (As)	micro-g/L	<1	-	-	<1	<1	-	<1	<1	-	<1	-	-
	Cadmium (Cd)	micro-g/L	<0.1	-	-	<0.1	<0.1	-	<0.1	<0.1	-	<0.1	-	-
	Cyanide (CN)	micro-g/L	<5	-	-	<5	<5	-	<5	<5	-	<5	-	-
	Chromium (Cr)	micro-g/L	<0.1	-	-	<0.1	<0.1	-	0.1	<0.1	-	<0.1	-	-
	Cobalt (Co)	micro-g/L	<0.1	-	-	<0.1	<0.1	-	<0.1	<0.1	-	<0.1	-	-
	Copper (Cu)	micro-g/L	2.5	-	-	2.2	0.1	-	<0.1	<0.1	-	<0.1	-	-
	Iron (Fe)	mg/L	<0.1	-	-	<0.1	<0.1	-	<0.1	<0.1	-	<0.1	-	-
	Methyl Mercury (Hg)	micro-g/L	<1	-	-	<1	<1	-	<1	<1	-	<1	-	-
	Mercury (Hg)	micro-g/L	<1	-	-	<1	<1	-	<1	<1	-	<1	-	-
	Manganese (Mn)	micro-g/L	<0.1	-	-	<0.1	<0.1	-	<0.1	<0.1	-	<0.1	-	-
	Magnesium (Mg)	mg/L	1942	-	-	1954	1930	-	1917	1899	-	1942	-	-
	Nickel (Ni)	micro-g/L	1.8	-	-	1.3	1.4	-	1.7	3.1	-	1.5	-	-
	Lead (Pb)	micro-g/L	<0.1	-	-	<0.1	<0.1	-	<0.1	0.10	-	1.50	-	-
	Zinc (Zn)	mg/L	<0.01	-	-	<0.01	<0.01	-	<0.01	<0.01	-	<0.01	-	-
	Phenols	micro-g/L	<1	-	-	<1	<1	-	<1	<1	-	<1	-	-

Category	Parameter	Unit	MS-5			MS-6			MS-7			MS-8		
			0.5m	2m	10m	0.5m	2m	10m	0.5m	2m	10m	0.5m	2m	10m
Water quality (General parameter)	Turbidity	NTU	41	48	45	25	32	41	37	51	60	22	20	26
	Suspended Solids	mg/L	32	60	42	44	20	50	40	50	60	22	28	32
	COD	mg/L as O2	22	16	8	12	8	8	14	8	8	12	8	8
	TOC	mg/L as C	2.0	2.7	2.6	2.0	2.6	2.6	2.1	2.2	2.0	2.2	2.4	2.5
	Oil contents	mg/L	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
	Coliform bacteria*1	MPN Index/100ml	< 2	< 2	-	< 2	-	-	< 2	-	-	< 2	-	-
	Total nitrogen	mg/L as N	0.78	0.81	0.75	0.76	0.78	0.92	0.65	0.81	0.85	0.78	0.80	1.30
	Total phosphorous	mg/L as P	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Water quaity (Heavy metal)	Aluminum (Al)	mg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	Arsenic (As)	micro-g/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Cadmium (Cd)	micro-g/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	Cyanide (CN)	micro-g/L	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
	Chromium (Cr)	micro-g/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	Cobalt (Co)	micro-g/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	Copper (Cu)	micro-g/L	<0.1	<0.1	<0.1	1.8	<0.1	0.9	1.4	<0.1	1.1	<0.1	<0.1	<0.1
	Iron (Fe)	mg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	Methyl Mercury (Hg)	micro-g/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Mercury (Hg)	micro-g/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Manganese (Mn)	micro-g/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.44	<0.1
	Magnesium (Mg)	mg/L	1917	1869	1869	1899	1869	1869	1911	1942	1917	1942	1924	1869
	Nickel (Ni)	micro-g/L	1.6	1.8	1.7	2.3	2.0	1.8	2.0	1.0	1.9	1.5	2.0	0.8
	Lead (Pb)	micro-g/L	0.20	0.50	0.20	0.30	<0.1	0.10	0.10	0.50	0.20	0.30	0.50	0.30
	Zinc (Zn)	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Phenols	micro-g/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1

Category	Parameter	Unit	MS-1			MS-2			MS-3			MS-4		
			0.5m	2m	10m	0.5m	2m	10m	0.5m	2m	10m	0.5m	2m	10m
Sediment quality	Specific Gravity	g/cm3		1.12			1.18			1.04			1.13	
	Moisture Content	Mass%		70.5			41.3			73.9			61.1	
	Total Organic Carbon (TOC)	Mass%		0.57			0.32			0.54			0.41	
	Total Petroleum Hydrocarbon	micro-g/g.dw		40			36			140			130	
	Aluminum (Al)	mg/g.dw		9.2			6.9			10.0			9.0	
	Arsenic (As)	micro-g/g.dw		1.5			1.5			1.6			1.5	
	Cadmium (Cd)	micro-g/g.dw		2.1			2.0			1.7			1.6	
	Cyanide (CN)	micro-g/g.dw		<0.1			<0.1			<0.1			<0.1	
	Chromium (total)	micro-g/g.dw		32.3			22.9			33.0			28.0	
	Chromium (Cr+6)	micro-g/g.dw		-			-			-			-	
	Cobalt (Co)	micro-g/g.dw		20.1			19.8			20.5			19.6	
	Copper (Cu)	micro-g/g.dw		17.2			13.0			18.5			16.6	
	Iron (Fe)	mg/g.dw		16.1			12.9			16.3			15.7	
	Methyl Mercury (Hg)	micro-g/g.dw		0.06			<0.01			<0.01			<0.01	
	Mercury (Hg)	micro-g/g.dw		0.70			0.26			1.90			0.34	
	Manganese (Mn)	micro-g/g.dw		372			354			347			355	
	Magnesium (Mg)	mg/g.dw		21.6			17.2			19.7			20.3	
	Nickel (Ni)	micro-g/g.dw		73			53			80			70	
	Lead (Pb)	micro-g/g.dw		22.0			22.3			25.3			22.0	
	Zinc (Zn)	micro-g/g.dw		62			47			69			53	
	Total Sulfur (T-S)	mg/g		1.90			8.00			2.00			2.00	
	Grain size													
	Sand (>0.04mm & <1mm)	%		4.0			38.0			6.0			8.0	
	Silt (>0.002mm & <0.04mm)	%		45.0			39.0			53.0			47.0	
	Clay (>0.0002mm & <0.002mm)	%		51.0			23.0			41.0			45.0	

Category	Parameter	Unit	MS-5			MS-6			MS-7			MS-8		
			0.5m	2m	10m	0.5m	2m	10m	0.5m	2m	10m	0.5m	2m	10m
Sediment quality	Specific Gravity	g/cm3		1.26			1.24			1.23			1.03	
	Moisture Content	Mass%		45.7			44.4			39.0			52.5	
	Total Organic Carbon (TOC)	Mass%		0.30			0.54			0.35			0.36	
	Total Petroleum Hydrocarbon	micro-g/g.dw		50			155			33			33	
	Aluminum (Al)	mg/g.dw		6.7			8.2			7.1			8.6	
	Arsenic (As)	micro-g/g.dw		1.8			1.6			1.8			2.3	
	Cadmium (Cd)	micro-g/g.dw		1.5			1.4			1.2			1.5	
	Cyanide (CN)	micro-g/g.dw		<0.1			<0.1			<0.1			<0.1	
	Chromium (total)	micro-g/g.dw		20.8			25.9			24.0			31.5	
	Chromium (Cr+6)	micro-g/g.dw		-			-			-			-	
	Cobalt (Co)	micro-g/g.dw		16.6			17.2			18.8			20.1	
	Copper (Cu)	micro-g/g.dw		12.9			13.2			14.0			18.7	
	Iron (Fe)	mg/g.dw		12.3			14.3			13.4			18.0	
	Methyl Mercury (Hg)	micro-g/g.dw		<0.01			<0.01			<0.01			<0.01	
	Mercury (Hg)	micro-g/g.dw		<0.05			<0.05			<0.05			0.10	
	Manganese (Mn)	micro-g/g.dw		271			324			308			298	
	Magnesium (Mg)	mg/g.dw		11.0			17.7			17.6			20.6	
	Nickel (Ni)	micro-g/g.dw		55			59			53			58	
	Lead (Pb)	micro-g/g.dw		22.2			21.3			21.1			26.7	
	Zinc (Zn)	micro-g/g.dw		42			41			36			69	
	Total Sulfur (T-S)	mg/g		1.50			1.30			1.90			1.40	
	Grain size													
	Sand (>0.04mm & <1mm)	%		34.0			34.0			34.0			16.0	
	Silt (>0.002mm & <0.04mm)	%		27.0			39.0			29.0			39.0	
	Clay (>0.0002mm & <0.002mm)	%		39.0			27.0			37.0			45.0	

[September, 2013]

	MS-1					MS-2					MS-3					MS-4				
Date	21 Sep., 2013					21 Sep., 2013					21 Sep., 2013					21 Sep., 2013				
Time	16:45					16:15					15:45					15:15				
Longitude	30° 27' 19.9"N					30° 27' 26.4"N					30° 26' 56.2"N					30° 26' 07.5"N				
Latitude	49° 06' 05.0"N					49° 06' 33.3"N					49° 07' 02.5"N					49° 07' 08.7"N				
Air temperature(ºC)	34.0					32.8					34.6					39.3				
Wind[1]	N, 2					N, 3					N, 4					N, 2				
Wave (cm)	25					100					100					70				
Depth (m)	2.0					4.0					5.5					4.5				
Current (Direction, knot)	S					S					S					S				
Water color[2]	10GY 4.5/7 (strong yellowish green)					5GY 6/4 (leaf)					5GY 5/8 (deep yellow green)					5GY 5/8 (deep yellow green)				
Transparency (m)	0.47					0.17					0.27					0.25				
Below water sur	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)
0.5	29.8	41.50	70.4	8.48	5.90	30.2	42.10	71.5	8.48	6.53	30.4	42.60	72.8	8.50	6.58	31.3	41.70	71.4	8.44	6.45
1	29.8	41.80	70.9	8.47	5.80	29.9	42.20	71.6	8.51	6.52	30.3	43.00	73.4	8.51	6.63	30.7	42.40	72.4	8.47	6.52
2						29.9	42.70	72.4	8.51	6.51	30.3	43.80	74.6	8.52	6.61	30.5	42.90	73.1	8.48	6.53
3						29.9	43.20	73.9	8.51	6.51	30.3	44.20	75.1	8.52	6.57	30.4	43.30	73.7	8.48	6.54
4						29.9	43.70	-	8.51	6.50	30.2	44.50	75.4	8.52	6.52	30.2	43.80	74.4	8.50	6.53
5											30.2	44.50	75.5	8.52	6.54					
6																				
7																				
8																				
9																				
10																				
Remarks																				

Note:
1 Beufort grade
2 Muncel color code

	MS-5					MS-6					MS-7					MS-8				
Date	22 Sep., 2013					22 Sep., 2013					22 Sep., 2013					22 Sep., 2013				
Time	17:00					16:00					15:30					15:00				
Longitude	30° 25' 16.6"N					30° 25' 07.2"N					30° 25' 02.2"N					30° 23' 24.1"N				
Latitude	49° 06' 15.2"N					49° 05' 20.5"N					49° 03' 44.6"N					49° 00' 27.6"N				
Air temperature(ºC)	32.0					32.5					34.9					31.1				
Wind[1]	N, 2					E, 2					N, 2					N, 1				
Wave (cm)	50					50					50					40				
Depth (m)	34.0					35.0					> 30					> 50				
Current (Direction, knot)	W					W					S					S				
Water color[2]	5GY 6/10 (strong yellow green)					5GY 6/10 (strong yellow green)					5GY 5/8 (deep yellow green)					5GY 6/10 (strong yellow green)				
Transparency (m)	0.15					0.15					0.38					0.15				
Below water surf	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)
0.5	30.3	42.30	74.5	8.61	6.58	30.3	41.80	71.8	8.53	6.57	30.4	41.30	70.7	8.53	6.52	30.0	40.60	69.5	8.50	6.49
1	30.1	42.60	74.5	8.54	6.56	30.4	41.90	71.9	8.53	6.57	30.3	41.40	71.0	8.54	6.49	30.0	41.10	70.3	8.53	6.51
2	30.2	43.00	74.5	8.53	6.55	30.3	42.70	73.1	8.53	6.55	30.3	42.30	72.3	8.54	6.49	30.1	42.00	71.7	8.55	6.54
3	30.1	43.60	74.9	8.53	6.54	30.3	43.40	74.0	8.54	6.52	30.3	42.80	73.0	8.54	6.49	30.2	42.60	72.5	8.55	6.55
4	30.2	43.90	75.3	8.53	6.53	30.2	43.70	74.4	8.53	6.50	30.3	43.10	73.5	8.54	6.49	30.2	43.00	73.1	8.55	6.54
5	30.2	44.10	75.5	8.53	6.53	30.2	43.90	74.8	8.54	6.48	30.3	43.40	73.8	8.54	6.49	30.2	43.20	73.5	8.55	6.54
6	30.3	44.30	75.2	8.53	6.52	30.1	44.10	74.8	8.54	6.48	30.2	43.60	74.2	8.54	6.49	30.2	43.30	73.6	8.55	6.55
7	30.2	44.50	75.5	8.53	6.51	30.1	44.20	74.9	8.54	6.47	30.2	43.80	74.4	8.54	6.48	30.1	43.40	73.7	8.55	6.53
8	30.2	44.60	75.7	8.53	6.51	30.1	44.30	75.2	8.54	6.47	30.2	43.80	74.5	8.54	6.49	30.1	43.50	73.9	8.55	6.53
9	30.2	44.60	75.8	8.53	6.51	30.1	44.40	75.3	8.54	6.47	30.2	44.00	74.7	8.54	6.47	30.1	43.60	74.1	8.55	6.54
10	30.2	44.70	76.0	8.53	6.51	30.1	44.50	75.4	8.54	6.45	30.2	44.10	74.9	8.54	6.47	30.1	43.70	74.2	8.55	6.53
Remarks																				

Note:
1 Beufort grade
2 Muncel color code

Category	Parameter	Unit	MS-1			MS-2			MS-3			MS-4		
			0.5m	2m	10m	0.5m	2m	10m	0.5m	2m	10m	0.5m	2m	10m
Water quality (General parameter)	Turbidity	NTU	31	-	-	148	167	-	52	42	-	55	-	-
	Suspended Solids	mg/L	20	-	-	120	140	-	10	190	-	44	-	-
	COD	mg/L as O2	18	-	-	16	14	-	26	16	-	48	-	-
	TOC	mg/L as C	2.9	-	-	2.8	2.2	-	3.4	2.9	-	3.8	-	-
	Oil contents	mg/L	< 0.2	-	-	< 0.2	< 0.2	-	< 0.2	< 0.2	-	< 0.2	-	-
	Coliform bacteria*1	MPN Index/100ml	71	-	-	11	-	-	9	-	-	21	-	-
	Total nitrogen	mg/L as N	0.63	-	-	0.61	0.86	-	0.63	0.65	-	0.57	-	-
	Total phosphorous	mg/L as P	< 0.2	-	-	< 0.2	< 0.2	-	< 0.2	< 0.2	-	< 0.2	-	-

*1 Fecal coliform was analyzed in this sampling.

Category	Parameter	Unit	MS-5			MS-6			MS-7			MS-8		
			0.5m	2m	10m	0.5m	2m	10m	0.5m	2m	10m	0.5m	2m	10m
Water quality (General parameter)	Turbidity	NTU	79	79	73	69	53	143	61	176	171	81	161	158
	Suspended Solids	mg/L	40	90	30	40	50	170	10	130	180	80	170	240
	COD	mg/L as O2	18	16.5	14	16	14	12	14	12	12	14.5	12.5	12
	TOC	mg/L as C	2.9	2.8	2.5	2.4	2.1	2.1	2.3	2.1	1.9	2.2	2.1	2.1
	Oil contents	mg/L	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
	Coliform bacteria*1	MPN Index/100ml	< 2	-	-	< 2	-	-	4	-	-	< 2	-	-
	Total nitrogen	mg/L as N	0.65	0.88	0.56	0.72	0.66	0.72	0.59	0.61	0.59	0.72	0.81	0.61
	Total phosphorous	mg/L as P	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2

*1 Fecal coliform was analyzed in this sampling.

[October, 2013]

	MS-1					MS-2					MS-3					MS-4				
Date	19 Oct., 2013					19 Oct., 2013					19 Oct., 2013					19 Oct., 2013				
Time	15:45					15:15					15:00					14:30				
Longitude	30° 27' 19.9"N					30° 27' 26.4"N					30° 26' 56.2"N					30° 26' 07.5"N				
Latitude	49° 06' 05.0"N					49° 06' 33.3"N					49° 07' 02.5"N					49° 07' 08.7"N				
Air temperature(ºC)	26.7					31.2					26.7					30.1				
Wind[1]	N					W					S					N				
Wave (cm)	50					50					50					50				
Depth (m)	1.0					2.5					5.0					1.0				
Current (Direction, knot)	S					S					S					S				
Water color[2]	5GY 5/8 (deep yellow green)					5.5Y 6/10					5.5Y 6.5/1.5 (grayish leaf)					5.5Y 6.5/1.5 (grayish leaf)				
Transparency (m)	0.55					0.24					0.23					0.23				
Below water surf	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)
0.5	25.5	39.40	62.0	8.66	7.67	25.1	39.40	61.9	8.62	7.01	25.4	42.30	65.5	8.56	7.35	25.4	42.60	65.9	8.53	7.39
1						25.2	39.60	62.1	8.66	6.99	25.2	42.40	65.6	8.59	7.35	25.3	42.70	66.0	8.55	7.34
2						25.2	39.80	62.4	8.66	6.98	25.2	42.70	65.9	8.60	7.34	25.2	42.90	66.1	8.59	7.33
3						25.3	40.00	62.6	8.66	6.98	25.1	43.00	66.4	8.61	7.32	25.1	43.10	66.5	8.60	7.31
4																25.0	43.50	66.9	8.61	7.31
5																				
6																				
7																				
8																				
9																				
10																				
Remarks																				

Note:
1 Beufort grade
2 Muncel color code

	MS-5					MS-6					MS-7					MS-8				
Date	20 Oct., 2013					20 Oct., 2013					20 Oct., 2013					20 Oct., 2013				
Time	13:00					16:45					16:00					15:30				
Longitude	30° 25' 16.6"N					30° 25' 07.2"N					30° 25' 02.2"N					30° 23' 24.1"N				
Latitude	49° 06' 15.2"N					49° 05' 20.5"N					49° 03' 44.6"N					49° 00' 27.6"N				
Air temperature(ºC)	31.9					25.6					26.1					29.3				
Wind[1]	N					NE					NE					NE				
Wave (cm)	50					50					50					50				
Depth (m)	35.0					> 40					> 40					> 50				
Current (Direction, knot)	E					E					E					W				
Water color[2]	5.5Y 6.5/1.5 (grayish leaf)					5GY 5/8 (deep yellow green)					5GY 5/8 (deep yellow green)					5GY 5/8 (deep yellow green)				
Transparency (m)	0.25					0.27					0.35					0.24				
Below water surf	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)	Water temperature (ºC)	Salinity	Conductivity (mS/cm)	pH	DO (mg/L)
0.5	25.1	43.00	66.2	6.34	7.34	25.3	47.40	72.4	8.56	7.56	24.8	36.50	57.2	8.58	7.41	25.3	35.60	56.1	8.57	7.24
1	25.1	43.20	66.5	6.51	7.30	25.2	47.80	72.9	8.58	7.53	24.8	36.70	57.4	8.61	7.39	25.1	35.80	56.3	8.58	7.26
2	25.0	43.20	67.3	6.58	7.30	25.1	48.20	73.5	8.59	7.51	24.8	37.20	58.1	8.62	7.37	25.0	36.40	57.2	8.60	7.28
3	24.9	44.10	67.6	7.93	7.29	25.1	49.10	74.8	8.60	7.49	24.9	37.60	58.8	8.62	7.35	25.0	37.10	58.1	8.61	7.29
4	24.9	44.20	67.8	7.92	7.29	25.1	49.70	75.5	8.60	7.47	24.9	38.00	59.3	8.62	7.34	25.0	37.60	58.8	8.61	7.28
5	24.9	44.30	67.9	7.92	7.27	25.1	49.80	76.0	8.61	7.45	24.9	38.20	59.7	8.62	7.33	25.0	37.80	59.0	8.62	7.27
6	24.9	44.40	68.1	7.93	7.27	25.1	49.90	76.1	8.61	7.44	25.0	38.50	60.0	8.62	7.31	24.9	38.00	59.3	8.62	7.27
7	24.9	44.60	68.3	7.92	7.26	25.1	50.00	76.4	8.61	7.42	25.0	38.60	60.1	8.62	7.30	24.9	38.10	59.7	8.62	7.27
8	24.9	44.70	68.4	7.89	7.26	25.2	50.10	76.6	8.61	7.40	25.0	38.70	60.2	8.62	7.29	25.0	38.20	59.8	8.62	7.28
9	24.9	44.80	68.5	7.90	7.26	25.1	50.20	76.7	8.62	7.39	25.0	38.80	60.4	8.62	7.28	25.0	38.30	59.9	8.63	7.26
10	24.9	44.90	68.6	7.87	7.24	25.1	50.30	76.8	8.62	7.38	25.0	38.90	60.5	8.63	7.27	25.0	38.40	64.6	8.63	7.27
Remarks																				

Note:
1 Beufort grade
2 Muncel color code

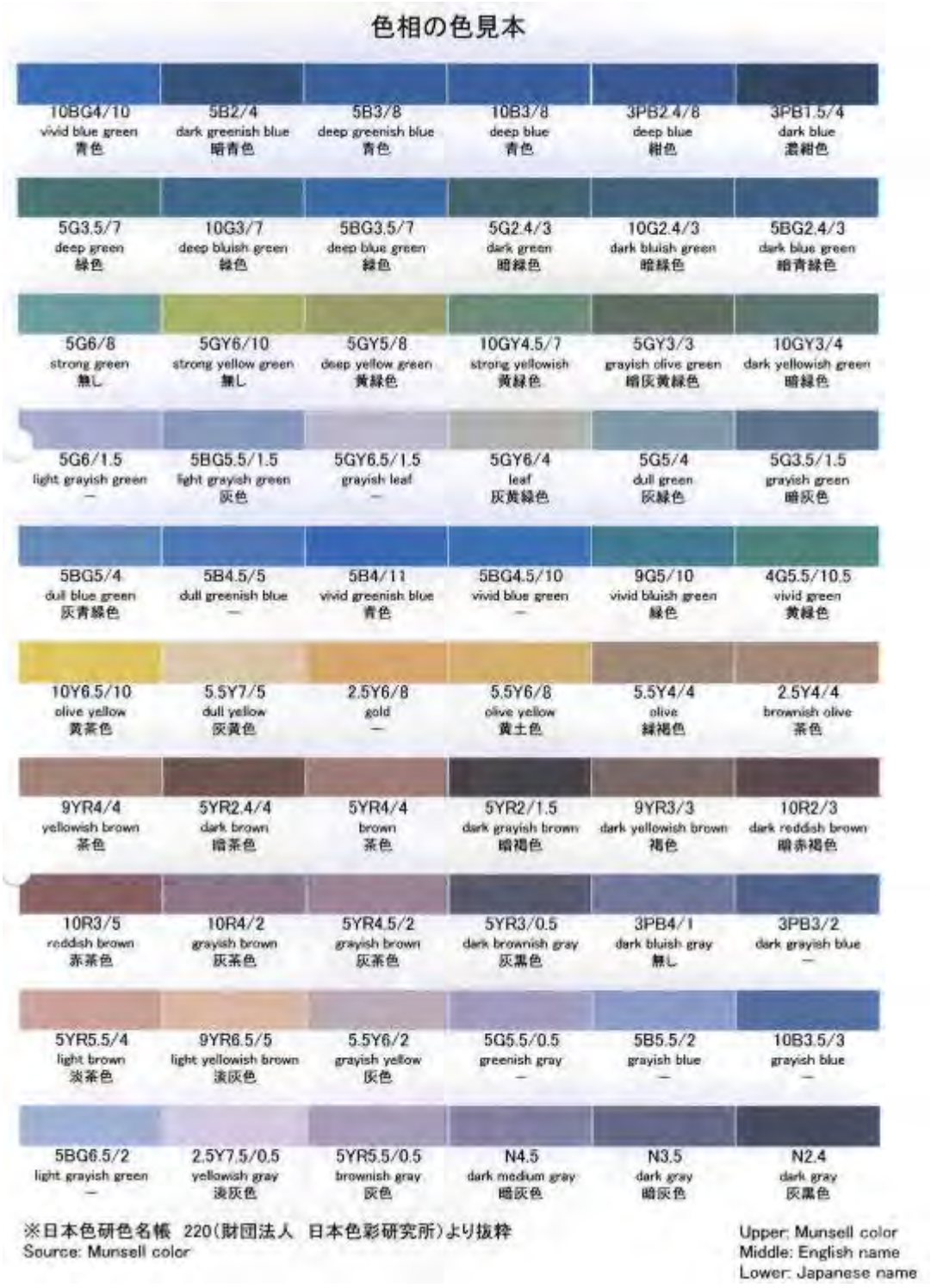
Category	Parameter	Unit	MS-1			MS-2			MS-3			MS-4		
			0.5m	2m	10m	0.5m	2m	10m	0.5m	2m	10m	0.5m	2m	10m
Water quality (General parameter)	Turbidity	NTU	19	-	-	74	96	-	33	40	-	83	-	-
	Suspended Solids	mg/L	200	-	-	100	120	-	80	150	-	110	-	-
	COD	mg/L as O2	24	-	-	22	16	-	23	14	-	25	-	-
	TOC	mg/L as C	2.6	-	-	3.1	2.7	-	3.5	2.4	-	2.4	-	-
	Oil contents	mg/L	< 0.2	-	-	<0.2	<0.2	-	<0.2	<0.2	-	< 0.2	-	-
	Coliform bacteria*1	MPN Index/100ml	23	-	-	11	-	-	<2	-	-	9	-	-
	Total nitrogen	mg/L as N	0.66	-	-	0.68	0.59	-	0.56	0.79	-	0.66	-	-
	Total phosphorous	mg/L as P	< 0.2	-	-	<0.2	<0.2	-	<0.2	<0.2	-	< 0.2	-	-

*1 Fecal coliform was analyzed in this sampling.

Category	Parameter	Unit	MS-5			MS-6			MS-7			MS-8		
			0.5m	2m	10m	0.5m	2m	10m	0.5m	2m	10m	0.5m	2m	10m
Water quality (General parameter)	Turbidity	NTU	62	74	88	60	74	76	57	69	79	63	78	88
	Suspended Solids	mg/L	70	70	100	80	70	100	70	200	90	70	90	80
	COD	mg/L as O2	20	16	12	18	16	12	18	16	10	14	12	10
	TOC	mg/L as C	3.2	2.8	2.9	2.2	2.9	2.5	2.9	2.6	2.8	2.5	2.4	2.4
	Oil contents	mg/L	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
	Coliform bacteria*1	MPN Index/100ml	3	-	-	<2	-	-	<2	-	-	<2	-	-
	Total nitrogen	mg/L as N	0.53	0.59	0.69	0.84	0.56	0.63	0.58	0.63	0.67	0.62	0.61	0.61
	Total phosphorous	mg/L as P	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2

*1 Fecal coliform was analyzed in this sampling.

Annex B Munsel color index

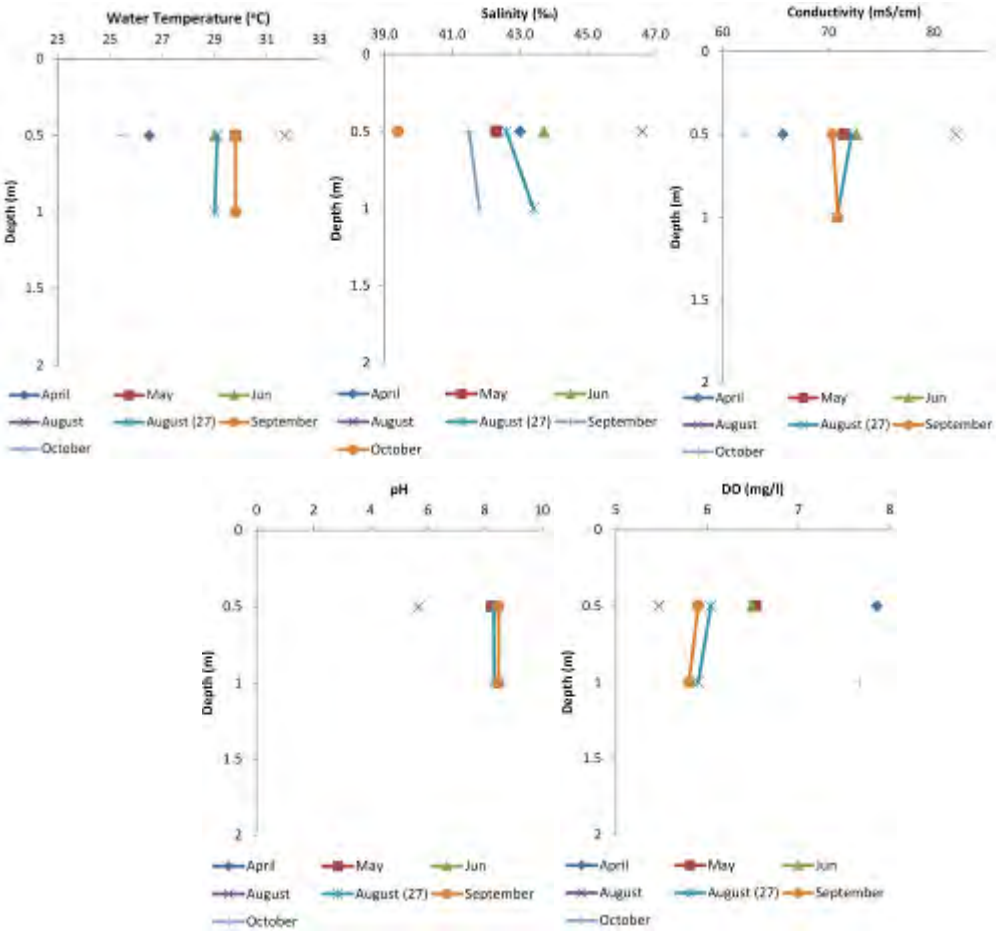


Annex C Beaufort scales

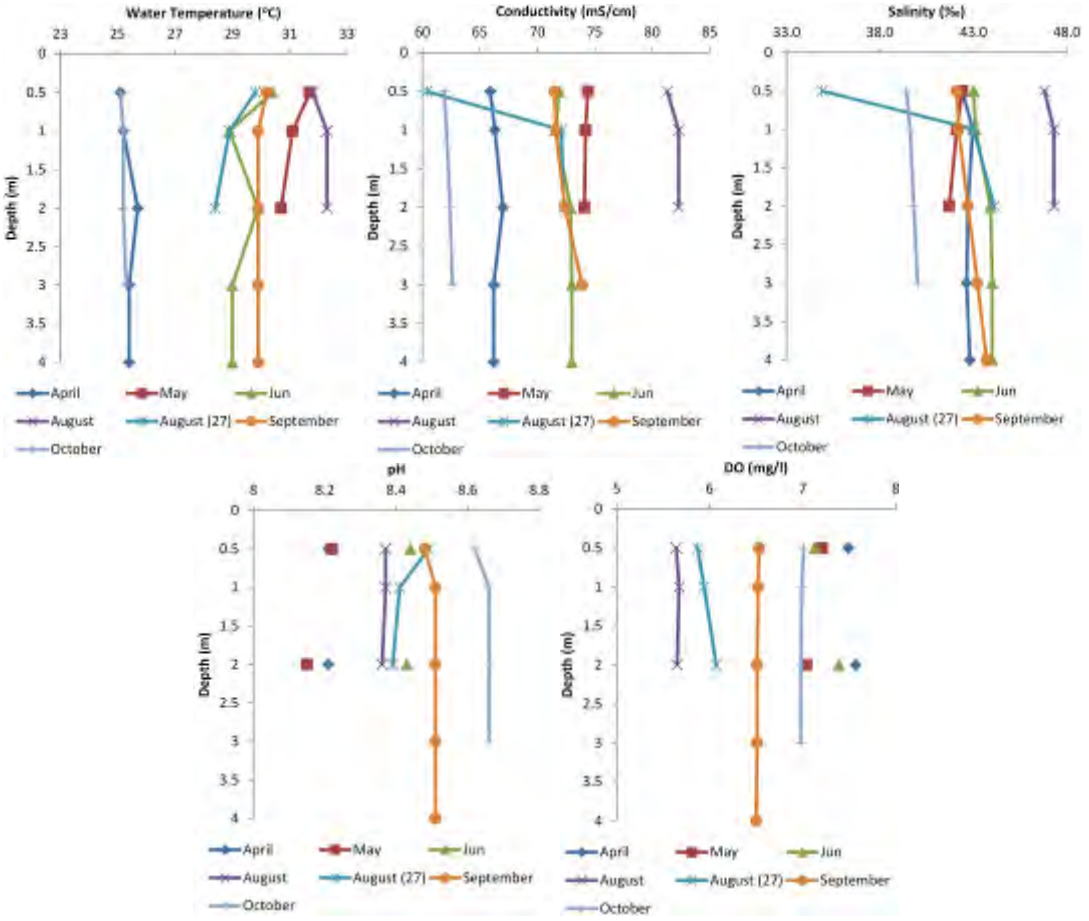
Class	Wind velocity		Explanation	
	m/s	Km/h	On the land	On the ocean
0	0.0 to 0.3	Under 1	Smoke rises straight.	Surface is like a mirror
1	0.3 to 1.6	1 to 6	We can know direction. But can't feel.	Ripples is like a scale
2	1.6 to 3.4	6 to 12	We can feel wind. Leaves are moved.	We see short waves clearly. The top of wave is glassy.
3	3.4 to 5.5	12 to 20	Leaves and twigs are moved always.	The top of wave becomes to break. Sometimes white-crested waves appeared.
4	5.5 to 8.0	20 to 29	A cloud of dust rises. Pieces of paper fly up.	White-crested waves increase.
5	8.0 to 10.8	29 to 30	Shrubs become to swing. A wave crest appears on a lake and a pond.	A many white-crested waves appear. Sometimes spray is appeared.
6	10.8 to 13.9	30 to 50	Big branches swing. It's difficult to put up an umbrella.	Big waves appear. The top of wave with white bubble appear everywhere.
7	13.9 to 17.2	50 to 62	Trees swing. It's difficult to walk against wind.	Waves become bigger. The top of wave is broken and makes white bubble. And it flows down the wind.

Scale	Explanation	Height of waves (m)
0	Surface is like a mirror	0
1	There are Ripples	0 to 0.1
2	Wave crest is glassy.	0.1 to 0.5
3	A little waves	0.5 to 1.25
4	Pretty waves	1.25 to 2.5
5	The height of wave is more or less high.	2/5 to 4/0
6	The height of wave is pretty high.	4.0 to 6.0
7	Waves become rough.	6.0 to 9.0
8	Waves become quite rough.	9.0 to 14.0
9	Abnormally.	Over 14.0

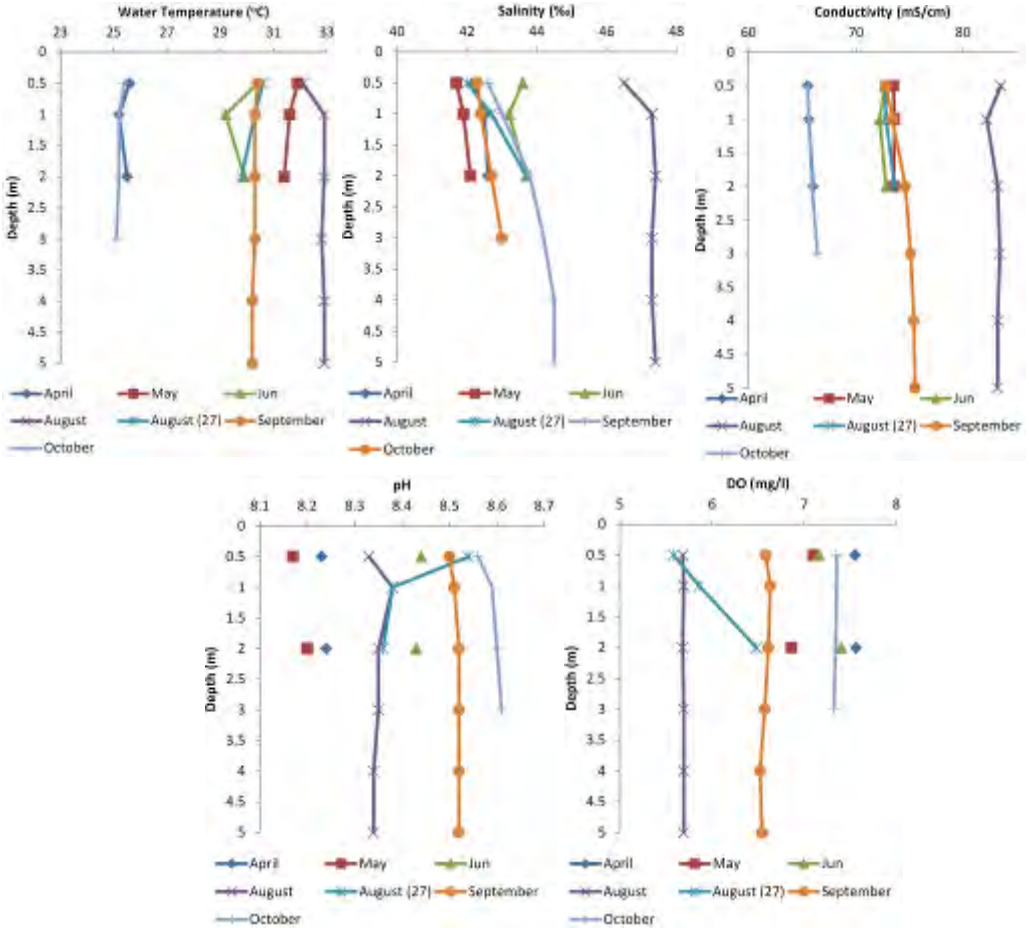
Annex D Vertical Profile of in-situ and laboratory parameters



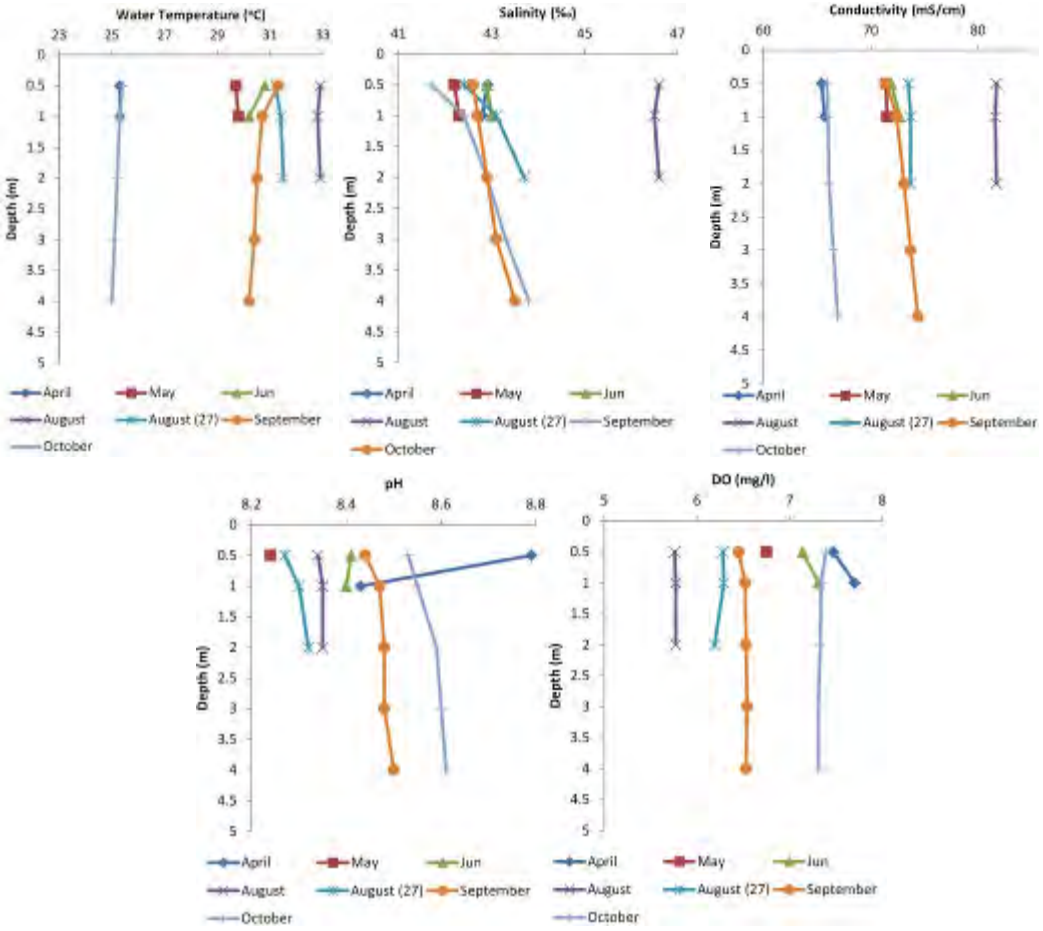
MS-1


Water Temperature (°C)
Conductivity (mS/cm)
Salinity (‰)
pH
DO (mg/l)
Depth (m)
April
May
Jun
August
August (27)
September
October

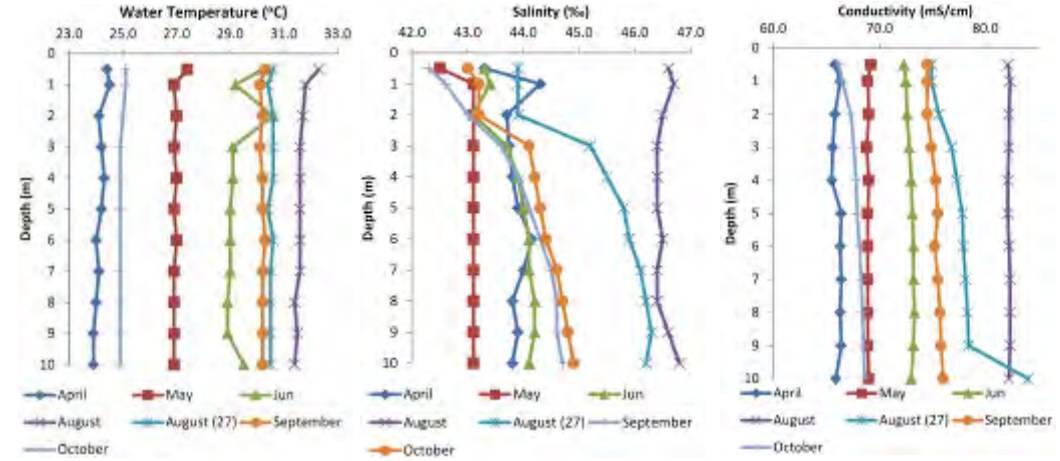
MS-2

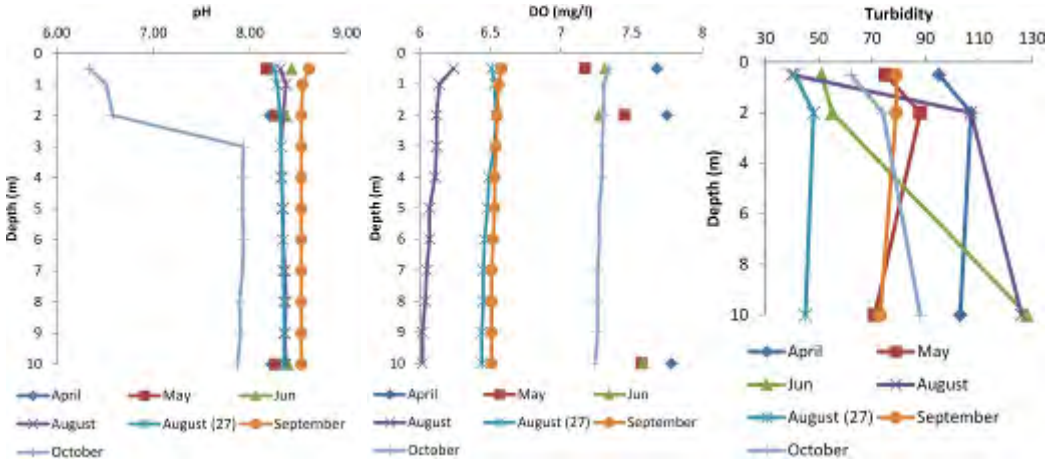

Water Temperature (°C)
Salinity (‰)
Conductivity (mS/cm)
pH
DO (mg/l)
Depth (m)
April
May
Jun
August
August (27)
September
October

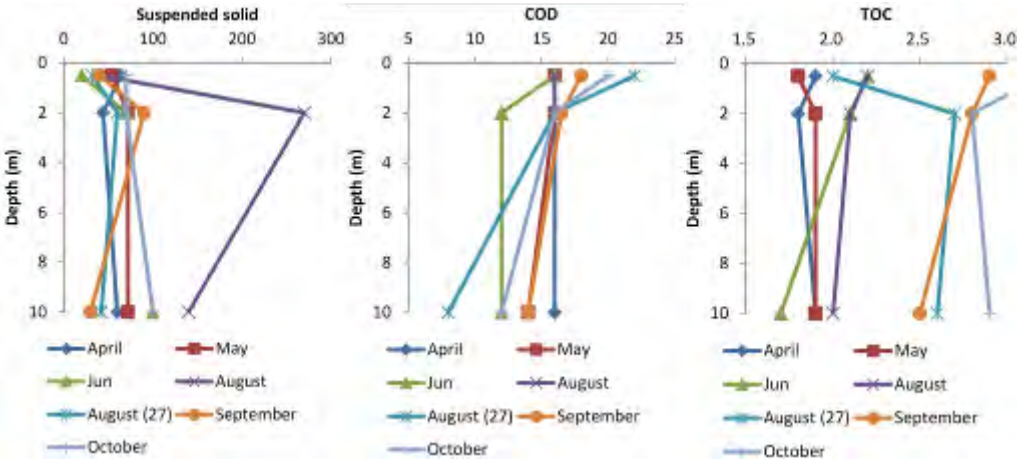
MS-3


Water Temperature (°C)
Salinity (‰)
Conductivity (mS/cm)
pH
DO (mg/l)
Depth (m)
April
May
Jun
August
August (27)
September
October

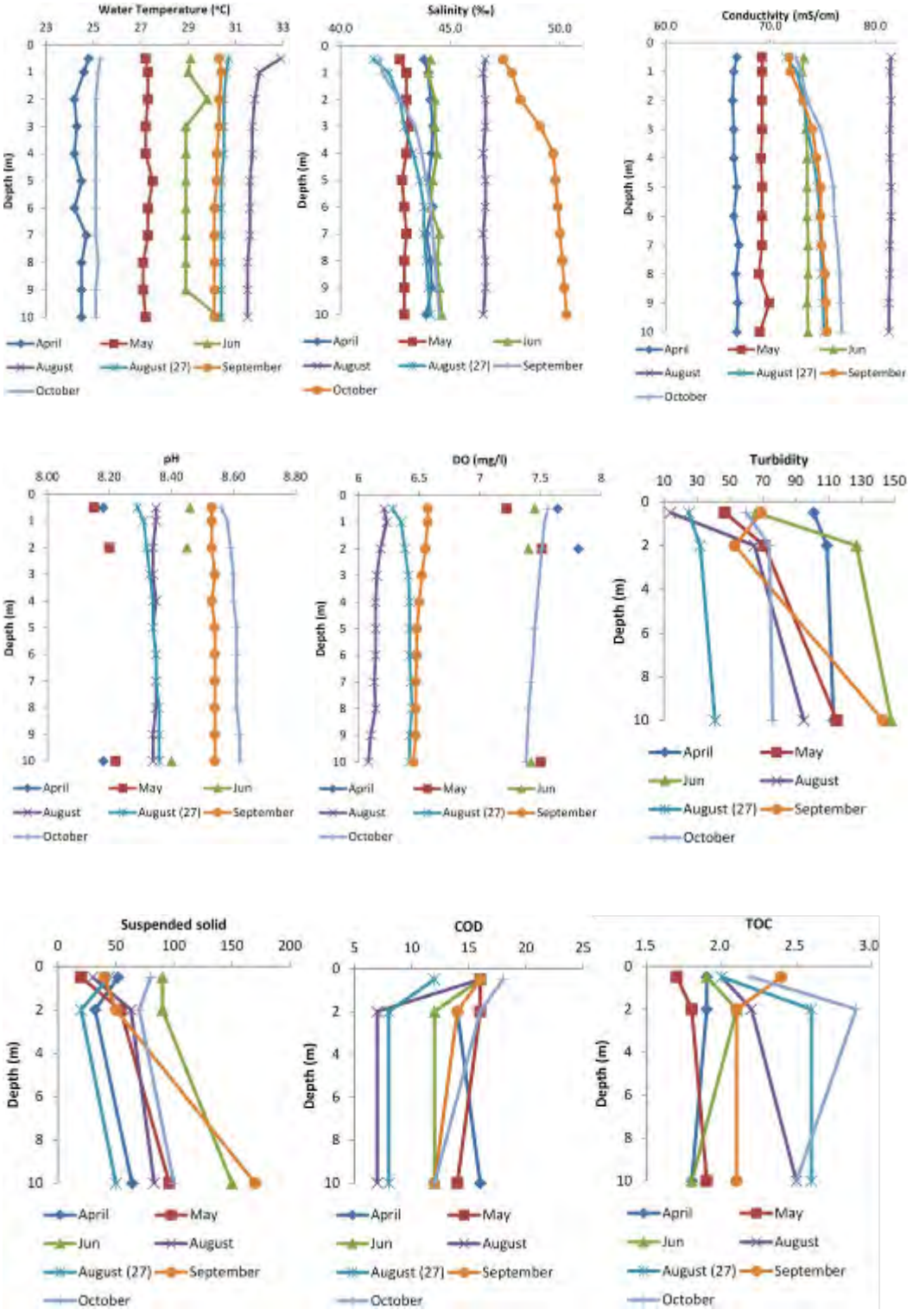
MS-4


Water Temperature (°C)
23.0 25.0 27.0 29.0 31.0 33.0
Salinity (‰)
42.0 43.0 44.0 45.0 46.0 47.0
Conductivity (mS/cm)
60.0 70.0 80.0
Depth (m)
0 1 2 3 4 5 6 7 8 9 10
April May Jun August August (27) September October

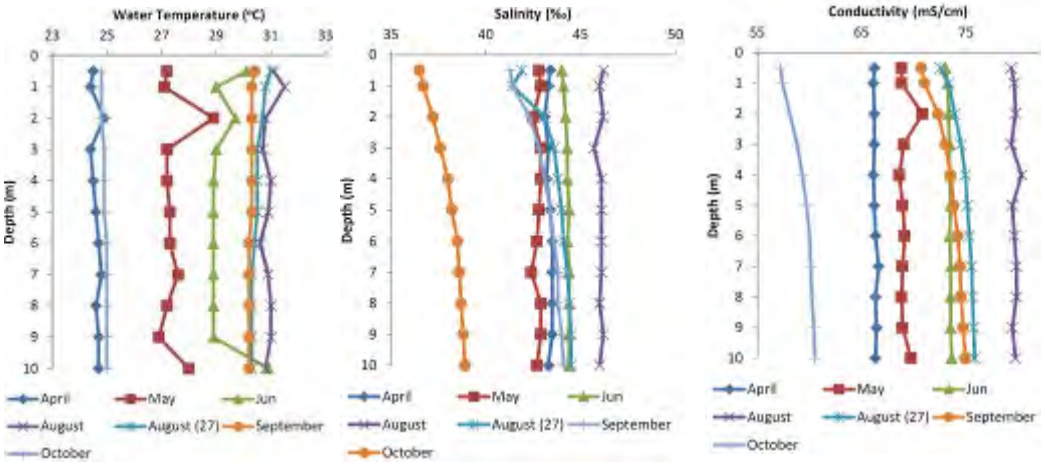

pH
6.00 7.00 8.00 9.00
DO (mg/l)
6 6.5 7 7.5 8
Turbidity
30 50 70 90 110 130
Depth (m)
0 1 2 3 4 5 6 7 8 9 10
April May Jun August August (27) September October


Suspended solid
0 100 200 300
COD
5 10 15 20 25
TOC
1.5 2.0 2.5 3.0
Depth (m)
0 2 4 6 8 10
April May Jun August August (27) September October

MS-5

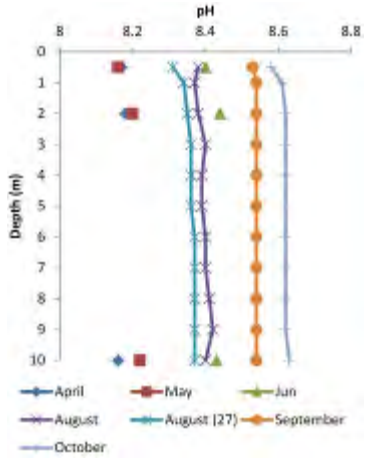

Water Temperature (°C)
Salinity (‰)
Conductivity (mS/cm)
pH
DO (mg/l)
Turbidity
Suspended solid
COD
TOC
Depth (m)
April
May
Jun
August
August (27)
September
October

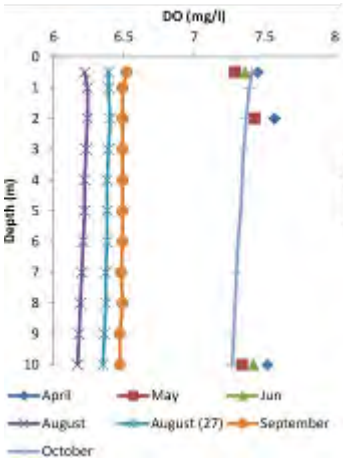
MS-6

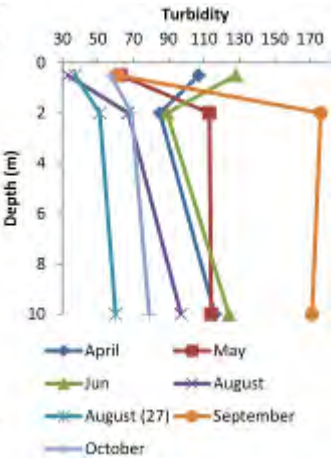

Water Temperature (°C)
Depth (m)
April
May
Jun
August
August (27)
September
October

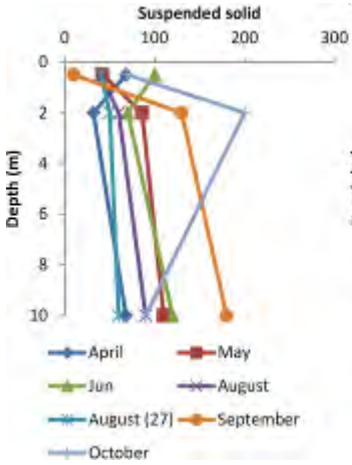
Salinity (‰)
Depth (m)
April
May
Jun
August
August (27)
September
October

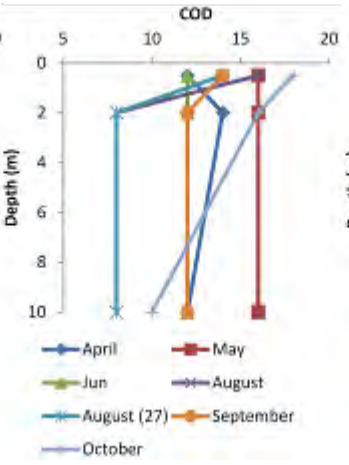
Conductivity (mS/cm)
Depth (m)
April
May
Jun
August
August (27)
September
October

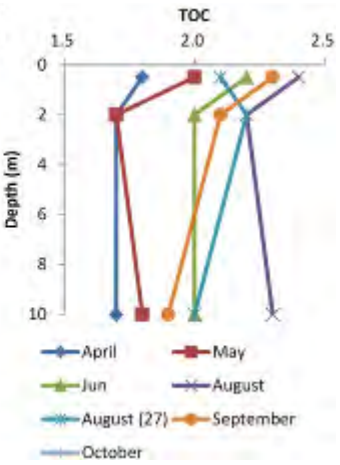

pH
Depth (m)
April
May
Jun
August
August (27)
September
October


DO (mg/l)
Depth (m)
April
May
Jun
August
August (27)
September
October

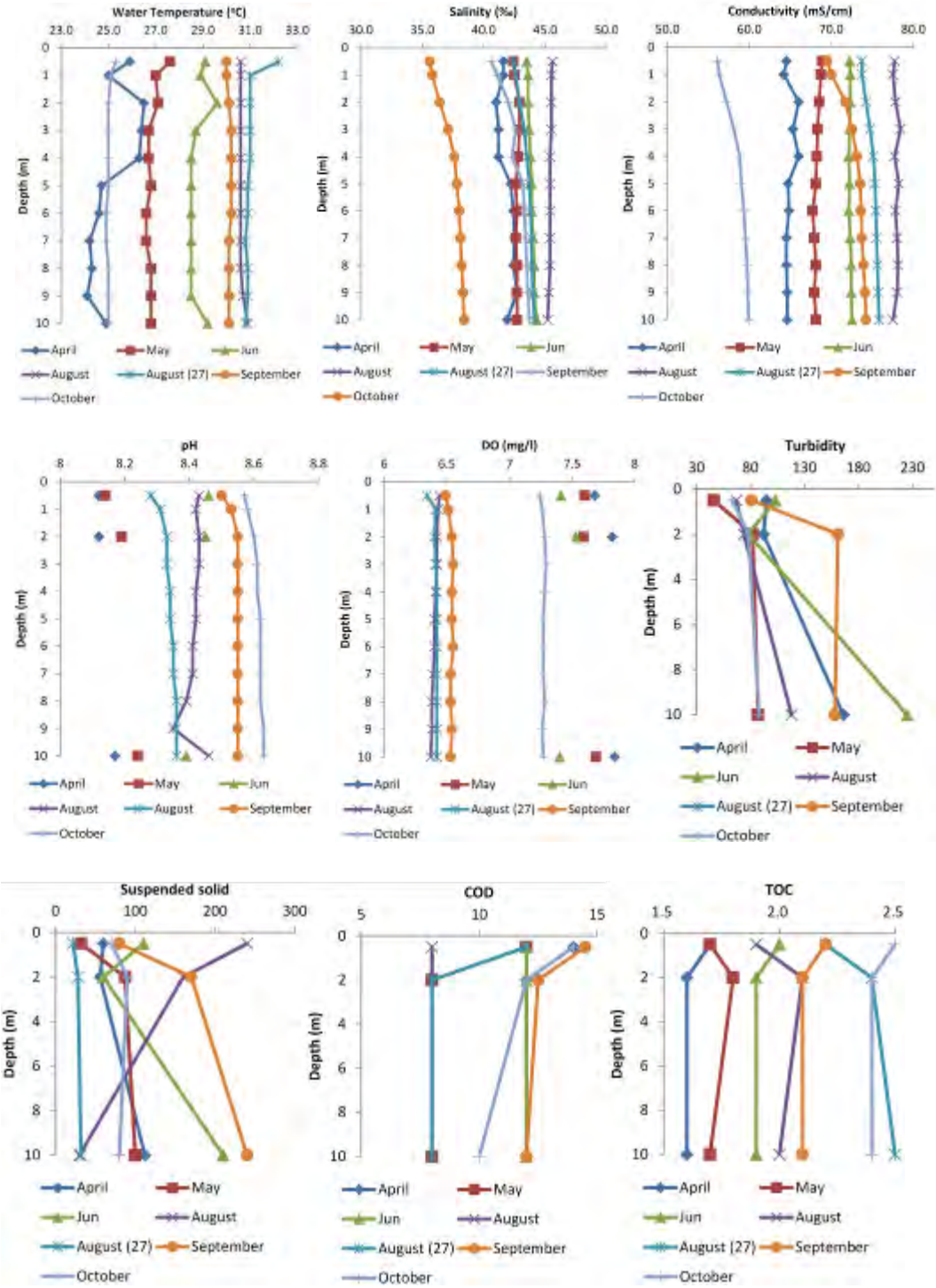

Turbidity
Depth (m)
April
May
Jun
August
August (27)
September
October


Suspended solid
Depth (m)
April
May
Jun
August
August (27)
September
October


COD
Depth (m)
April
May
Jun
August
August (27)
September
October


TOC
Depth (m)
April
May
Jun
August
August (27)
September
October

MS-7


Water Temperature (°C)
23.0 25.0 27.0 29.0 31.0 33.0
Salinity (‰)
30.0 35.0 40.0 45.0 50.0
Conductivity (mS/cm)
50.0 60.0 70.0 80.0
Depth (m)
0 1 2 3 4 5 6 7 8 9 10
April May Jun August August (27) September October
pH
8 8.2 8.4 8.6 8.8
DO (mg/l)
6 6.5 7 7.5 8
Turbidity
30 80 130 180 230
0 2 4 6 8 10
Suspended solid
0 100 200 300
COD
5 10 15
TOC
1.5 2.0 2.5
0 2 4 6 8 10

MS-8

Annex E National ambient water standards for Persian Gulf and Oman Sea

Parameter	Allowed value in different classification of Persian Gulf and Oman Sea waters					
	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6
Color[3]	No significant Color					
Odor	No Odor					
Temperature	Its temperature should not increase more than 1 C from regional temperature due to human activities and no more than 2 C in other seasons *			---	Its temperature should not increase more than 1 C from regional temperature due to human activities and no more than 2 C in other seasons	±3 of natural temperature of receptive source
pH	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5	6.5-9
Turbidity[4]	30 NTU (Nephelo Turbidity Unit)					---
Dissolved Oxygen (mg/l)	[5]>5 mg/l	[6]>5 mg/l	[7]>5 mg/l	>4 mg/l	>4 mg/l	>3 mg/l
	60% of Saturation	60% of Saturation	60% of Saturation	50% of Saturation	50% of Saturation	40% of Saturation

[3] This parameter is caused by parameters like Krizols, Phenols, Naftha, Benzene, Tolouen and etc. which produce a noticeable color of salt crystals and it contaminates fishes. Generally color and odor should not harm the uses of the area.

[4] If turbidity is measured by Secchi disk, the depth of Sechi disk should be more than 1 meter.
[5] To protect aquatic environment it should not be less than 3.5 ,g/l in the entire year.
[6] To protect aquatic environment it should not be less than 3.5 ,g/l in the entire year.
[7] To protect aquatic environment it should not be less than 3.5 ,g/l in the entire year.

Parameter	Allowed value in different classification of Persian Gulf and Oman Sea waters					
	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6
Total suspended[8] solids	Its increase should not be more than its daily, monthly, annual average considering standard deviation.					
Salinity	It should be no more than 10 percent of minimum natural salinity of the region					
Oil and floating grease	Oil slick, foam or other suspended material should not appear on its surface					There should be no oil layer, foam visible on its surface
(mg/l) BOD_5	1			3		5
(mg/l) COD	2			3		5
Anion Surfactant (mg/l) detergent (LAS)	0.03				0.10	
PAHs (µg/l)	<0.5			<1	<5	

[8] There should be no sanitary waste water or waste

Parameter	Amounts of allowed concentrations in various classes of Persian Gulf and Oman Sea Waters					
	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6
Total Petroleum Hydrocarbons (µg/l)	< 0.5			<1	<5	
Oil and Grease (mg/l)	0.1		Not visible to naked eye			
Total Coliform Bacteria MPN /100ml	< 500					
Fecal Coliform CFU/100ml	< 70				< 100	
Fecal Streptococci CFU/100ml	< 100					
Nitrate/Nitrogen (µg-N/l)	< 20		< 60			
Phosphate-Phosphorus (µg-N/l)	<15		<45	<15	<45	
Ionized Ammonium (µg-N/l)	<70		<100	<70		
None-organic Nitrogen (N)	<200		<300		<400	<400
Total Mercury (µg/l)	0.1		0.2		0.5	
Methyl Mercury (µg/l)	0.012		0.025		0.2	
Cadmium (µg/l)	1		5		10	
Total Chrome (µg/l)	5		10		50	
Lead (µg/l)	5		10		40	
Cupper (µg/l)	5		10		50	
Manganese (µg/l)	100					
Zinc (µg/l)	10		20		100	
Iron (µg/l)	300					
Arsenic (µg/l)	20		30		50	
Nickel (µg/l)	20		30		50	
Selenium (µg/l)	10		20		50	
Phenol (µg/l)	0.005		0.010		0.050	
Fluoride (µg/l)	1					
PCBs	Not visible					
Chlorinated pest control Alderin (µg/l)	No more than 1.3					

Parameter	Amounts of allowed concentrations in various classes of Persian Gulf and Oman Sea Waters					
	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6
Chloride (µg/l)	No More than 0.004					
DDT (µg/l)	No More than 0.001					
Delderin (µg/l)	No more than 0.0019					
Anderin (µg/l)	No more than 0.0023					
Andosolphan (µg/l)	No more than 0.0087					
Heptachlorine (µg/l)	No more than 0.0036					
Lepandan (µg/l)	No more than 0.16					
Pest Controls (µg/l) Alachlor Ametryn Atrazine Carbaryl Carbendazim Chlorpyrifos 2,4-D Diuron Glyphosate Malathion Mancozeb Methyl Parathion Parathion	Not Visible					

Since there's possibility that an area with one usage is also used for other purposes. In such cases that there might be more than one land usage for an area, it's suggested to consider the stricter standard for the area. For example: if in an area there are both sensitive coastal ecosystems and swimming usages, the standard for sensitive ecosystems is preferable.

ضمیمه ۵

مدل‌سازی نشت نفت

The project preliminarily examined the predicted trajectories, fates and probabilities of the oils accidentally spilled from the pilot areas defined by the project and major offshore crude production fields of Iran using trajectory model (GNOME and ADIOS2) and stochastic model (Trajectory Analysis Planner: TAP). The findings of the modeling are described hereunder.

1. Trajectory modeling

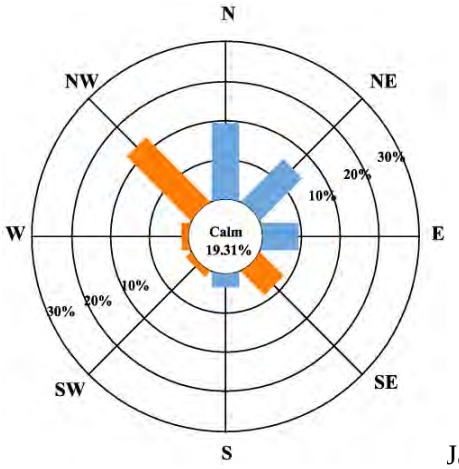
1.1 Conditions of simulation

(1) Basic condition

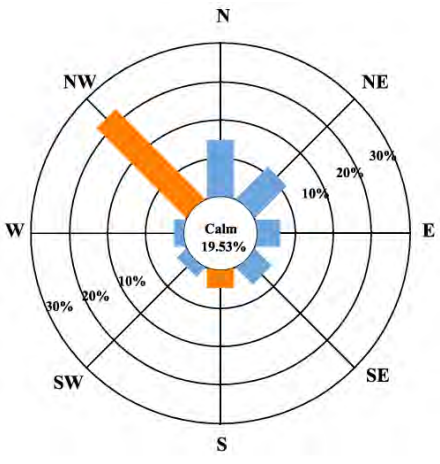
NOAA discloses the compiled file of the geography (shoreline) and oceanic condition (flow of the river, current field) for ROPME sea area. The modelling study by GNOME in this project utilized the data file after downloaded via internet.

(2) Meteorological condition

For the meteorological condition, it is possible to enter the wind direction and speed in GNOME and ADIOS2. For the wind data input condition, this application prepares two types which supports the constant and every time option. IOOC (2002) [1] reported that the wind direction and wind speed rose for every month, according to statistical data from 1989 to 1998 in Khark Island (Figure 5.4.2-1). This result is applied as the typical wind information in the Persian Gulf because this wind information was observed in the north part of the Persian Gulf and could be used as ocean wind. The wind direction in the Persian Gulf from February to October is predominantly from north west, and biased from the northeast from November to January. So the simulation will be carried out using the two separated seasons.



Jan.



Feb.

[1] Project on Environmental Studies of Siri, Lavan, Bahregan, Khark Operational Regions, Spring. 2002, IOOC.

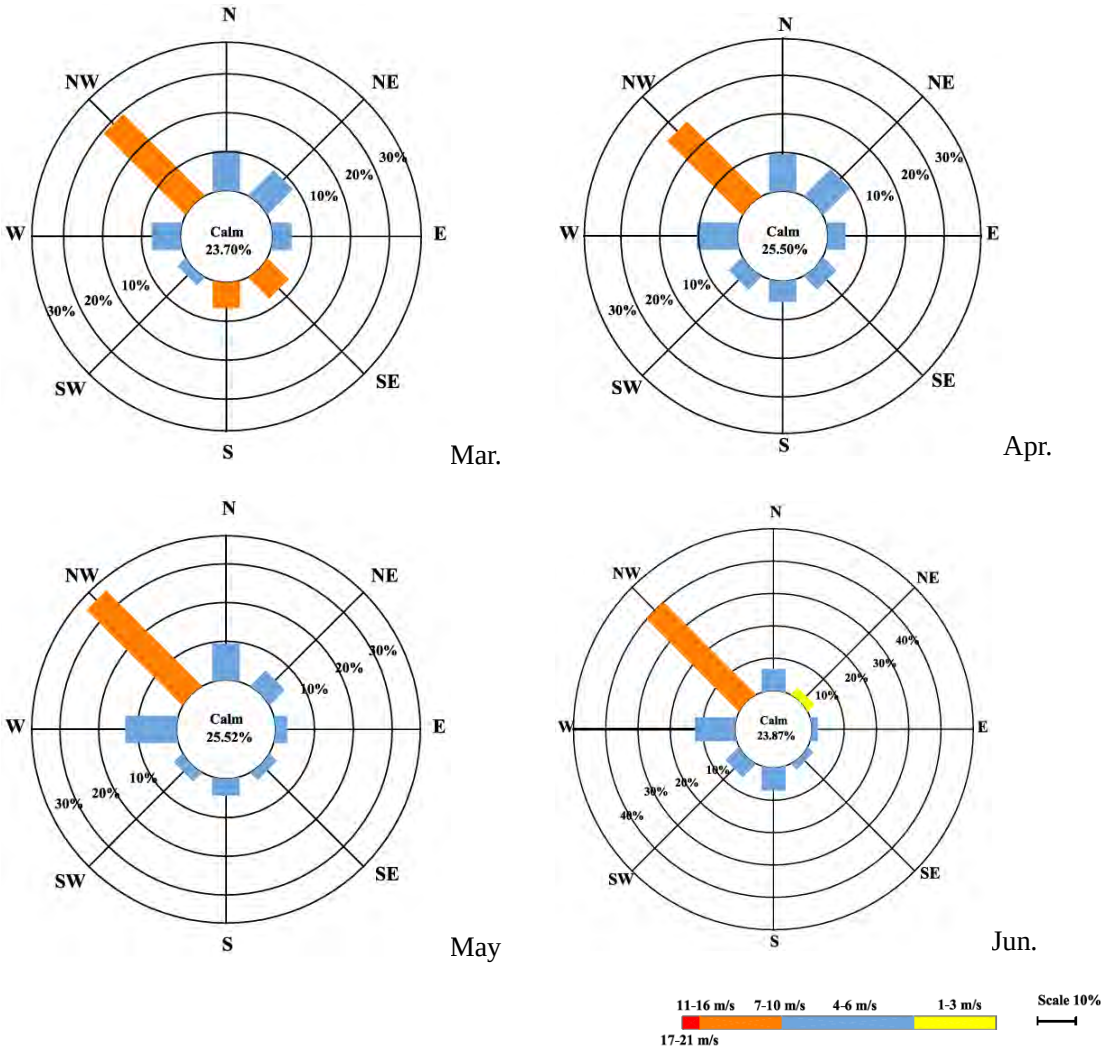
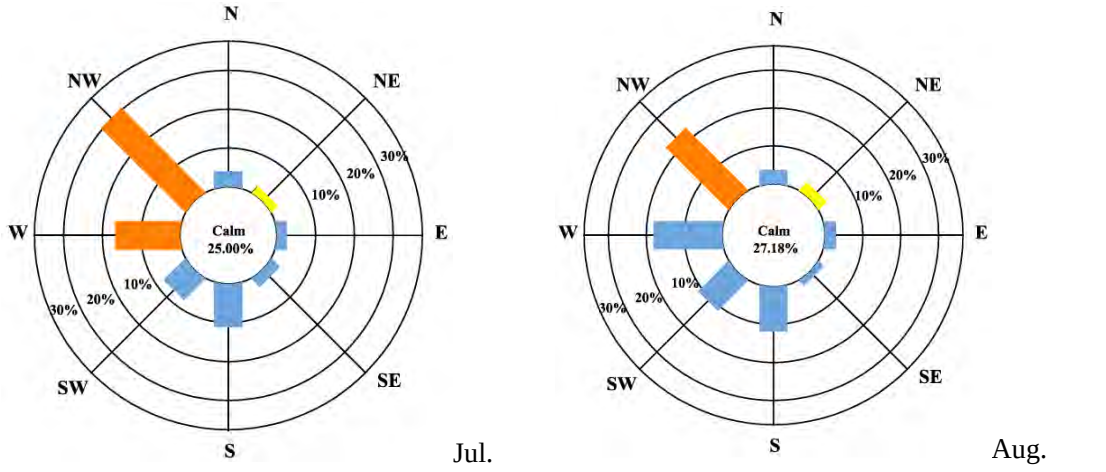


Figure 1.1-1 Windrose for Khark Island



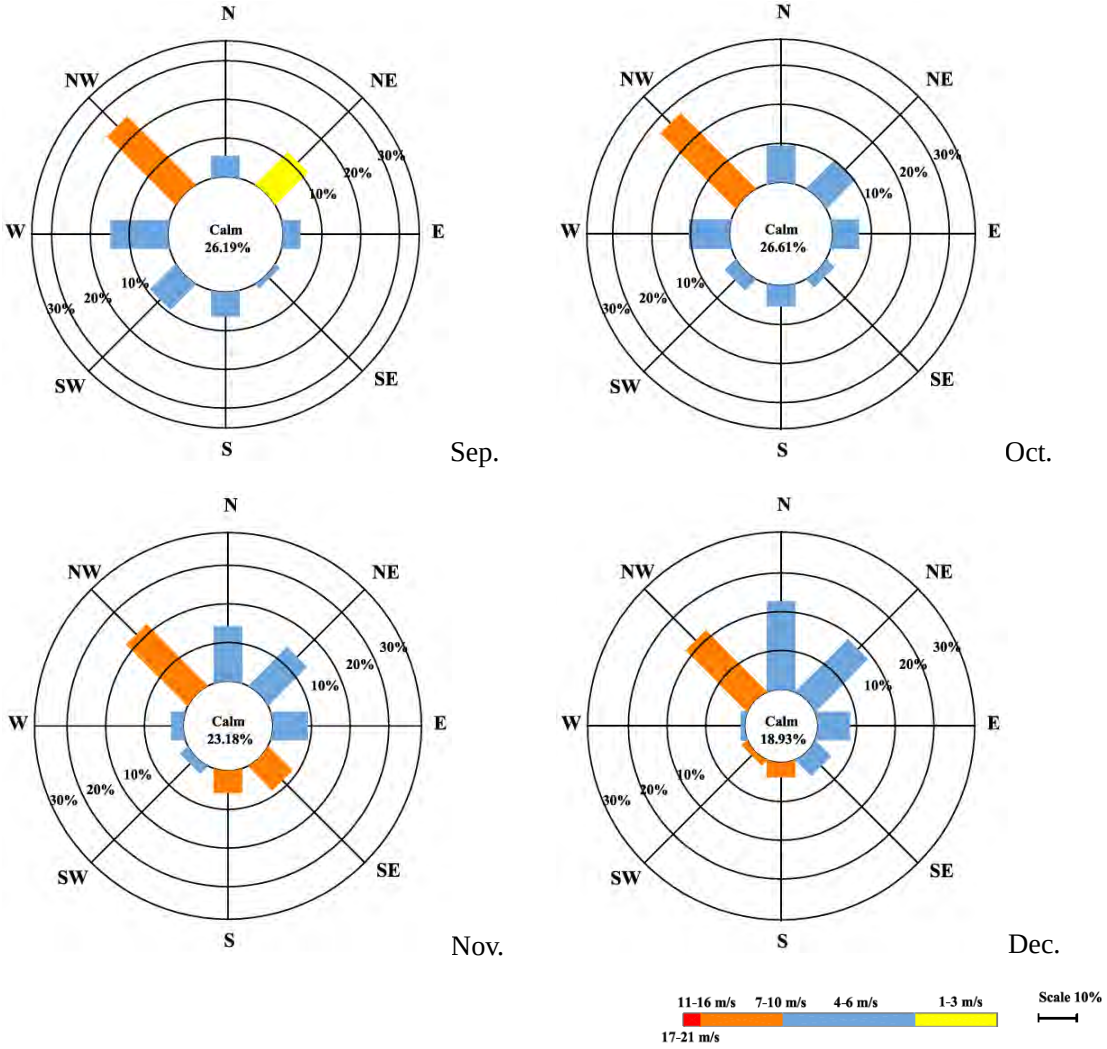


Figure 1.1-1 Windrose for Khark Island (continue)

1.2 Oil Spill Scenarios

The level of the oil spill accident assumed as Tier 1 scenario is 50 tons. This level indicates that each national corporation and its affiliated companies must protect the spilled oil by themselves if an oil spill accident occurred.

A number of the spill sources come from the loading facility and tanker and support boat due to collision with another boat. If the pipeline which was placed on the seafloor to transport the oil to mainland is aging, the leakage from it is considered.

The spill scenario for Mahshahr assumed that ship collision happened at the junction in Pilot area in the north part of the Persian Gulf. In Assaluyeh, some facility is treating the HNS such as condensate and has single point mooring (SPM) system for product loading. The spill scenario for Assaluyeh is assumed to happen at SPM system, offshore for loading of condensate. On Khark Island, there are 2 loading facilities. And there are many platforms around Khark Island as well. The spill scenario for Khark Island is assumed to happen at jetty, loading facility and main platform.

When simulated according to Tier 1 scenario (amount of spilled oil: 50 tons, release condition: instantaneous), each parameter are set as follows.

- GNOME and ADIOS2
  - Amount of spilled oil: 50 metric tons
  - Duration: 5 days
  - Season: 2 seasons (Feb-Oct, Nov-Jan)
  - Wind direction: Northwest (315 deg, Feb-Oct), Northeast (23 deg, Nov-Jan)
  - Wind speed: 6 knots (approx. 3 m/s), 10 knots (approx. 5 m/s), 14 knots (approx. 7 m/s)
  - Current field: Wind driven current, River outflow from the Shatt al Arab, Reverse Estuary
  - Release condition: instantaneous
- ADIOS2
  - Water temperature: 30 deg C (Feb-Oct), 25 deg C (Nov-Jan)
  - Salinity: 3.5%

Table 1.2-1 Oil spill scenarios in each pilot area

Scenario	Spill source	Longitude	Latitude	Types of oils	Spill situation
No.01	Closed-off section of the Persian Gulf	49 ° 01’ 16.62”	29 ° 56’ 04.60”	Bunker C Fuel Oil	Outflow of fuel oil due to ship collision
No.02	Bahrgan Sar oil field	49 ° 45’ 53.00”	29 ° 55’ 04.00”	Bahrgan Sar/ Nowruz (crude)	Spill accident at offshore unit
No.03	Nowruz oil field	49 ° 24’ 45.00”	29 ° 34’ 54.00”		
No.04	Aboozar oil field	49 ° 29’ 47.66”	29 ° 20’ 07.43”	Aboozar (crude)	
No.05	Foroozan oil field	49 ° 40’ 02.00”	28 ° 35’ 19.00”	Foroozan (crude)	
No.06	East Jetty, Khark Island	50 ° 20’ 22.31”	29 ° 13’ 46.76”	Iranian Heavy	Spill accident at loading facility
No.07	West Jetty, Khark Island	50 ° 17’ 10.90”	29 ° 13’ 35.06”		
No.08	SPM in Assaluyeh	52 ° 32’ 57.68”	27 ° 27’ 26.52”	Algerian condensate*	

*: Type of oil selected the kerosene/jet Fuels that evaporate readily for trajectory analysis and Algerian condensate for weathering processes.

1.3 Modeling Results

(1) Trajectory analysis

The trajectory of the spilled oil was analyzed using GNOME in accordance with the scenarios shown in Table 1.2-1.

The possibilities of oil drifting to shores of respective scenarios are indicated in Table 1.3-1 and predicted trajectories of each scenario are described below.

Table 1.3-1 Possibility of drifting ashore to each country after 5 days

Scenarios		No. 01	No. 02	No. 03	No. 04	No.05	No. 06	No. 07	No. 08
		Closed-off section of the Gulf	Bahrgan Sar oil field	Nowruz oil field	Aboozar oil field	Foroozan oil field	East Jetty , Khark Island	West Jetty Khark Island	SPM in Assaluyeh
Iran	Feb-Oct	-	-	-	-	-	✔	✔	✔
	Nov-Jan	-	-	-	-	-	✔	✔	✔
Other countries	Feb-Oct	-	-	-	-	-	-	-	-
	Nov-Jan	✔	-	-	-	-	-	-	-

- **Scenario No. 01 Closed-off section of the Persian Gulf**

Figure 1.3-1(1) Trajectory of the spilled oil after 5 days in the closed-off the Persian Gulf (Season: Feb-Oct, Wind direction: Northwest)

Figure 1.3-1(2) Trajectory of the spilled oil after 5 days in the closed-off the Persian Gulf (Season: Nov-Jan, Wind direction: Northeast)

If the wind direction is from northwest in Feb-Oct, the spilled oil is distributed in Iran territorial waters. For each wind speed, the spilled oil didn't drift down to the shoreline. If the wind direction is from the northeast in Nov-Jan, the spilled oil is distributed in Iran territorial waters. Although the spilled oil didn't drift down to the shoreline in 6 knots and 10 knots of wind speed, the spilled oil drifted down to remote Island located the east part of Failaka Island in Kuwait in 14 knots of wind speed.

- **Scenario No. 02 Bahrgan Sar oil field**

Figure 1.3-1(1) Trajectory of the spilled oil after 5 days at Bahrgan Sar oil field (Season: Feb-Oct, Wind direction: Northwest)

Figure 1.3-2(2) Trajectory of the spilled oil after 5 days at Bahrgan Sar oil field (Season: Nov-Jan, Wind direction: Northeast)

If the wind direction is from northwest in Feb-Oct, the spilled oil is distributed near the shoreline from north to middle in the province of Bushehr. But the spilled oil didn't drift down for each wind speed. If the wind direction is from the northeast in Nov-Jan, the spilled oil distributed in Iran territorial waters. However the part of spilled oil is distributed in Kuwait territorial waters if wind speed is 14 knots.

- **Scenario No. 03 Nowruz oil field**

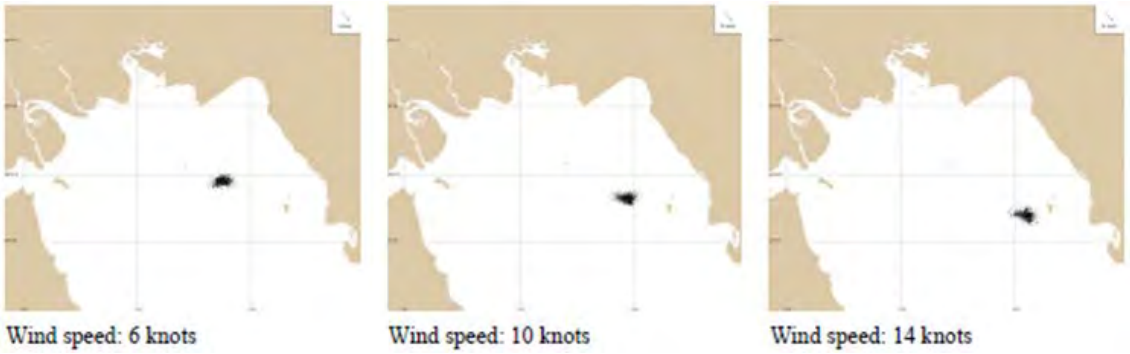


Figure 1.3-3(1) Trajectory of the spilled oil after 5 days at Nowruz oil field (Season: Feb-Oct, Wind direction: Northwest)

Figure 1.3-3(2) Trajectory of the spilled oil after 5 days at Nowruz oil field (Season: Nov-Jan, Wind direction: Northeast)

Although the spilled oil moved toward Khark Island if the wind direction is from northwest in Feb-Oct, the spilled oil didn't drift down to shoreline for each wind speed. If the wind direction is from the northeast in Nov-Jan, the spilled oil is distributed in Kuwait territorial waters.

- **Scenario No. 04 Aboozar oil field**

Figure 1.3-4(1) Trajectory of the spilled oil after 5 days at Aboozar oil field (Season: Feb-Oct, Wind direction: Northwest)

Figure 1.3-4(2) Trajectory of the spilled oil after 5 days at Aboozar oil field (Season: Nov-Jan, Wind direction: Northeast)

Although the spilled oil moved toward south in Khark Island if the wind direction is from northwest in Feb-Oct, the spilled oil didn't drift down to shoreline for each wind speed. If the wind direction is from the northeast in Nov-Jan, the spilled oil is distributed in Kuwait territorial waters. In 14 knots of wind speed, the spilled oil had the possibility to move toward Saudi Arabia territorial waters.

- **Scenario No. 05 Foroozan oil field**

If the wind direction is from northwest in Feb-Oct, the spilled oil didn't drift down to shoreline for each wind speed. If the wind direction is from the northeast in Nov-Jan, the spilled oil is distributed in Saudi Arabia territorial waters.

Figure 1.3-5(1) Trajectory of the spilled oil after 5 days at Foroozan oil field (Season: Feb-Oct, Wind direction: Northwest)

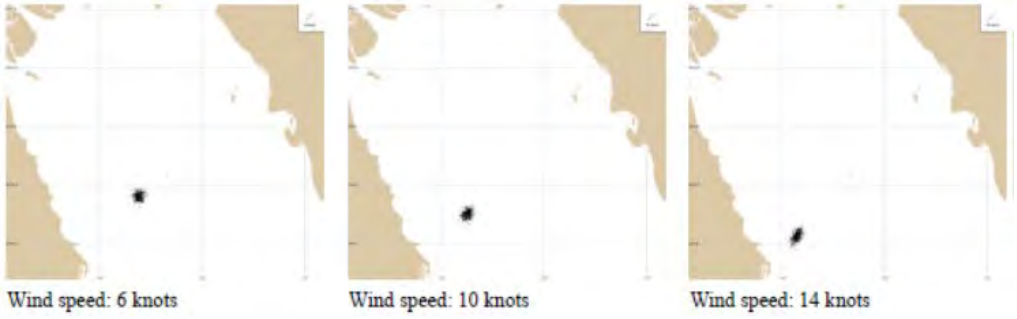


Figure 1.3-5(2) Trajectory of the spilled oil after 5 days at Foroozan oil field (Season: Nov-Jan, Wind direction: Northeast)

- **Scenario No. 06 East Jetty of Khark Island**

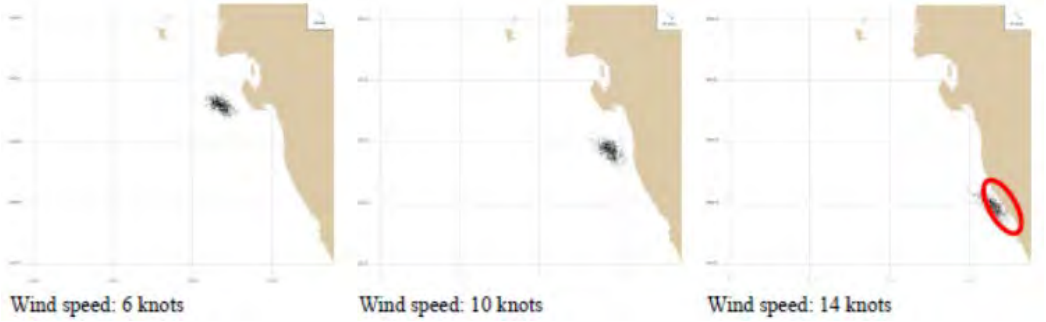


Figure 1.3-6(1) Trajectory of the spilled oil after 5 days at the jetty of east side in Khark Island (Season: Feb-Oct, Wind direction: Northwest)

Figure 1.3-6(2) Trajectory of the spilled oil after 5 days at the jetty of east side in Khark Island (Season: Nov-Jan, Wind direction: Northeast)

For 6 knots and 10 knots, although the spilled oil didn't drift down to shoreline if the wind direction is from northwest in Feb-Oct, the spilled oil drifted down to shoreline located approx. 13 km from Mond protection area if the wind speed is 14 knots. If the wind direction is from the northeast in Nov-Jan, the spilled oil drifted down to the south part of Khark Island. After that, although the spilled oil moves toward the southwest, it remained in Iran territorial waters.

- **Scenario No. 07 East Jetty of Khark Island**

Figure 1.3-7(1) Trajectory of the spilled oil after 5 days at the jetty of west side in Khark Island (Season: Feb-Oct, Wind direction: Northwest)

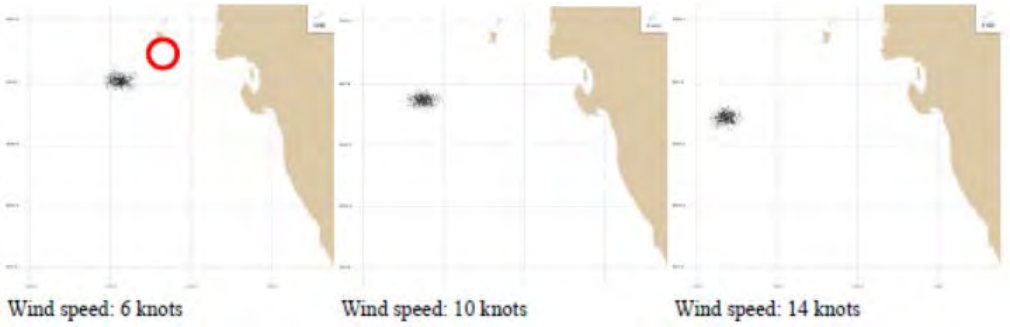


Figure 1.3-7(2) Trajectory of the spilled oil after 5 days at the jetty of west side in Khark Island (Season: Nov-Jan, Wind direction: Northeast)

If the wind direction is from northwest in Feb-Oct, the spilled oil drifted down to the south part of

Khark Island for each wind speed. After that, although the spilled oil didn't drift down to shoreline for 6 knots and 10 knots, it drifted down to shoreline located approx. 20 km from Mond protection area. However if the wind direction is from the northeast in Nov-Jan, the spilled oil drifted down to the south part of Khark Island in 6 knots because the wind speed was weak and the spilled oil became diffuse by dominated current field, preventing it from drifting down to the shoreline and distributed in Iran territorial waters.

- **Scenario No. 8 SPM system at Assaluyeh**

Figure 1.3-8(1) Trajectory of the spilled oil after 5 days at the SPM system at offshore for loading of condensate, Assaluyeh (Season: Feb-Oct, Wind direction: Northwest)

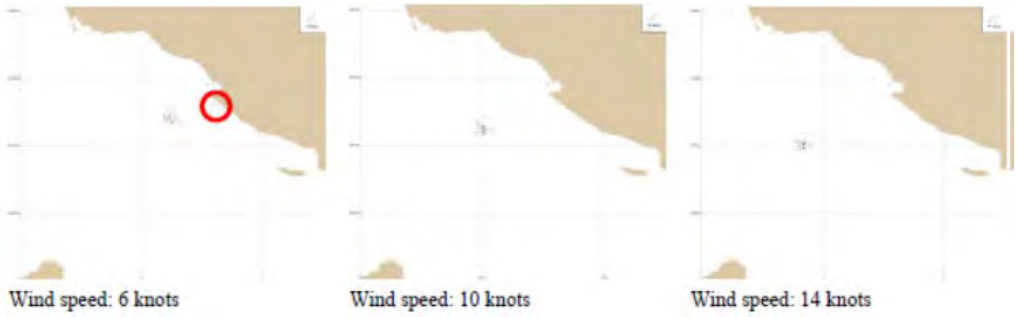


Figure 1.3-8(2) Trajectory of the spilled oil after 5 days at the SPM system at offshore for loading of condensate, Assaluyeh (Season: Nov-Jan, Wind direction: Northeast)

If the wind direction is from northwest in Feb-Oct, the spilled oil drifted down to the shoreline in bay of Naiband. However if the wind direction is from the northeast in Nov-Jan, the spilled oil drifted down to the nose section of the peninsula in 6 knots because the wind speed was weak and the spilled oil became diffuse by dominated current field, preventing it from drifting down to the shoreline and distributed in Iran territorial waters.

(2) Weathering processes

Weathering processes is calculated using Bunker C Fuel Oil, Algerian condensate and crude oils such as Bahrgan Sar /Nowruz, Aboozar, Foroozan, Iranian heavy which are produced in Iran. Duration of weathering is to be 5 days. The physical and chemical property of each oil mainly used the data by

Jokuty et al (1999) [2] in database on ADIOS2. For Foroozan, it used the data by McNamara (1995) [3] because the output by Jokuty et al (1999) seemed to be a failure.

When comparing the Bunker C Fuel Oil, Crude Oil (Aboozar) including Iranian Heavy and condensate, each condition of oil varied widely (Figure 5.4.2-2). If the wind speed is 6 knots, each oil evaporated and remained on the sea surface, not mostly be naturally dispersed. For the quantity of evaporation for each oil after 5 days, Bunker C Fuel Oil was approx. 10 %, Aboozar was approx. 40 % and condensate was approx. 98 %. If the wind speed is 14 knots, each oil is dispersed, evaporated and remain on the sea surface. The natural dispersion of Bunker C Fuel Oil depended on the wind speed remarkably and dispersed approx. 60 % of the total after 5 days. Natural dispersion of Aboozar crude oil and condensate was only a few %, and majorities of the crude oil and condensate were remaining and evaporation respectively.

For response to oil spill, chemical dispersant is practically applied and in general it is effective for the spilled oil on water if the viscosity of the spilled oil is not greater than 2,000 cSt. Table 1.3-2 shows the estimated time zone (hours) for effective dispersant application after released to sea where the viscosity of spilled oil reaches 2,000cSt.

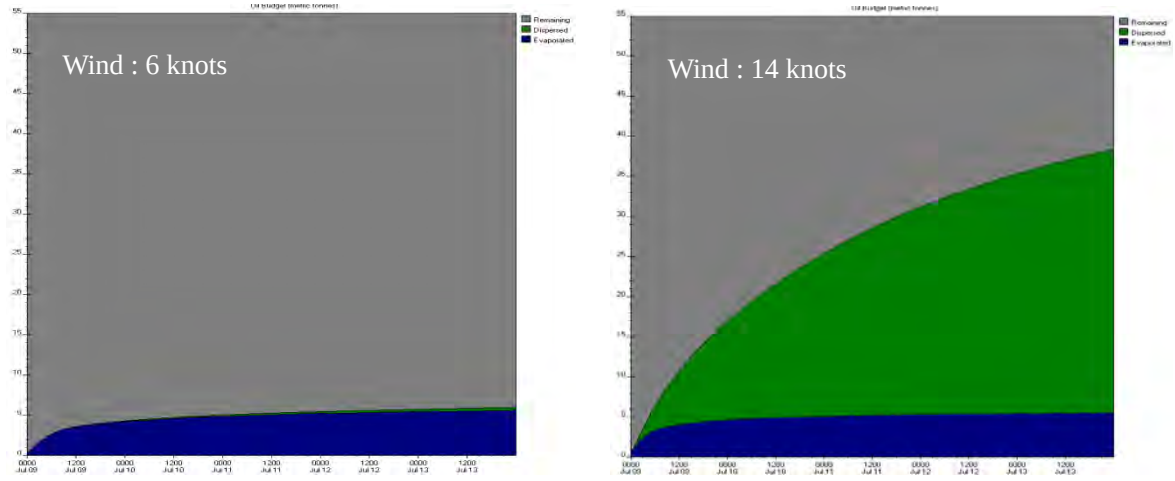
Table 1.3-2 Time zone (hour) for the chemical dispersant application in various weather conditions (wind speed)

	Type of spilled oil					
Water temp.	Wind speed (knots)	Bahrgan Sar /Nowruz crude	Aboozar crude	Foroozan crude	Iranian Heavy crude	Algerian condensate
25 deg C	6	9-12	15-18	33-36	33-36	21-24
	10	3-6	6-9	12-15	12-15	9-12
	14	0-3	3-6	6-9	6-9	3-6
30 degC	6	12-15	18-21	42-45	30-33	30-33
	10	6-9	6-9	15-18	9-12	12-15
	14	3-6	3-6	9-12	6-9	6-9

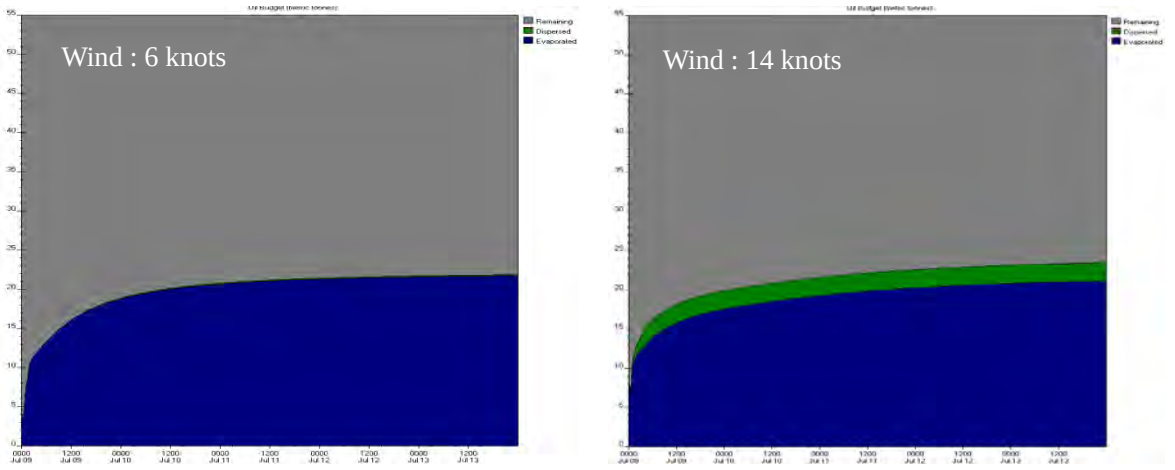
Figure 1.3-9 shows the comparison of weathering progress of the respective spilled oils on water as time passes.

[2] Jokuty, P., Z. Wang, M. Fingas, B. Fieldhouse, P. Lambert, and J. Mullin, "Properties of Crude Oils and Oil Products", EE-165, Environment Canada, Ottawa, ON, 1234 p., 1999.
[3] McNamara, J. (ed.) , 1995, Oil & Gas Journal Data Book. Tulsa, OK: Pennwell Books. 411pp.

Bunker C Fuel Oil



Aboozar crude



Algerian condensate

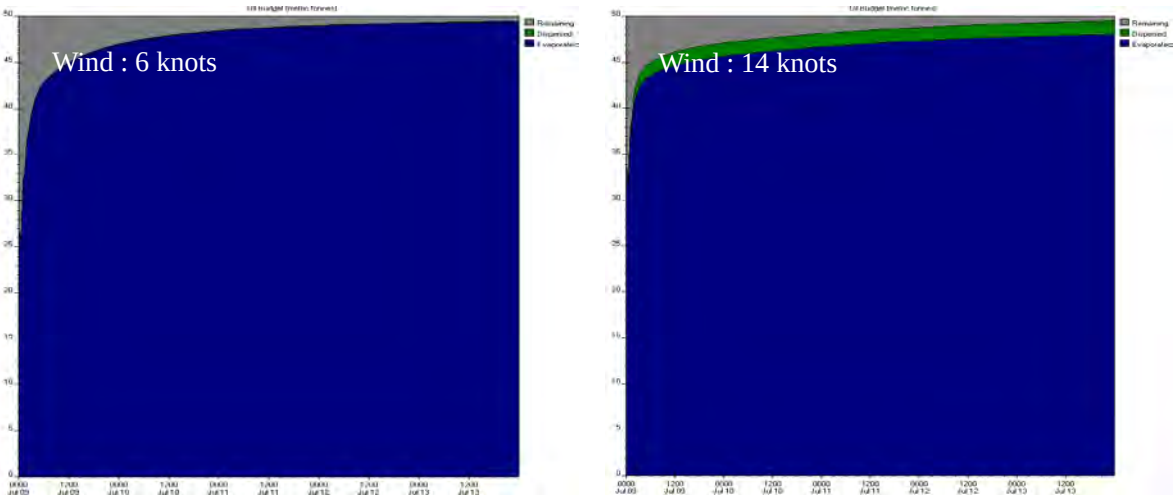


Figure 1.3-9 Comparison of weathering progress of spilled oils (Water temperature: 30 deg C)

The calculated weathering progress of the spilled oil in each spill scenario are summarized as follows.

- **Scenario No. 01 Closed-off section of the Persian Gulf (Bunker C Fuel Oil)**

The trend of viscosity of Bunker C Fuel Oil converged approx. 2,000 cSt, and is not dependent on the variation of the wind speed and water temperature. For the flux of Bunker C Fuel Oil, the percentage of evaporation was 10 % without relying on the variation of the wind speed and water temperature. The quantity of the natural dispersion increased depending on the variation of the wind speed and water temperature. As a result of the percentage of the natural dispersion, 20-30 % is dispersed if the wind speed is 10 knots and 50-60 % if the wind speed is 14 knots.

- **Scenario No. 02, & 03 Bahrgan Sar and Nowruz oil field (Bahrgan Sar/ Nowruz)**

The trend of the viscosity of Bahrgan Sar/ Nowruz is dependent on the variation of the wind speed. The viscosity of Bahrgan Sar/ Nowruz rose exponentially if the wind speed is 6 knots. If the wind speed is 10 knots, the viscosity rose exponentially till 4 days. After that, the viscosity converged approx. 200,000 cSt in case of 30 deg C and approx. 400,000 cSt in case of 25 deg C, water temperature. For 16 knots of the wind speed, the viscosity rose exponentially till 2 days. After that, the viscosity converged approx. 200,000 cSt in case of 30 deg C and approx. 400,000 cSt in case of 25 deg C, water temperature. For the flux of Bahrgan Sar/ Nowruz, the percentage of evaporation was approx. 38 % without relying on the variation of the wind speed and water temperature. The natural dispersion was 0 % in case of 6 knots and 1-2 % in case of 10 knots and 14 knots, wind speed. So if Bahrgan Sar/ Nowruz is released, it always remains approx. 60 % on the sea surface.

- **Scenario No. 04 Aboozar oil field (Aboozar)**

The trend of the viscosity of Aboozar depended on the variation of the wind speed. The viscosity of Aboozar rose exponentially if the wind speed is 6 knots. If the wind speed is 10 knots, the viscosity rose exponentially till 4 days. After that, the viscosity converged approx. 70,000 cSt in case of 30 deg C and approx. 15,000 cSt in case of 25 deg C, water temperature. For 16 knots, the viscosity rose exponentially till 2 days. After that, the viscosity converged approx. 70,000 cSt in case of 30 deg C and approx. 15,000 cSt in case of 25 deg C, water temperature. For the flux of Aboozar, the percentage of evaporation was approx. 38 % without relying on the variation of the wind speed and water temperature. The natural dispersion was 0 % in case of 6 knots and 2-4 % in case of 10 knots and 14 knots, wind speed. So if Aboozar is released, it always remains approx. 60 % on the sea surface.

- **Scenario No. 05 Foroozan oil field (Foroozan)**

The trend of the viscosity of Foroozan depended on the variation of the wind speed. The viscosity of Foroozan rose exponentially if the wind speed is 6 knots. If the wind speed is 10 knots, the viscosity rose exponentially till 4 days. After that, the viscosity converged approx. 15,000 cSt in case of 30 deg C and approx. 20,000 cSt in case of 25 deg C, water temperature. For 16 knots, the viscosity rose exponentially till 2 days. After that, the viscosity converged approx. 15,000 cSt in case of 30 deg C and approx. 20,000 cSt in case of 25 deg C, water temperature. For the flux of Foroozan, the percentage of

evaporation was approx. 40 % without relying on the variation of the wind speed and water temperature. The natural dispersion was 0 % in case of 6 knots and 6-10 % in case of 10 knots and 14 knots, wind speed. So if Foroozan is released, it always remains approx. 50-60 % on the sea surface.

- **Scenario No. 06 & 07 East and West Jetty of Khark Island (Iranian Heavy）**

The trend of the viscosity of Iranian Heavy depended on the variation of the wind speed. The viscosity of Iranian Heavy rose exponentially if the wind speed is 6 knots. If the wind speed is 10 knots, the viscosity rose exponentially till 4 days. After that, the viscosity converged approx. 20,000 cSt. For 16 knots, the viscosity rose exponentially till 2 days. After that, the viscosity converged approx. 20,000 cSt. For the flux of Iranian Heavy, the percentage of evaporation was approx. 36 % without relying on the variation of the wind speed and water temperature. The natural dispersion was 0 % in case of 6 knots and 5-6 % in case of 10 knots and 14 knots, wind speed. So if Iranian Heavy is released, it always remains approx. 60-65 % on the sea surface.

- **Scenario No. 08 SPM system in Assaluyeh (Algerian Condensate**)

The trend of the viscosity of Algerian Condensate depended on the variation of the wind speed. The viscosity of Algerian Condensate rose exponentially if the wind speed is 6 knots. If the wind speed is 10 knots, the viscosity rose exponentially till 4 days. After that, the viscosity converged approx. 20,000 cSt in case of 30 deg C and approx. 40,000 cSt in case of 25 deg C, water temperature. For 16 knots, the viscosity rose exponentially till 2 days. After that, the viscosity converged approx. 20,000 cSt in case of 30 deg C and approx. 40,000 cSt in case of 25 deg C, water temperature. For the flux of Algerian Condensate, the percentage of evaporation was approx. Over 95 % without relying on the variation of the wind speed and water temperature. The natural dispersion was 0 % in case of 6 knots and 1-2 % in case of 10 knots and 14 knots, wind speed. So if Algerian Condensate is released, it always remains approx. 1-3 % on the sea surface.

2. Stochastic model

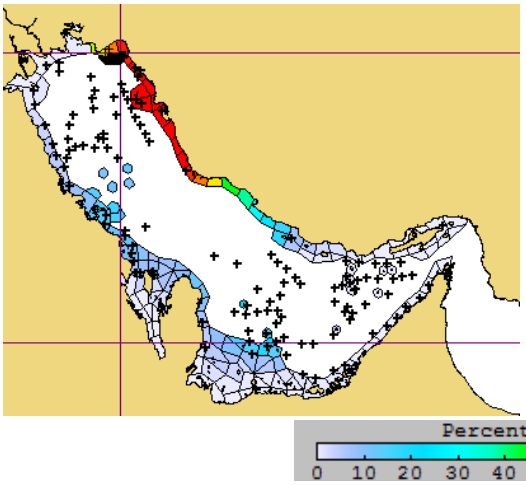
2.1 Impacts of spilled oil from major offshore oil fields on coastal areas

The project examined the possibilities of the impacts of spilled oils from the major offshore crude production facilities (Bahrgan Sar, Nowruz, Aboozar, Foroozan) located in north-east region of the Gulf on the environmental sensitive areas along the coasts using the functions of “Impact Analysis” and “Site Oiling Analysis” of the stochastic model of Trajectory Analysis Planner (TAP).
The parameters set in the model are as follows.

- Type of oil: Medium Crude
- Amount of spilled oil: 50 metric tons
- Season: Nov-Jan, Feb-Oct
- Acceptable amount on shoreline (threshold amount) : 1 metric ton
- Term: After 9, 33 and 60 days

(1) Bahrgan Sar platform

The impact from Bahrgan Sar platform in closed-off section of the Persian Gulf was forecasted.
The spilled oil after 9 days drifted down to the shoreline from closed-off section of the Persian Gulf to the middle of the province of Bushehr. The area with a high probability of drifting down to the shoreline was closed-off section of the Persian Gulf in all season. The percentage was 81 % in Nov-Jan and 74 % in Feb-Oct. The spilled oil after 33 days is extended to Mond protection area in the province of Bushehr, including Khark Island. The percentage of drifting down to Khark Island was approx. 99 % in Nov-Jan. The percentage of drifting down to the shoreline of Mond protection area was Over 50 % in Nov-Jan. The spilled oil after 60 days is extended to all parts of the province of Bushehr including Lavan Island. For other country, it drifted down to the shoreline of bordering countries of the Persian Gulf (excluding Iraq and Oman), about 10-20 % of the time.
The pilot area with the highest amount of the spilled oil on the shoreline was Khark Island. The pilot area with the smallest amount was Marshahr. One reason for such is due to the wind direction which is dominated from northwest. Another reason is the influence from the outflow of the Shatt Al Arab.



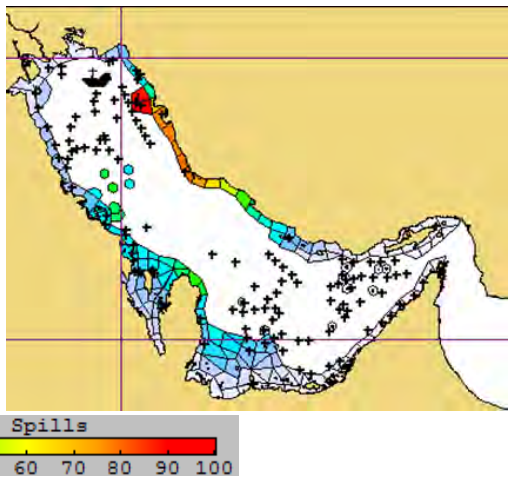


Figure 2.1-1 Bahrgan Sar (Feb-Oct, 60 days)　Figure 2.1-2　Nowruz/Abooizar(Nov-Jan, 60days)

(2) Nowruz and Aboozar platform

When forecasting the impact from Nowruz and Aboozar platform, the result was similar because both platforms are closed. The evaluation was conducted for Nowruz platform on behalf of both platforms.
The spilled oil after 9 days drifted down to around Khark Island. The percentage was 17 % in Nov-Jan and 7.2 % in Feb-Oct. The spilled oil after 33 days is extended to the shoreline of the province of Bushehr including Khark Island. And the spilled oil drifted down to Kuwait, Saudi Arabia and Bahrain. The spilled oil after 60 days is extended to all parts of the province of Bushehr including Lavan Island. For other country, it drifted down to the shoreline of bordering countries of the Persian Gulf but excluding Iraq and Oman.

The pilot area with the highest amount of the spilled oil on the shoreline was Khark Island. All the spilled oil drifted down to Khark Island. The pilot area with the smallest amount of drifting down to the shoreline was Marshahr. One reason why is due to the wind direction which is dominated from northwest. Another reason why is the influence from the outflow of the Shatt Al Arab.

(3) Foroozan platform

The impact from Foroozan platform bordering EEZ with Saudi Arabia was forecasted.
The spilled oil after 9 days didn't move to Iran. But it drifted down to a remote Island in Saudi Arabia. The spilled oil after 33 days is extended to Bahrain and Qatar in addition to Saudi Arabia. If the season is Feb-Oct, the spilled oil is extended to UAE. For Iran, a few percentage of the spilled oil drifted down to Khark Island in Nov-Jan. The spilled oil after 60 days drifted down to Saudi Arabia, Bahrain, Qatar and UAE. For the percentage of drifting down to Iran, it was 9.4 % in Khark Island and 3.4 % in Assaluyeh in Nov-Jan.

If the spill source is set in Foroozan platform, the quantity on the shoreline of each pilot area was small. The reason why is because Foroozan platform is located near the border of EEZ with Saudi Arabia. When occurred at Foroozan platform, the spilled oil is transported to Qatar because the wind direction dominates from northwest and the current direction around Foroozan platform is mainly from the northwest. Although the spilled oil drifted down to Khark Island and Assaluyeh when the accident occurred in Nov-Jan, the amount is small. In Feb-Oct, the amount of the spilled oil is very small.

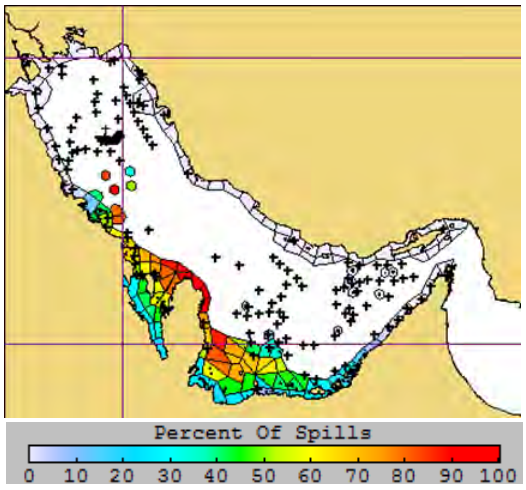


Figure 2.1-3 Foroozan (Feb-Oct, 60 days)

2.2 Impacts of spilled oil from major offshore oil fields on pilot areas

The possible impacts of oil spill from the major offshore oil fields on the designated pilot areas were evaluated using the function of "Threat Zone Analysis". The parameters for the modeling are as follows.

- Type of oil: Medium Crude
- Amount of spilled oil: 50 metric tons
- Season: Nov-Jan, Feb-Oct
- Acceptable amount on shoreline (threshold amount) : 1 metric ton
- Term: After 9, 33 and 60 days

(1) Mahshahr

The number of the spill point that influences Mahshahr is small because the incidence of the spill

accident around Mahshahr is low. And as Shatt Al Arab river positions is close to Mahshahr, it has no significant impact on Mahshahr too. If the spill accident occurred at Bahrgan Sar platform, the closest the spill point to Mahshahr, the extent of effect to Mahshahr is only a few percentage.

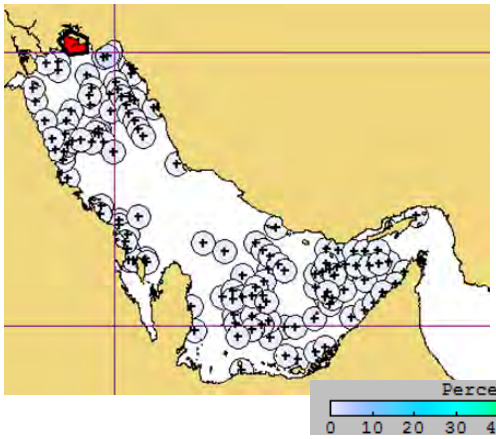


Figure 2.2-1 Mahshahr (Feb-Oct, 60 days)

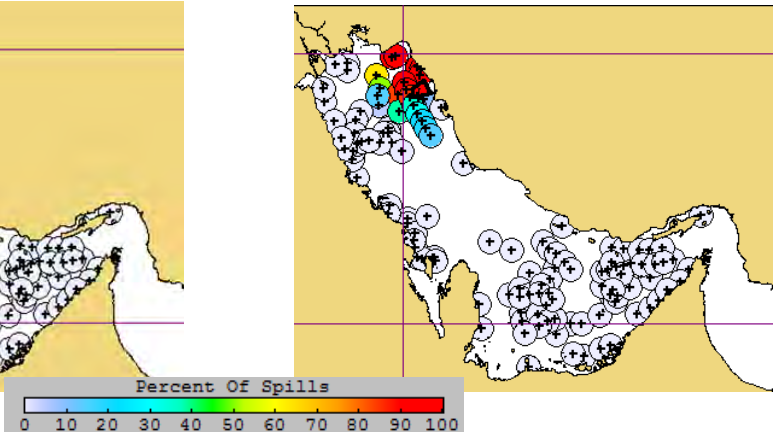


Figure 2.2-2 Khark Island (Feb-Oct, 60days)

(2) Khark Island

The spill point around Khark Island has a significant impact on Khark Island because the major platforms are located around it. The possibility of the spill drifting to Khark Island after 9 days was over 90 % of the spill points within a semicircle on the north that was set within approx. 40 km in radius centering around Khark Island. The elapsed time that Bahrgan Sar platform indicated over 80 % was after 15 days. The elapsed time that Nowruz and Aboozar platform indicated over 80 % was 33 days in Nov-Jan. The extent of effect from Nowruz and Aboozar platform was less than 65 % in Feb-Oct. If the spill accident occurred in other country, the extent of effect is low in all things. In this case, up to 2.2 % in Saudi Arabia close to Foroozan platform. Comparing the season, the term of Nov-Jan was higher than the term of Feb-Oct.

(3) Assaluyeh

The spill point that was set around Assaluyeh is small because this area has no potential for spill accident to occur. The spill point impacting after 9 days was just 1 site around the North Pars gas field (11 % in Nov-Jan, 1.6 % in Feb-Oct). The spill point impacting after 33 and 60 days is in Iran territorial waters only. Especially, the extent of effect at Khark Island and at northern part of the province of Bushehr was bigger. Comparing the season, the term of Nov-Jan was higher than the term of Feb-Oct.

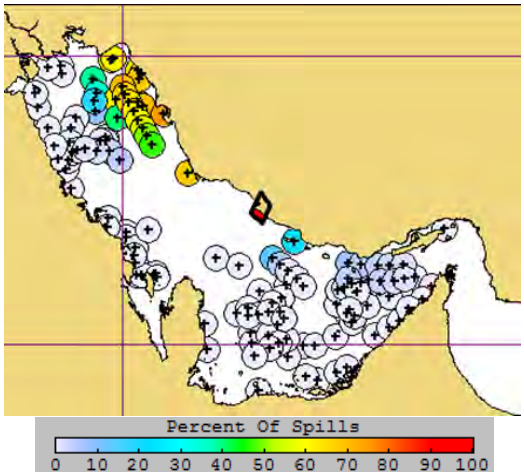


Figure **2.2-3 Assaluyeh (Nov-Jan, 60 days)**

2.3 Impacts spilled oil from major offshore oil fields on the natural conservation areas

The protection area in Iran is compiled by DOE. At the westward of Mahshahr, a quite large area named Shadegan Marsh spreads, which is designated as the National Wild Life Refuge, also as international wetland (Ramsar). A coral reef distributes around Khark Island. Kharko Island located at northeast of Khark Island is designated a wildlife refuge. In Assaluyeh, there is a Naiband National Park. Naiband National Park is designated as the first marine national park in 2004, combining Naiband protected area, Hara Naiband area and a part of the Persian Gulf. Naiband National Park consists of coral reefs, sandy beaches, mangrove forests and land area. Sandy beaches provide the nesting area for turtles. Other protection area adjoining coastal land area described in Figure 2.3-1 .

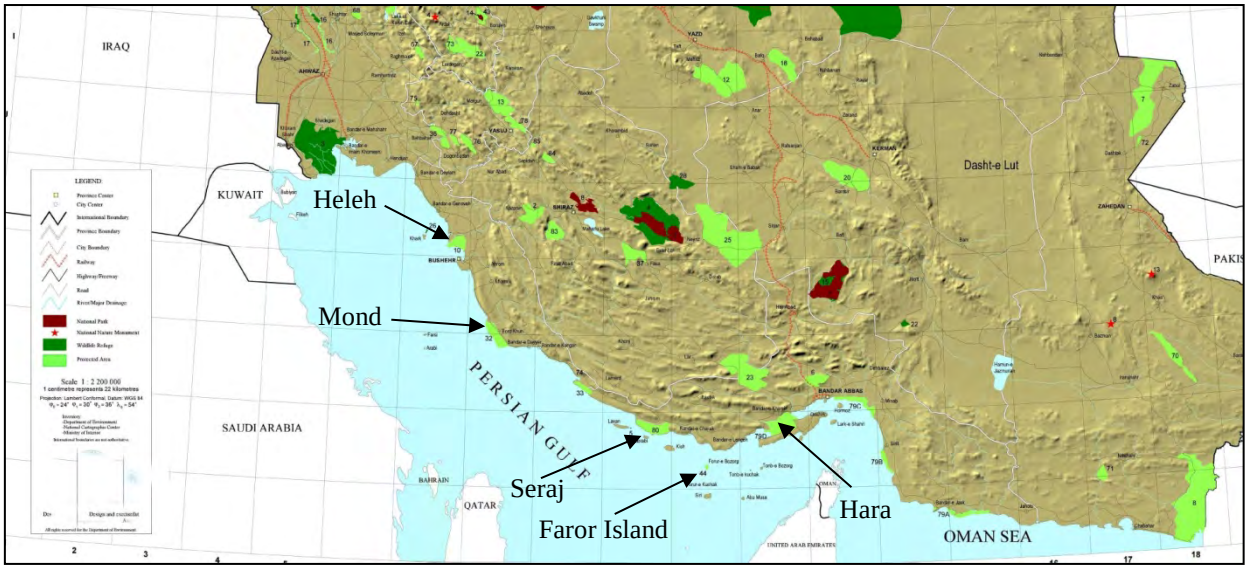


Figure 2.3-1 Protection area in Iran

Impact to each protection area is evaluated using the function of Threat Zone Analysis similar to each pilot area. Each parameter are set as follows. Also, the evaluation of Shadegan March spreads and Naiband National Park are omitted because the two areas is the same as that of Mahshahr and Assaluyeh.

- Type of oil: Medium Crude
- Amount of spilled oil: 50 metric tons
- Season: Nov-Jan, Feb-Oct
- Acceptable amount on shoreline (threshold amount) : 1 metric ton
- Term: After 9, 33 and 60 days

(1) Heleh protection area

The spill point influencing Heleh protection area is distributed at the north part of Persian Gulf in Iran

territorial waters. The influencing spill point after 9 days was 3 points around the shoreline of a northern part of the province of Bushehr. The level of impact was over 90 %. After 33, 60 days, Bahrgan Sar oil field including previous area was over 90 %. Comparing the season, the term of Nov-Jan was higher than the term of Feb-Oct.

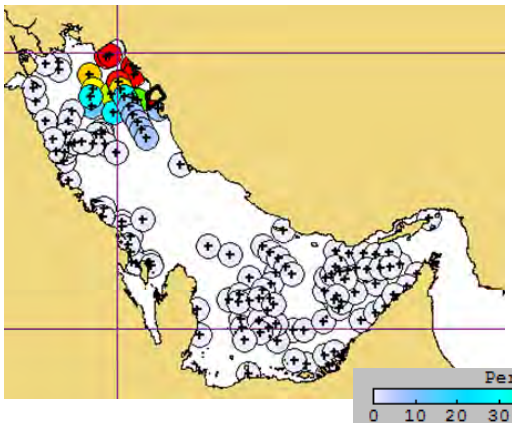


Figure 2.3-2 Heleh (Nov-Jan, 60 days)

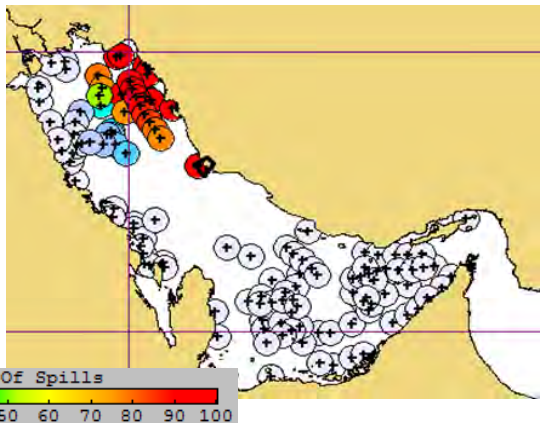


Figure 2.3-3 Mond (Nov-Jan, 60days)

(2) Mond protection area

The spill point influencing Mond protection area is distributed at the north part of Persian Gulf in Iran territorial waters. The influencing spill point after 9 days was 1 site at the bay entrance in Bushehr city and indicated over 80 %. After 33, 60 days, the extent of effect indicated over 80 % at Bahrgan Sar oil field and around Khark Island in Nov-Jan. On the other hand, the influencing spill point that indicated over 80 % after 33 days in Feb-Oct was 3 sites close to the shoreline at the north part of the province of Bushehr. The Bahrgan Sar oil field was added to the previous site after 60 days. For the extent of effect about other countries, the maximum value indicated 1.6 % after 33 days and 14 % after 60 days in Nov-Jan. These influencing spill points is located in Saudi Arabia territorial waters, near Foroozan platform. In Feb-Oct, the influencing spill point after 60 days is located in Saudi Arabia territorial waters and the extent of effect was low because the maximum value indicated is only 1.0 %. Comparing the season, the term of Nov-Jan was higher than the term of Feb-Oct.

(3) Seraj protection area

The spill point influencing Seraj protection area is distributed at the south part of the Persian Gulf. The influencing spill point, which indicated over 80 %, was just 1 site near Lavan Island. The value of the extent of effect was over 95 % after 9 days and approx. 100 % after 33 and 60 days. The influencing spill point that indicated 70-80 % is located near Lavan Island. The value of the extent of effect about these spill points indicated over 50 %. Comparing the season, the term of Nov-Jan was higher than the term of Feb-Oct.

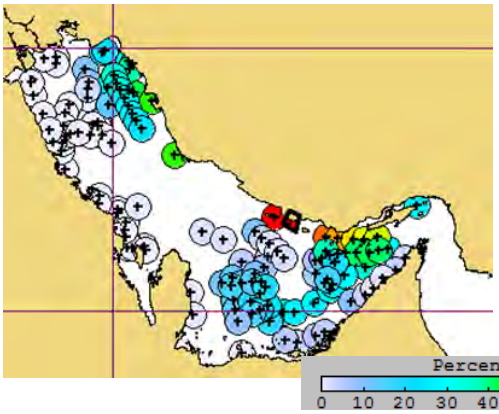


Figure 2.3-4 Seraj (Nov-Jan, 60 days)

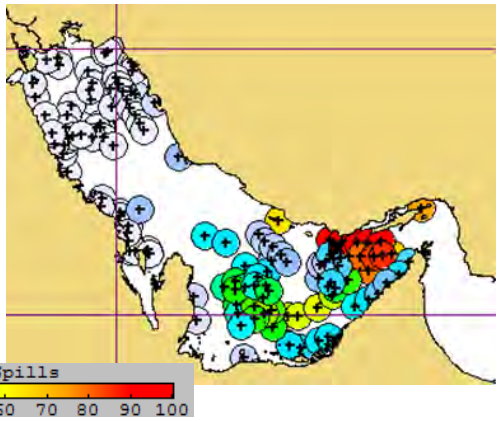


Figure 2.3-5 Faror (Nov-Jan, 60 days)

(4) Faror Island

The spill point influencing Faror Island is distributed at the south part of the Persian Gulf. The influencing spill points, which indicated over 80 %, is located close to the mainland from around Faror Island toward the strait of Hormuz. The values of the extent of effect was over 85 % after 9 days and approx. 100 % after 33 and 60 days. The influencing spill points, which indicated 70-80 %, is located at the part of UAE based on a line joining from Faror Island toward the Strait of Hormuz. Other spill points indicated below 50 %. As a result, there seems to be no difference between seasons.

(5) Hara protection area

The spill point influencing Hara protection area was just 1 site near the east part of Qeshm Island. For the value of the extent of effect about Hara protection area, it indicated 65-70 % in Nov-Jan and 50-60 % in Feb-Oct.

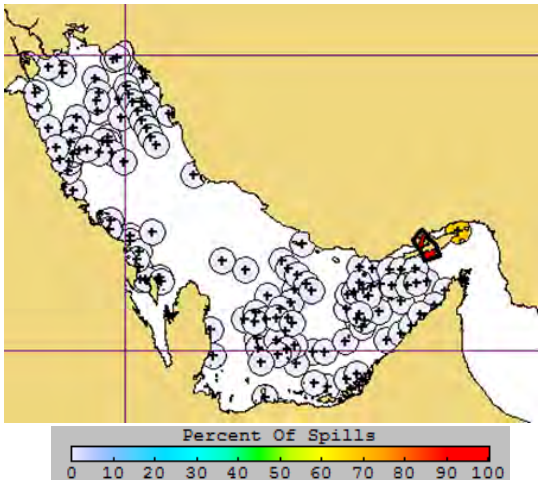


Figure 2.3-6 Hara (Nov-Jan, 60 days)

2.4 Estimated response time in case of oil spill accident occurring at the major offshore oil field

In the case of oil spill accident occurring in major offshore platform, the response time was estimated using the function of Response Time Analysis for each pilot area and protection area (Figure 5.4.2-8). For Aboozar platform, it was omitted because the result of Aboozar platform was similar to Nowruz platform. Each parameter are set as follows.

- Type of oil: Medium Crude
- Amount of spilled oil: 50 metric tons
- Season: Nov-Jan, Feb-Oct
- Acceptable amount on shoreline (threshold amount) : 1 metric ton
- Level of protection: 90 %

The results of the modeling are shown in Figure 2.4-1. They are summarized below.
For the protected areas in Mahshahr, no response is necessary to be considered to the spilled oil because the possibility of drifting down to Marshahr is low.

For Khark Island, if spill accident occurred at Bahrgan Sar platform, it must respond within 72 hours. If the spill accident occurred at Nowruz platform, it must respond within 144 hours (6 days) in Nov-Jan and 216 hours (9 days) in Feb-Oct. In the case of the spill accident at Foroozan platform, it will not need to consider the response to the spilled oil because the possibility of drifting down to K Island is low.

For Assaluyeh, if spill accident occurred at Bahrgan Sar platform, it must respond within 792 hours (33 days). If the spill accident occurred at Nowruz platform, it must respond within 792 hours (33 days) in Nov-Jan. In the case of spill accident at Nowruz and Forozaan platforms occurs in Feb-Oct, no response is necessary to be considered to the spilled oil because the possibility of drifting down to Khark Island is low.

For Heleh protection area, if spill accident occurred at Bahrgan Sar platform, it must respond within 144 hours (6 days). If the spill accident occurred at Nowruz platform, it must respond within 216 hours (9 days) in Nov-Jan and 360 hours (15 days) in Feb-Oct. In the case of spill accident at Foroozan platform, no response is necessary to be considered to the spilled oil because the possibility of drifting down to Heleh protection area is low.

For Mond protection area, if spill accident occurred at Bahrgan Sar platform, it must respond within 360 hours (15 days). If the spill accident occurred at Nowruz platform, it must respond within 360 hours (15 days) in Nov-Jan and 504 hours (21 days) in Feb-Oct. In the case of the spill accident at Foroozan platform in Nov-Jan, it must respond within 792 hours (33 days). With spill accident occurring between Feb-Oct however, no response is necessary to be considered to the spilled oil because the possibility of drifting down to Mond protection area is low.

For Seraj protection area, if spill accident occurred at Bahrgan Sar platform, it must respond within 1,008 hours (42 days) in Nov-Jan and 1,224 hours (51 days) in Feb-Oct. In the case of the spill accident at Foroozan platform, no response is necessary to be considered to the spilled oil because the possibility of drifting down to Seraj protection area is low.

For Faror Island and Hara protection area, no response is necessary because the possibility of drifting

down to the shoreline is low.

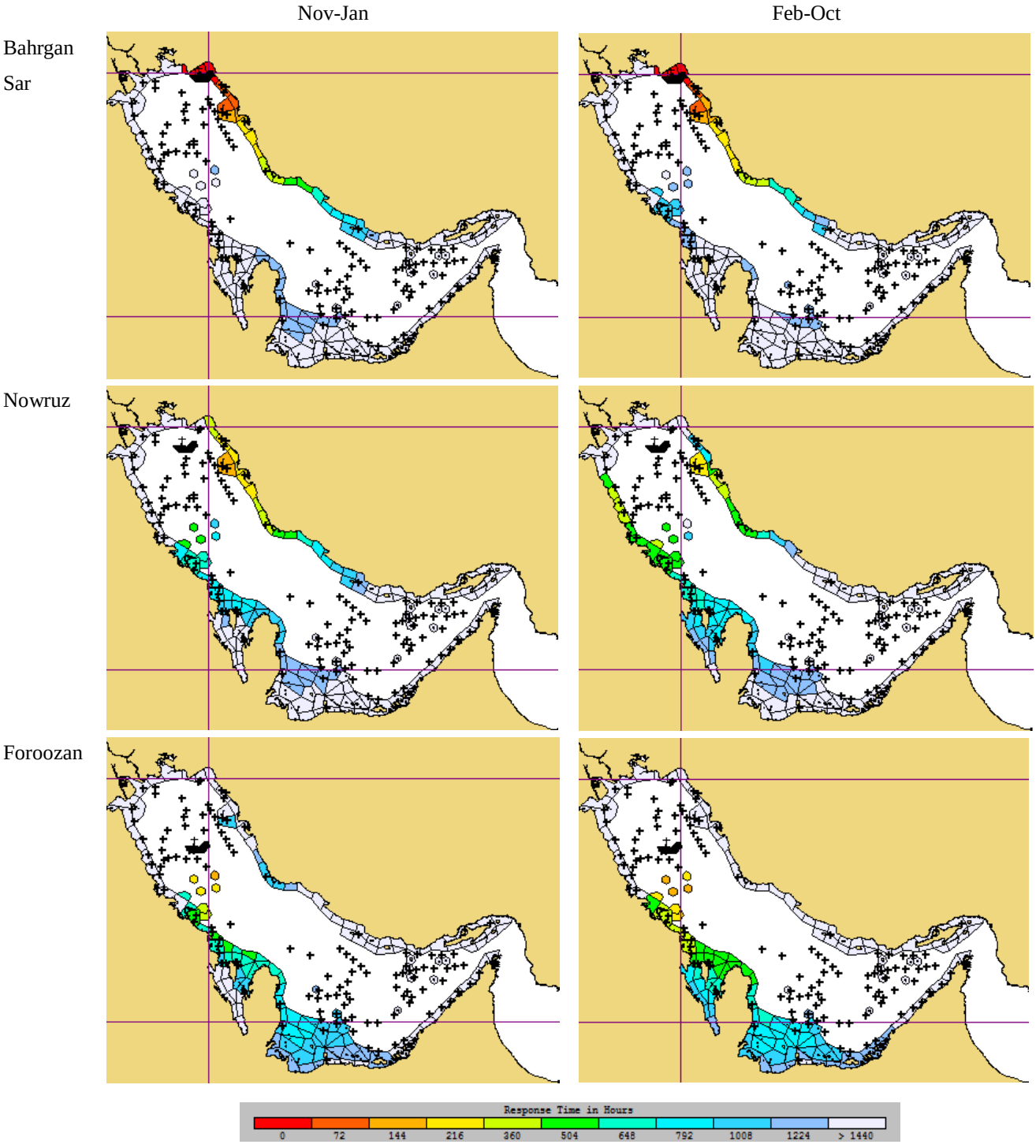


Figure 2.4-1 Estimated response time in case of oil spill accident occurring at the major offshore fields

ضمیمه ۷. ۵-۱

فرمت گزارش‌دهی پایش محیط زیست

(پیش‌نویس)

【Continuous monitoring: Preliminary report, Final report】

Date:

Continuous Monitoring (Preliminary, Final) Report

To: (name of the national company)

From: Zone manager

The (situation, measures carried out) on the accident this time is reported as follows.
The details are described in Annex (1. Preliminary report, 2. Final report).

Company/Factory		
Location		
Summary of the accident	Facility name	
	Date & Time	
	Location	
	Summary, degree, causes	a. Causes b. Spilled materials, volume c. Damages
	Measures (emergent measures)	See Annex
Contact department Name Tel. Mobile		
Note		

Annex-1 (Preliminary report)

[Description of the accident, situation, cause, damage, injury, measures, etc.]

(summary)

----------Details----------

1. Spilled materials, volume

[1] Oil, harmful substances, designated substances

( )

[2] Spilled volume

( )

2. Spilled area

a. river, b. lake, c. sea, d. permeation to the underground, e. others

(Specific location)

3. Spill route from accident source

4. Impact to health problem, ecosystem, public water, groundwater, etc.

a. Actual impact ( )

b. Possibility of impact ( )

5. Measures

* Accompanying drawing

a. Spill route

b. Structure plan of the facility, accident happened

Annex-2 (Final report)

【Shutdown, measures】

(Summary)

----------Details----------

1. Measures undertaken

[1] Conclusive health problem, impact to ecosystem, public water, groundwater etc.

[2] Details of the measures

[3] Period of the measures

a. Start date & time:

b. End date & time:

[4] Situation after the measures carried out, result of confirmation of the effect of the measures

[5] Reasons of judgment for the operation recommencement

2. Preventative measures for the accident

(Notification structure, monitoring method, improvement of the facility, etc.)

* Accompanying drawing

a. Figure that shows the measures carried out

b. Others

【Periodical monitoring: Daily report】

Date:

Periodical monitoring (Daily report)

To (name of the zone manager)

Company:

The result of the daily monitoring is reported as follows.

Company/Factory		
Location		
Items	Discharged water (Confirmed time:)	Abnormal data (Yes, No) COD (mg/L) pH ( ) Turbidity (NTU) Oil (mg/L)
	Flaring (Confirmed time:)	Condition ( ) Flaring volume (m^3/s) Pressure (PSI) Temperature (^oC)
	Waste (Confirmed time:)	Type of waste, volume ( ) Storage condition, location ( )
Note		
Contact department: Name: Tel: Mobile:		

*Annex:

【Periodical monitoring: Weekly report】

Date:

Periodical monitoring (Weekly report)

To (name of the national company

Zone manager:

The result of the weekly monitoring is reported as follows.

Item	Air	[Continuous monitoring] Abnormal data (Yes, No) Situation of the abnormal data, causes and measures ( ) [Manual monitoring] See Annex
	Flaring	Summary ( ) Abnormal data（Yes, No） Situation of the abnormal data, causes and measures ( )
	Noise	See Annex
	Wastewater	Summary ( ) Abnormal data（Yes, No） Situation of the abnormal data, causes and measures ( )
	Waste	Major waste（Harmful substance, etc.） ( ) Storage condition, location ( )
Note		
Contact department: Name: Tel: Mobile:		

* Annex: Results of air and noise measurement

[Result of air measurement]

(Summary)

Date of measurement:

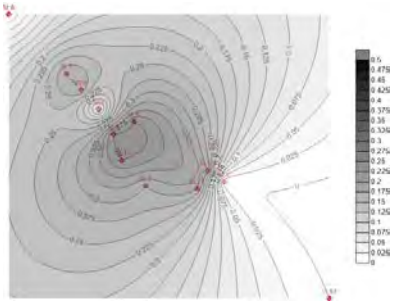
Measurement time: : - :

Number of locations: 10

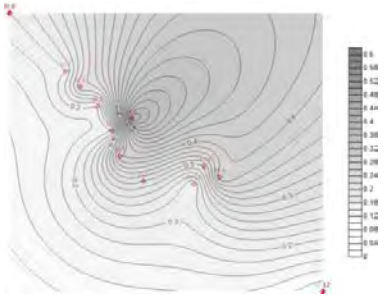
Wind direction, speed: NNE, 1m/s

	NO_2	SO_2	VOC	PM
Unit	PPM	PPM	mg/L	$\mu g/m^3$
Maximum				
Minimum				
Average				
Standard				
Number of excess	/10	/10	/10	/10

(Horizontal distribution)



NO_2

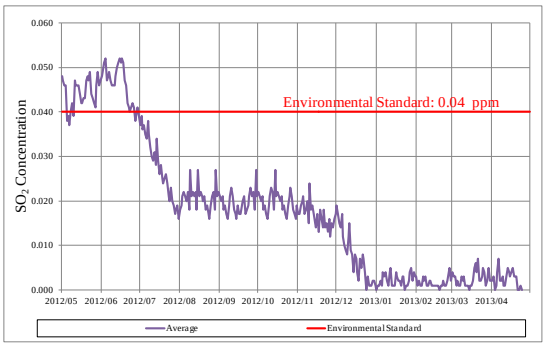


SO_2

VOC

PM

(Time series: average)



SO_2

NO_2

VOC

PM

(Comment, causes of excess of standard value, measures)

[Result of noise measurement]

(Summary)

Date of measurement:

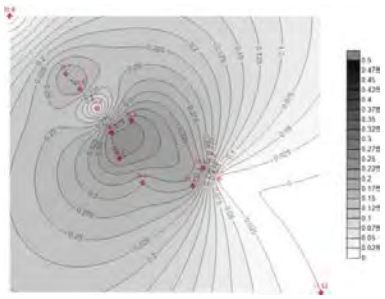
Measurement time: : - :

Number of locations: 10

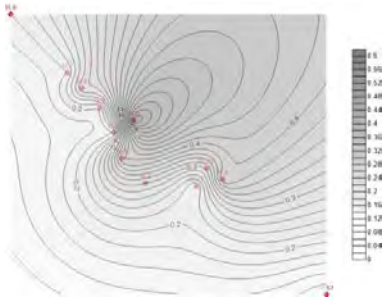
Wind direction, speed: NNE, 1m/s

	Noise Leq (30 min) dB(A)	
	7:00 - 22:00	22:00 - 7:00
Unit	dB	dB
Maximum		
Minimum		
Average		
Standard	75	65
Number of excedance	/10	/10

(Horizontal distribution)

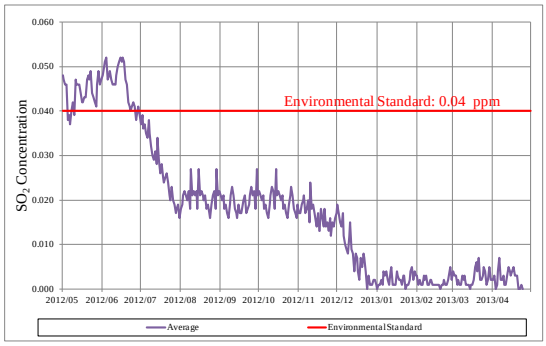


Noise (7:00-22:00)



Noise (22:00-7:00)

(Time series: average)



Noise

(Comment, causes of excess of standard value, measures)

【Periodical monitoring: Monthly report】

Date:

Periodical monitoring (Monthly report)

To Ministry of Petroleum

National company:

The result of the monthly monitoring is reported as follows.

Item	Air	[Continuous monitoring] Abnormal data (Yes, No) Situation of the abnormal data, causes and measures ( ) [Manual monitoring] Abnormal data (Yes, No) Situation of the abnormal data, causes and measures ( )
	Flaring	Summary ( ) Abnormal data（Yes, No） Situation of the abnormal data, causes and measures ( )
	Noise	Summary ( ) Abnormal data（Yes, No） Situation of the abnormal data, causes and measures ( )
	Wastewater	Summary ( ) Abnormal data（Yes, No） Situation of the abnormal data, causes and measures ( )
	Waste	[Summary] Major waste (harmful substance, etc.) ( ) Storage condition, location

		（ ） [Condition of temporary storage site] Major waste（harmful substance, etc.） （ ） Storage condition, location （ ） [Condition of final disposal site] Condition （ ） Water quality of the observation wells See Annex.
	Social environment （If conducted）	[Summary of complaint] （ ） [Health problem, etc.] （ ）
	Natural environment （If conducted）	[Water environment] （ ） [Ecosystem] （ ）
Environmental measures and evaluation of the results		
Present situation and issues regarding the environmental management		
Note		
Contact department: Name: Tel: Mobile:		

* Annex: Monitoring data

[Water quality at observation wells in final disposal site]

(Summary)

Date of sampling:

Sampling time: : - :

Number of locations: 4

	Unit	Maximum	Minimum	Average	Standard	Number of excess
Water temperature	°C					
Conductivity	cmS/s					
pH	-					
Turbidity	NTU					
BOD	mg/L					
Oil contents	mg/L					
Aluminum (Al)	mg/L					
Arsenic (As)	mg/L					
Cadmium (Cd)	mg/L					
Cyanide (CN)	mg/L					
Chromium (Cr)	mg/L					
Cobalt (Co)	mg/L					
Copper (Cu)	mg/L					
Iron (Fe)	mg/L					
Methyl Mercury (Hg)	mg/L					
Mercury (Hg)	mg/L					
Manganese (Mn)	mg/L					
Magnesium (Mg)	mg/L					
Nickel (Ni)	mg/L					
Lead (Pb)	mg/L					
Zinc (Zn)	mg/L					
Phenols	mg/L					

(Comment, causes of excess of standard value, measures)

[Result of complaint and health problem survey]

(Summary)

Date of the survey:

Survey time:　　:　-　:

Method of the survey: questionnaire

Number of questionnaires: 20

Item	Summary
Air	
Water quality	
Noise	
Odor	
Living environment	
Health problem	

(Comment, causes of complaints, measures)

[Result of water quality and sediment quality in the sea area]

(Summary)

Date of sampling:

Sampling time: : - :

Number of locations: 10

Category	Parameters	Unit	Maximum	Minimum	Average	Standard	Number of excess	Number of excedance in the previous year
Water quality (general parameter)	Water temperature	°C						
	Conductivity	cmS/s						
	Salinity	-						
	pH	NTU						
	DO	mg/L						
	Turbidity	mg/L						
	Suspended Solids	mg/L						
	COD	mg/L						
	TOC	mg/L						
	Oil contents	mg/L						
	Coliform bacteria	ind./100mL						
	Total nitrogen	mg/L						
	Total phosphorous	mg/L						
Water quality (heavy metal)	Aluminum (Al)	mg/L						
	Arsenic (As)	mg/L						
	Cadmium (Cd)	mg/L						
	Cyanide (CN)	mg/L						
	Chromium (Cr)	mg/L						
	Cobalt (Co)	mg/L						
	Copper (Cu)	mg/L						
	Iron (Fe)	mg/L						
	Methyl Mercury (Hg)	mg/L						
	Mercury (Hg)	mg/L						
	Manganese (Mn)	mg/L						
	Magnesium (Mg)	mg/L						
	Nickel (Ni)	mg/L						
	Lead (Pb)	mg/L						
	Zinc (Zn)	mg/L						
	Phenols	mg/L						
Sediment quality	Specific Gravity	g/cm3						
	Moisture Content	%						
	Total Organic Carbon (TOC)	mg/g						
	Total Petroleum	mg/g						

Category	Parameters	Unit	Maximum	Minimum	Average	Standard	Number of excess	Number of excedance in the previous year
	Hydrocarbon							
	Aluminum (Al)	mg/g						
	Arsenic (As)	mg/g						
	Cadmium (Cd)	mg/g						
	Cyanide (CN)	mg/g						
	Chromium (total)	mg/g						
	Chromium (Cr+6)	mg/g						
	Cobalt (Co)	mg/g						
	Copper (Cu)	mg/g						
	Iron (Fe)	mg/g						
	Methyl Mercury (Hg)	mg/g						
	Mercury (Hg)	mg/g						
	Manganese (Mn)	mg/g						
	Magnesium (Mg)	mg/g						
	Nickel (Ni)	mg/g						
	Lead (Pb)	mg/g						
	Zinc (Zn)	mg/g						
	Total Sulfur (T-S)	mg/g						

(Horizontal distribution: major parameters)

(Time series: major parameters)

(Comment, causes of excess of standard value, measures)

[Result of observation of biota]

(Summary)

Date of the survey:

Survey time:　　:　-　:

Number of location: 4

	Location	Summary of biota (observed species and number, index organism, etc.)
1		
2		
3		
4		

(Comment, causes and measures to change of biota)

【Periodical monitoring: Annual report】

Date:

Periodical monitoring (Annual report)

To Ministry of Petroleum

National company :

The results of the monitoring conducted in the zone this year are reported as follows.

Item	Air	[Continuous monitoring] Abnormal data (Yes, No) Situation of the abnormal data, causes and measures ( ) [Manual monitoring] Abnormal data (Yes, No) Situation of the abnormal data, causes and measures ( )
	Flaring	Summary ( ) Abnormal data（Yes, No） Situation of the abnormal data, causes and measures ( )
	Noise	Summary ( ) Abnormal data（Yes, No） Situation of the abnormal data, causes and measures ( )
	Wastewater	Summary ( ) Abnormal data（Yes, No） Situation of the abnormal data, causes and measures ( )
	Waste	[Summary] Major waste (harmful substance, etc.) ( ) Storage condition, location ( ) [Condition of temporary storage site] Major waste（harmful substance, etc.）

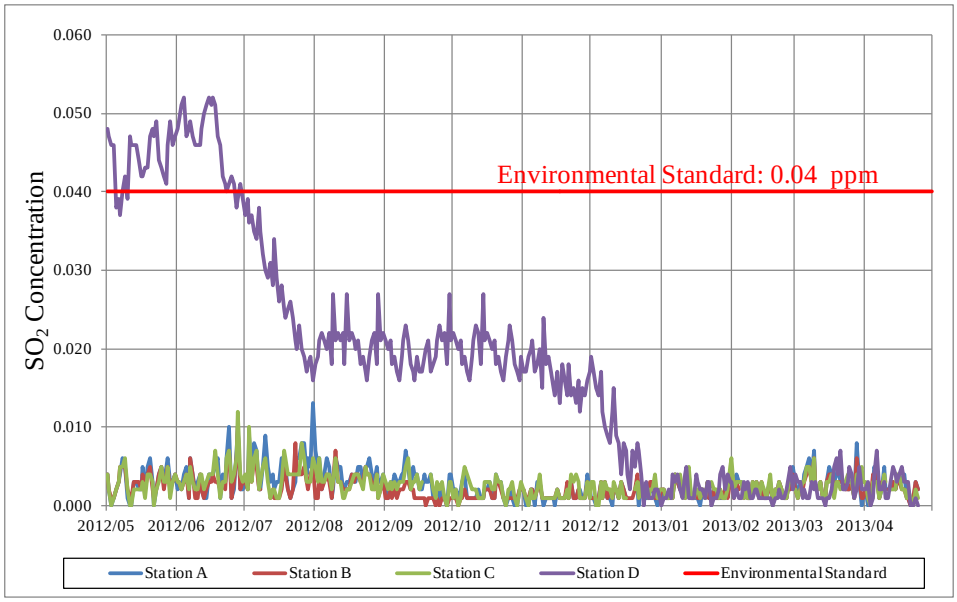
		( ) Storage condition, location ( ) [Condition of final disposal site] Condition ( ) Water quality of the observation wells See Annex.
	Social environment	[Summary of complaint] ( ) [Health problem, etc.] ( )
	Natural environment	[Water environment] ( ) [Ecosystem] ( )
Environmental measures and evaluation of the results		
Present situation and issues regarding the environmental management		
Degree of attainment to the target value		
Issues and target in the next year		
Note		
Contact department: Name: Tel: Mobile:		

* Annex: Monitoring data

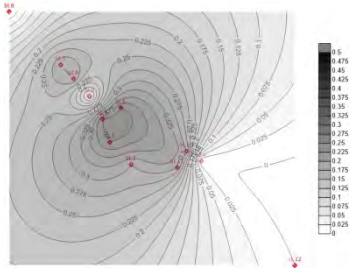
[Air, Noise, Water environment]

(Time series)

Monitoring period: dd/mm/yy - dd/mm/yy



(Horizontal distribution)

 Jan., 2012	Feb., 2012	Mar., 2012
Apr., 2012	May, 2012	Jun., 2012

● ● ●

(Comment, abnormal data and measures)

[Result of complaint/health problem survey]

(Summary)

Survey year: 2012

Survey method: questionnaire

Number of questionnaires: 20

Item	Previous year	This year
Air		
Water quality		
Noise		
Odor		
Living environment		
Health problem		

(Comment, comparison between the result of the previous year, causes of the complaint and measures)

[Result of observation of biota]

(Summary)

Survey year: 2012

Number of locations: 4

	Location	Summary of the previous year	Summary of this year
1			
2			
3			
4			

(Comment, comparison between the previous year, causes of the change of the biota and measures)

ضمیمه ۷. ۵-۲

پارامترهای خاص و اهداف مربوط به کیفیت آب، کیفیت رسوبات و خاک در پایش زیست‌محیطی

Water Quality, Sediment Quality, and Soil

Category	Parameter	Objective of the monitoring
Water quality (general parameter)	Water temperature	Water temperature, to know the existence of thermocline by vertical distribution
	Conductivity	Electrical conductivity, index of ionized substances
	Salinity	Salinity, to know the existence of salinity cline
	pH	To know the influence of wastewater and degree of primary production
	DO	To know the condition of oxidation/reduction
	Turbidity	To be used as an index of turbidity including soil particle, organism and organic matter
	Suspended Solids	To be used as an index of soil particle
	COD	To be used as an index of organic matter
	TOC	To be used as an index of organic matter
	Oil contents	To be used as an index of oil
	Coliform bacteria	To be used as an index of sewage water
	Total nitrogen	To be used as an index of nutrient
	Total phosphorous	To be used as an index of nutrient
Water quality (heavy metal)	Aluminum (Al)	To know the impact by the discharged water from the industrial area
	Arsenic (As)	
	Cadmium (Cd)	
	Cyanide (CN)	
	Chromium (Cr)	
	Cobalt (Co)	
	Copper (Cu)	
	Iron (Fe)	
	Methyl Mercury (Hg)	
	Mercury (Hg)	
	Manganese (Mn)	
	Magnesium (Mg)	
	Nickel (Ni)	
	Lead (Pb)	
	Zinc (Zn)	
	Phenols	
Sediment quality	Specific Gravity	Weight of unit volume
	Moisture Content	To be used for conversion to the concentration in dry sediment
	Total Organic Carbon (TOC)	To be used as an index of organic matter
	Total Petroleum Hydrocarbon	To know the impact by the heavy metals discharged from the industrial area
	Aluminum (Al)	
	Arsenic (As)	
	Cadmium (Cd)	
	Cyanide (CN)	
	Chromium (total)	
	Chromium (Cr+6)	
	Cobalt (Co)	
	Copper (Cu)	

Category	Parameter	Objective of the monitoring
	Iron (Fe)	
	Methyl Mercury (Hg)	
	Mercury (Hg)	
	Manganese (Mn)	
	Magnesium (Mg)	
	Nickel (Ni)	
	Lead (Pb)	
	Zinc (Zn)	
	Total Sulfur (T-S)	
Soil	Specific Gravity	Weight of unit volume
	Moisture Content	To be used for conversion to the concentration in dry sediment
	Cadmium (Cd)	To know the impact to the soil/ground water when leakage from the storage area occurs
	Chromium (Cr+6)	
	Cyanide (CN)	
	Mercury (Hg)	
	Lead (Pb)	
	Arsenic (As)	
	Total Petroleum Hydrocarbon	
	PCBs	
	Selenium	
	Fluorine	
	Boron	

ضمیمه ۷. ۵-۳

دلایل انتخاب نقاط پایش

[Mahshahr]

Location	Air(continuous)	Air (periodical)	Noise	Water quality/sediment quality	Biota	Reason （Target for impact study）
MA-A	x					Residential area (Existing point: DOE）
MA-B	x					Residential area (Existing point: DOE)
MA-C	x					Inside the zone (Existing point: PSEZ)
MA-D	x					Port (Existing point: DOE)
MA-1		x	x			Boundary
MA-2		x	x			Boundary
MA-3		x	x			Boundary
MA-4		x	x			Inside of the area
MA-5		x	x			Residential area
MW-1				x		Upper stream
MW-2				x		Abadan area
MW-3				x		Middle point, ecosystem
MW-4				x		Outlet from retention pond
MW-5				x		Discharge outlet
MW-6				x		Port area
MW-7				x		Port area
MW-8				x		Ecosystem
MW-9				x		Ecosystem
MW-10				x		Back ground
MB-1					x	Upper stream
MB-2					x	Ecosystem near to the outlet from retention pond
MB-3					x	Protected area
MB-4					x	Protected area

[Khark]

Location	Air(continuous)	Air (periodical)	Noise	Water quality/sediment quality	Biota	Reason （Target for impact study）
KA-A	x					Residential area (Existing point)
KA-B	x					Residential area (New point)
KA-C	x					Inside of the area (Existing point)
KA-D	x					Inside of the area (Existing point)
KA-E	x					Inside of the area (Existing point)
KA-1		x	x			Ecosystem
KA-2		x	x			Residential area
KA-3		x	x			Port area
KA-4		x	x			Residential area
KA-5		x	x			Port area
KW-1				x		Ecosystem, back gorund
KW-2				x		Ecosystem
KW-3				x		Ecosystem
KW-4				x		Ecosystem
KW-5				x		Ecosystem (coral)
KW-6				x		Ecosystem
KW-7				x		Ecosystem
KW-8				x		Port area
KW-9				x		Port area
KW-10				x		Ecosystem
KB-1					x	Ecosystem (protected area)
KB-2					x	Ecosystem (protected area)
KB-3					x	Ecosystem
KB-4					x	Ecosystem

[Assaluyeh]

Location	Air(continuous)	Air (periodical)	Noise	Water quality/sediment quality	Biota	Reason （Target for impact study）
AA-A	x					Residential area (New point)
AA-B	x					Inside of the area (New point)
AA-C	x					Inside of the area (New point)
AA-D	x					Residential area (New point)
AA-1		x	x			Boundary
AA-2		x				Inside of the area
AA-3		x	x			Port area, Inside of the area
AA-4		x				Inside of the area
AA-5		x	x			Inside of the area
AA-6		x				Inside of the area
AA-7		x				Inside of the area
AA-8		x	x			Ecosystem
AA-9		x				Inside of the area
AA-10		x	x			Residential area
AW-1				x		Back ground
AW-2				x		Port area
AW-3				x		Port area
AW-4				x		Port area
AW-5				x		Discharge outlet
AW-6				x		Boundary
AW-7				x		Ecosystem
AW-8				x		Ecosystem
AW-9				x		Ecosystem
AW-10				x		Ecosystem
AB-1					x	Ecosystem (mangrove)
AB-2					x	Ecosystem (sand beach)
AB-3					x	Ecosystem (sea grass bed)
AB-4					x	Ecosystem (sea grass bed, coral)

ضمیمه ۱۰

برنامه اجرایی: رسمی کردن

”اصل یک مدیر برای هر منطقه“

Implementation Program for Priority Action on Improvement of Environmental Management

Strategy 3 Formulating specific regulations for the environmental protection

Action 3-2 Institutionalizing the "One Zone One Management Principle"

[Project Brief]

1. Background

[Environmental Administration Aspect]

Basically, the DOE is the single organization that has the authority to enforce the national environmental laws, regulations and standards. Local DOE offices have a relation with the operating companies in their jurisdiction and gather the information from those companies. However, both the central and local DOE offices do not have a function to control the environmental management in each industrial zone. Therefore, in order to control the emission from the operating companies in the petroleum industrial zones, a supervising body that has the strong authority for the environmental management is required.

[HSE Management Aspect]

Currently, coordination and collaboration of the environmental management efforts between sections/departments/companies has not been considered. Each operating company monitors the environmental indices within its complex and report the monitoring results to their mother company. However, the monitoring indices and unit used vary one company to another. The monitoring records have not been shared with organizations concerned. Besides, the environmental monitoring systems within the whole industrial area and in its surrounding area where is likely to be affected by the pollutants from the area have not been well organized. Therefore, the unified/centralized environmental monitoring systems should be operated under one single authority. The best solution to the issue is to introduce the "One Zone One Management Principle".

2. Objective

Overall goal and purpose of this action are as follows:

Overall goal:	Integrated environmental management systems of the petroleum industry are operated.
Project purpose:	Environmental management based on the "One Zone One Management Principle" is enhanced.

3. Implementation Steps

There are nine (9) steps to realize the "One Zone One Management Principle" as follows:

- Investigating the legal framework to establish the Principle
- Fixing the roles of the Zone Management Company under the Principle
- Concluding an agreement with four (4) mother companies
- Institutionalizing the Principle
- Appointing a zone management company for each petroleum industry zone
- Delegating the authority of environmental management to the appointed companies
- Gathering information of emission sources & pollutants from operating companies
- Forming an Environmental Management Committee
- Preparing an environmental hazard map showing the emission sources and pollutants

(1) Investigating the legal framework to establish the Principle (Action to be taken by the HSE-MOP)

The Action, Institutionalizing the "One Zone One Management Principle", aims at integration of the environmental management and monitoring in one industrial zone. Under the concept of the Principle, the authority to control the environmental management in one industrial zone should be delegated to a zone management company. In order to control the environmental management in the industrial zone, the zone management company should gather information such as emission sources, pollutants emitted and monitoring records to evaluate the environmental performance of the operating companies, initiate collective actions towards the environmental protection in the whole zone and give a direct order for companies on remediation/improvement as appropriate if a violation of laws/regulation/standards is found. This might be required to take a legal step to authorize such management procedure. Therefore, it is necessary to make it clear whether or not such a legal step should be followed to establish the "One Zone One Management Principle". Types of legal documents to be investigated are as follows, but not limited to:

- National laws and regulations
- Ministerial decrees/ordinances
- Ministerial regulations/rules
- Others if any

(2) Fixing the roles of the Zone Management Company under the Principle (Action to be taken by the HSE-MOP)

The following are the expected basic roles of the zone management company on the environmental management in the whole zone:

- Holding liaison meetings (so called “Environmental Management Committee”) regularly for the purpose of discussing collective actions to be taken, such as setting the common environmental goals, sharing good practices and collaborating on training (The liaison meeting members are HSE managers of the zone management company and operating companies in the zone.)
- Organizing a separate meeting to discuss an individual issue such as environmental management in the zone (establishing a regional air quality control committee as a separate meeting to the regular liaison meeting as appropriate
- Setting and managing the monitoring stations within the zone and in the surrounding areas such as residential zones, national parks and protected areas
- Gathering the information about potential emission sources, types of pollutants and the environmental monitoring records from operating companies
- Preparing a hazard map that shows the potential emission sources and types of pollutants in the zone
- Evaluating the performance of environmental protection by the operating companies
- Giving direct orders for a company that violates the regulations and standards to remedy a fault or improve the operations/facilities and imposing penalties (operation shutdown or fine) if necessary

The roles of the zone management company and job descriptions should be elaborated based on the basic ones above mentioned.

(3) Concluding an agreement between the four (4) mother companies (Action to be taken by the mother companies)

There is an industrial area where subsidiaries under different mother companies operate, such as Assaluyeh. Under the “One Zone One Management Principle”, the MOP will appoint the existing companies as the zone management company such as PSEZ that falls under NPC and PSEEZ Organization that falls under NIOC. Every company should follow the instructions/orders from the zone management company regardless of the group company. The overall goal of the environmental management is the same for all the mother company groups. However, the interest and approach to meet the requirements of the environmental management could vary from on mother company group to another. Therefore, it is recommended that the four mother companies should conclude an agreement on cooperation in the execution of the one zone one management. The agreement may consist of the general and specific parts. The general part includes the common conditions that are applicable to all the petroleum industry zones, while the specific part provides local conditions depending on the characteristics of industrial zones. The draft agreement for the pilot sites should be prepared based on the local conditions.

(4) Institutionalizing the Principle
(Action to be taken by the HSE-MOP)

In accordance with the examined result, the MOP should prepare the necessary documents to institutionalize the principle. The documents should include the following:

- The objective of institutionalizing the “One Zone One Management Principle”
- Definition of words
- Authority of the zone management companies
- Tasks of the zone management companies
- Responsibility of operating companies under the principle
- Punishment/penalty against nonobservance of the principle
- Settlement of disputes on the integrated zone management

(5) Appointing a zone management company for each petroleum industry zone
(Action to be taken by the HSE-MOP)

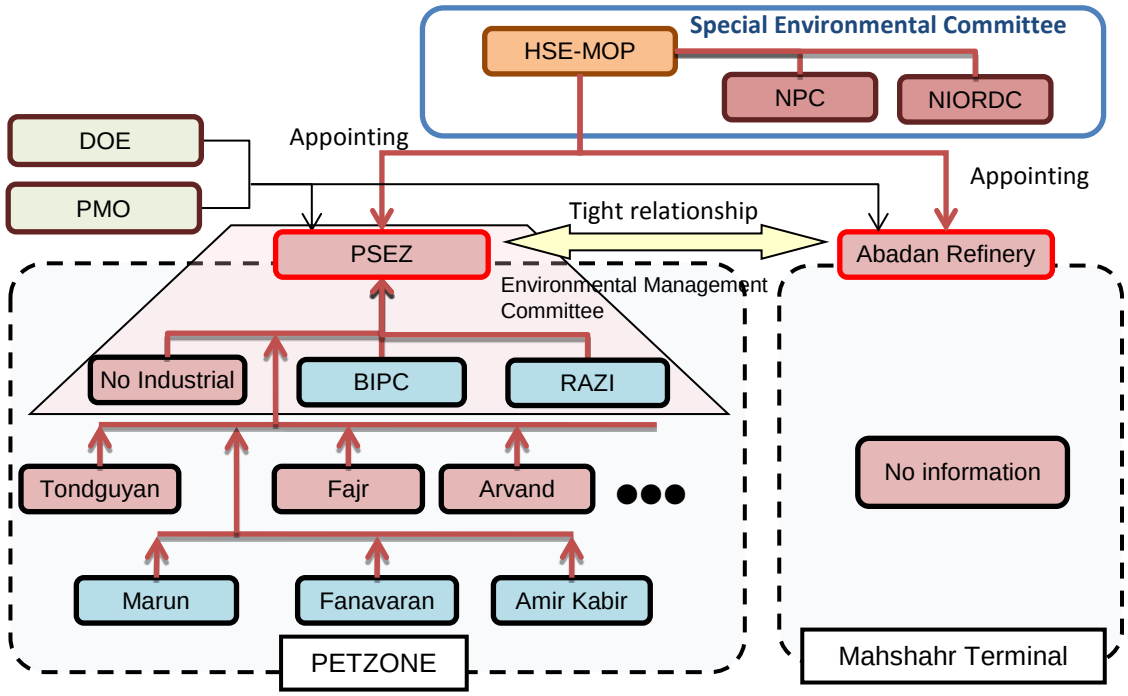
After institutionalizing the principle, the MOP will appoint the zone management companies for all the petroleum industry zones and publicize the appointed zone management companies.

PSEZ can be the zone management company in PETZONE, Mahshahr as it is. Mahshahr Terminal is managed by Abadan Refinery. Therefore, PSEZ and Abadan Refinery should have tight relationship to monitor the environmental protection in Mahshahr area.

In Khark Island, there is no company who is made responsible for the environmental management in the entire industrial zone. Considering the scale and sphere of the business activities, it is recommended that IOOC should play the role of the zone management company. The HSE Central Office of IOOC is desirable to be appointed as the zone management company in Khark Island.

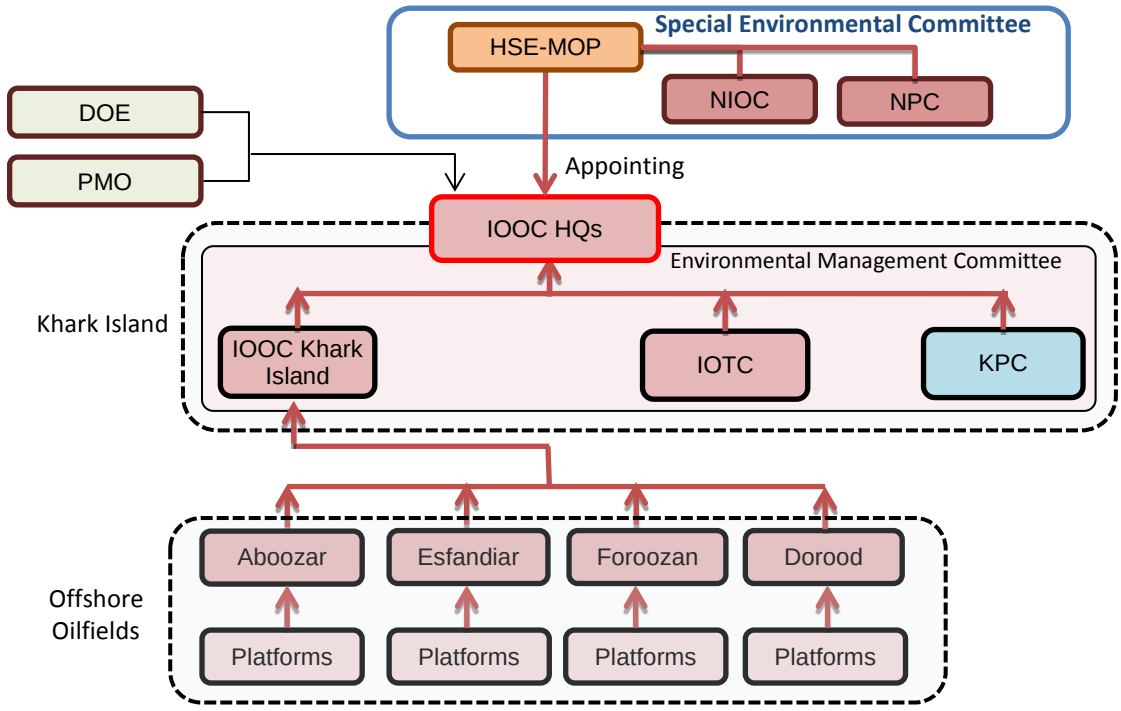
Current management structure in Assaluyeh is very complicated and partially duplicated because three company groups operate their management systems independently. It is recommended that PSEEZ Organization should be appointed as the zone management company in Assaluyeh have the centralized authority to control the environmental management in the zone.

The following figures show the tentative structure of one zone one management in the pilot sites.



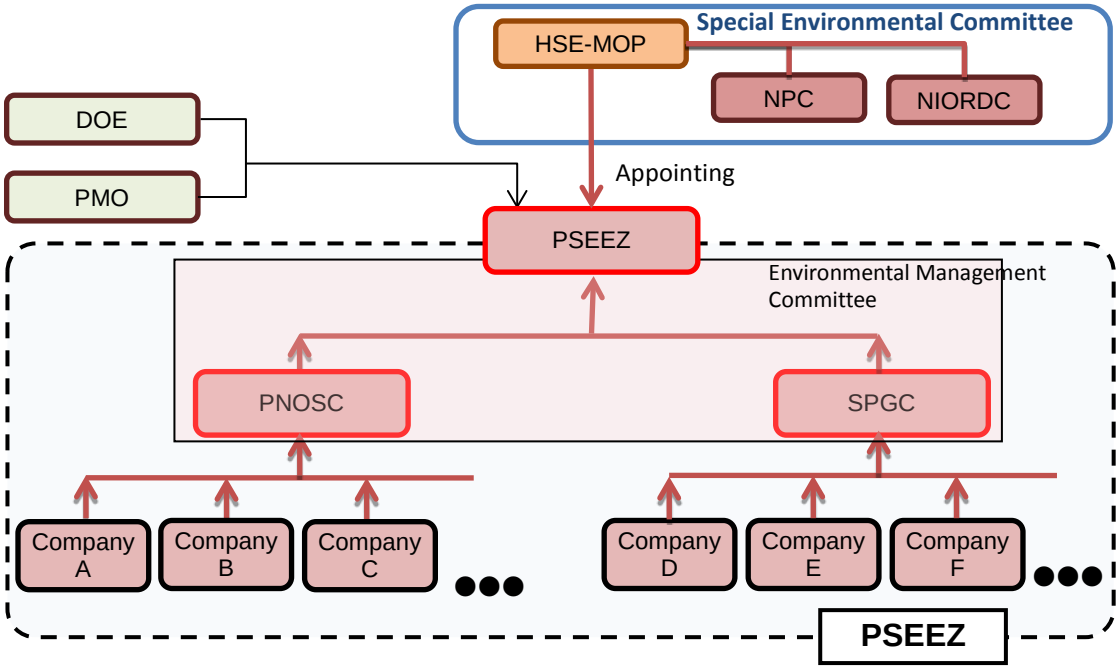
Note: The petrochemical companies highlighted in blue are privatized.
Source: Study team

Figure 1 One Zone One Management Structure: Mahshahr Area



Notes: The petrochemical company highlighted in blue is privatized.
Source: Study team

Figure 2 One Zone One Management Structure: Khark Island Area



Source: Study team

Figure 3 One Zone One Management Structure: Assaluyeh Area

(6) Delegating the authority of environmental management to the appointed companies (Action to be taken by the HSE-MOP)

The MOP will delegate the authority of the environmental management to the appointed companies with official documents.

(7) Gathering information of emission sources & pollutants from operating companies (Action to be taken by the zone management companies and operating companies)

The appointed zone management companies will gather information of emission sources and possible pollutants to prepare an environmental hazard map. The map should be used as a tool to evaluate the environmental performance in the zones. The operating companies should share the information and monitoring records with the zone management companies.

(8) Forming an Environmental Management Committee (Action to be taken by the zone management companies and operating companies)

The appointed zone management companies and operating companies should form an environmental management committee to discuss collective actions to be taken, such as setting the common environmental goals, sharing good practices and collaborating on training.

(9) Preparing an environmental hazard map showing the emission sources and pollutants (Action to be taken by the zone management companies)

The appointed zone management companies will prepare the environmental hazard map based on the information gathered from operating companies in the zones. The map should show the emission sources such as locations of flare stacks, treated wastewater discharge points and solid waste collection and storage and possible pollutants emitted/discharged from the sources. This map will be used as the baseline of environmental monitoring in the zones. It is also recommended that the environmental hazard map should be shared with the governmental authorities related to the environmental management, such as DOE and PMO.

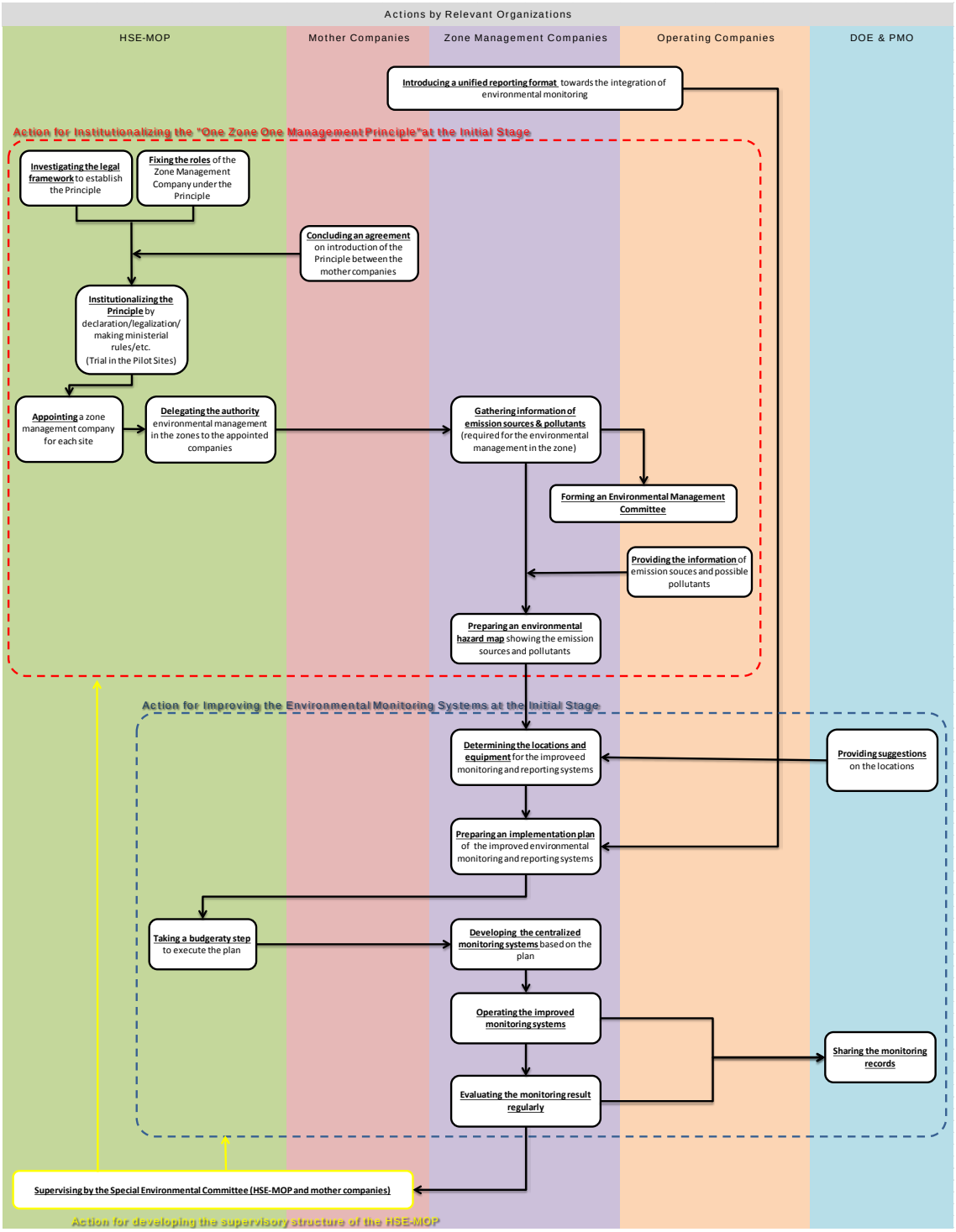
Figure 4 shows the work breakdown structure of the action.

Strategies and Actions	Responsible Body	Short-Term		
		1st Year	2nd Year	
		1393	1394	
		2014	2015	2016
[Environmental Management]				
3. Formulating specific regulations for the environmental protection				
3-2 Institutionalizing the "one zone one management principle"				
(1) Investigating the legal framework to establish the Principle	HSE-MOP			
(2) Fixing the roles of the Zone Management Company under the Principle	HSE-MOP			
(3) Concluding an agreement with four (4) mother companies	Mother Companies			
(4) Institutionalizing the Principle	HSE-MOP			
(5) Appointing a zone management company for each petroleum industry zone	HSE-MOP			
(6) Delegating the authority of environmental management to the appointed companies	HSE-MOP			
(7) Gathering information of emission sources & pollutants from operating companies	Zone Management Companies (Operating Companies)			
(8) Forming an Environmental Management Committee	Zone Management Companies Operating Companies			
(9) Preparing an environmental hazard map showing the emission sources and pollutants	Zone Management Companies			

Source: Study team

Figure 4 Work Breakdown Structure of Action 3-2

Figure 5 shows the framework of actions related to the integrated environmental management systems (institutionalizing the One Zone One Management Principle and improving the environmental monitoring systems).



Source: Study team

Figure 5 Framework of Actions related to the Integrated Environmental Management Systems (Flow of actions by relevant organization)