MINISTRY OF REGIONAL DEVELOPMENT, CONSTRUCTION, HOUSING AND COMMUNAL SERVICES OF UKRAINE
KIEV CITY STATE ADMINISTRATION
PUBLIC JOINT STOCK COMPANY "Kyivvodokanal" (KVK)

EXPERTS FOR FORMULATING RECONSTRUCTION PLAN OF BORTNICHESKAYA WASTEWATER TREATMENT PLANT IN UKRAINE

FINAL REPORT

MARCH 2014

JAPAN INTERNATIONAL COOPERATION AGENCY

TEC INTERNATIONAL CO., LTD.
NIHON SUIKO SEKKEI CO., LTD.

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1 Euro	**10.87**	**Ukrainian Hryvnia (UAH)**
1 Euro	**129.64**	**Japanese Yen (JPY)**

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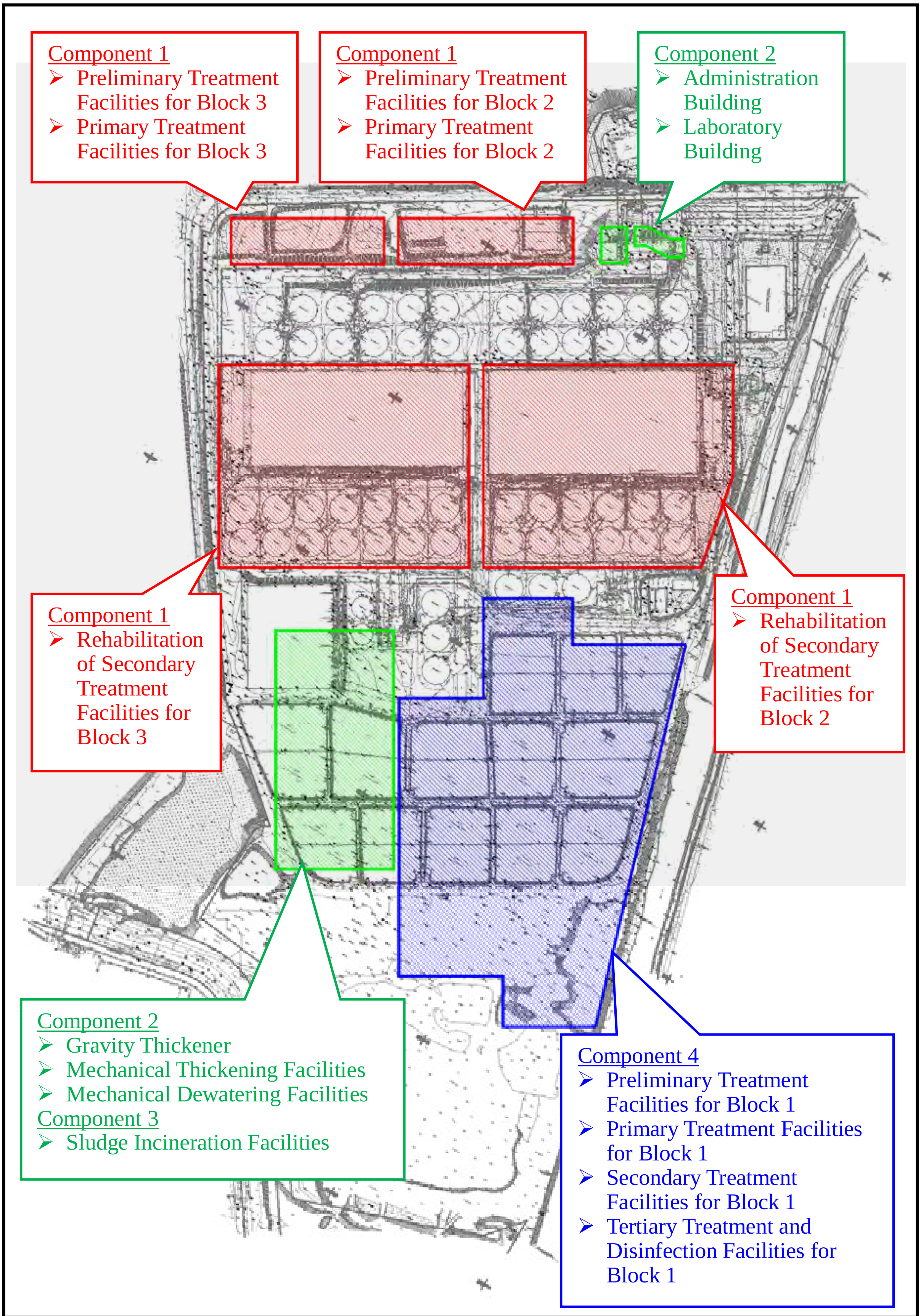
S Sludge Fields
0 2 4 6 8 10 Kilometers



Bortnychy Aeration Station

SUMMARY

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Abbreviation

BAS	Bortnychy Aeration Station
B/C ratio	Benefit and cost ratio
BOD	Biological Oxygen Demand
CD	Conceptual Design
CHP	Cogeneration System
COD	Chemical Oxygen Demand
CV	Calorific Value
C1	Component 1
C2	Component 2
C3	Component 3
C4	Component 4
C5	Component 5
C6	Component 6
C7	Component 7
C8	Component 8
C9	Component 9
C10	Component 10
D	Depth
Dia.	Diameter
DO	Dissolved Oxygen
DS	Dry Solids
EIA	Environmental Impact Assessment
EU	Europe Union
FBI	Conventional fluidized bed incinerator
FC	Foreign Currency
FIRR	Financial Internal Rate of Return
FOG	Fat, Oil & Grease
FY	Fiscal Year
F/S	Feasibility Study
IL	Ignition Loss
JICA	Japan International Cooperation Agency
JST	JICA Study Team
KIP	Kyivinzhproekt Institute of PJSC Kyivproekt
KCSA	Kiev City State Administration
KVK	Public Joint Stock Company “KyivVodokanal”
MLIT	Ministry of Land, Infrastructure and Transportation
MLSS	Mixed liquor suspended solids
MWh	Megawatt-hour
M/D	Minutes of Discussion
MoEDR	Ministry of Economic Development and Trade
MoENR	Ministry of Ecology and Natural Resources
MoF	Ministry of Finance
MoJ	Ministry of Justice
MoRDCH	Ministry of Regional Development, Construction and Housing and Communal Services

M&E	Mechanical & Electrical
NCSPUR	National Commission for the State Public Utilities Regulation
NPV	Net present value
NSS	Nihon Suiko Sekkei Co., Ltd.
N/A	Not Available
NRW	Non Revenue Water
ODA	Official Development Assistance
O&M	Operation & Maintenance
PCC	Project Coordination Committee
PD	Project Director
P/S	Pumping Station
PEA	Project Execution Agency
PFBI	Pressurized fluidized bed incinerator
PIA	Project implementation agency
PIU	Project implementation unit
SCADA	Supervisory Control and Data Acquisition
SPZ	Sanitary Protection Zone
SRT	Solid retention time
STEP	Special Terms for Economic Partnership
SS	Suspended Solids
SV	Sludge volume
SVI	Sludge volume index
TDS	Total Dissolved Solids
TECI	TEC International Co., Ltd.
TKN	Total Kjeldahl Nitrogen
TOR	Terms of Reference
TSS	Total Suspended Solids
T-N	Total Nitrogen
T-P	Total Phosphorus
UAH	Ukrainian Hryvnia
US$、USD	United States Dollars
VAT	Value Added Tax
VSS	Volatile Suspended Solids
VVVF	Variable Voltage Variable Frequency
W	Width
WWTP	Wastewater Treatment Plant

1. Introduction

1.1 Background of the Study

Ukraine, established in 1991 as a result of the demise of Soviet Union, consists of 24 regions, the autonomous republic of Crimea and two cities with special status – Kiev and Sevastopol. The main issue of the country requiring urgent resolution is the restoration of aged social infrastructures constructed during the Soviet Union period. Bortnychy Aeration Station (BAS), treating all the sewage generated in the capital city of Kiev, consists of three sewage treatment trains. The first train, beginning its operation in 1964, has been aged to the worst extent and requires reconstruction as early as possible. Liquid sludge after some stabilization processes is pumped to sludge fields. However, the sludge fields are nearly full of disposed sludge and a sludge reduction facility such as sludge incinerator has to be constructed urgently. Ukraine has targeted to be a member of EU as a political goal and tries to adjust its effluent standards to the EU directives. Above all, existing facilities cannot remove nitrogen and phosphorus to the extent required. In this regard, upgrading and/or additional facilities are required to ensure advanced treatment.

Public Joint Stock Company "Kyivvodokanal" (KVK) as an executing agency is preparing a feasibility study that includes the construction of sewage treatment facilities with a capacity of 1.58 million cubic meters per day, sludge treatment facilities and incinerator facilities. To materialize the feasibility study, the Government of Ukraine has requested for a Japanese ODA loan.

1.2 Objective and Scope of the Study

The study aims to assist KVK to finalize the feasibility study in the form that meets JICA's project appraisal criteria, which is a prerequisite for JICA to finance the reconstruction of BAS.

The scope of the study shall be in accordance with the M/D (Minutes of Discussion) agreed on May 24, 2013 between the KVK and JICA.

1.3 Facilities Covered by the Study

The study covers the facilities listed below:

- Bortnychy Aeration Station (BAS)
- Sludge fields

1.4 Implementing Organization of Ukraine

The counterpart agencies of the Ukrainian side include Ministry of Regional Development, Construction, Housing and Communal Services of Ukraine, Kiev City State Administration and KVK.

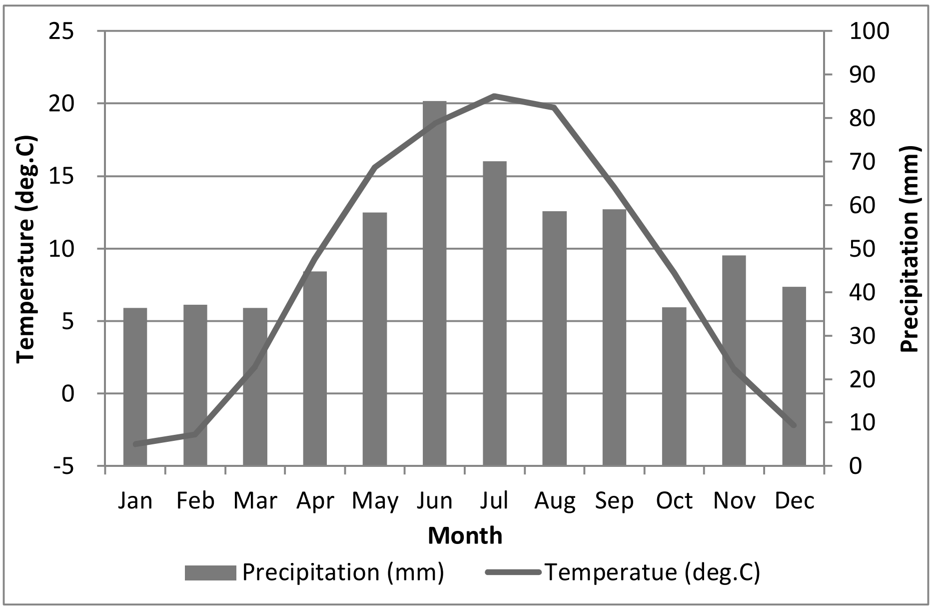
2. Collection and Evaluation of Basic Information

2.1 Basic Information

(1) Topographic and Meteorological Characteristics

Kiev City is located at latitude 50°27'00" N and longitude 30°30'24" E and its total area is around 539 km^2, mean altitude is at +179 m. The climate is grouped in a humid continental climate and its average air temperature is recorded around 20 degrees centigrade (in August) and average lowest is around -3.5 degrees centigrade (in January), and yearly precipitation is recorded around 662 mm according to historical data.

The summarized monthly climate information is shown in Figure 2.1.



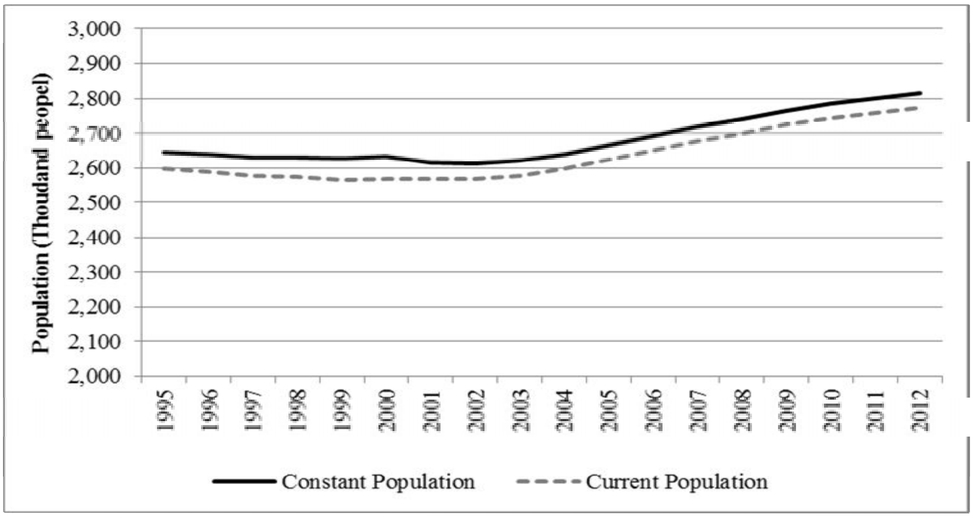
Source: Japan Weather Association

Figure 2.1 Monthly Temperature and Precipitation in Kiev City

(2) Transitions in Population

The population in Kiev City which includes temporary population without official registration is around 2,800,000 according to City's statistical information as of 2012 and the number is kept growing steadily at 0.5 – 1.0 % of the yearly increase rate for the last ten years.

Actual growth of residential population is shown in Figure 2.2.



Source: Main Statistics Department, Kiev City State Administration

Figure 2.2 Transitions in Population in Kiev City (Total and Registered Population)

The city has ten administrative districts and 58% of the population is shared in the right bank side which is located on the west side of the Dnieper River and formed a central area of the city. On the other hand, the left bank side, or eastern side of the city has been developed as residential zone very rapidly in these 20 – 30 years and now the development is spread in satellite towns because of the escalation of real estates and lack of proper land for large scaled developments in the boundaries of Kiev City. The summary of Kiev City districts is shown in Table 2.1.

According to the historical number of visitors to Kiev City sourced from statistical yearbook, yearly visitors are recorded between 500 to 700 thousand people, and vaguely a half of them are in business and education purposes.

Table 2.1 Population in Kiev City Sorted by Administrative District

No.	Location	District	Area (km^2)	Ratio (%)	Population Density (people/km^2, 2013)
1	Right Bank	Holosiiv	156	18.7%	1,534
2	Left Bank	Darnytsia	133	15.9%	2,408
3	Left Bank	Dnipro	148	17.7%	2,447
4	Left Bank	Desna	67	8.0%	5,206
5	Right Bank	Obolon	110	13.2%	2,886
6	Right Bank	Pechersk	20	2.4%	7,239
7	Right Bank	Podil	34	4.1%	5,684
8	Right Bank	Sviatoshyn	101	12.1%	3,341
9	Right Bank	Solomianka	40	4.8%	8,779
10	Right Bank	Shevchenko	27	3.2%	8,537
Sub Total of Right Bank Districts			488	58.4%	3,717
Sub Total of Left Bank Districts			348	41.6%	2,963
Total			836	100.0%	3,403

Source: Statistical Yearbook of Kiev City, 2011

(3) Current Situation of Water Supply System

The water supply system is operated and maintained by KVK in the city and the ownership of the supply system reaches to 100%. Recently water consumptions become declined due to introducing a metered tariff system which formerly managed by the fixed rate system and currently per capita water consumption is ranged between 200 – 250 L/people/day. Supplied water is sourced from tributary rivers to the Dnieper River and ground water is also taken from local wells as a potable water source.

(4) Current Situation of Sewerage System

The sewerage system in Kiev City has commenced since the end of the 19th century with the development of local drainage network and nearly 50 years has passed since the modern system, which was equipped with a wastewater treatment plant, was introduced. The current percentage of the coverage of sewerage system has reached around 99% of the whole city area and it covers almost all the part of the city.

The wastewater collector system has been laid around 2,480 km and 90% of the network use gravity sewers and the remaining 10% is functioned as pressure lines to send wastewater to the wastewater treatment plant via pump stations. The pump stations are located in the network at total 30 sites.
According to the rehabilitation plan which was formulated by the city, deep gravity sewer pipes are to be laid in order to decrease electricity consumptions which were used in the pump stations.

The overview of sewer network in Kiev City is shown in Table 2.2.

Table 2.2 Overview of Sewer Network in Kiev City

Item	Length (m)	Ratio
Gravity Sewers	2,159,500	87%
Deep Gravity Sewer Mains	170,300	7%
Pressure Sewer Mains	151,500	6%
Total	2,481,300	100%

Source: Schemes of Water Supply and Sewage Systems of Kiev City by 2020, Kiev City (2007)

Bortnychy Aeration Station has three blocks. It started the operation in 1964 using Block 1, the first treatment line and two additional lines called Block 2 and Block 3 were established using standard designs from the former Soviet Union. All three blocks were constructed as a conventional activated sludge process.

The overview of Bortnychy Aeration Station is shown in Table 2.3.

Table 2.3 Overview of Bortnychy Aeration Station

Item	Year of Commissioning	Capacity (m^3/day)
Block 1	1964	600,000
Block 2	1975	600,000
Block 3	1986	600,000
Total	-	1,800,000

Source: KVK

Affected by the declined water supply trends, the influent volume reaches to the treatment plant also shows decreasing trends in recent years and the current average flow is typically below 1,000,000 m^3/day.

In related to the sludge treatment, the generated sludge in the initial stage of the operation was distributed as fertilizers in dried form to the farmers in the left bank area. However, since the ban of using dried sludge for agricultural use because of the concentrated heavy metal components which were contained in the sludge materials, the generated sludge has been transported to the three sludge fields which were located 10 to 20 km from the plant by pressure lines. The capacity of sludge fields are now reached to 2.5 – 3 times larger than the original capacity because the sludge fields were constructed for temporary storage. The current volume of daily generated and transferred sludge is around 10,000 – 15,000 m^3/day.

(5) Priorities of Water Environment Protections in the National and Municipal Programs

In Ukraine, aging water supply and sewerage structures and their outdated technological conditions became impending problem as well as other main infrastructures in the nation, the Nationwide Program of Reforming and Development of the Utilities Sector was formulated in 2004 by the government and the program stated to form detailed development plans and urgent implementations for the utilities which required urgent activities for reformulations.

The program has been revised in 2009 and the current target year is set at 2014. Kiev City has promoted its action plans under the guidance of the national government and the development project for the sewerage system is also a part of this program.

(A) Amended Nationwide Program for Reforming and Development of the Utilities Sector, 2004-2010

Totaling 1.4 million UAH of budgets is nominated for water supply and sewerage sectors during the project period in 2010 – 2014. The program stated urgent rehabilitations and reconstructions for aged and outdated facilities, the acceleration of energy saving and the improvement in revenue structures. The outline of Amended Nationwide Reforming and Development Program is shown in Table 2.4.

Table 2.4 Descriptions in Amended Nationwide Reforming and Development Program

Item	Unit	2010	2011	2012	2013	2014	Total
Reconstruction of Centralized Water Supply and Sewerage System	million UAH	340.3	586.5	227.6	140.8	120.0	1,415.2
	million EUR	31.3	54.0	20.9	13.0	11.0	130.2
Accomplishment of Action Plans (in Particular Capital Investments)	%	25	70	90	100	100	-
Percentage of Recovery of Revenues	%	-3~0	0~3	3~5	5~7	7~12	-
Reduction of Electric Energy for Water and Sewage Treatments	kWh/m^3	0.580	0.539	0.518	0.497	0.476	-

1 EUR = 10.87 UAH

Source: Amendment on Nationwide Program for Reforming and Development of the Utilities Sector, 2004-2010, the Government of Ukraine (2009)

(B) Nationwide Program for Drinking Water of Ukraine, 2011-2020

In this program, allocation of budgets and prioritized activities are raised to promote quick measures to recover the functions of deteriorated infrastructures for water supply and sewerage system and based on this nation program, action programs are formulated by city level entities.

(C) Amended Program for Reforming and Development of Utility Sector of the City of Kiev, 2010-2014

This is the detailed action plan in accordance with the nationwide program formulated in 2007 and current program was updated in 2010 and stated main activities and budget plan during the period of 2010 – 2014. As for the newest framework of effective decisions made by Ukrainian side, Resolution of the Cabinet of Ministers of Ukraine 27.02.2013 No.187 “On approval of the State program of activation of economic development for 2013-2014” and Decree of the Cabinet of Ministers of Ukraine of 17.10.2013 No.818p “On approval of the plan of priority measures to prevent manmade accidents n BAS” were announced in order to clarify the target of priority project objectives and to accelerate the reconstruction project in place.

The overview of Amended Program for Reforming and Development in Kiev City is summarized in Table 2.5.

Table 2.5 Overview of Amended Program for Reforming and Development in Kiev City

Unit: million UAH [million EUR]

Item	2010	2011	2012	2013	2014	Total
Reconstruction of Sludge Field No.1 & 2	26.00 [2.4]	82.80 [7.6]	44.65 [4.1]			153.45 [14.1]
Screen Chamber of Block 2 & 3, Kollectorna PS	4.52 [0.4]					4.52 [0.4]
Improvement of Sludge Treatment Process	13.58 [1.2]					13.58 [1.2]
Construction of 5 Main Collectors	213.60 [19.7]	439.30 [40.4]	371.80 [34.2]	120.00 [11.0]	143.90 [13.2]	1,288.60 [118.5]
Reconstruction of Sewage & Sludge Line in BAS	129.00 [11.9]	583.00 [53.6]	800.00 [73.6]	900.00 [82.8]	900.00 [82.8]	3,312.00 [304.7]
Total	386.70 [37.8]	1,105.10 [106.1]	1,216.45 [115.4]	1,020.00 [94.9]	1,043.90 [97.3]	4,772.15 [451.4]

Source: Decision on Approval of the Program for Reforming and Development of Utility Sector of the City of Kiev for 2010-2014, Kiev City (2010)

In this program, the wastewater flows are estimated in future stages and the target flow in 2012, as the Second Phase, was determined at 1,572,900 m^3/day.

The estimated sewage volume is shown in Table 2.6.

Table 2.6 Estimated Sewage Volume in Target Years

Items	Target Horizon	Sewage Amount (m^3/day)
Initial Stage	2003	1,077,700
First Phase	2011	1,245,600
Second Phase	2012	1,572,900

Source: Schemes of Water Supply and Sewage Systems of Kiev City by 2020, Kiev City (2007)

(6) Laws and Regulations in Relation to Water Environment Protection

Bortnychy Aeration Station is operated under the agreement among Kiev City and relevant state's authorities and KVK undertakes operation and maintenance works to meet the determined current agreed standard (valid until December 2014) for effluent. In addition, the national standards for discharging sewage from households and business utilities are also stipulated.

The current effluent standard is shown in Table 2.7.

Table 2.7 Effluent Criteria for the Treated Wastewater from BAS

No.	Indicator	mg/L
1	Suspended solids	15.00
2	BOD_5	15.00
3	COD_{Cr}	80.00
4	Mineralization	600.00
5	Sulphates	120.00
6	Chlorides	350.00
7	Ammonia nitrogen	8.90
8	Nitrites	3.30
9	Nitrates	45.00
10	Phosphates	8.00
11	Petroleum products	0.20
12	Synthetic surface active substances (anionic)	0.50
13	Total ferrum	0.33

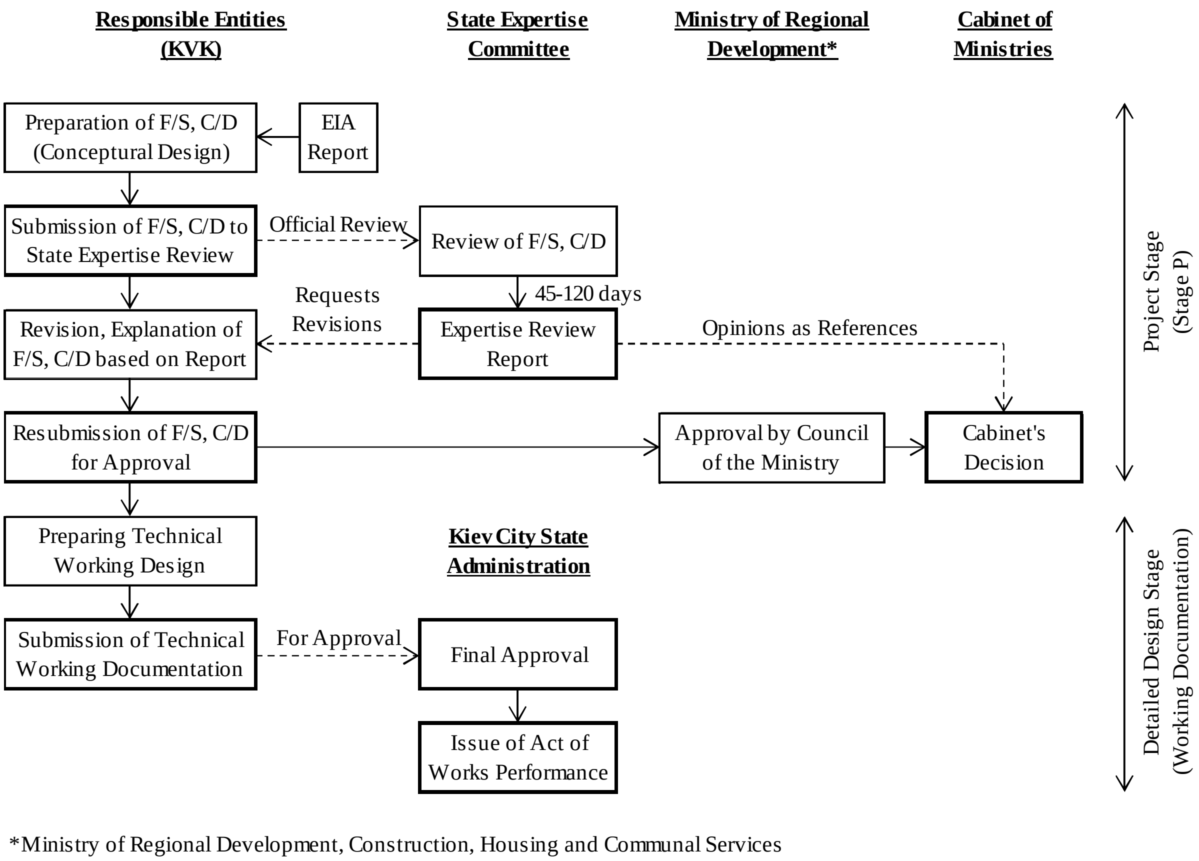
Source: State Administration for Environmental and Natural Resources Management in Kiev (2011)

(7) Process of Preparation and Approval of the Project

The reconstruction of BAS is required to be approved by the cabinet’s decisions as a large scaled project in related to infrastructures and the process consists two major parts called “Stage P (Project Stage)” and “Working Documentation (Detailed Designing Stage)”. For this project, KVK has prepared draft documents for the approval of “Stage P” and the documents are to be reviewed by the members of states expertise committee and the committee will prepare “review report” requesting revisions and further clarifications with supplemental information provided with the document.

KVK will revise the documents based on this report and resubmit the final version of “Stage P” documents applying for the official approvals from the council of Ministry of Regional Development, Construction, Housing and Communal Services and followed by the final decision of the cabinet of ministers. As for the working documentation stage, later stage of designing works is approved by Kiev City State Administration before the commencement of construction tendering for the final approval by issuing Act of Works Performance.

The simplified scheme of preparation and approval is shown in Figure 2.3.



Source: JICA Study Team

Figure 2.3 Scheme of Preparation and Approval of the Project

Bortnychy Aeration Station is operated under the agreement among Kiev City and relevant state's authorities and KVK undertakes operation and maintenance works to meet the determined current agreed standard (valid until December 2014) for effluent. In addition, the national standards for discharging sewage from households and business utilities are also stipulated. The current effluent standard is shown in Table 2.7.

2.2 Review of the Existing Feasibility Studies

KVK conducted two feasibilities in 2007 with assistance of Belinwasser-Ost and in 2012 with assistance of Sources, both studies were aimed to smooth promotions of the reconstruction project of BAS after the announcement of Amended Nationwide Program for Reforming and Development Program. This review was done based on the feasibility study prepared in 2012 (2012 F/S) which incorporated technical proposals from French Companies by updating up-to-date technologies.

(1) Design Criteria

The design criteria identified in the existing feasibility plan by KVK in 2011 were reviewed in the study and following characteristics were found:

- To cover the whole city area which is same as the current sewerage service area
- To target the year of 2021
- Future population was not determined and used officially stated future population in the general plan of Kiev City
- To adopt separate sewer system as same as the current system
- 1,573,000 m^3/day of design wastewater flow which comes from an authorized city plan

The design wastewater flow in 2012 F/S is shown in Table 2.9.

Table 2.8 Design Wastewater Flow in 2012 F/S

Item	Unit	Value (2021)
Daily Average Flow	m^3/day	1,123,600
Daily Maximum Flow	m^3/day	1,573,000
Hourly Maximum Flow	m^3/hour	81,800
Ratio of Daily Max Flow / Daily Average Flow	-	1.40
Ratio of Hourly Maximum Flow / Daily Maximum Flow	-	1.25

Source: KVK

The design capacity of each block was determined in 2012 F/S is shown in Table 2.10.

Table 2.9 Design Capacities by Water Treatment Line in 2012 F/S

Item	Unit	Value (2021)			
		Block 1	Block 2	Block 3	Total
Distribution Ratio	%	36.68	36.68	26.64	100.00
Ratio of Daily Max Flow / Daily Average Flow	-	1.40	1.40	1.40	1.40
Ratio of Hourly Maximum Flow / Daily Maximum Flow	-	1.25	1.25	1.25	1.25
Daily Average Flow	m^3/day	412,150	412,150	299,300	1,123,600
Daily Maximum Flow	m^3/day	577,000	577,000	419,000	1,573,000
Hourly Maximum Flow	m^3/hour	30,000	30,000	21,800	81,800

Source: KVK

The design effluent criteria were determined based on existing agreement applied to BAS. Among the items, nitrogen and phosphorus were added to the current design effluent criteria because of the demands in the future requirements while other items were set out based on the current agreement which is applied the present wastewater treatment plants.

The design effluent criteria in 2012 F/S is shown in Table 2.10.

Table 2.10 Design Effluent Criteria in the Existing Planning

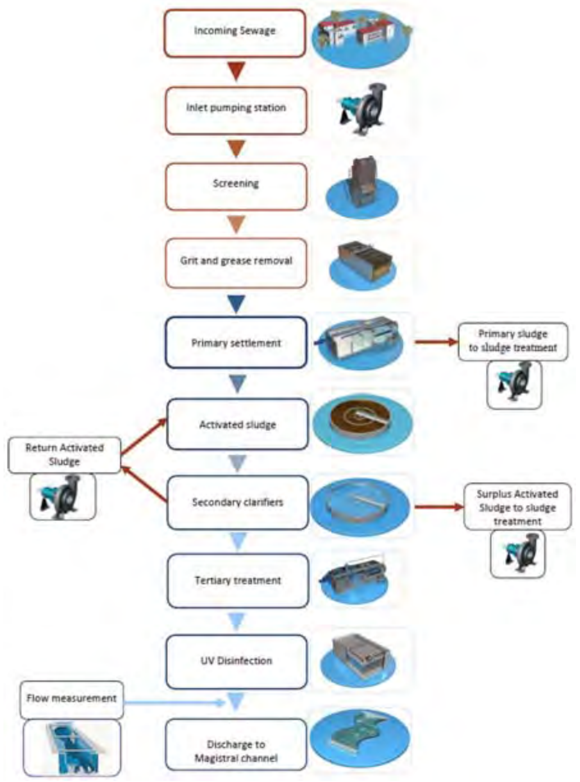
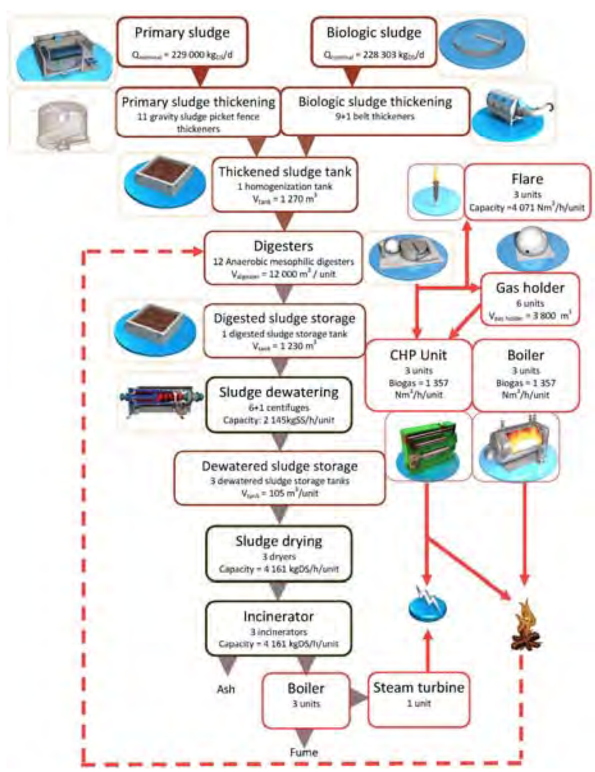
Item	Unit	Effluent Concentration (2021)
BOD_5	mg/L	15
COD_{Cr}	mg/L	80
TSS (Total Suspended Solid)	mg/L	15
Total N	mg/L	10
NH_4-N	mg/L	Not Specified
NO_2-N	mg/L	3.3
NO_3-N	mg/L	45
Total P	mg/L	1
Dissolved Oxygen	mg/L	4 or larger
Enterococci	units/100mL	400
E. Coliform	units/100mL	1,000

Source: KVK

(2) Proposed Process Flow

Process flows which were proposed in the existing feasibility plan were reviewed. Major characteristics of the proposed process are as in Table 2.11.

Table 2.11 Process Flow for Water and Sludge Treatment

<table>
<tr><th>Water Treatment Process</th><th>Sludge Treatment Process</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>

- Primary pumps, screens, sand basins and primary sedimentation process are covered and accommodated in building structures in order to eliminate emission of smells
- Introducing Anaerobic – Anoxic – Oxic Process for biological nitrogen and phosphorus removals
- Secondary sedimentation
- ACTIFLO Process for tertiary treatment process
- Ultraviolet lamps for disinfection

</td><td>

- Gravity and mechanical sludge thickening processes
- Anaerobic digestion and heat power production system
- Mechanical sludge dewatering
- Sludge incinerators

</td></tr>
</table>

Source: KVK

2.3 Survey on Water Quality and Inflow of Bortnychy Aeration Station

(1) Analysis on Water Quality of Sewage and Characteristics of Sludge

Water quality of sewage and characteristics of sludge were analyzed in this study. The results of analysis on water quality of sewage and characteristics of sludge are summarized as shown in Table 2.12.

Table 2.12 Results of Water Quality and Sludge Analysis

	Results of Analysis
Results of water quality analysis	Average of water qualities of raw sewage from 2008 to 2012 in BAS are followings: SS: 330 mg/l; BOD_5: 251 mg/l; COD_{Cr}: 668 mg/l; NH_4-N: 30.3 mg/l; PO_4: 18.08 mg/l; T-N*: 24.6 mg/l; T-P*: 6.2 mg/l *: T-N and T-P were measured in the study for reference purpose.
Results of sludge analysis	The characteristics of sludge measured by Japan CCL are as follows: ➢ Average solid contents of raw sludge and excess sludge are 2.32 % and 1.19 %, respectively ➢ Average ignition loss of raw sludge and excess sludge are 70.5 % and 71.9 %, respectively ➢ Average calorific value of raw sludge and excess sludge are 4,350 kcal/kg-dry and 3,836 kcal/kg-dry, respectively ➢ Sludge contains flammable sulfide from 0.40 dry-% to 0.76 dry-%. ➢ Sludge contains flammable chlorine from 0.15 dry-% to 0.69 dry-%.
Heavy metals contained in sewage and sludge	The characteristics of heavy metal concentrations in sewage in BAS and WWTPs in Japan were found to be very similar to each other. While high concentration of heavy metals in the sludge of BAS had been very significant, heavy metals such as Cd, As, Se and Hg contained in the samples of sludge were not detectable at present. Hence, the concentrations of heavy metals in sewage sludge produced from BAS have decreased significantly most probably owing to the relocation of the factories.

Source: JICA Study Team

(2) Analysis on Influent Flowrate

The results of analysis on influent flowrate are summarized as shown in Table 2.13.

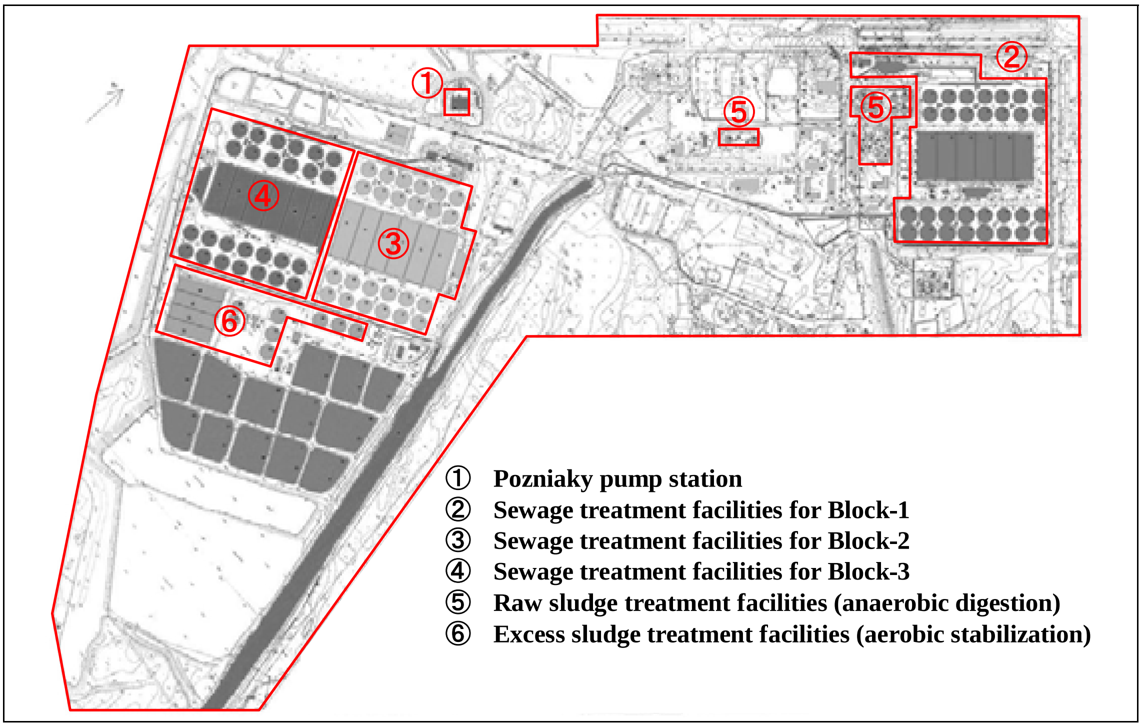
Table 2.13 Results of Influent Flowrate Analysis

	Results of Analysis
Average flow	➢ Influent flowrate from January to March was high ➢ Monthly average, maximum and minimum influent flowrates in 2012 were 796,394m^3/day, 882,121m^3/day and 722,935m^3/day, respectively
Daily maximum flow	➢ Daily maximum flow was observed on 25 Feb 2012 at 1,015,100m^3/day ➢ Ratio of daily maximum flow and daily mean flow was calculated at 1.30
Hourly maximum flow	➢ Hourly maximum flow was observed from 16:00 to 19:00 at 52,700m^3/hour ➢ Ratio of daily maximum flow and daily mean flow was calculated at 1.25

Source: JICA Study Team

2.4 Evaluation of the Existing Conditions of Bortnychy Aeration Station

Visual inspections were conducted at the location shown in Figure 2.4 in order to evaluate the existing conditions of the facilities of BAS.



Source: JICA Study Team

Figure 2.4 Groups of Evaluated Facilities

The reconstruction order of the evaluated facilities was prioritized taking the urgency and importance of the facilities into consideration. The priorities of the reconstruction are proposed as shown in Table 2.14.

Table 2.14 Priority of the Reconstruction of the Facilities

Facilities	Priority
Pozniaky pump station	C
Sewage treatment facilities for Block-1	A
Sewage treatment facilities for Block-2	B*1
Sewage treatment facilities for Block-3	B*1
Raw sludge treatment facilities	A
Excess sludge treatment facilities	A
Electrical facilities	B

Remark: A: high, B: middle, C: low
Remark *1: Overall priority is middle, but rehabilitation of mechanical and electrical equipment is given high priority.
Source: JICA Study Team

2.5 Evaluation of the Performances of Bortnychy Aeration Station

(1) Evaluation of the Performance of Operation of the Existing Facilities

The performance of operation of BAS is evaluated and summarized as shown in Table 2.15.

Table 2.15 Evaluation of the Performance of Operation of the Excising Facilities

Evaluation of performance of sewage treatment facilities
➢ 100% of monthly average of all blocks satisfy effluent standard for BOD_5 (15 mg/l) ➢ 100% of monthly average of all blocks satisfy effluent standard for COD_{Cr} (80 mg/l) ➢ 93% of monthly average of Block 1, 60% of Block 2 and 60% of Block 3 satisfy effluent standard for SS (15 mg/l) ➢ 23% of monthly average of Block 1, 7% of Block 2 and 13% of Block 3 satisfy effluent standard for total nitrogen (10 mg/l) even though removal efficacy is approximately 58% on average and considerably high for conventional treatment ➢ 73% of monthly average of Block 1, 40% of Block 2 and 30% of Block 3 satisfy effluent standard for total phosphorus (1 mg/l) since removal efficacy is approximately 66% on average and considerably high for conventional treatment ➢ Negative influence on effluent qualities caused by side stream from sludge treatment process is acknowledged since effluent qualities (SS and T-P) of Block 2 and Block 3 are worse than Block 1 ➢ Superiority of renovation of Block 3 is not acknowledged from the view point of nutrient removal (effluent of Block 3 is mixture of renovated system and old system and facilities are not adequately operated since no control system has been installed)
Evaluation of performance of sludge treatment facilities
➢ Digestion rate of anaerobic digestion is calculated as 24% on average and rather low since 50% is generally expected ➢ Digestion rate of aerobic stabilization is calculated as 9% on average and rather low since 40-50% is generally expected ➢ Both anaerobic digestion and aerobic stabilization are not effective according to the evaluation of performance from operation experiences
Evaluation of power consumption
➢ Percentage of power consumption of the WWTP in 2011 is 21%: pump stations, 66%: sewage treatment facilities, 11% sludge treatment facilities and 2% others ➢ Percentage of power consumption of the WWTP in 2012 is 18%: pump stations, 64%: sewage treatment facilities, 7% sludge treatment facilities and 11% others ➢ Unit power consumption of sewage treatment facilities for Block 1 is 40% higher than those for Block 2 and Block 3 due to several reasons such as the deterioration of the facilities, enhancing nitrogen removal, no aeration control with the exiting blowers etc.
Evaluation of operation indicator
➢ Surface loading of primary settling tanks is maintained 30-50 m^3/m^2day ➢ Unit air flow per sewage of Block 1 and Block 2 is considerable high while that of Block 3 is seemed to be reasonable ➢ Solid retention time (SRT) is 8-10 days on average and enough to retain nitrifying bacteria for nitrification of ammonium nitrogen ➢ Mixed liquor suspended solid (MLSS) of aeration tanks is maintained more than 3,000 mg/l ➢ Surface loading of secondary settling tanks is maintained 25-30 m^3/m^2day ➢ Sedimentation of activated sludge in secondary settling tanks is relatively good condition since sludge volume index (SVI) is kept less than 200 cm^3/g on average

Source: JICA Study Team

(2) Recommendation on Operation

Recommendations to improve operation of BAS considering the results of evaluation of operation experiences are summarized as shown in Table 2.16.

Table 2.16 Recommendations on Operation of the Excising Facilities

Anaerobic-Oxic Operation	
In anaerobic-oxic operation, an anaerobic condition is maintained in the front stage of aeration tanks while an aerobic condition is maintained in the latter stage. In the anaerobic zone, agitation is required in order to mix sewage and return sludge and prevent activated sludge from settling down. Hence, installation of agitators in anaerobic zones is preferable in order to create a complete anaerobic condition. However, it is also beneficial to reduce air flow amount so as to create pseudo anaerobic condition by utilizing the existing facilities. Further study and trial operation with the pilot-scale application are recommended before the full-scale application since effectiveness varies depending on actual operation conditions for every WWTP.	
Expected results	➢ Improvement of removal efficiency of nitrogen and phosphorous ➢ Improvement of sedimentation of activated sludge in secondary settling tanks ➢ Prevention of filamentous bulking ➢ Prevention of destruction of activated sludge caused by excess aeration ➢ Reduction of power consumption of the blowers
Aeration Control System	
Adjustment of aeration supplied to aeration tanks is important in order to improve the performance and efficiency of biological treatment. Optimization of aeration is possible by introducing blowers with flow control function, panels with control sequence of the blowers and instrumentation. There are following two control methods for optimization of aeration. The constant air capacity control method is a kind of control logic to adjust air flow so as to keep constant capacity of air against sewage amount. The DO control method is a kind of control logic to adjust air flow so as to keep designated dissolved oxygen in aeration tanks.	
Expected results	➢ Reduction of power consumption of the blowers ➢ Prevention of destruction of activated sludge caused by excess aeration ➢ Prevention of flotation of activated sludge in secondary settling tanks
Optimization of Sludge Treatment Process	
The performance of the existing sludge treatment facilities is deteriorated considering a rather low digestion rate. The limitation to continue the current sludge treatment from the viewpoint of sustainability is realized since sludge fields are almost full. The existing sludge treatment process also gives negative influence on sewage treatment process due to a side stream containing high secondary pollution load from sludge treatment facilities and inadequate sludge withdrawal from sewage treatment facilities. Those result from inadequate performance and capacity shortage of sludge treatment process. Hence, reconstruction of the entire sludge treatment process is inevitable.	
Expected results	➢ Securing the sustainability of sludge disposal ➢ Improvement of effluent quality by avoiding negative influences caused by sludge treatment process ➢ Reduction of unpleasant odorous compounds and greenhouse gases

Source: JICA Study Team

3. Facilities Planning of Bortnychy Aeration Station

3.1 Basics for Planning

(1) Basic Conditions

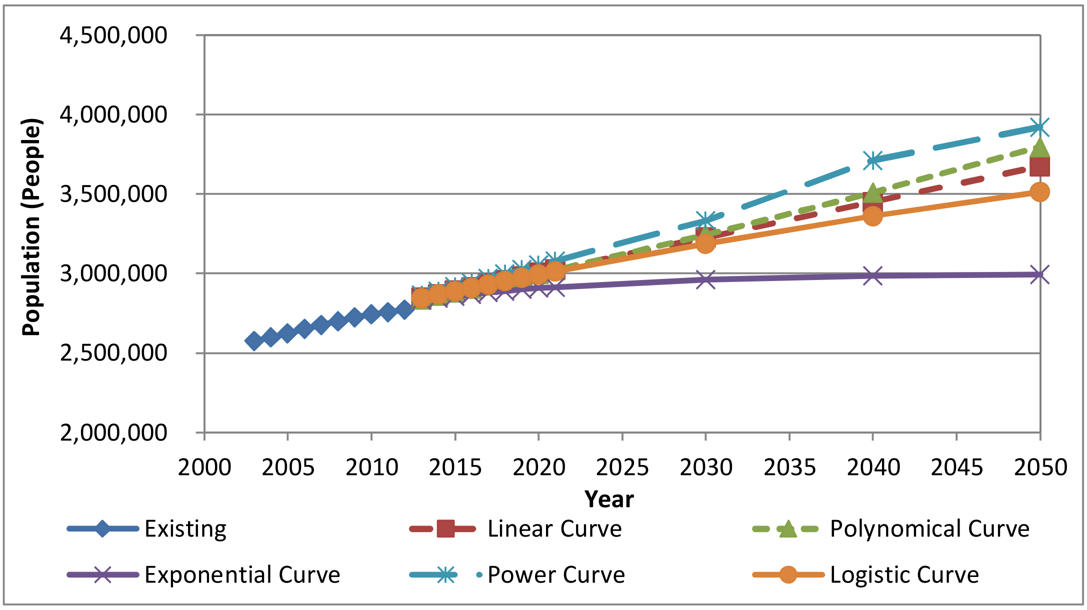
Basic conditions were determined in the following basis.

- Coverage area is whole Kiev City area as same as the current service area.
- Design horizon is set out in 2030 with intermediate year of 2021.
- Separate sewerage system is adopted as same as the current sewerage system

(2) Design Population

The design population was determined from comparisons in future projections using historical transitions obtained from the statistical information of the city in addition to the influences of external population, which practically treats its wastewater at BAS in the future states to 2030.

As a results of the comparison using mathematical analyses according to the actual transitions Eventually the design population was considered its stabled increasing tends from the historical figures and residential population in the city was proposed using Linear Curve for estimating population. The projection of future population is shown in Table 3.1 and Figure 3.1.



Source: JICA Study Team

Figure 3.1 Projection of Future Population in Kiev City

Table 3.1 Proposed Design Residential Population in Kiev City

Unit: People

Year	Projected Population (Linear Curve)	Design Population (Rounded Value)	Remarks
2012	2,814,300	2,814,300	Historical Value
2013	2,847,180	2,847,200	
2014	2,869,527	2,869,500	
2015	2,891,875	2,891,900	
2016	2,914,222	2,914,200	
2017	2,936,569	2,936,600	
2018	2,958,916	2,958,900	
2019	2,981,264	2,981,300	
2020	3,003,611	3,003,600	
2021	3,025,958	3,026,000	
2030	3,227,084	3,227,100	
2040	3,450,556	3,450,600	
2050	3,674,029	3,674,000	

Source: JICA Study Team

In addition, the external population was identified by using historical coverage ratio of 53% (as of 2013) in seven municipalities surrounding the city and the study estimated 100% of coverage will be attained in 2030 which currently utilize the sewerage system belonged to Kiev City.

Other external population which was contained in the city general plan, the estimated percent of coverage was assumed at 20% of connectivity rate of the total living population and the design population was proposed at 257,000 in 2030.

The proposed design external population in satellite municipalities is shown in Table 3.2.

Table 3.2 Proposed Design External Population in Satellite Municipalities

Unit: People

No.	Name	Category	Population	Assumed Ownership			Served Population		
			2013	2013	2021	2030	2013	2021	2030
1	Vyshgorod	Town	32,000	53%	77%	100%	16,960	24,500	32,000
2	Irpin	Town	76,900	53%	77%	100%	40,757	58,800	76,900
3	Vyshneve	Town	26,536	53%	77%	100%	14,064	20,300	26,500
4	Boryspil	Town	59,545	0%	10%	20%	0	6,000	11,900
5	Brovary	Town	98,250	0%	10%	20%	0	9,800	19,700
6	Bucha	Town	28,483	0%	10%	20%	0	2,800	5,700
7	Vasylkiv	Town	36,672	0%	10%	20%	0	3,700	7,300
8	Bila Tserkva	Town	210,919	0%	10%	20%	0	21,100	42,200
9	Berezan	Town	16,543	0%	10%	20%	0	1,700	3,300
10	Obykhiv	Town	33,102	0%	10%	20%	0	3,300	6,600
11	Boyarka	Town	35,320	0%	10%	20%	0	3,500	7,100
12	Ukrainka	Town	15,644	0%	10%	20%	0	1,600	3,100
13	Petropavlivska Borshchagivka	Village	6,125	53%	77%	100%	3,246	4,700	6,100
14	Sofiivska Borshchagivka	Village	6,571	53%	77%	100%	3,483	5,000	6,600
15	Novosilky	Village	941	53%	77%	100%	499	700	900
16	Bortnychi	Village	2,000	53%	77%	100%	1,060	1,500	2,000
-	Total	-	685,551	12%	25%	38%	80,069	169,000	257,900

Source: JICA Study Team

In total, design population was proposed at 3,485,000 in 2030. The summary of design population is summarized in Table 3.3.

Table 3.3 Summary of Design Population

Unit: People

Item	Description	Present	Estimated	
		2012	2021	2030
Proposed Served Population	Population in Kiev City	2,814,300	3,026,000	3,227,100
	Population in Satellite Towns	80,069	169,000	257,900
	Total	2,894,369	3,195,000	3,485,000
Feasibility Study	Sewerage Served Population	Not Specified		
Existing Sewerage Plan	Sewerage Served Population	Not Specified		
Unapproved General Plan	Population in Kiev City	3,144,900	-	3,680,000

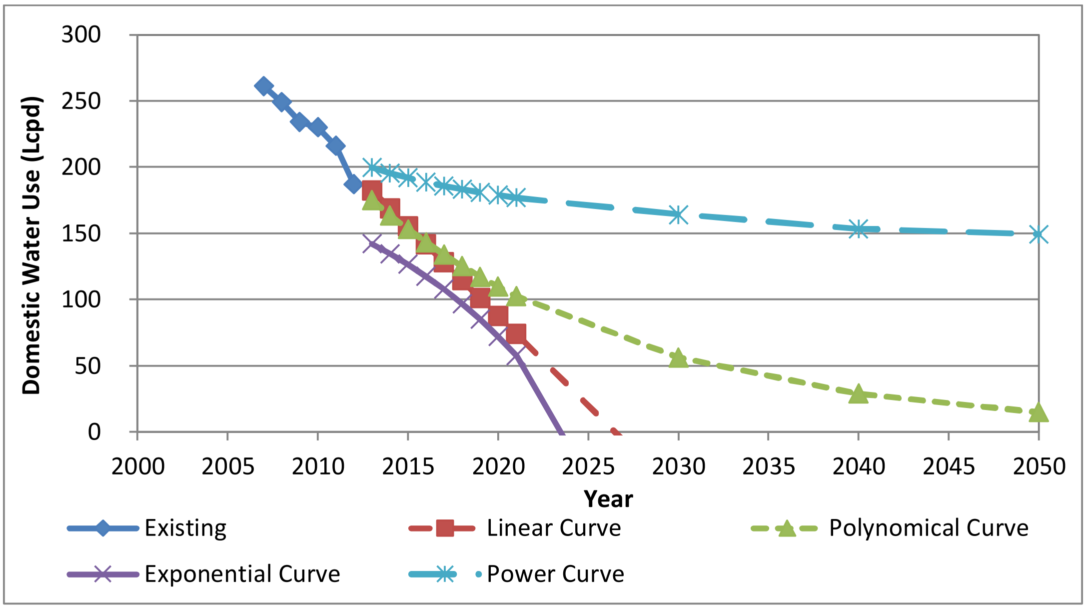
Source: JICA Study Team

(3) Design Wastewater Flow Rate

The design wastewater flow rates were calculated by determining domestic wastewater flow, which generally generated from daily water consumptions by residential population, industrial wastewater flow and underground water flow that infiltrates into the sewer network individually.

For determining domestic wastewater, unit wastewater flow was set at 200 L/people/day. The historical trends of per capita waster use were used for an analysis for its future projection by several regression curves. While any regressions indicate further decreasing, it was set out at 200 L/people/day by assuming that decreasing trends was influenced by significant reductions by the introduction of metered water supply system and the trend would be appeared temporally.

The results of future projection of domestic water supply are shown in Figure 3.2 and the design unit domestic wastewater flow is shown in Table 3.4.



Source: JICA Study Team

Figure 3.2 Projection of Unit Domestic Water Supply per Capita

Table 3.4 Design Unit Domestic Wastewater Flow

Unit: L/People/day

Year	Projected Water Use (Power Curve)	Design Domestic Wastewater per Capita	Remarks
2012	187	187	Historical Value
2013	200	200	
2014	195	200	
2015	192	200	
2016	189	200	
2017	186	200	
2018	183	200	
2019	181	200	
2020	179	200	
2021	177	200	
2030	164	200	

Source: JICA Study Team

The domestic wastewater flows were calculated by multiplying design population with unit domestic wastewater flow and yearly mean daily value was found out at 697,000 m^3/day in 2030. The design domestic wastewater flow is shown in Table 3.5.

Table 3.5 Design Domestic Wastewater Flows

Item	Unit	Present	Estimated	
		2012	2021	2030
Served Population	People	2,894,369	3,195,000	3,485,000
Unit Domestic Water Flow	L/People/day	187	200	200
Domestic Wastewater Flow	m^3/day	541,247	639,000	697,000

Source: JICA Study Team

The industrial wastewater flows were calculated at 21.5% of domestic wastewater flows from the comparisons of historical water supplies provided for industrial purposed in past years and future amount is estimated at 150,000 m^3/day at yearly mean value in 2030. The design industrial wastewater flows are summarized in Table 3.6.

Table 3.6 Design Industrial Wastewater Flows

Item		Unit	Present	Estimated	
			2012	2021	2030
Domestic Wastewater Flow		m^3/day	541,247	639,000	697,000
% of Industrial Wastewater		%	-	21.50%	21.50%
Industrial Wastewater Flow	Raw	m^3/day	127,052	137,385	149,855
	Rounded	m^3/day	-	137,000	150,000
Total		m^3/day	668,299	776,000	847,000

Source: JICA Study Team

Daily Maximum Wastewater Flows and Hourly Maximum Wastewater Flows were identified for dimensioning sewerage facilities from the historical behaviors in current BAS by giving ratios based on Daily Mean Wastewater Flows and the proportions were determined as Daily Mean Wastewater Flow : Daily Maximum Wastewater Flow : Hourly Maximum Wastewater Flow = 0.70 : 1.00 : 1.25.

The summary of design domestic and industrial wastewater flows is given in Table 3.7.

Table 3.7 Summary of Design Domestic and Industrial Wastewater Flows

Item		Ratio	Unit	Present	Estimated (Rounded)	
				2012	2021	2030
Daily Mean Wastewater Flow	Domestic	0.70	m^3/day	541,247	639,000	697,000
	Industrial		m^3/day	127,052	137,000	150,000
	Total		m^3/day	668,299	776,000	847,000
Daily Maximum Wastewater Flow	Domestic	1.00	m^3/day	773,210	913,000	996,000
	Industrial		m^3/day	181,503	196,000	214,000
	Total		m^3/day	954,713	1,109,000	1,210,000
Hourly Maximum Wastewater Flow	Domestic	1.25	m^3/day	966,513	1,141,000	1,245,000
	Industrial		m^3/day	226,879	245,000	268,000
	Total		m^3/day	1,193,391	1,386,000	1,513,000

Source: JICA Study Team

The Design Underground Water was determined at 30% of total generated wastewater flow which was discharged into the sewerage system by comparing historical inflows and water qualities into BAS in addition to the design parameters set in the previous development plans in Kiev City. The design underground water is shown in Table 3.8.

Table 3.8 Design Underground Water

Item		Unit	Present	Estimated (Rounded)	
			2012	2021	2030
Daily Mean Wastewater Flow	Domestic & Industry Wastewater	m^3/day	668,299	776,000	847,000
	Ratio of Underground Water	%	30.00%		
	Underground Water	m^3/day	200,490	233,000	254,000
Daily Maximum Wastewater Flow	Domestic & Industry Wastewater	m^3/day	954,713	1,109,000	1,210,000
	Ratio of Underground Water	%	30.00%		
	Underground Water	m^3/day	286,414	333,000	363,000
Hourly Maximum Wastewater Flow	Domestic & Industry Wastewater	m^3/day	1,193,391	1,386,000	1,513,000
	Ratio of Underground Water	%	30.00%		
	Underground Water	m^3/day	358,017	416,000	454,000

Source: JICA Study Team

Finally proposed design wastewater flows in the design horizon (2030) were calculated at 1,101,000 m^3/day as Daily Mean Wastewater Flow, 1,573,000 m^3/day as Daily Maximum Wastewater Flow and 1,967,000 m^3/day as Hourly Wastewater Flow.

The summary of design wastewater flows is shown in Table 3.9 and the comparison of the present and estimated design flows is shown in Table 3.10.

Table 3.9 Summary of Design Wastewater Flows

Item		Unit	Present	Estimated (Rounded)	
			2012	2021	2030
Daily Mean Wastewater Flow	Domestic Wastewater	m^3/day	541,247	639,000	697,000
	Industrial Wastewater	m^3/day	127,052	137,000	150,000
	Underground Water	m^3/day	200,490	233,000	254,000
	Total	m^3/day	868,789	1,009,000	1,101,000
Daily Maximum Wastewater Flow	Domestic Wastewater	m^3/day	773,210	913,000	996,000
	Industrial Wastewater	m^3/day	181,503	196,000	214,000
	Underground Water	m^3/day	286,414	333,000	363,000
	Total	m^3/day	1,241,127	1,442,000	1,573,000
Hourly Maximum Wastewater Flow	Domestic Wastewater	m^3/day	966,513	1,141,000	1,245,000
	Industrial Wastewater	m^3/day	226,879	245,000	268,000
	Underground Water	m^3/day	358,017	416,000	454,000
	Total	m^3/day	1,551,408	1,802,000	1,967,000

Source: JICA Study Team

Table 3.10 Comparisons of Proposed Design Flow (Daily Maximum)

Item	Unit	Present	Estimated	
		2012	2021	2030
Proposed Wastewater Flow	m^3/day	1,241,127	1,442,000	1,573,000
Feasibility Study	m^3/day	-	1,573,000	-
Existing Sewerage Plan	m^3/day	1,572,800	-	-
Unapproved General Plan	m^3/day	1,332,750	1,542,800	-

Source: JICA Study Team

(4) Design Water Qualities

Design influent qualities were identified by historical values at BAS and effluent qualities were determined based on the existing feasibility plan by KVK. The design influent and effluent qualities are shown in Table 3.11 and Table 3.12, respectively.

Table 3.11 Design Influent Qualities

Unit: mg/L

Item	Influent Quality (2021)		Influent Quality (2030)	
	Daily Mean Flow	Daily Max Flow	Daily Mean Flow	Daily Max Flow
BOD_5	270	203	270	203
COD_{Cr}	730	550	730	550
SS	350	264	350	263
T-N	50	38	50	38
T-P	5.9	4.6	5.9	4.6

Source: JICA Study Team

Table 3.12 Design Target Effluent Qualities

mg/L

Item	Target Effluent Quality	
	2021	2030
BOD_5	15	15
COD_{Cr}	80	80
SS	15	15
T-N	10	10
T-P	1	1

Source: JICA Study Team

3.2 Wastewater Treatment Process

(1) Secondary Treatment Process

The selection of wastewater treatment processes was conducted by considering the achievement of effluent criteria, capabilities of biological treatments for nitrogen and phosphorus, prerequisites in terms of land availability and other constrains when reconstruction projects for the existing treatment plants is implemented. The comparisons were made among three candidates from Conventional Activated Sludge Process (CAS Process), Anaerobic – Anoxic – Oxic Process (A2O Process) and Advanced Oxidation Ditch Process and finally Anaerobic – Anoxic – Oxic Process (A2O Process) was selected. In the existing study, preliminary designs of water treatment process were proposed using European technologies and modified Anaerobic – Anoxic – Oxic Process (A2O Process) using deep endless tanks on limited land for reconstruction sites. This treatment process is theoretically same as conventional Anaerobic – Anoxic – Oxic Process (A2O Process) and the study adopted the process as the proposed process. However, it is advised to conduct further considerations to prove the performances in biological nitrogen treatment especially in the winter seasons and optimized dimensioning in the detailed design process at the latter stages of the project.

(2) Tertiary Treatment Process

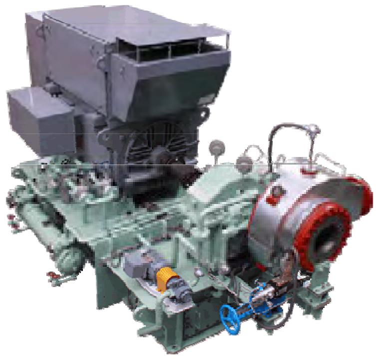
As for the tertiary treatment process which will be established in order to remove finer suspended particles and phosphorus contained in those substances, ACTIFLO Process was proposed as same as the existing feasibility study by comparing two alternatives from ACTIFLO Process and Disc Filter and the performances for phosphorus removals and smaller footprint were the main reasons of the selection.

As for disinfection process existing feasibility study proposed using ultraviolet lamps which are substituted by existing treatment philosophy because using chloride agent is restricted in order to protect the possibility of generating trihalomethane in the discharged water bodies, which aimed to follow the directions from EU. The study concluded that the use of ultraviolet lamps are quite proper solution for the treatment.

3.3 Selection of Sewage Treatment Equipment

The results and reasons of selections of sewage treatment equipment are summarized as shown in Table 3.13.

Table 3.13 Selection of Sewage Treatment Equipment

Aeration equipment	
Ultrafine bubble diffuser 	➢ It is most effective in terms of energy saving due to its high efficiency of dissolving oxygen. ➢ It can be utilized for a relatively longer time period due to its non-clogging feature in case of adequate operation. ➢ It has a high level of flexibility for various operations due to its feature of wide operational range of air flow. ➢ It is the most economical in terms of life cycle cost since it requires the lowest O&M cost due to its high efficiency.
Blower	
Gear-drive single stage turbo bower 	➢ Operation and maintenance is easier since the type of blower is the same as the existing blowers. ➢ Replacement of blowers is easily conducted in the same position owing to the same type and capacity as the existing blowers while multistage turbo blower requires modification of structures for installation. ➢ The number of blowers is minimized since larger capacity blowers can be manufactured. ➢ Efficiency is higher than that of multistage turbo blower in wide range of operation. ➢ It is the most economical option in terms of net present value.

Source: JICA Study Team

3.4 Selection of Sludge Treatment Process

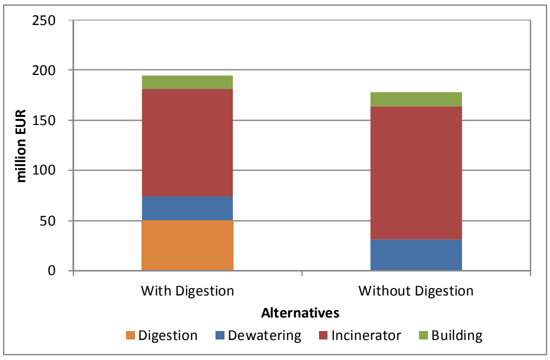
(1) With/Without Anaerobic Digestion Process

In the existing feasibility plan, thickened sludge would be sent to anaerobic digestion tanks and utilized to generate electricity and to heat gas tanks through CHP, or combined heat and power system. On the other hand, the existing anaerobic digestion system has been suffered from heavy corrosion in digestion tanks and part of the system has stopped operations for a long time. Moreover, additional heating energy is needed to maintain temperature inside the tanks by providing steam in all time and the system has problems in stabilized operations.

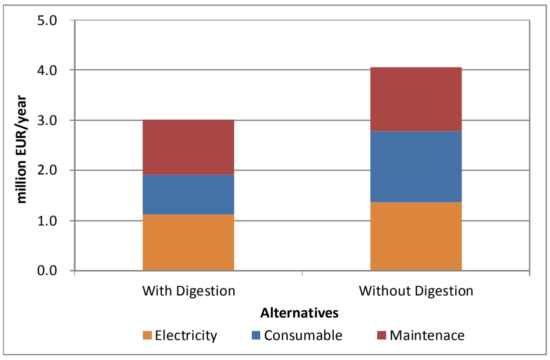
In this study, sludge treatment was proposed to be conducted without digestion process by comparing characteristics of processes in terms of generation of recycling materials, initial costs, O&M costs and net present values (NPV).

- In terms of recycled energy recovery comparing the system sludge incineration with anaerobic digestion and incineration without digestion, incineration process without digestion turned out producing lower energy because of smaller supplemental heat generated
- Initial costs for incineration without digestion became less investment when the comparisons were made under the assumption that main equipment was to be procured using Japanese technology
- O&M costs showed lower in incineration with anaerobic digestion, however NPV turned out that incineration without digestion became more competitive during the life time period
- Interference of biological phosphorus removal in anaerobic digestion process because release of phosphorus component occurs when sludge is kept in anaerobic condition after the uptake of phosphorus from liquid phase in the aeration tank on account of biological removal process in the water treatment process
- Some of equipment proposed in F/S for anaerobic digestion has not been commonly applied in Japanese practices and it can't be contained in the process flow using Japanese products when the STEP (Special Terms for Economic Partnership) conditions are deemed as prerequisite
- The system using digestion process require complicated procedures to maintain the system fully functional throughout the season as well as the commencement period of the system which needs to consider lower productivity until the time when design flow comes to BAS

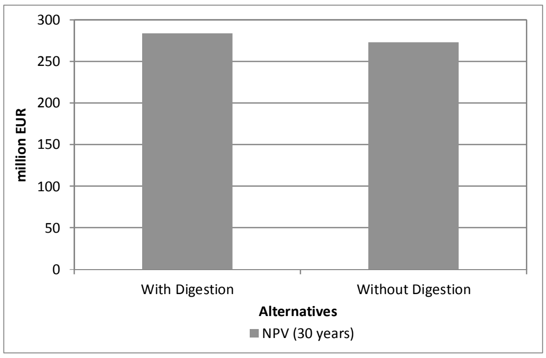
The comparisons of initial investment costs, O&M costs, NPV are shown in Figure 3.3.



Initial Costs



O&M



NPV (30 years)

Source: JICA Study Team

Figure 3.3 Comparisons of Initial Costs, O&M Costs and NPV

(2) Final Disposal of Sewage Sludge

Final disposal of sewage sludge should be considered mainly from the viewpoints of sustainability and mitigation of environmental impact. Nowadays, utilization of sewage sludge is encouraged so as to assist the establishment of material recycling society. The final form of sewage sludge is ash since the sludge treatment process includes incineration. Utilization of ash as construction materials is summarized as shown in Table 3.14.

Table 3.14 Utilization of Ash as Construction Materials

Utilization	Contents
Ingredient of Cement	The chemical components of ash are generally similar to those of clay ingredient for cement. Hence, ash is utilized to produce cement as substitute of clay.
Ingredient of Asphalt Mixture	Ash is utilized to produce asphalt mixture as substitute of asphalt filler.
Concrete Products	Ash is utilized to produce concrete products such as interlocking blocks, reinforced concrete pipes, street gully and system manhole.
Calcination Products	Ash is utilized to produce calcination products such as tiles, bricks (normal brick, interlocking brick, etc.), clay pipes, aggregate and soil improvement material.

Source: JICA Study Team

It is inevitable to find utilization options showing stable demand for a long period of time in order to ensure sustainable utilizations of sewage sludge as construction materials. Hence, it is important to conduct market research to understand the possibility of utilization, market scale, demand estimates, willingness to pay for the products, marketing routes and so forth. Viewpoints of market research are summarized as below.

- Analysis of demand (Quantity demanded, users, compatibility with requirement of users, etc.)
- Analysis of sales efficiency (Marketing routes, marketing methods, sales promotion, necessity and selection of channel of distribution, etic.)
- Analysis of business environment (Socio-economic environment, sales competition, trend of business conditions, influences of other markets, influences of politics and legislations, etc.)

3.5 Selection of Sludge Treatment Equipment

The results and reasons of selections of sludge treatment equipment are summarized as shown in Table 3.15.

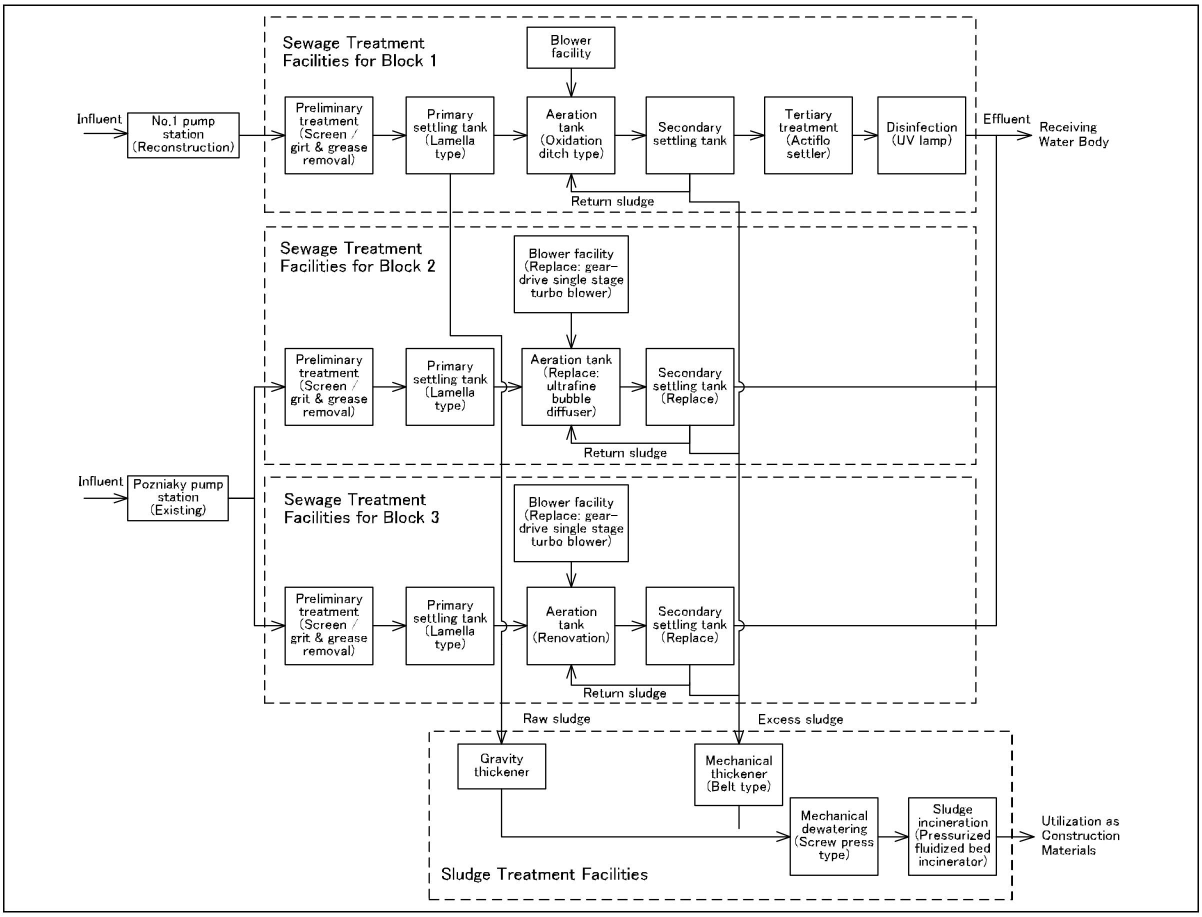
Table 3.15 Selection of Sludge Treatment Equipment

Mechanical thickener	
Belt type thickener 	➢ Operation and maintenance cost is the least owing to lowest energy consumption and maintenance cost. ➢ Initial investment is the lowest. ➢ Maintenance is relatively easy and is handled at the site by maintenance staff. ➢ Belt type thickener can achieve stable operation by adjusting running speed of belts, dosing rate of coagulant and sludge feeding amount according to characteristics of excess sludge. ➢ It is the most economical option in terms of net present value.
Mechanical dewatering	
Screw press dewatering machine 	➢ Operation and maintenance cost is the least due to lowest energy consumption and maintenance cost. ➢ Maintenance is relatively easy since belt press requires periodical replacement of belts and centrifugal dewatering machine requires to be taken to factories to replace edges. ➢ Screw press can optimize operation by adjusting screw rotation speed, dosing rate of coagulant, mixing speed of flocculation devices, feeding pressure, pressure of presser and sludge feeding amount according to sludge characteristics. ➢ It is the most economical option in terms of net present value.
Sludge incinerator	
Pressurized fluidized bed incinerator 	➢ Operation and maintenance cost is less owing to lower energy consumption and maintenance cost. ➢ Initial investment is less owing to the compact facilities. ➢ Total emission of greenhouse gas is less owing to pressurized combustion, higher partial pressure of oxygen and decomposition of N_2O. ➢ Operation under low loading condition is easier since PFBI can be operated efficiently with less combustion air. ➢ It is the most economical option in terms of net present value

Source: JICA Study Team

3.6 Proposed Optimum Plan

The schematic flow of the optimized treatment process recommended for BAS is shown in Figure 3.4.



Source: JICA Study Team

Figure 3.4 Schematic Flow of Treatment Process

3.7 Reconstruction Plan of Sewage Treatment Facilities for Block 2 and Block 3

Outlines of reconstruction plan of sewage treatment facilities for Block 2 and Block 3 are summarized in Table 3.16.

Table 3.16 Outlines of Reconstruction Plan of Sewage Treatment Facilities

No	Works	Scope of reconstruction plan
1.	Secondary treatment facilities for Block 2	
1-1	Civil and architecture works	➢ Removing degraded concrete surface by 10mm thickness and refilling with mortar by 30mm thickness for aeration tank ➢ Painting for blower building ➢ Reconstruction of trough supports for secondary settling tank ➢ Laying bypass pipes from primary treatment to aeration tank
1-2	Mechanical and electrical works	➢ Replacement of air diffuser for aeration tank ➢ Replacement of blowers, filters and crane of blower building ➢ Replacement of sludge collectors and gates for secondary settling tank ➢ Installation of electrical panel and instrumentation

No	Works	Scope of reconstruction plan
2.	Secondary treatment facilities for Block 3	
2-1	Civil and architecture works	➢ Removing degraded concrete surface by 10mm thickness and refilling with mortar by 30mm thickness for aeration tank ➢ Constructing dividing walls and corner walls to renovate as endless channel type aeration tank ➢ Painting for blower building ➢ Removing degraded concrete surface by 10mm thickness and refilling with mortar by 20mm thickness for secondary settling tank ➢ Laying bypass pipes from primary treatment to aeration tank
2-2	Mechanical and electrical works	➢ Replacement of air diffuser and installation of gates and mixers for aeration tank ➢ Replacement of blowers, filters and crane of blower building ➢ Replacement of sludge collectors and gates for secondary settling tank ➢ Installation of electrical panel and instrumentation

Source: JICA Study Team

3.8 Facility Planning

The outlines of the facilities are summarized in Table 3.17. The general layout of the facilities is shown in Figure 3.5 .

Table 3.17 Outlines of Facilities Planning

No	Facilities / Dimension / Specification	Number
1.	Preliminary and primary treatment facilities for Block 1	
1-1	1st stage fine screen (channel: 2.5m)	5 nos. (1 standby)
1-2	2nd stage fine screen (channel: 2.5m)	5 nos. (1 standby)
1.3	Grit and grease removal (8mW * 31mL)	5 channels
1.4	Primary settling tank (lamella type: 16mW * 16mL * 8mD)	14 tanks
2	Secondary treatment facilities for Block 1	
2.1	Aeration tank (oxidation ditch type)	4 nos.
2.2	Secondary settling tank (diameter 59m × 5mD)	12 tanks.
2.3	Return activated sludge pump ($33m^3$/min × 12m × 110kW)	16 nos. (4 standbys)
2.4	Sludge collector (circular type)	12 nos.
2.5	Blower building	2 nos.
2.6	Blower ($340m^3$/min × 95kPa × 710kW)	12 nos. (4 standbys)
3.	Tertiary treatment facilities for Block 1	
3-1	Actiflo settler	4 tanks
4.	Disinfection facilities for Block 1	
4-1	Disinfection channel (UV lamp)	4 channels
5.	Preliminary and primary treatment facilities for Block 2	

No	Facilities / Dimension / Specification	Number
5-1	1st stage fine screen (channel: 2.5m)	5 nos. (1 standby)
5-2	2nd stage fine screen (channel: 2.5m)	5 nos. (1 standby)
5.3	Grit and grease removal (8mW * 31mL)	5 channels
5.4	Primary settling tank (lamella type: 16mW * 16mL * 8mD)	14 tanks
6.	Preliminary and primary treatment facilities for Block 3	
6-1	1st stage fine screen (channel: 2.5m)	4 nos. (1 standby)
6-2	2nd stage fine screen (channel: 2.5m)	4 nos. (1 standby)
6.3	Grit and grease removal (8mW * 31mL)	4 channels
6.4	Primary settling tank (lamella type: 16mW * 16mL * 8mD)	10 tanks
7.	Reconstruction of secondary treatment facilities for Block 2	Refer to Table 3.16
8.	Reconstruction of secondary treatment facilities for Block 3	Refer to Table 3.16
9.	Gravity thickener facilities	
9-1	Gravity thickener (diameter 33m × 4mD)	4 tanks
9-2	Sludge collector (circular type)	4 nos.
10.	Mechanical thickening facilities	
10-1	Belt type thickener (capacity: 150m^3/hour)	9 nos. (1 standby)
10-2	Polymer preparation tank (continuing type)	2 nos.
11.	Mechanical dewatering facilities	
11-1	Screw press dewatering machine (diameter 1200mm*2 screw)	10 nos. (1 standby)
11-2	Polymer preparation tank (continuing type)	6 nos.
11-3	Sludge cake silo (capacity: 140m^3)	1 no.
11-4	Sludge cake hopper	1 no.
11-5	Sludge cake receiving hopper	1 no.
11-6	Sludge cake pump (from sludge cake silo to incinerator)	4 nos.
11-7	Sludge cake pump (from receiving hopper to sludge cake silo)	1 no.
12.	Sludge incineration facilities	
12-1	Pressurized fluidized bed incinerator (capacity: 425ton/day)	4 nos.
12-2	Steam turbine generation system	1 no.
13.	Common facilities	
13-1	Administration building (5 stories building)	1 no.
13-2	SCADA system	1 set
13-3	CCTV system	1 set
13-4	Laboratory building (4 stories building)	1 no.

Source: JICA Study Team

Source: JICA Study Team

Figure 3.5 General Layout

4. Cost Estimation and Implementation Schedule

4.1 Project Cost

(1) Condition of Cost Estimation

The project cost is estimated based on the conditions stated below.

- The project cost comprises construction cost, administration cost, engineering cost, contingency (physical and price escalation), interest during construction, commitment charge (front end fee) and relevant taxes.
- The project cost is composed of a local currency potion (L.C.) and a foreign currency portion (F.C.).
- Administration cost in recipient country is assumed to be 5.0 percent of the construction cost.
- Engineering cost is estimated based on man-months of consulting services.
- Physical contingency is considered as 5.0 percent of total of construction cost and engineering cost.
- Price contingency of 6.0 percent per annum for the local currency portion and 1.3 percent per annum for the foreign currency portion are applied based on implementation schedule shown in Table 4.7.
- The base period of cost estimation is December in 2013 and the exchange rate is considered to be 1 UAH=11.93 Yen, 1 Euro=129.64 Yen and 1Euro=10.87 UAH.
- Interest during construction is estimated considering that Project cost is financed by Japanese ODA loan. (Loan condition: Special Terms of Economic Partnership (STEP), Interest rate for main components=0.10%, Interest rate for consulting services=0.01%, Repayment period=40 years, Grace period=10 years)
- Front end fee is imposed by 0.2% of the commitment amount. (The rate of 0.1% is retroactively applied instead of 0.2% in the event that all disbursement is completed within the original disbursement period.)
- Customs rate is 5 % for imported goods taking the Customs tariff of Ukraine into account, and tax rate, i.e. value added tax, in Ukraine is 20 %.
- Construction cost, engineering cost contingency (physical and price escalation), interest during construction and front end fee are portions eligible for ODA loan, while administration cost and relevant taxes are portions non-eligible for ODA loan, considering that the Project cost is to be financed by a Japanese ODA loan.

(2) Options of the Project Financed by Japanese ODA Loan

All of the activities for reconstructing BAS require a large amount of investment to complete. Hence, KVK has prioritized activities necessary for reconstructing the WWTP and decided the scope of activities for Project Stage 1 considering urgency, improvement of performance, investment efficiency, etc. Then, the prioritized activities are classified into the following five components as shown in Table 4.1 considering functions of facilities and size of investment.

Table 4.1 Components of Prioritized Activities

Component	Main works
Component 0 (C0)	Dismantling of the existing facilities Land preparation of the WWTP site
Component 1 (C1)	Preliminary treatment facilities for block 2 and block 3 Primary treatment facilities for block 2 and block 3 Rehabilitation of existing secondary treatment for block 2 Rehabilitation of part of existing secondary treatment for block 3
Component 2 (C2)	Gravity thickener Mechanical thickening facilities Mechanical dewatering facilities Administration building and laboratory building
Component 3 (C3)	Sludge incineration facilities
Component 4 (C4)	Preliminary treatment facilities for block 1 Primary treatment facilities for block 1 Secondary treatment facilities for block 1 Tertiary treatment and disinfection facilities for block 1

Source: JICA Study Team

KVK has decided to implement the package of activities listed in Component 0 (C0) using own funds since these preparation works for main construction works are technically and financially manageable by KVK. The following options of scope of packages shown in Table 4.2 are proposed in order to allow financial investment institutions to make investment decision considering financial resources.

Table 4.2 Options of the Project Financed by Japanese ODA Loan

Option	Components included in Options
Option 1	Component 1 (C1), Component 2 (C2), Component 3 (C3) and Component 4 (C4)
Option 2	Component 2 (C2), Component 3 (C3) and Component 4 (C4)
Option 3	Component 2 (C2) and Component 3 (C3)

Source: JICA Study Team

(3) Estimated Project Cost of Option 1

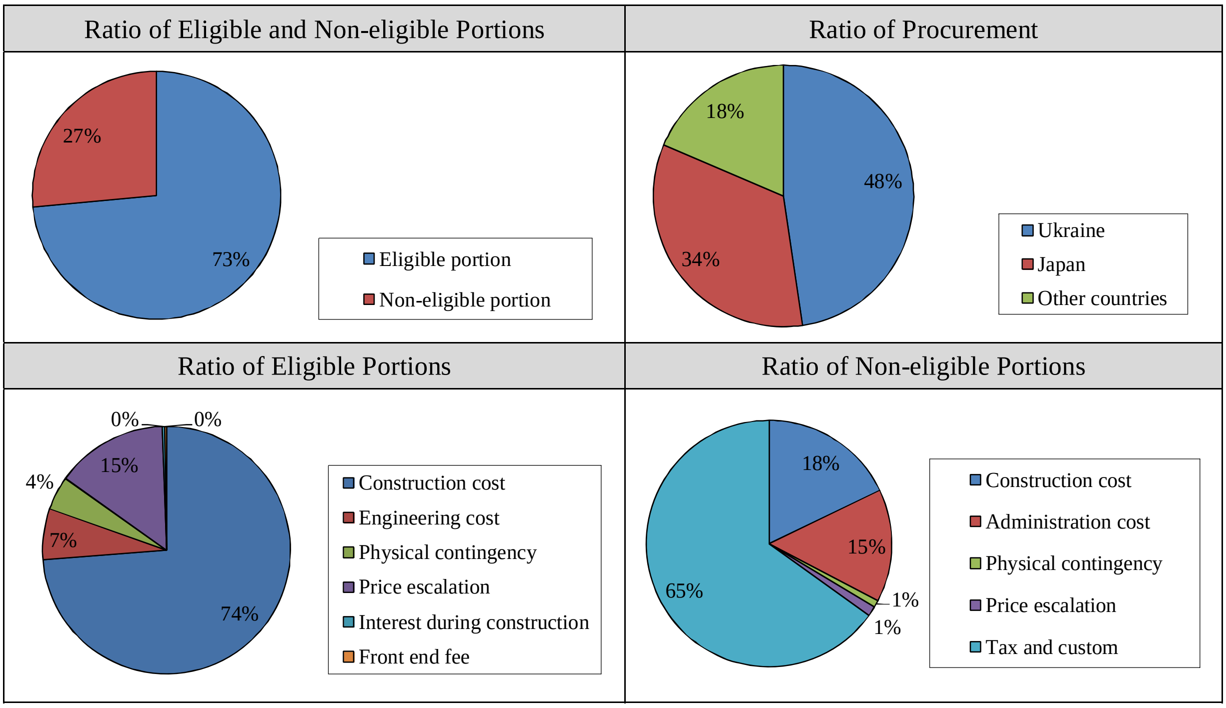
Cost estimation of Option 1 has been carried out and is shown in Table 4.3. The estimated project cost for the Project is 1,123 million Euro (JPY 145.5 billion). The eligible portions of the estimated project cost for the Project is 825 million Euro (JPY 106.9 billion) while non-eligible portions of the estimated project cost for the Project is 298 million Euro (JPY 38.6 billion).

Table 4.3 Estimated Project Cost of Option 1

No	Items	L.C. (1,000 Euro)	F.C. (1,000 Euro)	Total (1,000 Euro)
	Eligible portions for JICA ODA Loan			
1.	Construction cost			
A	Component 1	75,685	57,816	133,501
B	Component 2	65,029	40,106	105,135
C	Component 3	36,766	145,965	182,731
D	Component 4	112,788	74,495	187,283
	Sub-total of 1	**290,268**	**318,382**	**608,650**
2.	Engineering cost	26,970	27,577	54,547
3.	Physical contingency	19,470	16,983	36,453
4.	Price contingency	99,159	21,282	120,441
5.	Interest during construction	0	3,051	3,051
6.	Front end fee	0	1,646	1,646
	Sub-total of (2-6)	**145,599**	**70,539**	**216,138**
	Total of eligible portions	**435,867**	**388,921**	**824,788**
	Non-eligible portions for JICA ODA Loan			
1.	Construction cost			
A	Component 0	53,266	0	53,266
	Sub-total of 1	**53,266**	**0**	**53,266**
2.	Administration cost	44,000	0	44,000
3.	Physical contingency	2,860	0	2,860
4.	Price contingency	3,912	0	3,912
5.	Tax and duty	193,824	0	193,824
	Sub-total of (2-5)	**244,596**	**0**	**244,596**
	Total of non-eligible portions	**297,862**	**0**	**297,862**
	Total	**733,729**	**388,921**	**1,122,650**

Source: JICA Study Team

The ratio of eligible and non-eligible portions, the ratio of the goods and services procured for the construction works and the ratio of the estimated project cost are shown in Figure 4.1.



Source: JICA Study Team

Figure 4.1 Analysis of Project Cost of Option 1

(4) Estimated Project Cost of Option 2

Cost estimation of Option 2 has been carried out and is shown in Table 4.4. The estimated project cost for the Project is 895 million Euro (JPY 116.1 billion). The eligible portions of the estimated project cost for the Project is 645 million Euro (JPY 83.7 billion) while non-eligible portions of the estimated project cost for the Project is 250 million Euro (JPY 32.4 billion).

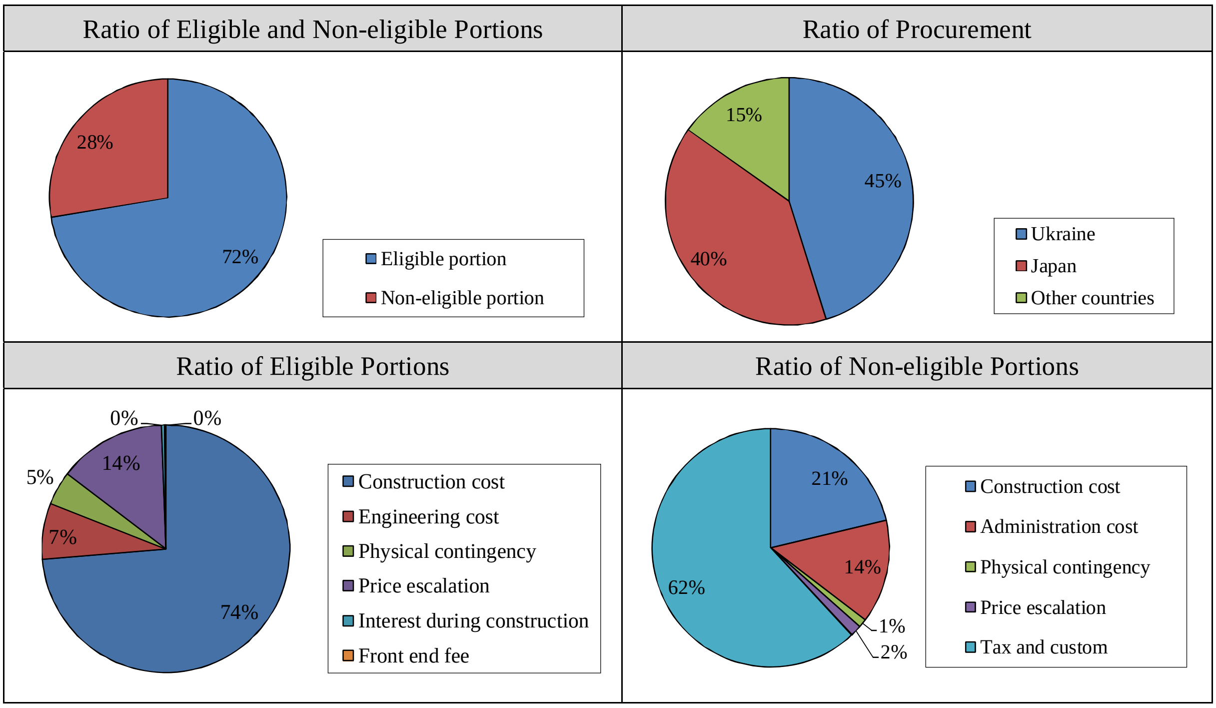
Table 4.4 Estimated Project Cost of Option 2

No	Items	L.C. (1,000 Euro)	F.C. (1,000 Euro)	Total (1,000 Euro)
	Eligible portions for JICA ODA Loan			
1.	Construction cost			
A	Component 2	65,029	40,106	105,135
B	Component 3	36,766	145,965	182,731
C	Component 4	112,788	74,495	187,283
	Sub-total of 1	**214,583**	**260,566**	**475,149**
2.	Engineering cost	24,568	22,935	47,503
3.	Physical contingency	14,398	13,898	28,296
4.	Price contingency	73,324	17,417	90,741
5.	Interest during construction	0	2,372	2,372
6.	Front end fee	0	1,288	1,288

No	Items	L.C. (1,000 Euro)	F.C. (1,000 Euro)	Total (1,000 Euro)
	Sub-total of (2-6)	**112,290**	**57,910**	**170,200**
	Total of eligible portions	**326,873**	**318,476**	**645,349**
	Non-eligible portions for JICA ODA Loan			
1.	Construction cost			
A	Component 0	53,266	0	53,266
	Sub-total of 1	**53,266**	**0**	**53,266**
2.	Administration cost	35,083	0	35,083
3.	Physical contingency	2,859	0	2,859
4.	Price contingency	3,913	0	3,913
5.	Tax and duty	154,921	0	154,921
	Sub-total of (2-5)	**196,776**	**0**	**196,776**
	Total of non-eligible portions	**250,042**	**0**	**250,042**
	Total	**576,915**	**318,476**	**895,391**

Source: JICA Study Team

The ratio of eligible and non-eligible portions, the ratio of the goods and services procured for the construction works and the ratio of the estimated project cost are shown in Figure 4.2.



Source: JICA Study Team

Figure 4.2 Analysis of Project Cost of Option 2

(5) Estimated Project Cost of Option 3

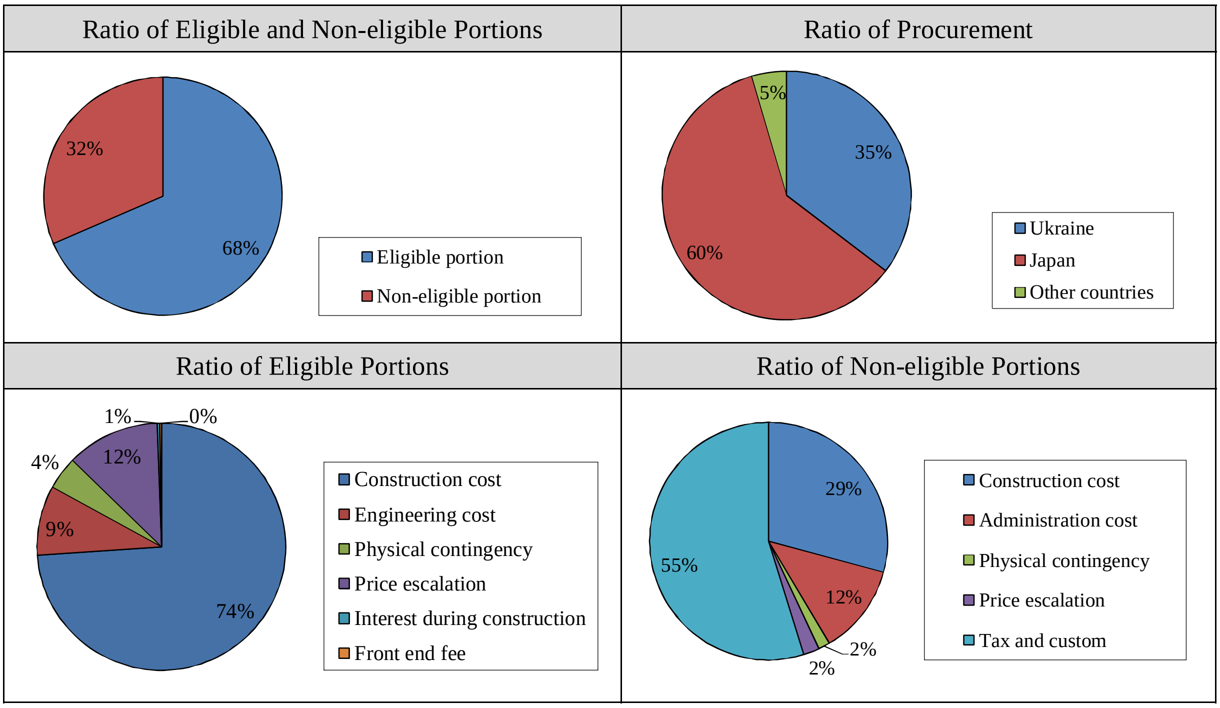
Cost estimation of Option 3 has been carried out and is shown in Table 4.5. The estimated project cost for the Project is 572 million Euro (JPY 74.2 billion). The eligible portions of the estimated project cost for the Project is 390 million Euro (JPY 50.5 billion) while non-eligible portions of the estimated project cost for the Project is 182 million Euro (JPY 23.6 billion).

Table 4.5 Estimated Project Cost of Option 3

No	Items	L.C. (1,000 Euro)	F.C. (1,000 Euro)	Total (1,000 Euro)
	Eligible portions for JICA ODA Loan			
1.	Construction cost			
A	Component 2	65,029	40,106	105,135
B	Component 3	36,766	145,965	182,731
	Sub-total of 1	**101,795**	**186,071**	**287,866**
2.	Engineering cost	19,806	15,893	35,699
3.	Physical contingency	6,832	9,925	16,757
4.	Price contingency	34,792	12,438	47,230
5.	Interest during construction	0	1,410	1,410
6.	Front end fee	0	778	778
	Sub-total of (2-6)	**61,430**	**40,444**	**101,874**
	Total of eligible portions	**163,225**	**226,515**	**389,740**
	Non-eligible portions for JICA ODA Loan			
1.	Construction cost			
A	Component 0	53,266	0	53,266
	Sub-total of 1	**53,266**	**0**	**53,266**
2.	Administration cost	22,378	0	22,378
3.	Physical contingency	2,859	0	2,859
4.	Price contingency	3,912	0	3,912
5.	Tax and duty	99,931	0	99,931
	Sub-total of (2-5)	**129,080**	**0**	**129,080**
	Total of non-eligible portions	**182,346**	**0**	**182,346**
	Total	**345,571**	**226,515**	**572,086**

Source: JICA Study Team

The ratio of eligible and non-eligible portions, the ratio of the goods and services procured for the construction works and the ratio of the estimated project cost are shown in Figure 4.3.



Source: JICA Study Team

Figure 4.3 Analysis of Project Cost of Option 3

(6) Estimated Operation and Maintenance Cost

The operation and maintenance cost required for operating BAS after implementation of the Project is estimated and summarized in Table 4.6. Annual operation and maintenance cost in the condition of receiving design flow is 50.5 million Euro/year (6.6 billion Yen/year).

Table 4.6 Estimated Anuial Operation and Maintenance Cost

No	Items	Total (1,000 Euro)
1.	Salary	5,113
2.	Electricity	21,836
3.	Maintenance	4,135
4.	Disposal of ash	969
5.	Consumables	13,883
6.	Others	4,594
	Total	**50,530**

Source: JICA Study Team

4.2 Implementation Schedule and Disbursement Schedule of Priority Project

(1) Implementation Schedule

If the Project is financed through Japanese ODA Loan, the Government of Ukraine must follow JICA procurement guidelines for the selection of the consultants and contractors to implement the Project. Implementation schedule starting from the signing of Loan Agreement has been developed as shown in Table 4.7 taking into account necessary steps that would be required. Implementation of the project has been estimated to extend to over 96 months (8 years) in total.

Table 4.7 Implementation Schedule

	Period	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
Signing of LA	-	▼								
Selection of Consultant	9 months	■	■							
Detailed Design	15 months		■	■						
Selection of Contractor	12 months			■	■					
Land Preparation	30 months	■	■	■						
Construction Works	48 months				■	■	■	■	■	
Trial Operation Period	12 months								■	■

Source: JICA Study Team

(2) Disbursement Schedule of Option 1

The disbursement schedule of Option 1 based on the implementation schedule has been prepared as shown in Table 4.8.

Table 4.8 Disbursement Schedule of Option 1

(Million Euro)

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Total
Eligible portions of the project cost										
L.C	00.0	2.65	2.55	48.14	100.91	107.00	113.45	60.65	0.53	435.87
F.C	1.65	3.66	4.12	46.94	92.41	93.88	95.32	49.52	1.41	388.92
Total	1.65	6.30	6.67	95.08	193.32	200.88	208.77	110.07	1.94	824.79
Non-eligible portions of the project cost										
L.C	13.98	31.22	33.09	25.92	52.65	54.55	56.53	29.63	0.29	297.86
F.C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	13.98	31.22	33.09	25.92	52.65	54.55	56.53	29.63	0.29	297.86
Total project cost										
L.C	13.98	33.87	35.54	74.06	153.56	161.55	169.98	90.28	0.82	733.73
F.C	1.65	3.66	4.12	46.94	92.41	93.88	95.32	49.52	1.41	388.92
Total	15.63	37.53	39.66	121.00	245.97	255.43	265.30	139.80	2.23	1,122.65

Source: JICA Study Team

(3) Disbursement Schedule of Option 2

The disbursement schedule of Option 2 based on the implementation schedule has been prepared as shown in Table 4.9.

Table 4.9 Disbursement Schedule of Option 2

(Million Euro)

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Total
Eligible portions of the project cost										
L.C	0.00	2.48	2.42	36.08	75.32	79.88	84.71	45.43	0.55	326.87
F.C	1.29	3.15	3.52	38.45	75.56	76.76	77.94	40.54	1.24	318.48
Total	1.29	5.63	5.94	74.53	150.88	156.64	162.65	85.97	1.79	645.35
Non-eligible portions of the project cost										
L.C	13.98	31.05	32.91	20.39	41.26	42.72	44.23	23.21	0.30	250.04
F.C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	13.98	31.05	32.91	20.39	41.26	42.72	44.23	23.21	0.30	250.04
Total project cost										
L.C	13.98	33.54	35.32	56.47	116.59	122.60	128.93	68.65	0.85	576.92
F.C	1.29	3.15	3.52	38.45	75.56	76.76	77.94	40.54	1.24	318.48
Total	15.27	36.69	38.84	94.92	192.15	199.36	206.87	109.19	2.09	895.39

Source: JICA Study Team

(4) Disbursement Schedule of Option 3

The disbursement schedule of Option 3 based on the implementation schedule has been prepared as shown in Table 4.10.

Table 4.10 Disbursement Schedule of Option 3

(Million Euro)

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Total
Eligible portions of the project cost										
L.C	0.00	1.96	1.96	17.97	37.05	39.32	41.72	22.68	0.57	163.23
F.C	0.78	2.14	2.45	27.33	53.80	54.66	55.49	28.93	0.94	226.52
Total	0.78	4.10	4.41	45.30	90.85	93.98	97.21	51.61	1.50	389.74
Non-eligible portions of the project cost										
L.C	13.98	30.67	32.52	12.58	25.25	26.04	26.86	14.15	0.29	182.35
F.C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	13.98	30.67	32.52	12.58	25.25	26.04	26.86	14.15	0.29	182.35
Total project cost										
L.C	13.98	32.63	34.49	30.55	62.30	65.36	68.58	36.83	0.86	345.57
F.C	0.78	2.14	2.45	27.33	53.80	54.66	55.49	28.93	0.94	226.52
Total	14.76	34.77	36.94	57.88	116.10	120.02	124.07	65.76	1.80	572.09

Source: JICA Study Team

According to the disbursement schedules, non-eligible portions of the project cost should be timely prepared by Ukrainian government in order to implement the Project smoothly

4.3 Consulting Services

If this Project is financed through a Japanese ODA Loan, the procurement procedure of Design-Bid-Build contract applying “FIDIC Conditions of Contract for Construction Multilateral Development Bank (MDB) Harmonized Edition for Building and Engineering Works Designed by the Employer” is a common practice for the construction project. In the procurement of Design-Bid-Build contract, detailed design and supervision of the construction works are performed by the consultants. Consulting services including the followings will be required for smooth implementation of the Project by assisting KVK, the executing agency.

- Implementation of detailed design
- Preparation of tender documents for the contract
- Assistance in tender/qualification evaluation and contract negotiation
- Supervision of the construction works
- Technical assistance of management, operation and maintenance

5. Financial and Economic Evaluation of the Project

5.1 Results of Financial Evaluation

The incremental benefits of the Project are not able to cover the initial construction costs, replacement and rehabilitation costs and O&M costs, thereby the result is not able to indicate financial soundness of the Project.

The results of financial viability indicators for Option 1-3 shows a negative work as shown below.

Table 5.1 Results of Financial Evaluation of Project

	NPV (mil Euro)	B/C ratio	FIRR (%)
Option 1	- 924	0.13	N.A.
Option 2	- 724	0.12	N.A.
Option 3	- 500	-	-

[Note]
N.A. ---Not accountable
- --- Estimation is not available due to a lack of incremental benefits.
Source: JICA Study Team

5.2 Results of Economic Evaluation

As a result of the economic analysis for Option 1, the Project feasibility turned out to be 13.0%. NPV and B/C ratio is estimated at respective of 218 million Euro and 1.24. The results of Option 2 and Option 3 also indicate positive figures as shown in the table below.

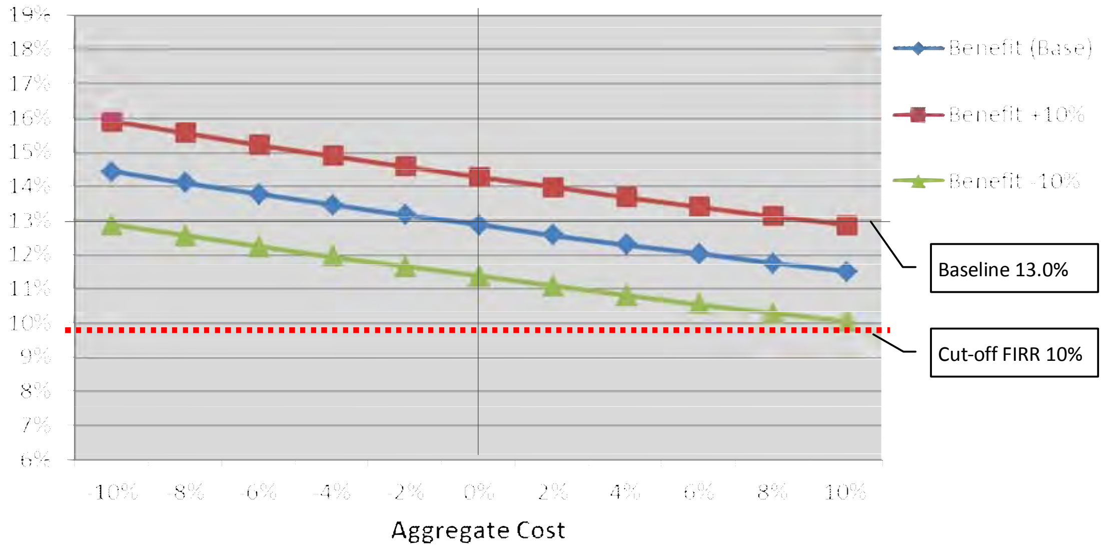
With current opportunity cost of capital standing at 10% per year, the result of EIRR for the Project exceeds the applied discount rate as an opportunity cost of capital. Hence, it could be said that the project is considered worthy for implementation as economically viable. These positive figure of NPV reveals financial soundness of the Project.

Table 5.2 Results of Economic Evaluation of Project

	NPV (mil. Euro)	B/C Ratio	EIRR
Option 1	218	1.24	13.0%
Option 2	61	1.07	11.0%
Option 3	225	1.39	14.9%

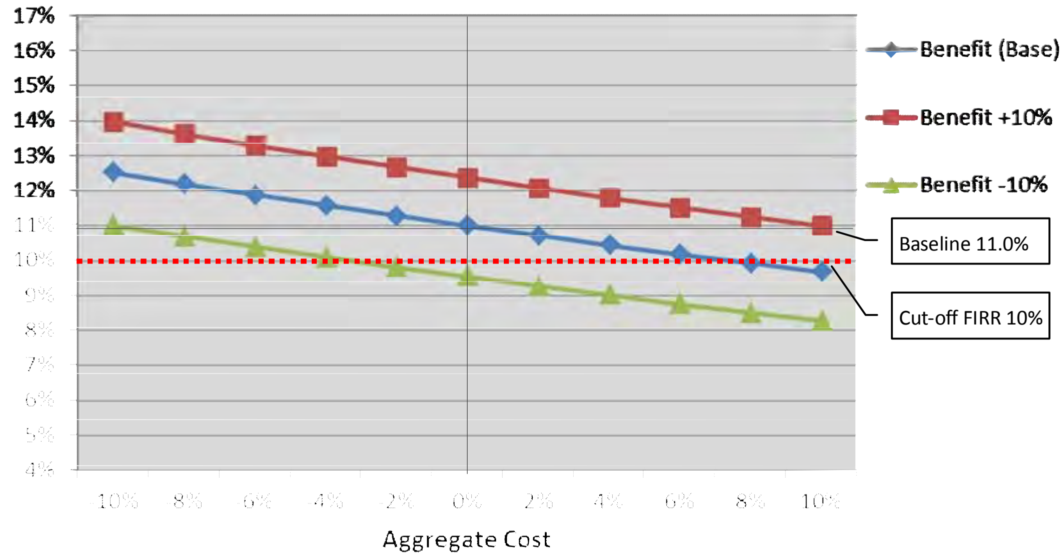
Source: JICA Study Team

The results of sensitivity analysis for Option 1-3 indicate that marginal resiliency can be seen in the all options, except for 3 cases in Option 2.



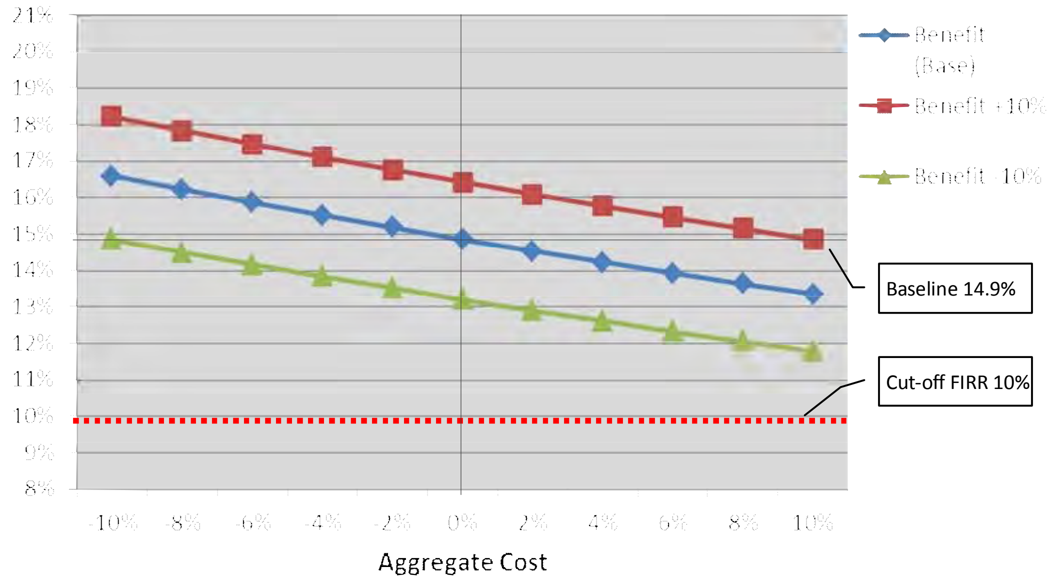
Source: JICA Study Team

Figure 5.1 EIRR Sensitivity of Project (Option 1)



Source: JICA Study Team

Figure 5.2 EIRR Sensitivity of Project (Option 2)

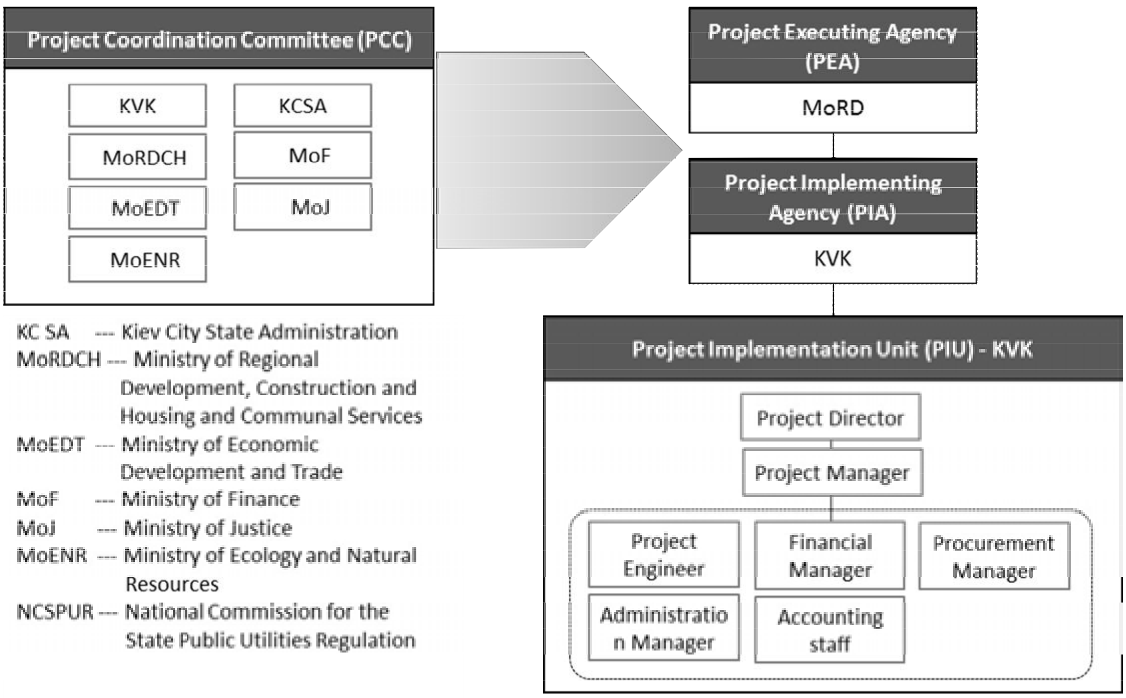


Source: JICA Study Team

Figure 5.3 EIRR Sensitivity of Project (Option 3)

6. Operation and Management System

An institutional framework consisted of PEA, PIA, PIU and PCC for the Project implementation shall be proposed after an exchange of views with KVK as the following Figure.



Source: JICA Study Team

Figure 6.1 Project Implementation Structure

7. Environmental and Social Considerations

7.1 EIA Report Preparation

The EIA reports for component 1 to 10 have been developed by KIP with which KVK made the contract for project document preparation. TOR of this Study is to review the existing EIA report to confirm the necessity of additional survey based on JICA's Guidelines for Environmental and Social Considerations (April 2010) (hereinafter referred as "JICA Guidelines"), and propose the additional survey to KVK. EIA report was reviewed, the comments were submitted to KVK and EIA report was modified. The results of environmental and social considerations are described in this Chapter.

7.2 Major Environmental and Social Impacts and Mitigation Measures

The environmental and social impacts will be generated by the construction and operation of the Project. By taking the mitigation measures, the impacts will be mitigated and the environmental quality standards will be complied.

- Air quality, Odor: The pollutant substances will be generated by the operation of wastewater and sludge treatment process including incinerator. The flue gas from the incinerator will comply with EU standards (Directives 2000/76/EC). By the results of simulation of air quality, the ambient air quality at the border of SPZ (1,000 m from the boundary of BAS) will meet the air quality standards. However, the results are calculated based on the assumption that chemical scrubbing in the wastewater treatment process and combustion process in the sludge treatment process, thus the installation of those facilities is inevitable. At present, odor is the baggiest problem and by the rehabilitation/reconstruction of BAS the odor problem will be solved as the air quality will comply with the standards.
- Waste: The waste will be generated during the reconstruction by the demolition of existing facilities. The waste should be recycled to a maximum extent and non-recyclable waste should be disposed by the appropriate method such as construction waste landfill based on the legislation on waste. During operation, the incinerated ash of 120 ton/day will be generated. The incinerated ash can be reused as cement and roadbed materials. Preliminary acceptance to use ash as cement material was given by the cement factory to KVK.
- Noise and Vibration: Noise and vibration will be generated by the construction and operation of the Project. During the construction, measures such as use of low-noise and vibration machineries, avoidance of simultaneous use of machineries, and noise-proof sheet will mitigate the impact level to acceptable level. During the operation, measures such as installation of facilities inside the building, use of anti-vibration pads and regular maintenance will reduce the noise and vibration.

The impacts can be mitigated by taking proper measures. The monitoring will be implemented to check the proper implementation of mitigation measures and unforeseen impacts during construction and operation.

7.3 Public Consultation

The public consultation was organized on October 10, 2013 by KVK in cooperation with Kiev City State Administration at the assembly hall of Damytsia district state administration in the City of Kiev. 189 people and medias were participated in the public consultation. Another meeting with the representatives of about 50 NGOs and associations which are member of the Public Council at Damytsia District State Administration was held on October 28, 2013.

8. Conclusion and Recommendations

The survey prepared the project plan of reconstruction of BAS which has three blocks of wastewater treatment complexes with daily capacity of 1.57 mil. m^3/day. It has been over 50 years since the beginning of operation in 1964 and the facilities have been aging. BAS is too large to reconstruct in one project in view of financial resources. Therefore, the survey was conducted for efficient project performance through the evaluation of existing BAS.

- As a result of evaluation of existing BAS, it is found that Block 1 facilities are the most deteriorated by aging. However, the treatment performance is good.
- On facilities planning, it is found that design wastewater flow and design influent qualities are almost same as those of current KVK plan. As for the wastewater treatment process, Anaerobic-Anoxic- Oxic Process (A2O Process) and rapid coagulation systems are proposed. As the sludge handling process, thickening, dewatering and incineration process are selected.

In order to formulate project planning, the following items are considered.

- Discussions between KVK and JICA brought to a conclusion that the survey should focus on Stage 1 and needs to estimate its cost. Stage 1 consists of 5 components whose main activities are rehabilitation of Block 2 and 3, reconstruction of Block 1 and new construction of sludge facilities. Land preparation for these facilities and demolishing of existing facilities are responsibility of KVK.
- Scale-wise, the cost of three cases was estimated; i) rehabilitation of Block 2 and 3 + reconstruction of Block 1 + new construction of sludge facilities, ii) reconstruction of Block1 + new construction of sludge facilities and iii) new construction of sludge facilities
- This project is supposed to use Special Terms for Economic Partnership (STEP) of Japanese ODA Loan. Since STEP Loan conditions stipulate that the ratio of goods and services to be procured from Japan shall be not less than thirty percent (30%), cost estimation was conducted by this rule.

Due to problems with aging existing facilities, dearth of sludge disposal site and odor from BAS, towards the realization of projects, concerned organizations such as the Government of Ukraine, Kiev City State Administration, KVK are required to take necessary actions in accordance with each organization's competence.

Recommendations to Government of Ukraine

- The Government of Ukraine is required to take a positive action to International Financial Organizations (IFO) towards the realization of the Project.
- Due to the necessity of a large amount of total project cost, the Central Government is advised to take an appropriate responsibility for the project financing through subsidy in consideration of public interest in the project.

- For To ensure sound financial operation, it is required to consider the possibility in perspective of prospective future revision of sewage tariff rates. Since KVK doesn't have the competent competence to set and revise sewage tariffs, Kiev City State Administration is required to negotiate and coordinate with the National Commission for the State Public Utilities Regulation (NCSPUR) on at its own initiative.
- In order to supervise project and coordinate with the related organizations, a Project Coordination Committee (PCC) is strongly recommended to be established.
- Public tax and charge such as Corporate Tax imposed to general contractors are desirable to be exempted for reduction for international procurement barrier with complicated institutions.

Recommendations to Kiev City State Administration

- Kiev City State Administration is one of the bodies administering the sewage works as well as a property owner, and is proposed to be a member of PCC. It should supervise the project in close cooperation with KVK.
- The gap between revenue from sewage tariffs and sewage expenditure shall be compensated by Kiev City State Administration. Therefore, Kiev City State Administration is needed to provide KVK with enough subsidies till KVK establishes financially sustainable sewage works, whose subsidy should be enough to cover at least the operation and maintenance costs.
- Based on City General Plan of Kiev City State Administration which has been revising for accepting sewage from satellite cities, accepting facilities such as pumping stations should be constructed according to the project progress.

Recommendations to KVK

- A Project Implementation Unit (PIU) is strongly recommended to be established within KVK as the organization for implementation and responsibility of the project.
- KVK is required to promote feasibility of the project for understanding revision of sewage tariff rates and willing-to-pay through the awareness of residents.
- As for Stage P documents prepared by the Government of Ukraine, it is required to revise the Environment Impact Assessment (EIA) report properly, since IFOs request EIA report which corresponds to screening items of International Finance Organizations (IFOs) such as JICA.
- As the sludge incinerators will be constructed in Ukraine for the first time, KVK has to obtain the understanding about the environmental and social impacts of the construction and operation of the facilities from its residents. KVK has to monitor the environmental and social impacts caused by the facilities regularly and implement appropriate mitigation measures if necessary.
- KVK is required to secure an appropriate portion of the budget of the Government of Ukraine and to secure the implementation of land preparation and demolition of existing facilities in the WWTP since these are a perquisite of the project.
- It is required to secure the capacity of the disposal site and reinforcement of the banks during construction period because of dearth of sludge disposal sites and deteriorated banks.

- It is required that the first rise pumping station which is rehabilitated by fund of Government of Ukraine should be sustainably designed for feeding sewage to existing Block 2 and Block 3, as well as Reconstructed Block1.
- Ongoing rehabilitation of aeration tanks (No.15-18) applying Danish technology in sewage treatment facilities for Block 3 is required to be completed rapidly along with this project to cope with capacity decrease of BAS by aged existing facilities, as well as sewage increase in wet weather.
- Securing of Power receiving facility owned by the power company is required to be discussed with power company since they are also aging.
- Ash from the incinerators should be beneficially used by securing cooperation with relevant companies such as cement manufacturers.
- Tentative measures are required for odor control such as covers of facilities and deodorant equipment.
- It is well understood that the situations around BAS and the sludge fields require the expeditious project implementation. As the Report proposes the Project Implementation Schedule following the procedures ordinarily required in JICA Loan projects, KVK is required to seek for any possible measures to shorten the schedule considering the pressing situations during its negotiation when JICA Loan is applied.

MAIN REPORT

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Abbreviation

BAS	Bortnychy Aeration Station
BOD	Biological Oxygen Demand
B/C ratio	Benefit and cost ratio
CD	Conceptual Design
CHP	Cogeneration System
COD	Chemical Oxygen Demand
CV	Calorific Value
CVM	Contingent Valuation Methods
C1	Component 1
C2	Component 2
C3	Component 3
C4	Component 4
C5	Component 5
C6	Component 6
C7	Component 7
C8	Component 8
C9	Component 9
C10	Component 10
D	Depth
Dia.	Diameter
DO	Dissolved Oxygen
DS	Dry Solid
DSCR	Debt Service Coverage Ratio
DSSE	Department of Sewerage System Exploitation, KVK
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
EMP	Environmental Management Plan
EU	Europe Union
FBI	Conventional fluidized bed incinerator
FC	Foreign Currency
FIRR	Financial Internal Rate of Return
FOG	Fat, Oil & Grease
FY	Fiscal Year
F/S	Feasibility Study
HICC	Head Information and Computing Centre
IFRS	International Financial Reporting Standards
IL	Ignition Loss
JICA	Japan International Cooperation Agency
JST	JICA Study Team
KCSA	Kiev City State Administration
KIP	Kyivinzhproekt Institute of PJSC Kyivproekt
KVK	Public Joint Stock Company “KyivVodokanal”
MAC	Maximum Allowable Concentration

MLIT	Ministry of Land, Infrastructure and Transportation
MLSS	Mixed liquor suspended solids
MWh	Megawatt-hour
M/D	Minutes of Discussion
MoEDR	Ministry of Economic Development and Trade
MoENR	Ministry of Ecology and Natural Resources
MoF	Ministry of Finance
MoJ	Ministry of Justice
MoRDCH	Ministry of Regional Development, Construction and Housing and Communal Services
MPC	Maximum Permissible Concentration
MPD	Maximum Permissible Discharge
M&E	Mechanical & Electrical
NSS	Nihon Suiko Sekkei Co., Ltd.
N/A	Not Available
NCSPUR	National Commission for the State Public Utilities Regulation
NPV	Net present value
NRW	Non Revenue Water
ODA	Official Development Assistance
OJSC KVK	Open Joint Stock Company KVK
O&M	Operation & Maintenance
P/S	Pumping Station
PCC	Project Coordination Committee
PD	Project Director
PEA	Project Execution Agency
PFBI	Pressurized fluidized bed incinerator
PIA	Project implementation agency
PIU	Project implementation unit
PJSC KVK	Public Joint Stock Company KVK
SCADA	Supervisory Control and Data Acquisition
SPZ	Sanitary Protection Zone
SRT	Solid retention time
SS	Suspended Solids
STEP	Special Terms for Economic Partnership
SV	Sludge volume
SVI	Sludge volume index
TDS	Total Dissolved Solids
TECI	TEC International Co., Ltd.
TKN	Total Kjeldahl Nitrogen
TOR	Terms of Reference
TSS	Total Suspended Solids
T-N	Total Nitrogen
T-P	Total Nhosphorus
UAH	Ukrainian Hryvnia
UNDP	United Nations Development Programme
US$, USD	United States Dollars
VAT	Value Added Tax

VSS	Volatile Suspended Solids
VVVF	Variable Voltage Variable Frequency
W	Width
WHO	World Health Organization
WTP	Willingness-to-pay
WWTP	Wastewater Treatment Plant

1. Introduction

1.1 Background of the Study

Ukraine, established in 1991 as a result of the demise of Soviet Union, consists of 24 regions, the autonomous republic of Crimea and two cities with special status – Kiev and Sevastopol. The main issue of the country requiring urgent resolution is the restoration of aged social infrastructure constructed during the Soviet Union period. Bortnychy Aeration Station (BAS), treating all the sewage generated in the capital city of Kiev, consists of three sewage treatment trains. The first train, beginning its operation in 1964, has been aged to the worst extent and requires reconstruction as early as possible. Liquid sludge after some stabilization processes is pumped to sludge fields. However, the sludge fields are nearly full of disposed sludge and a sludge reduction facility such as sludge incinerator has to be constructed urgently. Ukraine has targeted to be a member of EU as a political goal and tries to adjust its effluent standards to the EU directives. Above all, existing facilities cannot remove nitrogen and phosphorus to the extent required. In this regard, upgrading and/or additional facilities are required to ensure advanced treatment.

Public Joint Stock Company "Kyivvodokanal" (hereinafter referred to as "KVK") as an executing agency is preparing a feasibility study that includes the construction of sewage treatment facilities with a capacity of 1.58 million cubic meters per day, sludge treatment facilities and incinerator facilities. To materialize the feasibility study, the Government of Ukraine has requested for a Japanese ODA loan.

1.2 Objective and Scope of the Study

The study aims to assist KVK to finalize the feasibility study in the form that meets JICA's project appraisal criteria, which is a prerequisite for JICA to finance the reconstruction of BAS.

The scope of the study shall be in accordance with the M/D (Minutes of Discussion) agreed on May 24, 2013 between the KVK and JICA.

1.3 Facilities Covered by the Study

The study covers the facilities listed below:

- Bortnychy Aeration Station (BAS)
- Sludge fields

1.4 Implementing Organization of Ukraine

The counterpart agencies of the Ukrainian side include Ministry of Regional Development, Construction, Housing and Communal Services of Ukraine, Kiev City State Administration and KVK.

1.5 JICA Study Team Member

The JICA Study Team (hereinafter referred to as JST) consists of the members listed in Table 1.1.

Table 1.1 List of JICA Study Members

Name	Position	Organization
TAKECHI Akira	Team Leader	TECI
NOJIRI Maremori	Deputy Team Leader / Sewerage Planning	NSS
TANAKA Norio	Mechanical Facility Design	TECI
KAWASAKI Shigeru	Electrical Facility Design	TECI
KUBOTA Naomasa	Civil Structure Design	NSS
MURASAME Yusuke	Architectural Design	NSS
YAMADA Masatoshi	Cost Estimation/Construction Planning	TECI
IWAMOTO Koichi	Civil Structure Design (2) / Cost Estimation (2)	TECI
YAMADA Shoko	Environmental and Social Considerations	TECI
OHNO Atsuo	Economics and Finance Analysis	TECI

TECI: TEC International Co., Ltd.

NSS: Nihon Suiko Sekkei Co., Ltd.

1.6 Implementation Schedule

The study started in August 2013 and finished in March 2014. The following reports were submitted according the schedule as shown in Table 1.2.

Table 1.2 Time Schedule of Reports Submission

Report	Submission
Inception Report (IC/R)	August 2013
Interim Report (IT/R)	December 2013
Draft Final Report (DF/R)	January 2014
Final Report (F/R)	March 2014

2. Current Situation of KVK

2.1 Public Joint Stock Company (PJSC) KVK

2.1.1 Organizational Transformation of KVK

“Kyivvodokanal" has been responsible for centralized water and sewerage services more than 140 years and 118 years respectively. During the privatization process of state utility organizations, on 19 July 2001, “Kyivvodokanal" was incorporated into an open joint stock company as “OJSC KVK”. It was transformed from Kyivvodokanal state utility organization of water supply and sewerage by Order No.359 of the Regional Department of Ukrainian State Property Fund in the Kiev City. The company became a successor of property usage rights and obligations of state utility association of water and sewerage.

Order No.359 defined the following main issues:

- To transfer state utility organization “Kyivvodokanal” into the “OJSC Kyivvodokanal”
- To establish a joint-stock company to be legal successor of the organization privatized
- To consider this Order as a deed of establishment on the creation of OJSC

Afterwards, the company is renamed into a “Joint-Stock Company Kyivvodokanal” on 20 December 2010. In the stakeholder’s meeting, the company type was determined as public in accordance with the requirements of Ukrainian Law “On Joint Stock Companies[1]. The capital amounting to 175 million UAH (16 million Euro) was divided into ordinary registered shares.

2.1.2 Main Features of PJSC KVK

The main direction of company activities is to provide services of centralized water supply and sewerage. PJSC KVK is aimed to ensure continuous and reliable service taking into account the requirements on environmental protection and rational use of water resources.

The service provided by PJSC KVK has covered Kiev city and some of the surrounding satellite towns partly located in Kiev Region. PJSC KVK occupies a monopolistic position on the market of central water supply and sewerage in Kiev.

2.1.3 Organizational Structure of PJSC KVK

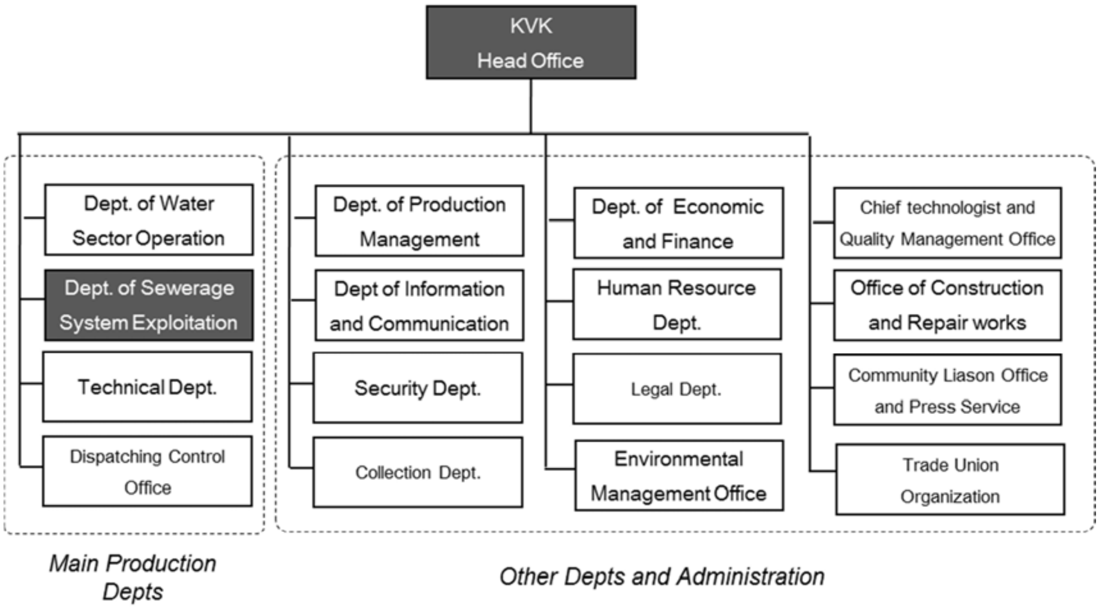
KVK has structural divisions, which are not legal entities and use internal regulations and provisions approved by the head of the board to regulate their activities. The Board consists of 7 members including the major stakeholders, a chairman of the board, a chairman of the supervisory board, its members and a chairman of the audit committee.

[1] OJSC Kyivvodokanal (2010), Extract from the Protocol from the meeting of stakeholders of the OJSC “Kyivvodokanal”

Total number of employees is amounts to 6,491, including 73 part-time workers according to the 2012 annual report.

The organizational structure of PJSC KVK is mainly divided into two major parts, main production departments and management and other departments. The Department of Sewerage System Exploitation (DSSE) with approximately 3,000 staff is the second largest department after water supply sector operation department with approximately 4,000 staff.

An overall organogram of PJSC KVK is shown as follows.



Source：KVK

Figure 2.1 Organogram of Overall PJSC KVK

2.1.4 Department of Sewerage System Exploitation (DSSE)

The DSSE is a central section to encompass sewerage services in the covered areas. The main tasks are to ensure smooth sewerage services as well as appropriate wastewater treatment with high wastewater quality meeting the standards prior to discharge into the Dnipro River.

Executive and administrative authority is represented by the Director of DSSE, who is appointed by the chairman of PJSC KVK.

DSSE performs the following main activities according to the protocol summarized as follows.

Table 2.1 Main Activities of DSSE

Main Activities
• Enforcement of environmental and sanitation measures and regulations in accordance with the current legislation of Ukraine • Development and implementation of technical programs for facility repair and renovation of sewerage systems • Development and taking measures for conservation of material and technical resources (materials, reagents), electricity, introducing energy-saving technologies • Reduction of operating costs • Improving financial conditions of the Department due to expansion of economic and financial activity, which does not prevent the main activities • Technical re-equipment of the industry based on modern science and technology with the introduction of new world technologies • Implementation of methodological and organizational support, determination of and implementation of training, retraining or additional training • Promoting the involvement of investors for modernization, technical upgrading, reconstruction and construction of the Department facilities • Providing operational units with technical and working documentation, necessary materials, spare parts, tools, uniforms, equipment, etc. • Technical acceptance for exploitation of new and renovated buildings, equipment and drainage systems • Participation in the preparation and issuance of permits and technical conditions for connecting the centralized waste water systems of residential and public buildings, industrial and domestic companies and other facilities, approved by the project of waste water disposal • Development of hydraulic schemes of pumping stations and networks, monitoring their implementation, selection of optimum modes of pumping stations and sewage systems, continuous analysis of their work • Studying the composition of sewage and their impact on the stability and operation of the sewerage networks and treatment facilities, development of measures to improve the reliability of structures

Source: KVK

There are two main sections for operation such as: (1) sewerage networks and pumping stations, and (2) BAS.

Their main features are summarized in the following table.

Table 2.2 Main Features of Two Major Sections for Operation

Name	Main Roles
Sewerage networks and pumping stations	• To manage operation of sewerage networks of 4 operational areas • To manage operation of pumping stations
Bortnychy aeration station (BAS)	• To manage operation of mechanical and biological treatment of wastewater from residential users, industries, budgetary institutions and others.

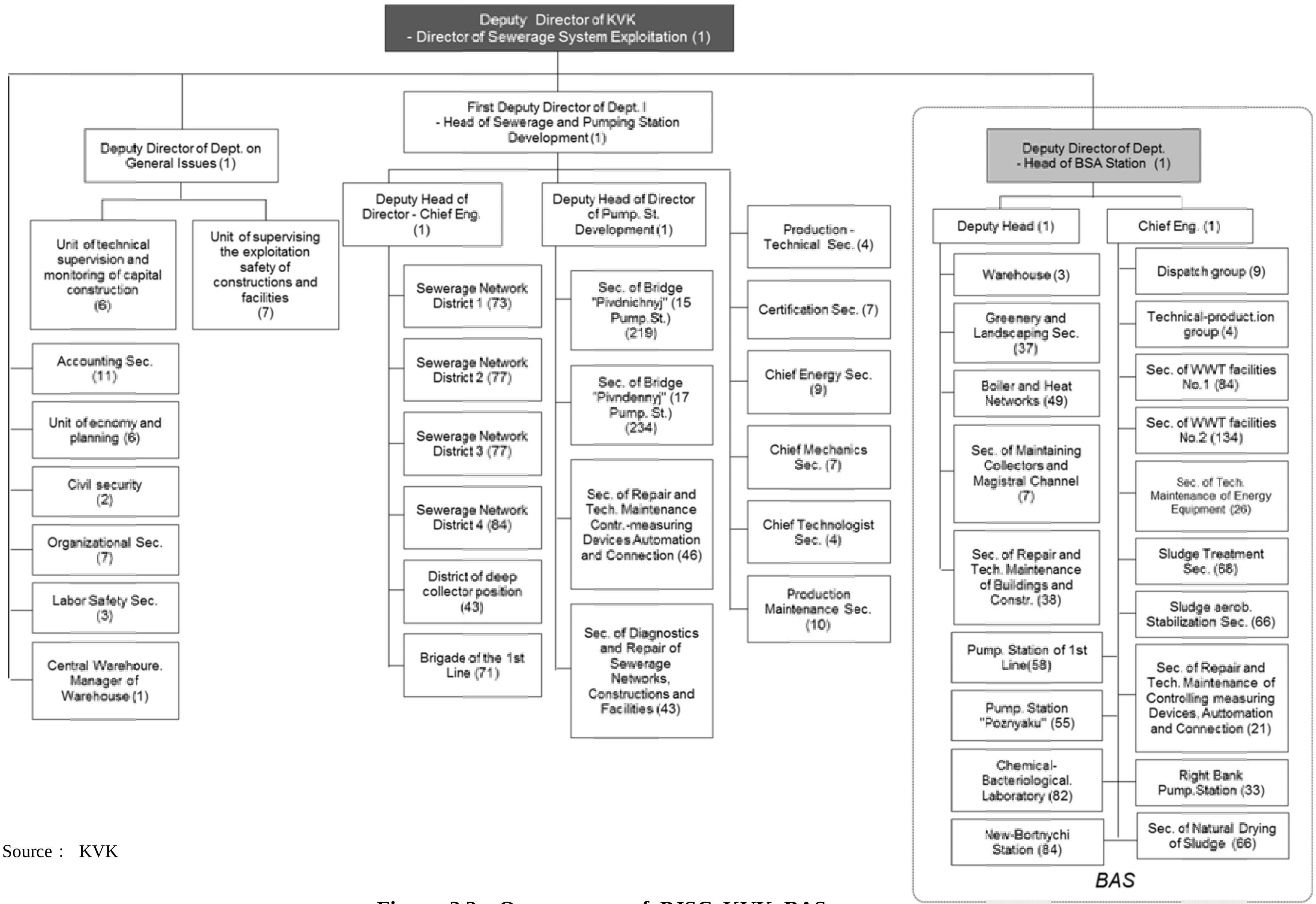
Source: JICA Study Team

2.1.5 BAS

(1) Main Features of BAS

BAS is headed by Director of BAS who also serves as Deputy Director of Department. Under the head, there are two positions, Chief Engineer and Deputy Head. The Chief Engineer is mainly responsible for the technical overseeing of operation and maintenance of facilities in BAS. Deputy Head is responsible for remaining facilities such as buildings and administrative works. The number of employees in BAS amounts to 927 as of December 2013.

An organogram of BAS is shown at the following table.



Source : KVK

Figure 2.2 Organogram of PJSC KVK BAS

The functions of main section/group of BAS are shown as below.

Table 2.3 Functions of Main Divisions/Sections of BAS

Name of Section/ Group	Main Functions
Section of Wastewater Treatment Facilities	• Providing complete mechanical and biological treatment of wastewater in accordance with the established technological process • Providing disposal of settled grit to sand areas, raw sludge and excess thickened activated sludge - to digesters • Compliance with the technological requirements for allocation of raw sludge to digesters, for thickening the excessive activated sludge, and for eliminating sand from sand catchers and established schedule for its disposal to sand areas
Section of Technical Production	• Regulating the production process, coordinate operation of the Units and their steady work • Provide work of technical supervision service for the safe exploitation of facilities buildings, structures and networks at the BAS
Pumping Station	• Continuous pumping of sewage water of the Right/Left banks of Kiev to the treatment facilities of BAS • Maintaining the technological requirements of pumping sewage water • Ensuring smooth operation of equipment and facilities of the pumping station
Section of Sludge Treatment	• Providing sludge treatment in accordance with the established technological process with further pumping of digested sludge to the sludge fields • Collecting gas from digesting tanks into gas holders with its further use for production needs • Compliance with technological regime of sludge treatment and established schedules of pumping sludge to sludge fields.
Section of Sludge Aerobic Stabilization	• Providing aerobic stabilization of excess sludge in accordance with the established process, followed by pumping to the sludge fields and pioneering sludge fields • Maintaining production schedules of aerobic sludge stabilization and schedule established for its pumping to the sludge fields
Section of Natural Sludge Dehydration	• Ensuring input and natural drying of sludge in accordance with the established technological process of pumping side stream back to BAS • Ensuring the discharge of treated water into River Dnipro through the main discharge canal • Providing uninterrupted reception of digested sludge and maintaining the technological process of its drying and pumping the supernatant
Chemical and Bacteriological Laboratory	• Performance of laboratory control of composition and properties of sewage water and sludge, ensuring implementation and performance of measurement of sewage water and sludge processed at treatment facilities of the BSA • Conducting internal quality control of measured results. • Timely providing measurement results of sewage water and sludge composition required for control of wastewater treatment facility operation
Dispatch Group	• Adjusting wastewater input for the facilities of the station and coordination of operation of major technological Units • Leading the production and technological process by shift engineers of the Units during the absence of management on weekends and holidays, as

Name of Section/ Group	Main Functions
	well as on workdays from 17.00 to 8.00.
Section of Technical Maintenance of Energy Equipment	• Carrying out planned preventative examinations of electrical equipment of electric mounting • Operational maintenance of electrical equipment and electrical mounting

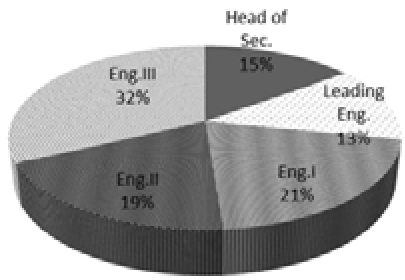
Source: KVK BAS

(2) Type of Engineers

The Engineers are categorized into the following 5 types: (1) Head of section、(2) Leading engineer、(3) Engineer I、(4) Engineer II、(5) Engineer III. Most of engineers are allocated as officers. The number of engineers in BAS amounts to 121 persons, which is equivalent to 13% of the total employees in BAS.

The largest group is composed by Engineer III with 32%, followed by Engineer I with 21% and Engineer II with 19%.

The composition of Engineers is indicated in the Figure and Table.



Source: KVK

Figure 2.3 Composition of Engineers in BAS

Table 2.4 Composition of Engineers in BAS

Position	Head of Sec.	Leading Eng.	Eng.I	Eng.II	Eng.III	Total
Deputy Director of Station	1					1
Chief Engineer	1					1
Technical Production Group		1	1	2		4
Group of Material and Technical Supply		1			1	2
Right Bank Pumping Station	1	1		6	1	9
Pumping Station of the First Line	1		1	1	1	4
Sewage Pumping Station "Poznyaky"	1	2	1	1	3	8
Sec. of Block of Treatment Facilities No.1	1	1			6	8
Sec. of Block of Treatment Facilities No.2	1	1			7	9
Sec. of Sludge Treatment	1	1	1	1	4	8
Sec. of Natural Drying of Sludge	1		2	2		5
New-Bortnychi Aeration Station	1	1		1	5	8
Sec. of Sludge Aerobic Stabilization	1	1	1	1	4	8
Sec. of Technical Maintenance of Energy Equipment	1	1	6	1	1	10
Sec. of Boiler and Heating Networks	1	1		1	5	8

Position	Head of Sec.	Leading Eng.	Eng.I	Eng.II	Eng.III	Total
Sec. of Repair and Technical Maintenance of Controlling and Measuring Devices, Automatics and Means of Connection	1	1	1	1		4
Chemical-bacteriological Laboratory	1	1	4	3	1	10
Sec. of Greenery and Landscaping	1	1				2
Dispatch Group		1	6	2		9
Sec. of Maintaining Collectors and Main Disposal Channel	1					1
Sec. of Repair and Technical Maintenance of Buildings and Constructions	1		1			2
Total in BAS	18	16	25	23	39	**121**

Source: KVK BAS

2.2 KVK's Contract for Ownership and Usage of Kiev City Property

2.2.1 Background and Basic Information

The management right of communal property of Kiev City, related to water supply and sewerage facilities, was transmitted to OJSC KVK on 1st July 2003. Afterwards, the Contract for ownership and usage of Kiev city property was made on 20 November 2003. The ownership and usage of the property was transferred from OJSC KVK to current PJSC KVK by the new edition of the Contract dated 1 December 2006. The contract term is 10 years until 31 December 2017, defined by the order No.575/575 of KCSA on 30th October 2008. It is described in the order No.17/1851 of KCSA on 26th June 2007.that annual payments of 10% of net profit of KVK are provided to KCSA for using property.

2.2.2 Ownership and Duties

In principle, the ownership of water and sewerage facilities still remains at Kiev City, except for some of administrative facilities. PJSC KVK has the right to use the property for provision of water supply and sewerage service, and of maintaining the property with technological appropriations according to the list of transferred property. PJSC KVK bears full responsibility for maintaining, exploiting, reconstruction and repair of the property. In addition, disposing of the property and transferring the property rights to the third parties are not allowed without approvals from KCSA by the Contract.

Main rights and duties of KVK and KCSA defined by the Contract are summarized as follows.

Table 2.5 Main Rights and Duties Defined by the Contract

	KVK	KCSA
Responsibility	• Using property • Providing stability of water supply and sewerage • Conducting effective actions for exploiting, renewing, maintaining and improving property • Not to transfer the property rights to the third party • Preparing and submitting quarterly report on assets	• Not to transmit the ownership/usage to the third parties • Revising and considering offers from KVK on tariffs on water supply and sewerage • Assuring appropriation of funds for paying the cost of water
Right	• Using property	• Receiving reports from KVK including reports on the conditions and effectiveness of property usage • Controlling conditions for property usage • Controlling efficiency of property usage

Source: Order No.575/575 of KCSA

2.3 Training

Some training for technical workers and managers/specialists/clerks has been organized by KVK BAS. The total number of trainees amounted to 259 for technical workers and 232 for managers/specialists/clerks in 2013. The engineers and technical workers are required to participate in training every three years and every year respectively. In 2013, approximately a half of employees of BAS participated in a certain training session per annum.

The training institution is limited to only one, the National Business Training Centre "Innovator". The training programs have been prepared by the institution, not by KVK, so that training programs should be planned by KVK according to the practical situation of BAS in future.

Training areas and the number of trainees for BAS personnel are shown as the following table.

Table 2.6 Training Areas and the Number of Trainees for BAS's Personnel

S/N	Area	1 Q	2 Q	3 Q	4 Q	Total
	Technical workers					
1	Chemical water purification	5				5
2	Safe methods and means of metal flame treatment installations exploitation works	7	8	1	1	17
3	Tree feller			1		1
4	Access to the works by lifting facilities, controlled from the floor	19	37	32	41	129
5	Access to maintenance of containers operating under pressure	11	15		3	29
6	Knowledge of instructions and regulatory acts of work safety methods according to the approved work program of fitters of repair and maintenance of steam and hot water pipelines	4				4
7	Knowledge of instructions and regulatory acts of work safety methods according to the approved work program of boiler equipment repair workers	4				4
8	Machinist of the movable crane, according to NPAOP 0.00-5.18-96	1		1		2
9	Boiler operator		1	2	11	14
10	Solid fuel boiler operator				4	4
11	Testing the hose for gas welding		1		2	3
12	Work with instruments and devices (power saw, gas trimmer)	20				20
13	Exploitation and repair of gas equipment	7		1	3	11
14	Repair and maintenance of the lifting crane	10	4	2		16
Technical workers - Total		**88**	**66**	**40**	**65**	**259**
	Manager/Specialist/Clerk					
1	Education and knowledge testing of the Safety Measures of gas supply systems of Ukraine	2		10	3	15
2	Education and knowledge testing of Rules of Construction and safe exploitation of the lifting cranes	2		7	2	11
3	Education and knowledge testing of Rules of Construction and safe exploitation of steam and water heating boilers	6				6
4	Education and knowledge testing of Rules of Construction and safe exploitation of containers operating under pressure	3		2	9	14
5	Education and knowledge testing of Rules of Construction and safe exploitation of steam and hot water pipelines			7		7
6	High altitude work safety		11			11
7	Education and knowledge testing of the exploitation and safety of technical equipment and Rules of heat economies preparation for the heating period			14	11	25
8	Heat installations and equipment maintenance	2	19	4	2	27
9	Access to works at height using the individual safety measures	22	34	40	20	116
Manager/Specialist/Clerk - Total		**37**	**64**	**84**	**47**	**232**
Total		**125**	**130**	**124**	**112**	**491**

Source: KVK

2.4 Financial Situation of KVK

2.4.1 Financial Situation of Waterworks and Sewerage works

The activities of KVK are financed through primarily their own funds obtained from operational, investment and financing activities, as well as subsidies from the governmental budget for compensation of difference between actual unit cost and actual tariff revenue. Significant problems include low revenue collection for services attributing to increase of prime cost components such as reagents, materials, energy etc., economically non-grounded current tariffs for water supply and sewerage, and the highly aged facilities with low efficiency. The details are described as follows.

(1) Operating Revenue Income of KVK

The operating revenue income for 2012/2013 is accounted for 2,020 million UAH (185.8 million Euro). In comparison to 2008, the operating revenue income shows 2.8 times growth. The main reason is attributed to a large increase of other operating income such as: (1) rental of operational assets, (2) reserving the electricity supply capacity, (3) collecting payments for exceeding permissible concentration of contaminants in sewage water, (4) sale of scrap metal, (5) sale of fixed assets.

While, with regard to the operating income only for water supply and sewerage service, the income scale indicates 45% growth during the recent 5 years. The trend for the recent 3 years, however, has been steady with 1.4% growth.

(2) Operating Expenditure of KVK

The operating expenditure of KVK for the period 2012/2013 totaled about 2,075 million UAH (190.9 million Euro), which was increased 2.4 times in the recent 5 years. The operating expenditure for water and sewerage services indicates 60% growth during the recent 5 years.

(3) Current Account Balance and Trend

For a long time, KVK has been in an unhealthy financial status due to the influence of loss-provoking tariffs for services of water supply and sewerage. The current account balance considering operating revenue income and operating expenditure for water supply and sewerage service for FY2012/2013 is in deficit amounting to minus 57 million UAH (5.2 million Euro).

The latest results indicates that current tariffs revenue from water supply and sewerage services for domestic users who consume 81 per cent of the services, cover just 54 per cent of the expenses of their production during the recent 8 months of activity in 2013.

The financial balance of operating income and operating expenditure for the recent 5 years has not been balanced according to the Profit and Loss Sheet of KVK. The operating expenditure from water supply and sewerage services has been in excess during the recent 5 years in the range of minus 30 – 157 million UAH (2.8 – 14.4 million Euro). The operating revenue income met approximately 45 % growth, meanwhile the increase of operating expenditure exceeded it with 60% during the recent 5 years. The recent trend indicates that other operating income has contributed to the reduction of the deficit amount of operating revenue income for 5 years.

The profit and loss sheet, the balance sheet and the cash flow statement during the recent 5 years is shown in the following table.

Table 2.1 Account Balance of Operating Activity – Profit and Loss Sheet (UAH and Euro)

(1,000 UAH)

Account items	2008	2009	2010	2011	2012
Operating income	**710,933**	**1,502,935**	**989,801**	**962,289**	**2,018,596**
Operating income from service	639,212	831,271	913,061	941,363	926,125
Other operating income	71,721	671,664	76,740	20,927	1,092,471
Operating expenses	**853,524**	**1,533,187**	**1,115,074**	**1,119,431**	**2,075,727**
Cost of products	599,709	687,663	789,201	871,512	1,016,719
VAT	106,535	138,545	152,177	156,747	154,353
Administrative expenses	39,149	79,470	71,513	36,296	48,658
Selling expenses	44,142	38,232	37,264	39,207	46,032
Other operating expenses	63,989	589,277	64,919	15,667	809,965
Operating balance	**-142,591**	**-30,252**	**-125,273**	**-157,142**	**-57,131**
Other income on ordinary activities	105,352	39,038	43,482	44,158	100,857
Other expenses on ordinary activities					
Financial expenses	807	1,681	3,249	1,944	643
Other expenses	42,229	48	479	3	6,280
Balance before taxation	**-80,275**	**7,057**	**-85,519**	**-114,931**	**36,802**
Profit/Loss from tax on ordinary activities	17,427	8,695	8,522	36,079	33,635
Net profit/loss	**-62,848**	**-1,638**	**-76,997**	**-151,010**	**3,167**

(1,000 Euro)

Account items	2008	2009	2010	2011	2012
Operating income	**65,399**	**138,255**	**91,052**	**88,521**	**185,691**
Operating income from service	58,801	76,469	83,992	86,596	85,194
Other operating income	6,598	61,786	7,059	1,925	100,496
Operating expenses	**78,516**	**141,038**	**102,576**	**102,976**	**190,946**
Cost of products	55,167	63,258	72,599	80,170	93,528
VAT	9,800	12,745	13,999	14,419	14,199
Administrative expenses	3,601	7,310	6,578	3,339	4,476
Selling expenses	4,061	3,517	3,428	3,607	4,234
Other operating expenses	5,886	54,208	5,972	1,441	74,509
Operating balance	**-13,117**	**-2,783**	**-11,524**	**-14,455**	**-5,255**
Other income on ordinary activities	9,691	3,591	4,000	4,062	9,278
Other expenses on ordinary activities					
Financial expenses	74	155	299	179	59
Other expenses	3,885	4	44	0	578
Balance before taxation	**-7,384**	**649**	**-7,867**	**-10,573**	**3,385**
Profit/Loss from tax on ordinary activities	1,603	800	72	3,319	3,094
Profit from tax on ordinary activities	1,603		784		
Loss from tax on ordinary activities		800		3,319	3,094
Net profit / loss	**-5,781**	**-151**	**-7,083**	**-13,891**	**291**

Source: KVK

Table 2.2 Account Balance of Operating Activity – Balance Sheet (UAH)

(1,000 UAH)

Account items		2008	2009	2010	2011	2012
Non-current Assets	Fixed assets	1,226,152	1,182,301	1,192,203	1,195,329	1,615,493
	Intangible fixed assets	47,564	45,358	88,137	74,711	63,238
	Deferred tax assets	58,089	75,867	67,738	76,818	58,608
	Incomplete capital investments	612,259	618,072	281,390	198,764	0
	Other non-current assets	4,244	395	395	0	0
	Non-current assets total	1,948,308	1,921,993	1,629,863	1,545,622	1,737,339
Current Assets	Cash and cash equivalent	9,695	7,845	12,891	1,575	28,460
	Inventories	22,811	23,265	27,014	32,440	42,207
	Receivables	407,150	574,319	563,340	672,626	823,242
	Other current assets	42,851	50,848	72,865	62,388	69,092
	Current asset total	482,507	656,277	676,110	769,029	963,001
Others	Future period expenses	384	1,287	1,784	2,313	0
Assets total		**2,431,199**	**2,579,557**	**2,307,757**	**2,316,964**	**2,700,340**
Long-term Liabilities	Long-term liabilities	4,855	3,838	2,819	1,800	1,521,072
Current Liabilities	Short-term bank loans	0	0	0	19,313	0
	Notes payables	0	36,313	83,268	0	0
	Receivable for goods, services and works	371,683	561,094	472,194	704,204	993,982
	Other current liabilities	55,033	62,751	84,244	106,524	167,140
	Provisions for liabilities and charge	548,055	565,933	290,236	186,069	594
	Liabilities total	1,246,306	1,263,167	968,201	1,038,809	1,161,716
Equity and Capital	Authorized capital	175,489	175,489	175,489	175,489	175,489
	Retained earnings (accumulated deficit)	39,144	801	21,812	33,524	-157,937
	Other equity and capital	1,219,132	1,139,990	1,142,153	1,068,558	0
	Equity and capital total	1,433,765	1,316,280	1,339,454	1,277,571	17,552
Others	Future period revenue	0	110	102	94	0
Liabilities and equity total		**2,431,199**	**2,579,557**	**2,307,757**	**2,316,964**	**2,700,340**

Source: KVK

Table 2.3 Account Balance of Operating Activity – Balance Sheet (Euro)

(1,000 Euro)

		2008	2009	2010	2011	2012
Non-current Assets	Fixed assets	112,794	108,760	109,671	109,958	148,609
	Intangible fixed assets	4,375	4,172	8,108	6,873	5,817
	Deferred assets	5,344	6,979	6,231	7,066	5,391
	Incomplete capital investments	56,322	56,856	25,885	18,284	0
	Other non-current assets	390	36	36	0	-0
	Non-current assets total	179,225	176,804	149,931	142,182	159,818
Current Assets	Cash and cash equivalent	892	722	1,186	145	2,618
	Inventories	2,098	2,140	2,485	2,984	3,883
	Receivables	37,454	52,832	51,822	61,875	75,730
	Other current assets	3,942	4,678	6,703	5,739	6,356
	Current asset total	44,386	60,371	62,195	70,743	88,586
Others	Future period expenses	35	118	164	213	0
Assets total		**223,646**	**237,293**	**212,291**	**213,138**	**248,404**
Long-term Liabilities	Long-term liabilities	447	353	259	166	139,923
Current Liabilities	Short-term bank loans	0	0	0	1,777	0
	Notes payables	0	3,340	7,660	0	0
	Receivable for goods, services and works	34,191	51,615	43,437	64,780	91,436
	Other current liabilities	5,062	5,772	7,750	9,799	15,375
	Provisions for liabilities and charge	50,416	52,060	26,699	17,116	55
	Liabilities total	744,258	116,199	89,065	95,560	106,866
Equity and Capital	Authorized capital	16,143	16,143	16,143	16,143	16,143
	Retained earnings (accumulated deficit)	3,601	74	2,006	3,084	-14,529
	Other equity and capital	112,148	104,868	105,067	98,297	0
	Equity and capital total	131,892	121,085	123,216	117,524	1,615
Others	Future period revenue	0	110	102	9	0
Liabilities and equity total		**223,646**	**237,293**	**212,291**	**213,138**	**248,404**

Source: KVK

Table 2.4 Account Balance of Operating Activity – Cash Flow Statement (UAH)

(1,000 UAH)

Account tittle	2008	2009	2010	2011	2012
Operating Cash Flow					
Revenue income					
Income from sales of products, goods, service			751,412	776,642	824,238
Repayment of notes receivable			0	0	0
Buyers and advances of customers			20,824	20,245	17,195
Recovery of advances			2,673	672	175
Interests according current accounts of banking institutions			220	362	2,127
Recovery of other taxes and duties (mandatory payments)			324	0	1
Obtaining subsidies, grants			29,438	35,912	1,077,450
Targeted financing			21,654	8,919	37,849
Forfeits (fines, penalties) of debtors			66	927	1,689
Other operating revenues			18,035	19,933	
Cost for payment					
Goods (works, services)			323,186	299,077	1,409,124
Advances			22,198	40,671	19,930
Recovery of advances			75	222	221
Employees			201,586	202,820	235,041
Travel expenses			102	285	223
Value Added Tax obligations			29,861	41,750	34,465
Income tax obligations			979	17,027	8,461
Deductions for social activities			118,457	103,696	118,457
Obligations for other taxes and duties (mandatory payments)			49,264	54,028	60,935
Other operating expenses			137,283	21,687	20,997
Sub-total	-29,887	-23,797	-14,955	82,349	63,274
Investment Cash Flow					
Financial investment			395	0	0
Non-current assets			-13,122	-34,366	-24,227
Others			0	0	0
Sub-total	31,785	18,712	-12,727	-34,366	-24,227
Financial Cash Flow					
Equity dividend			0	0	0
Repayment of loans			-45,269	-19,313	0
Other payment			61,623	-1,773	-571
Sub-total	0	0	16,354	-21,086	-571
Net cash flow for accounting period	1,898	-5,085	-11,328	26,897	38,476
Balance of the cost at the beginning of the year	-9,696	-7,798	12,891	1,563	28,460
Influence on rate change	0	-8	0	0	0
Total	**-7,798**	**-12,891**	**1,563**	**28,460**	**66,936**

Source: KVK

Table 2.5 Account Balance of Operating Activity – Cash Flow Statement (Euro)

(1,000 Euro)

Account tittle	2008	2009	2010	2011	2012
Operating Cash Flow					
Revenue income					
Sales of products, goods, service			69,122	71,443	75,822
Repayment of notes receivable			0	0	0
Buyers and advances of customers			1,916	1,862	1,582
Recovery of advances			246	62	16
Interests according current accounts of banking institutions			20	33	196
Recovery of other taxes and duties (mandatory payments)			30	0	1
Obtaining subsidies, grants			2,708	3,304	99,115
Targeted financing			1,992	820	3,482
Forfeits (fines, penalties) of debtors			6	85	155
Other revenues			1,659	1,834	
Cost for payment					
Goods (works, services)			29,730	27,512	129,625
Advances			2,042	3,741	1,833
Recovery of advances			7	20	20
Employees			18,544	18,657	21,621
Travel expenses			9	26	21
Value Added Tax obligations			2,747	3,841	3,170
Income tax obligations			90	1,566	778
Deductions for social activities			10,897	9,539	10,897
Obligations for other taxes and duties (mandatory payments)			4,532	4,970	5,605
Other expenses			12,629	1,995	1,932
Sub-total	-2,749	-2,189	-1,376	7,575	5,821
Investment Cash Flow					
Financial investment			36	0	0
Non-current assets			-1,207	-3,161	-2,229
Others			0	0	0
Sub-total	2,924	1,721	-1,171	-3,161	-2,229
Financial Cash Flow					
Equity dividend			0	0	0
Repayment of loans			-4,164	-1,777	0
Other payment			5,669	-163	-53
Sub-total	0	0	1,504	-1,940	-53
Net cash flow for accounting period	175	-468	-1,042	2,474	3,539
Balance of the cost at the beginning of the year	-892	-717	1,186	144	2,618
Influence on rate change	0	-1	0	0	0
Total	**-717**	**-1,186**	**144**	**2,618**	**6,157**

Source: KVK

(4) Average Revenue and Unit Operational Cost for Water and Wastewater

Average revenue of water supply and wastewater management is 3.39 UAH/m^3 (0.32 Euro/ m^3). Total unit operational cost for water supply and wastewater service is provided including depreciation costs is 4.46 UAH/m^3 (0.41 Euro/m^3), consisted of water supply 2,43 UAH/m^3 (0.22 Euro/m^3) and sewerage 2,03 UAH/m^3 (0.19 Euro/m^3). As a result, the balance is 1.07 UAH/m^3 (0.10 Euro/m^3) loss. The average revenue of sewerage accounts for 1.36 UAH/m^3 (0.13 Euro/m^3) without VAT, therefore this rate is unprofitable generating loss of 0.67 UAH/m^3 (0.06 Euro/ m^3).

Table 2.6 Average Revenue and Unit Operational Cost for Wastewater

Type of service	UAH/m^3			Euro/m^3		
	Average revenue[2]	Unit operational costs[3]	Difference	Average revenue	Unit operational costs	Difference
Water supply	2.03	2.43	- 0.40	0.19	0.22	0.04
Sewerage	1.36	2.03	- 0.67	0.13	0.19	0.06
Total	3.39	4.46	- 1.07	0.32	0.41	0.10

Source: KVK

(5) Operation and Maintenance Costs of BAS

The O&M costs of BAS indicated in the annual budget is amounted for 280,923 UAH or equivalent to 25,842 Euro in the year 2013[4].

The electricity cost which has been continuously increased shares the largest portion as 52%, which could be a too heavy burden for BAS. An another concern could be the small portion of material, repair and maintenance costs and chemical costs which shares only 2% and 1% of the overall costs respectively.

There is no exact information on how much the O&M costs of sewerage service is covered by sewerage tariff revenue. It can be, however, estimated by deducting the depreciation portion of sewerage facilities that the shortage is equivalent to be 0.56 UAH/m^3 (0.05 Euro/m^3). Hence, it is difficult to say that the budget for material, repair and maintenance costs and chemical are sufficiently secured under the insufficiently subsidy for compensation between the approved tariff rates and the actual production costs, as mentioned in the previous section.

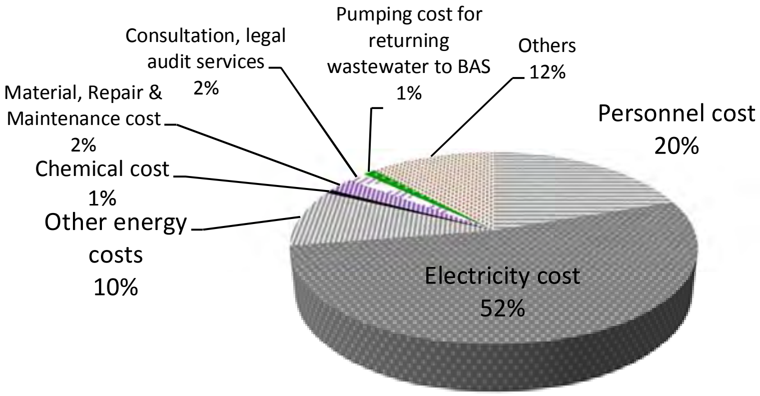
The composition of O&M costs and the trend of electricity charge rates are shown in the following

2 Average operational revenue = Annual operating water (sewerage) revenues / Annual amount of water (treated wastewater) sold, IBNET

3 Unit operational cost = Annual operational water (sewerage) expenses / Annual amount of water (treated wastewater) sold, IBNET

4 The O&M costs does not includes depreciation costs of sewerage facilities in BAS..

figure.



Source: KVK BAS

Figure 2.4 Composition of O&M Costs of BAS

Source: Kievenergo Homepage, http://kyivenergo.ua/ee-company/tarifi

Figure 2.5 Trend of Electricity Charge Rates

(6) Accounting System

The concept of International Financial Reporting Standards (IFRS) has been applied to the accounting system of KVK since 2012. Preliminary financial statements were prepared from the date of 1st January 2012 in accordance with IFRS. The first financial statements complying with all IFRS standards will be completed at the year end of 2013.

(7) Financial Ratio Analysis

Financial condition of KVK is analyzed by using some key indicators of financial ratio, which are estimated both by a financial distress classification model and by others. The results are shown in the following table and figure.

The distress model is utilized to measure related to liquidity, financial leverage, efficiency and profitability[5]. The results are turned out to be 3.59 in 2012, so that the financial distress condition of KVK may be acknowledged as “weak to marginal”[6].

With regard to the profitability aspect, the results of indicator 1 and indicator 7 during the recent 3 years show a slight increase between 2010-2011 and a significant decrease between 2011-2012. The result of liquidity indicator with less than 1.0 could be not sufficient from the viewpoint that more than 1.0 is desirable in general. From the aspect of leverage, it could be notable that leverage as indicator 3 and likely represents the weak symptom. Especially this low performance of leverage may be paid attention since financial leverage is more important to measure the capability to service debt.

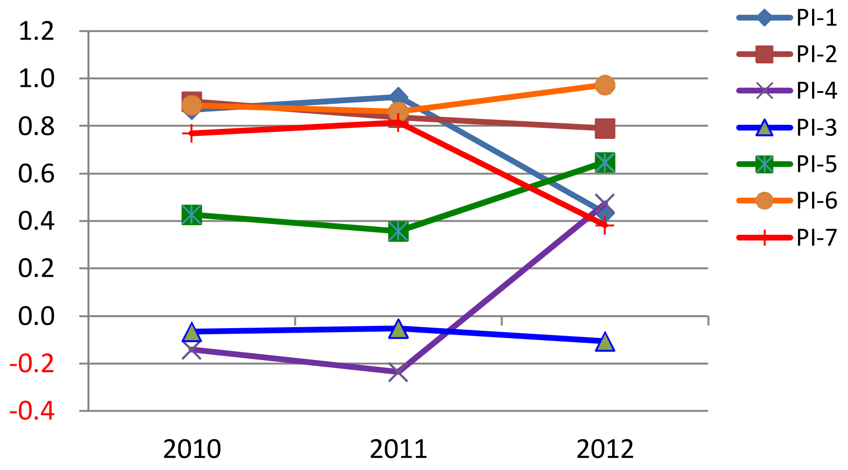
Table 2.7 Financial Ratios by Distress Classification Model

Indicators	Formula	Financial Ratio		
		2010	2011	2012
1 Profitability	Net income + Depreciation / Annual operating revenue	0.87	0.92	0.43
2 Liquidity	Current assets / Current liabilities	0.90	0.84	0.79
3 Leverage	Common stock equity / Total assets	-0.07	-0.05	-0.11
4 Profit trend	Retained earning / Common stock equity	-0.14	-0.24	0.47
5 Growth and efficiency	Annual operating revenues / Total assets	0.43	0.36	0.65
6 Efficiency and profitability	Annual operating revenues / Annual operating expenses	0.89	0.86	0.97
7 Profitability	Net income / Annual operating revenues	0.77	0.82	0.38
Total		3.65	3.50	3.59

Source: JICA Study Team

5 A financial distress classification model created by the National Regulatory Research Institute in USA is applied. If utilities score 4.0 or more, they are regarded as “Good to excellent”. The scoring of “3.0-3.9” or “3.0 or less” are classified as “Weak to marginal” or “Distressed” respectively.

6 If the score is 4.0 or more, the utility is regarded as “Good to excellent”. Those scoring 3.0-3.9 and 3.0 or less are classified as “Weak to marginal” and “Distressed” respectively.



Source: JICA Study Team based on KVK's information

Figure 2.6 Financial Ratios Trends by Distress Classification Model

In terms of other indicators, the performance is shown in the following table. The main features are described as below.

The equity ratio in 2012 decreased rapidly and it was assessed as not healthy below the approximate standard at 0.3. The main reason of this is considered that the value of equity capital is revised according to the methodological recommendation issued by the state commission, under the application process of IFRS.

The return on assets ratio in 2012 was also recovered from the negative value in 2010 and 2011, however it is still weak performance.

Current assets turnover ratio in 2012 is indicating a relatively healthy condition at more than 1.0.

Quick assets ratio during the recent 3 years were not sufficient at less than 1.0, thus the short-term liquidity may be not large.

Table 2.8 Other Main Financial Ratios

Indicators	Formula	Financial Ratio		
		2010	2011	2012
1 Equity ratio	Equity capital / Total assets	0.55	0.48	0.01
2 Return on equity ratio	Net profit/ loss / Invested equity	-0.06	-0.11	0.02
3 Return on assets	Net profit/ loss / Total assets	-0.03	-0.06	0.00
4 Current assets turnover ratio	Net profit from sales / Current assets (beginning + end)/ 2	1.05	0.90	1.13
5 Quick assets ratio	Current assets – Inventories / current liabilities	0.96	0.87	0.79

Source: JICA Study Team

Indicators	References
1 Equity ratio	Equity ratio measures the proportion of the total assets that are financed by stockholders and not creditors. A higher equity ratio or a higher contribution of shareholders to the capital indicates a company's better long-term solvency position. A ratio of 0.2-0.3 may be still recognized as a relatively better performance.
2 Return on equity ratio	It reveals how much profit a company earned in comparison to the total amount of shareholder equity found on the balance sheet. A ratio of around 0.1 may be still recognized as an average performance.
3 Return on assets	Return on assets is a key profitability ratio which measures the amount of profit made by a company per dollar of its assets. It shows the company's ability to generate profits before leverage, rather than by using leverage. A ratio of around 0.01-0.02 may be still recognized as an average performance.
4 Current assets turnover ratio	It indicates that the current assets are turned over in the form of sales more number of times. A high current assets turnover ratio indicates the capability of the organization to achieve maximum sales with the minimum investment in current assets. A ratio of more than 1.0 is desirable.
5 Quick assets ratio	The quick ratio measures a company's ability to meet its short-term obligations with its most liquid assets. The higher the quick ratio, the better the company's liquidity position.

Source: JICA Study Team

2.4.2 Subsidy Provision System

(1) Subsidy System by the Government

For a long time, the financial situation of water and sewerage services has tended to be in deficit under the state-regulated tariffs. This may be attributed to a social direction of tariff policy of the central and the municipal government. The role of tariff setting for water supply and sewerage is defined by the newly established NCSPUR under current Ukrainian legislation, thus KVK as a provider does not have direct authority over it.

Meanwhile, the compensation of the difference between established tariffs and economically substantiated expenses for production and services is based on the following formulation:

- Article 31 of the Law of Ukraine "On Housing and Utility Services"
"In case of a self-governance body for housing and utility services, if it is impossible to obtain profit, the body which establish tariffs shall compensate the difference between the established prices/tariffs and the production cost of services from respective local budget to contractors/producers";
- Article 15 of the Law of Ukraine "On Prices and Price Formation"
"If the established state-regulated prices for goods are lower than the production costs, Cabinet of Ministers of Ukraine, executive and local self-governance bodies shall compensate the difference between such amounts at the expense of respective budget funds to the economic subjects".

To regulate the compensation of difference in tariffs, the Cabinet of Ministers of Ukraine also issued the following decrees "On the Procedure of Transferring Subsidy from the State Budget to Local Budgets to Clear Debt from the Difference in Tariffs...": No. 705 of May 22, 2006; No. 440 of April 25, 2008; No. 193 of March 5, 2009; No. 517 of June 11, 2012; No. 167 of March 20, 2013.

(2) Challenges on Subsidy System

The compensation amount is reported and submitted by KVK to KCSA, then KCSA submits a request of compensation to the central government. The compensation of this debt attributing to the difference of tariff rate and cost was not timely allocated and distributed from KCSA's budget. For instance, the subsidy for 3 years during FY2008-2011 was allocated in FY2012 behindhand. This subsidy provision for compensation seems to be less certain and to depend upon the decision making by the central government.

Another issue is that this subsidy for compensation is not fully paid as requested. In case of the subsidy for FY2008-2012 provided in FY2012, the depreciation costs were not included and not covered. The sufficient investment costs for replacement and rehabilitation of facilities has been not chronically secured. The actual allocated investment amount for replacement and rehabilitation is limited to 5-7% of the total necessary amount.

2.4.3 Tariff Setting and Current Tariff Structure

(1) Tariff Setting and National Commission for Regulation

The authority of setting tariffs for water supply and sewerage service including other public utility services belongs to the competence of National Commission for the State Public Utilities Regulation (NCSPUR).

The Decree No. 243 and No.245 issued by the predecessor of NCSPUR, National Commissions for

Electric Power Regulation, defined tariff setting procedure for water supply and sewerage.

(2) Conditions for Tariff Adjustment

The conditions of tariff adjustment are defined by Decree No.253. Some main conditions are referred as follows.

1. Tariff change may be initiated by the licensee to the NCSPUR by providing relevant application with the specified documents.
2. The necessity of rates change is arisen under the following circumstances:
   - Change the volume of centralized water and wastewater by more than 5%
   - Change in the investment program of the licensee, if it leads to change tariff rates by more than 5% of the previous level
   - Change in the amount of expenses incurred in the licensed activities of water supply and sewerage, if it leads to by more than 5% of the previous level
3. Tariff change may be initiated by the NCSPUR in the following circumstances:
   - Failure by the licensee of the investment program
   - Failure by the licensee conditions of the procurement of goods, works and services
   - Cases if cross-subsidization between water supply and sewerage service and other economic activities of the licensee is happened

(3) Tariff Setting Procedure

To set the tariff, the KVK as the licensee will submit a request to NCSPUR in the printed and electronic copies for calculating tariffs in the format defined by Decree No.245. The submission needs to include an investment program and financial information of licensee for the planned period.

After consideration and an analysis of the applicant documents, public meetings will be held for the discussion of tariff setting and revision.

The relevant documents on the tariff setting for water supply and sewerage are shown as below:

- NERC Resolution No. 243, “Approving the Formation of Tariffs for Water Supply and Sewerage” dated 17 February 2011
- NERC Resolution No.245, “Procedure of Forming Tariffs for Water Supply and Sewerage Services” dated 17 February 2011
- NERC Resolution No. 279, “On Approval of License Conditions for Providing Economic Activities on Centralized Water Supply and Sewerage” dated 10 August 2012

(4) Current Tariff Structure

KVK has applied 2 types of tariff structure, namely metered rate system and flat rate system by customer types. Customer types are mainly divided into three groups such as domestic, budgetary institutions and others. Current tariff rates have been adopted since March 2012 for domestic and since November 2011 for budgetary institutions and others.

A flat rate system applied to non-metered customers defines monthly water tariff per cubic meter by customer type. Non-metered customers are categorized into five by the combination of installation of water supply and heating pipes. The rate is calculated by multiplying average consumption per capita by unit sewerage tariff rates which is same as the metered rate.

For metered customers, an uniform metered rate system which has a constant or universal tariff rate within metered rate systems has been in practice. The tariff rate of sewerage service is within the range of 78-84% of the rate of cold water service. The tariff rate of budgetary institution and other institutions are respectively set at 1.7 times and 1.9 times higher than that of domestic users.

Table 2.9 Sewerage Tariff Structure in Use (As of December 2013)

(UAH (Euro))

	Customer type	Cold water	Sewerage	Total
Metered rate	Domestic	1.79 (0.16)	1.39 (0.13)	3.18 (0.29)
	Budgetary institutions	2.76 (0.25)	2.32 (0.21)	5.08 (0.47)
	Others	3.36 (0.31)	2.66 (024.)	6.02 (0.55)

		Average consumption	Rate/m^3	Total
	Unit	m^3/month/capita	UAH (Euro) Inc. VAT	UAH (Euro) /month/capita
Flat rate	Canalization without plumbing (well)	2.85	1,392 (128.05)	3.97 (0.37)
	Canalization without plumbing (heating)	5.7	1,392 (128.05)	7.93 (0.73)
	Plumbing and canalization without water heating	2.85	3,180 (292.53)	9.06 (0.83)
	Plumbing and canalization with heating (gas, electric heater)	5.7	3,180 (292.53)	18.13 (1.67)
	Canalization with the central hot water supply	9.0	1,392 (128.05)	12.53 (1.15)

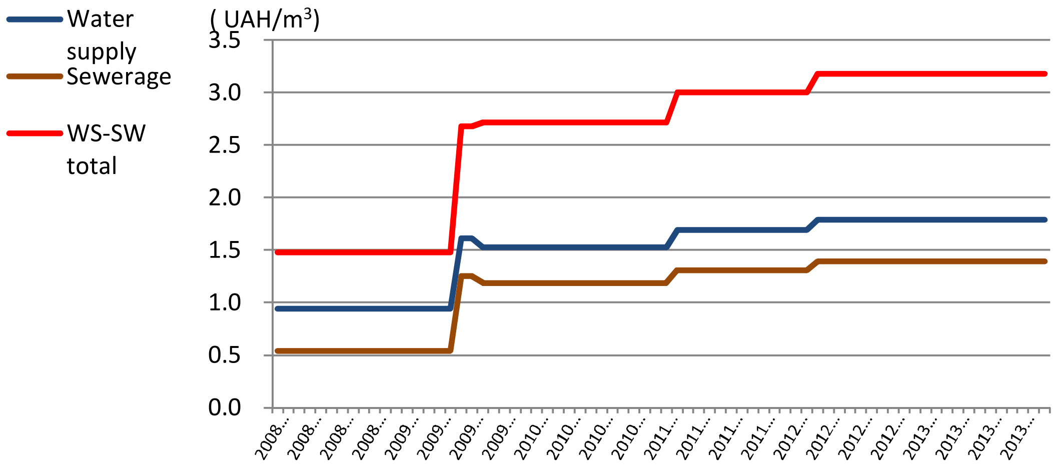
Note: 20% of Value Added Tax is included in the above tariff rates

Source: KCSA

(5) Transition of Sewerage Tariff Rates

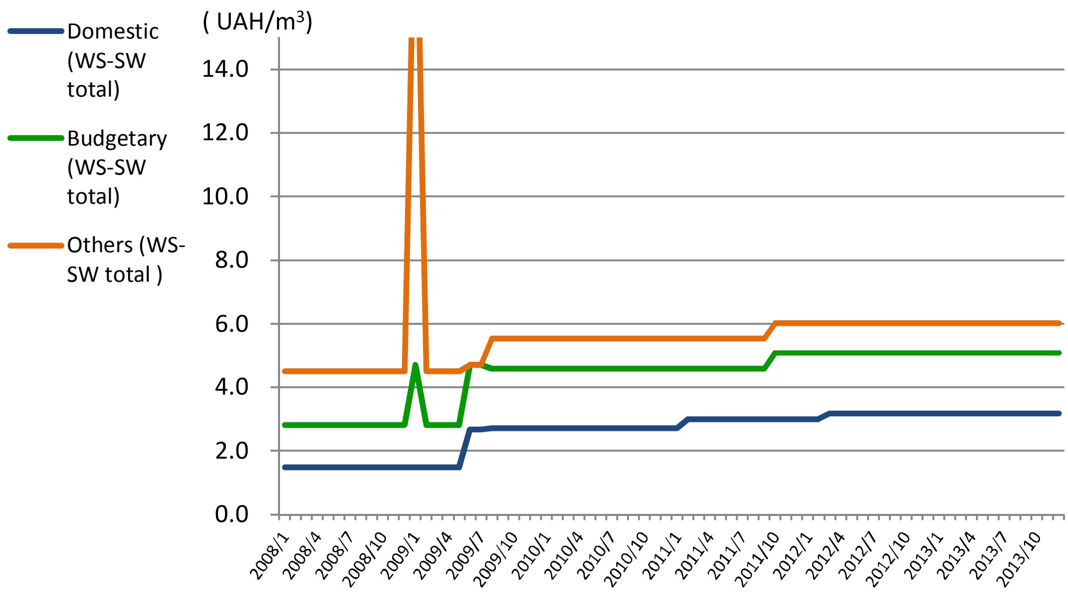
Transition of tariff rates for water supply and sewerage for 5 years (2008-2013) is shown in the following Figures.

During the recent five years, sewerage tariff rates indicate 2.6 time growth, which is relatively larger than that of water supply at 1.9 times. The increase ratio combined water supply and sewerage records 2.2 times growth. It is observed that the tariff revision has been conducted several 4 times for domestic and 8 times for budgetary institutions and other institutions since 2008.



Source: KVK

Figure 2.7 Transition of Tariff Rates for Water Supply and Sewerage



Source: KVK

Figure 2.8 Transition of Sewerage Tariff Rates by Customer Type

2.4.4 Customer Type and Number of Connections

According to the information from KVK, the total number of connection amounts 61,588 both in Kiev city and the satellite towns of Kiev region as of January 2013. However, in case of the number of connections for communal housing, the number of bulk connection at the entrance of communal housing block owned by owners is counted. KVK mentioned that they do not know the exact number of household sewerage connections in communal housing.

The majority of connections are composed of domestic customers with approximately 91.6%, followed by commercial and industrial customers sharing 7.8%, and governmental institutions sharing 0.4% to the total customers.

Metered customer is 76% of the total customers. For various customer types the ratio of customers that are metered varies, it is 75 % for domestic, 84 % for commercial and industrial, 31 % for governmental offices and houses, therefore metering for commercial and industrial customer have met a progress and that of governmental customers is relatively lagging behind.

The number of customers during recent three years indicates a steady annual growth with approximately 5%. The composition of annual growth rates by customer type shows 8.5% for domestic, 7.4% for commercial and industry, -0.4% for governmental institution and houses. The growth rate of domestic and commercial and industrial customers are remarkable.

The composition of number of sewerage connections and the trend are shown in the following table.

Table 2.10 Number of Sewerage Connections in Kiev City and Kiev Region

Area	District/ Regional city	Population		Metered			Non-metered			Total			Grand total
		Population census 2001	Population estimation 2013	Domestic	Bud. Ins.	Ind./ Com./ Others	Domestic	Bud. Ins.	Ind./ Com./ Others	Domestic	Bud. Ins.	Ind./ Com./ Others	
Kiev city with special status	Darnytsia	282,359	320,234	642	155	551	149	3	9	791	158	560	1,509
	Densa	336,209	362,127	688	181	462	250	4	24	938	185	486	1,609
	Dnipro	331,618	348,804	1,379	231	657	292	13	16	1,671	244	673	2,588
	Holosiiv	202,993	239,340	1,080	291	721	907	8	42	1,987	299	763	3,049
	Obolon	306,173	317,419	887	191	650	124	3	13	1,011	194	663	1,868
	Pechersk	131,127	144,785	1,101	298	668	216	16	34	1,317	314	702	2,333
	Podil	180,424	193,263	1,276	199	681	1,145	4	50	2,421	203	731	3,355
	Shevchenko	237,213	230,489	1,916	515	1,151	880	12	38	2,796	527	1,189	4,512
	Solomyanka	287,801	351,169	1,681	405	756	1,152	11	32	2,833	416	788	4,037
	Svatoshyn	315,410	337,393	88	222	686	1,200	6	28	1,288	228	714	2,230
	Total in Kiev	**2,295,917**	**2,507,630**	**10,650**	**2,466**	**6,297**	**5,115**	**74**	**258**	**15,765**	**2,540**	**6,555**	**24,860**
Kiev region - satelite town	Kyiv Svyatoshyn district	**156,015**	**158,835**	1,833	36	467				1,833	36	467	2,336
	Petropavlivska Borshchagivka	6,139	6,125	80	2					80	2		82
	Chaiky		4,000	30	1					30	1		31
	Gatne	3,120	3,800	56		2				56		2	58
	Chabany	3,655	7 650	21	3					21	3		24
	Gorenka	5,408	6,800	553	1					553	1		554
	Vyshneve	34,465	37,457	876	25	455				876	25	455	1,356
	Sofiivska Borshchagivka	6,569	6,571	217	4	10				217	4	10	231
	Irpin	40,593	42,924	14,960	32	415	6,476	8	54	21,436	40	469	21,945
	Bucha	28,533	28,483	8,650	9	119	2,815		4	11,465	9	123	11,597
	Vyshhorod district	72,446	72,500	118	61		24	55	361	142	116	361	619
	Vyshgorod	22,933	26,536										
	Total in Satellite towns	**151,415**	**162,696**	**25,778**	**142**	**1,011**	**9,315**	**63**	**419**	**35,093**	**205**	**1,430**	**36,728**
Grand Total		**2,447,332**	**2,670,326**	**36,428**	**2,608**	**7,308**	**14,430**	**137**	**677**	**50,858**	**2,745**	**7,985**	**61,588**
				46,344			**15,244**			**61,588**			

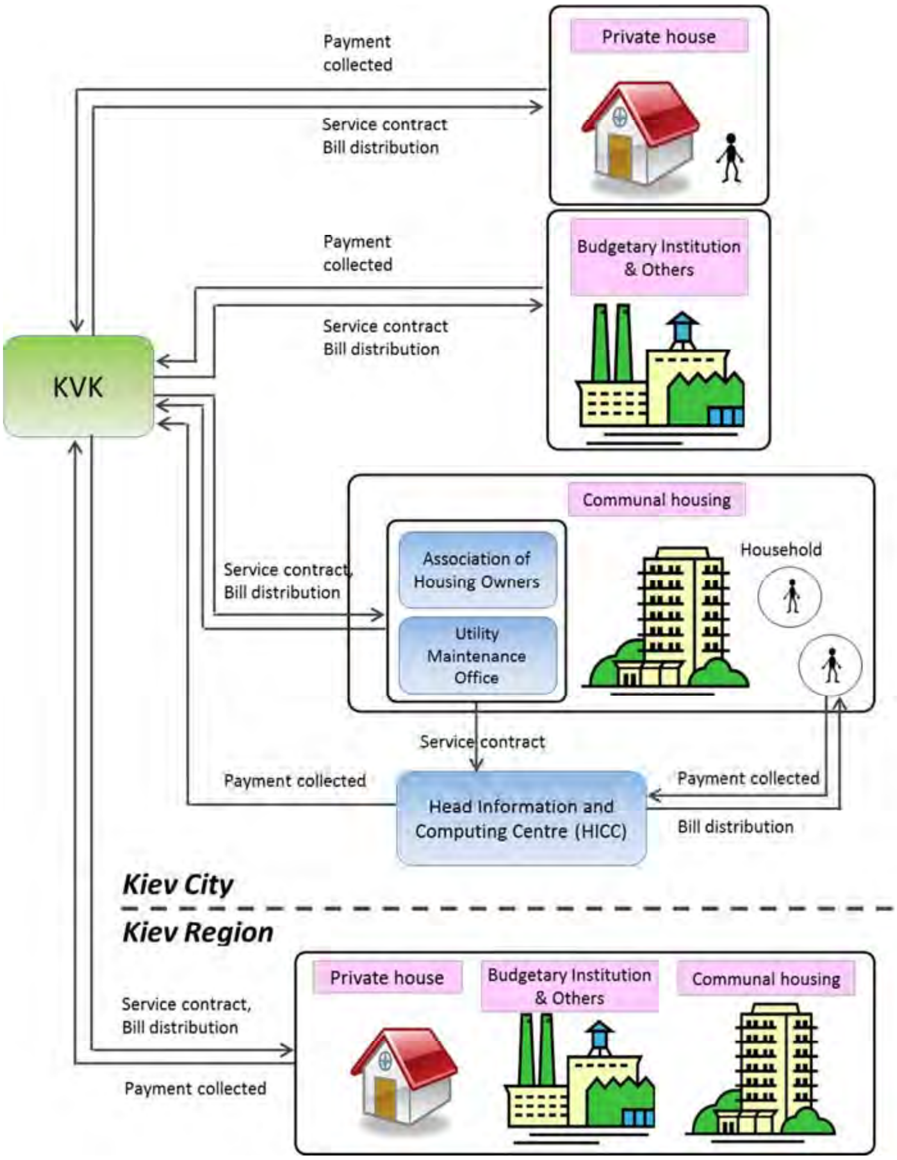
Source: JICA Study Team base on the information from KVK

* Number of connection in the above table does not indicate the total number of household connections. In case of communal housing, the number of bulk meter at the entrance of communal housing block owned by same owners is counted

* Among the connection number of Kyiv Svyatoshyn district, the metering situation of budgetary institutions, industrial/ commercial/ others is not unknown. These numbers, however, are counted as metered customers in the table.

2.4.5 Billing and Collection Mechanism

In billing and collection practice, in principle, KVK distributes the bill to the customer of private households and budgetary institutions and others in the both areas of Kiev city and Kiev region, and collect the tariff payment. An exception of this can be seen in the case of communal housing customers in Kiev city. In that case, KVK has sewerage service contract with the owners of communal housing and distribute the bill to them. The communal housing owners have a responsibility for billing and collection for each residential household living in their communal housing. There is two ways for billing and collection, either that the owners conduct the billing and the collection by themselves or that the owners ask the practice to an outsourcing public company, namely Head Information and Computing Centre (HICC) by an service contract. Billing and collection mechanism for sewerage service is shown as the following figure.



Source: KVK

Figure 2.9 Billing and Collection Mechanism for Sewerage Service

3. Collection and Evaluation of Basic Information

3.1 Basic Information

3.1.1 Topographic Characteristics

(1) Topography

The main features of topographic information are summarized in Table 3.1.

Table 3.1 Basic Topographic Information in Kiev City

Item	Description	Remarks
Latitude	50°27'00" N	
Longitude	30°30'24" E	
Area	839km^2	As of 2012
Average Elevation	+179 m	
Population	2,814,300	As of 2012

Source: Statistical Yearbook of Kiev City (2012)

In relation to the current land use, nearly a half of the land is currently allotted as green areas and landscaping utilities, while residential areas constitute around 12% according to the statistical information.

The current land use of Kiev City is presented in the Table 3.2.

Table 3.2 Land Use of Kiev City

Unit: ha

Item	2011
Residential buildings, including;	10,230.5
Residential - Public Buildings	48.4
Public Buildings	3,863.5
Industrial, Research - Industrial Utility	6,912.3
Transportation Infrastructure	632.9
Street and Road Networks	4,341.8
External Transport	1,215.9
Landscape - Recreational and Green Areas, including;	45,449.2
Water Surfaces	5,569.3
Agricultural Land	2,788.0
Other Territories	2,506.8
Total	83,558.6

Source: Draft Updated General Planning of Kiev City, Kiev City State Administration (2013)

(2) Geology

The typical soil condition of BAS is fine sand, and the feasibility study has conducted boring surveys and has unanimously shown similar profiles within the territories for the reconstruction project.

A sample of boring survey results is presented in Table 3.3.

Table 3.3 Boring Survey Results at the Proposed Construction Site in BAS

Type of Soil	Depth (m)	Elevation (m)		Remarks
		Upper	Lower	
Filled soil	5.3	99.1	93.8	Ground level: +99.10 m
Alluvial soil-sand	1.5	93.8	92.3	
Plant Soil	0.4	92.3	91.9	As of 2012
Fine Sand with silt	7.8	91.9	84.1	Foundation layer
Total Depth of Bore Hole Survey	15.0	-	-	Station: CB-16

Source: KVK

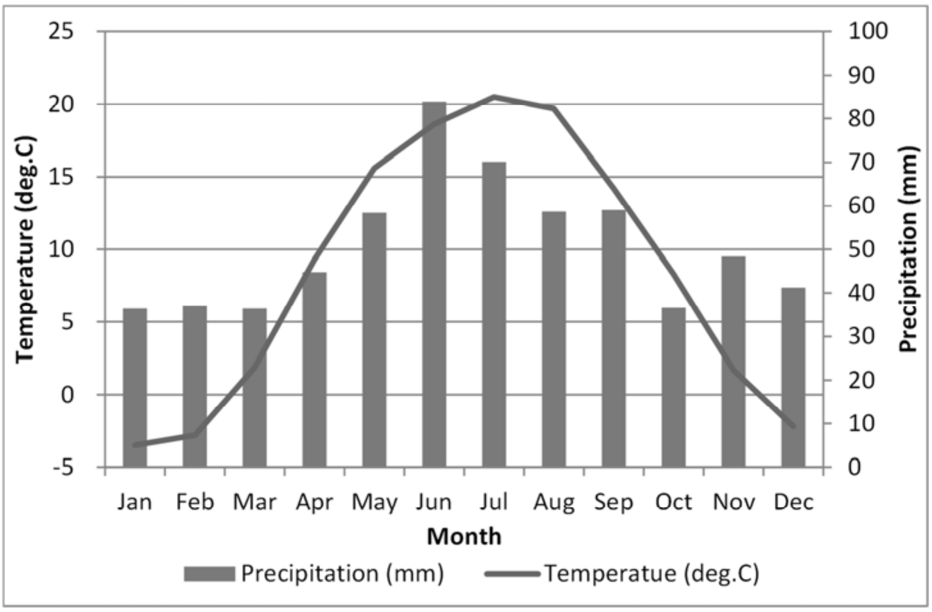
(3) Climate

The summarized monthly climate information is provided in Table 3.4 and Figure 3.1.

Table 3.4 Monthly Temperature and Precipitation in Kiev City

Month	Average Temperature (deg.C)	Average Precipitation (mm/month)	Remarks
January	-3.5	36.4	Average during 1981-2010
February	-2.8	37.1	
March	1.9	36.4	
April	9.3	44.8	
May	15.6	58.4	
June	18.6	83.9	
July	20.5	70.1	
August	19.7	58.7	
September	14.2	59.0	
October	8.3	36.6	
November	1.7	48.4	
December	-2.2	41.3	
Average	8.4	50.9	
Total	-	662.0	

Source: Japan Meteorological Agency (2012)



Source: Japan Meteorological Agency (2012)

Figure 3.1 Monthly Temperature and Precipitation in Kiev City

3.1.2 Current Situation of Population

(1) Current Population in Kiev City

The current population of Kiev is approximately 2,800,000 in living population, which represents total of statistical population including non-permanent residents, and 2,770,000 in permanent population as of 2012. The growth rates have been comparably stable in the recent ten years, ranging between 0.5 – 1.0% per year.

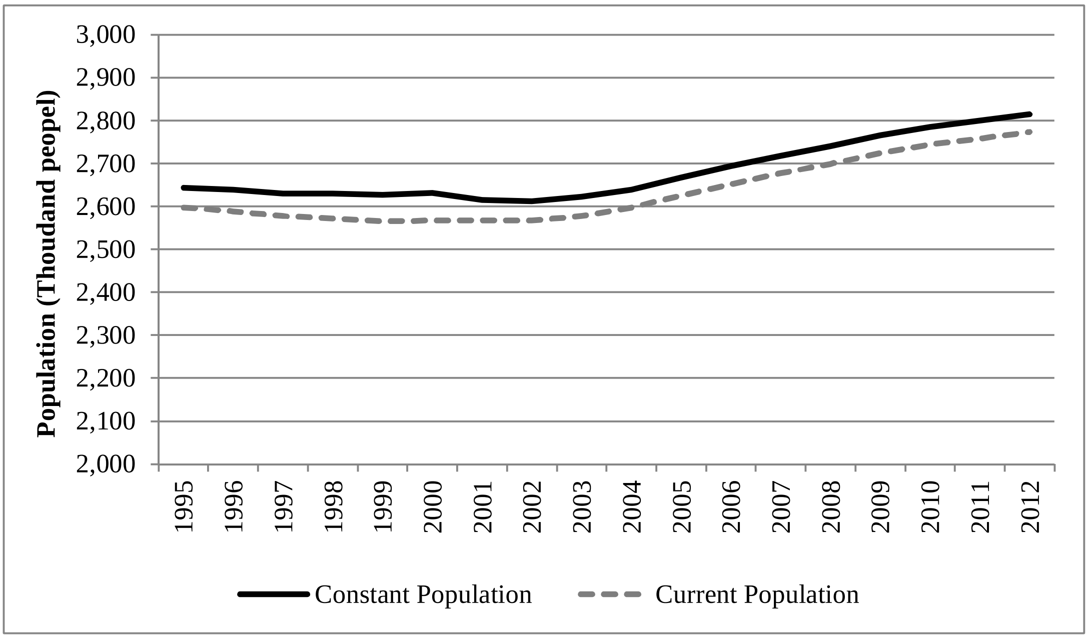
The summary of historical population transitions in Kiev City is presented in Table 3.5 and Figure 3.2.

Table 3.5 Historical Transitions of Population in Kiev City

Unit: People

Year	Living Population			Growth Rate	Permanent Population			Growth Rate	Gross/ Residential
	Urban	Rural	Total		Male	Female	Total		
1995	2,643,800	-	2,643,800	100.00%	1,222,100	1,375,200	2,597,300	100.00%	98.24%
1996	2,638,700	-	2,638,700	99.81%	1,215,900	1,372,900	2,588,800	99.67%	98.11%
1997	2,630,400	-	2,630,400	99.69%	1,208,900	1,368,100	2,577,000	99.54%	97.97%
1998	2,629,300	-	2,629,300	99.96%	1,205,000	1,367,300	2,572,300	99.82%	97.83%
1999	2,626,500	-	2,626,500	99.89%	1,200,000	1,365,700	2,565,700	99.74%	97.69%
2000	2,631,900	-	2,631,900	100.21%	1,198,500	1,368,500	2,567,000	100.05%	97.53%
2001	2,615,300	-	2,615,300	99.37%	1,196,300	1,371,300	2,567,600	100.02%	98.18%
2002	2,611,300	-	2,611,300	99.85%	1,193,400	1,373,600	2,567,000	99.98%	98.30%
2003	2,621,700	-	2,621,700	100.40%	1,197,000	1,380,300	2,577,300	100.40%	98.31%
2004	2,639,000	-	2,639,000	100.66%	1,206,000	1,391,700	2,597,700	100.79%	98.44%
2005	2,666,400	-	2,666,400	101.04%	1,217,900	1,407,200	2,625,100	101.05%	98.45%
2006	2,693,200	-	2,693,200	101.01%	1,229,000	1,422,900	2,651,900	101.02%	98.47%
2007	2,718,100	-	2,718,100	100.92%	1,239,300	1,437,500	2,676,800	100.94%	98.48%
2008	2,740,200	-	2,740,200	100.81%	1,248,100	1,450,800	2,698,900	100.83%	98.49%
2009	2,765,500	-	2,765,500	100.92%	1,258,700	1,465,500	2,724,200	100.94%	98.51%
2010	2,785,100	-	2,785,100	100.71%	1,267,500	1,476,300	2,743,800	100.72%	98.52%
2011	2,799,200	-	2,799,200	100.51%	1,273,500	1,484,400	2,757,900	100.51%	98.52%
2012	2,814,300	-	2,814,300	100.54%	1,279,500	1,493,500	2,773,000	100.55%	98.53%

Source: Main Statistics Department, Kiev City State Administration



Source: Main Statistics Department, Kiev City State Administration

Figure 3.2 Actual Growth of Population in Kiev City

The summary of Kiev City districts is shown in Table 3.6. The location of districts is shown in Figure 3.3.

Table 3.6 Summary of Districts in Kiev City

No.	Location	District	Area (km^2)	Ratio (%)	Population Density (people/km^2, 2013)
1	Right Bank	Holosiiv	156	18.7%	1,534
2	Left Bank	Darnytsia	133	15.9%	2,408
3	Left Bank	Dnipro	148	17.7%	2,447
4	Left Bank	Desna	67	8.0%	5,206
5	Right Bank	Obolon	110	13.2%	2,886
6	Right Bank	Pechersk	20	2.4%	7,239
7	Right Bank	Podil	34	4.1%	5,684
8	Right Bank	Sviatoshyn	101	12.1%	3,341
9	Right Bank	Solomianka	40	4.8%	8,779
10	Right Bank	Shevchenko	27	3.2%	8,537
Sub Total of Right Bank Districts			488	58.4%	3,717
Sub Total of Left Bank Districts			348	41.6%	2,963
Total			836	100.0%	3,403

Source: Statistical Yearbook of Kiev City, 2011

Source: JICA Study Team

Figure 3.3 Location Map of Districts in Kiev City

According to the existing conditions, the right bank side has 58.4% of the total area of Kiev City.

Regarding the current population, about 63% of total population is shared in the right bank side and almost all districts keep increasing in number of population except for Shevchenko District, the business and political center of the city.

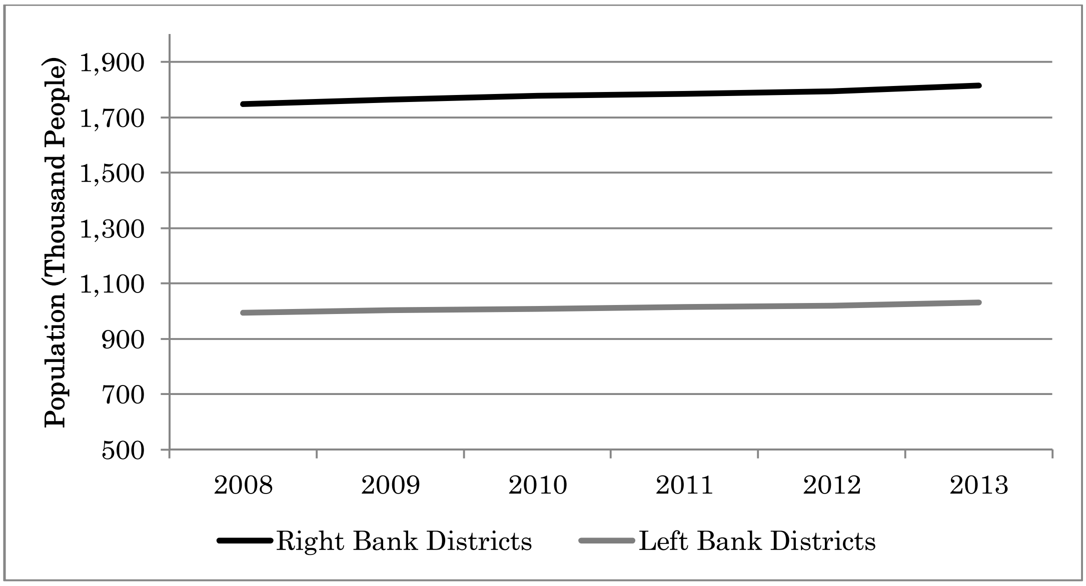
The historical transitions of living population in the districts are shown in Table 3.7 and Figure 3.4.

Table 3.7 Historical Transitions of Living Population in Districts of Kiev City

Unit: People

No.	Location	District	2008	2009	2010	2011	2012	2013	Growth Rate (%)
1	Right Bank	Holosiiv	224,707	228,146	230,932	233,157	235,143	239,340	106.51%
2	Left Bank	Darnytsia	302,560	305,842	308,817	311,476	315,174	320,234	105.84%
3	Left Bank	Dnipro	350,084	352,428	354,585	356,374	358,589	362,127	103.44%
4	Left Bank	Desna	340,996	343,611	344,911	345,781	346,527	348,804	102.29%
5	Right Bank	Obolon	311,947	313,086	314,211	314,797	315,608	317,419	101.75%
6	Right Bank	Pechersk	135,994	137,749	138,905	139,672	140,601	144,785	106.46%
7	Right Bank	Podil	186,708	188,156	189,198	190,069	191,441	193,263	103.51%
8	Right Bank	Sviatoshyn	327,969	330,631	332,687	334,169	335,848	337,393	102.87%
9	Right Bank	Solomianka	326,725	333,453	338,834	342,376	345,058	351,169	107.48%
10	Right Bank	Shevchenko	232,543	232,429	232,051	231,328	230,269	230,489	99.12%
Total of Right Bank Districts			1,746,593	1,763,650	1,776,818	1,785,568	1,793,968	1,813,858	103.85%
Total of Left Bank Districts			993,640	1,001,881	1,008,313	1,013,631	1,020,290	1,031,165	103.78%
Total			2,740,233	2,765,531	2,785,131	2,799,199	2,814,258	2,845,023	103.82%

Source: Main Statistics Department, Kiev City State Administration



Source: Main Statistics Department, Kiev City State Administration

Figure 3.4 Historical Growth of Living Population in Districts of Kiev City

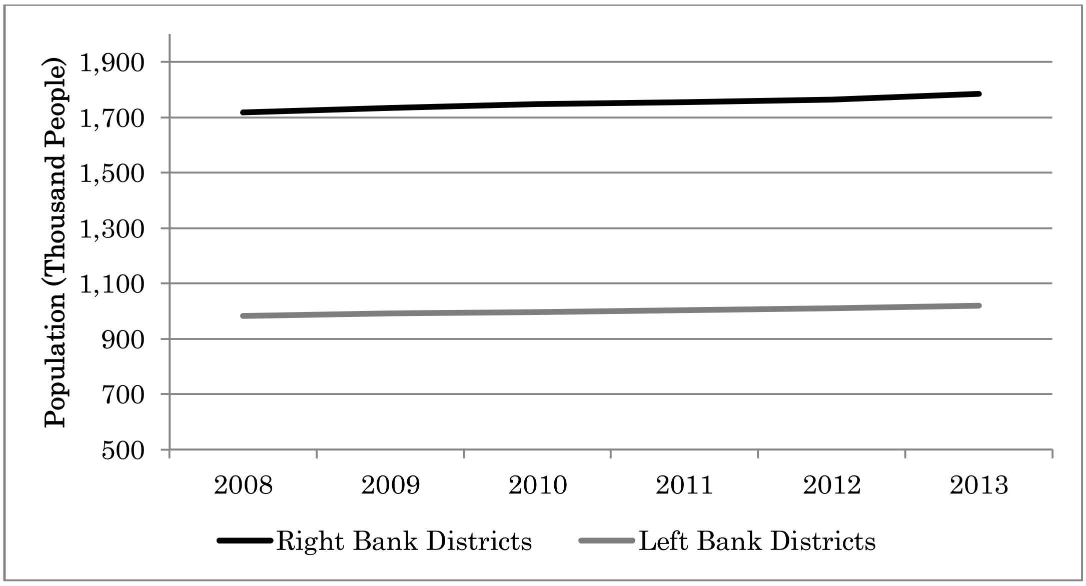
The historical transitions of permanent population in the districts are shown in Table 3.8 and Figure 3.5.

Table 3.8 Historical Transitions of Permanent Population in Districts of Kiev City

Unit: People

No.	Location	District	2008	2009	2010	2011	2012	2013	Growth Rate (%)
1	Right Bank	Holosiiv	222,609	226,048	228,834	231,059	233,045	237,242	106.57%
2	Left Bank	Darnytsia	296,061	299,343	302,318	304,977	308,675	313,735	105.97%
3	Left Bank	Dnipro	347,194	349,538	351,695	353,484	355,699	359,237	103.47%
4	Left Bank	Desna	339,267	341,882	343,182	344,052	344,798	347,075	102.30%
5	Right Bank	Obolon	309,073	310,212	311,337	311,923	312,734	314,545	101.77%
6	Right Bank	Pechersk	131,271	133,026	134,182	134,949	135,878	140,062	106.70%
7	Right Bank	Podil	183,298	184,746	185,788	186,659	188,031	189,853	103.58%
8	Right Bank	Sviatoshyn	322,049	324,711	326,767	328,249	329,928	331,473	102.93%
9	Right Bank	Solomianka	324,679	331,407	336,788	340,330	343,012	349,123	107.53%
10	Right Bank	Shevchenko	223,425	223,311	222,933	222,210	221,151	221,371	99.08%
Total of Right Bank Districts			1,716,404	1,733,461	1,746,629	1,755,379	1,763,779	1,783,669	103.92%
Total of Left Bank Districts			982,522	990,763	997,195	1,002,513	1,009,172	1,020,047	103.82%
Total			2,698,926	2,724,224	2,743,824	2,757,892	2,772,951	2,803,716	103.88%

Source: Main Statistics Department, Kiev City State Administration



Source: Main Statistics Department, Kiev City State Administration

Figure 3.5 Actual Growth of Permanent Population in Districts of Kiev City

(2) Current Population outside Kiev City

Kiev City is located in the center of Kiev Region. The total area of the region is 28.4 thousand square km. The region may be considered as the most important region in Ukraine in terms of its location which enables easier access to the nation's capital.

The statistical information on the overall population in Kiev Region is presented in Table 3.9, and the location map is shown in Figure 3.6.

Table 3.9 Transition of Population in Kiev Region (Except Kiev City)

Unit: People

Year	Living Population			Permanent Population		
	Total	Breakdown		Total	Breakdown	
		Urban	Rural		Male	Female
1999	1,875,600	1,065,900	809,700	1,868,400	863,200	1,005,200
2000	1,861,500	1,058,700	802,800	1,851,900	856,000	995,900
2001	1,843,400	1,059,700	783,700	1,835,100	848,200	986,900
2002	1,827,900	1,053,500	774,400	1,821,100	841,500	979,600
2003	1,808,300	1,049,400	758,900	1,802,600	833,000	969,600
2004	1,793,900	1,051,500	742,400	1,788,100	826,000	962,100
2005	1,778,900	1,050,100	728,800	1,773,100	818,700	954,500
2006	1,763,800	1,049,700	714,100	1,758,000	811,100	946,900
2007	1,751,100	1,050,400	700,700	1,745,300	804,700	940,600
2008	1,737,300	1,048,800	688,500	1,731,500	797,800	933,700
2009	1,727,900	1,049,800	678,100	1,722,100	793,400	928,700
2010	1,721,800	1,052,100	669,700	1,716,000	790,800	925,200
2011	1,717,700	1,053,600	664,100	1,711,900	789,700	922,200
2012	1,719,500	1,059,100	660,500	1,713,800	791,400	922,400
2013	1,722,000	1,064,800	657,200	1,716,300	793,300	923,000

Source: Department of Statistics, Kiev Region

Source: Wikipedia (Ukrainian Site)

Figure 3.6 Location Map of Kiev Region

As for the surrounding suburb towns of Kiev City, the population is growing at a very rapid rate and residential areas are expanding due to an increase of people who work in Kiev City, and the current population constitutes approximately 670,000 as of 2013.

The statistical information on the overall population in Kiev Region is presented in Table 3.10.

Table 3.10 Population of Satellite Townships from Kiev City

Unit: People

No.	Name	Category	2011	2012	2013
1	Vyshgorod	Town	25,694	26,198	32,000
2	Irpin	Town	41,533	76,841	76,900
3	Vyshneve	Town	36,712	37,012	26,536
4	Boryspil	Town	16,527	58,868	59,545
5	Brovary	Town	95,979	97,146	98,250
6	Bucha	Town	27,460	27,909	28,483
7	Vasylkiv	Town	36,357	36,427	36,672
8	Bila Tserkva	Town	209,396	210,551	210,919
9	Berezan	Town	16,559	16,527	16,543
10	Obykhiv	Town	32,615	32,876	33,102
11	Boyarka	Town	34,951	35,130	35,320
12	Ukrainka	Town	15,338	15,458	15,644
	Total		589,121	670,943	669,914

Source: Statistical Office of Kiev Region

(3) Current Situation with Tourists

According to the statistical information in relation to the visitors including school students, business visitors and tourists, the yearly total number of visitors is recorded between 500,000 and 700,000. 48% of visitors come for business/education purposes, while 40% arrive for leisure.

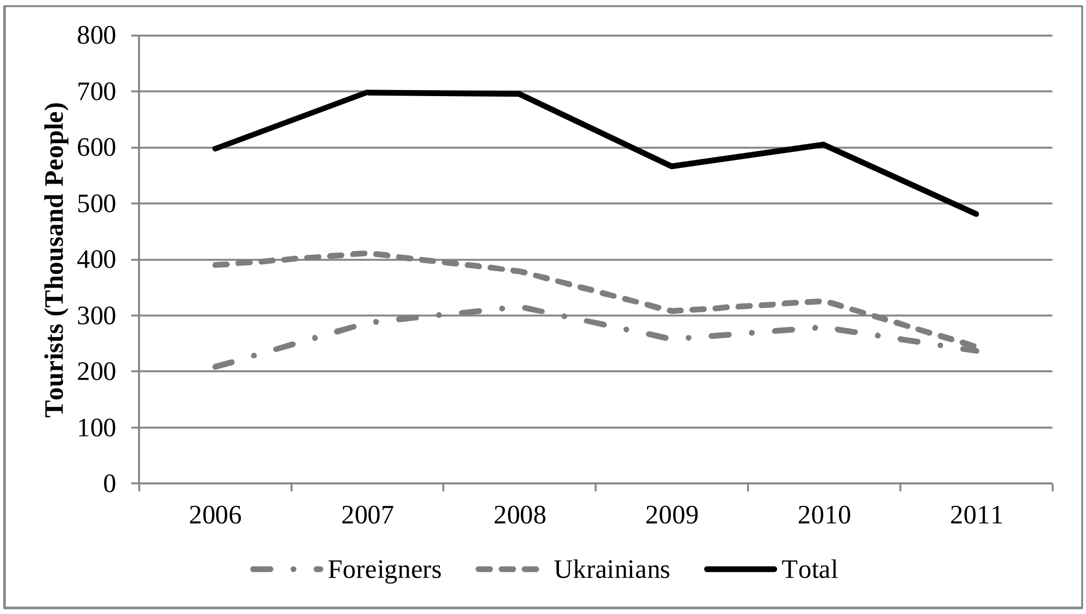
The statistical information on the overall population of Kiev Region is presented in Table 3.11 and Figure 3.7. The proportion of visitors by type of purposes is also shown in Figure 3.8.

Table 3.11 Statistical Information related to Tourists

Unit: People/Year

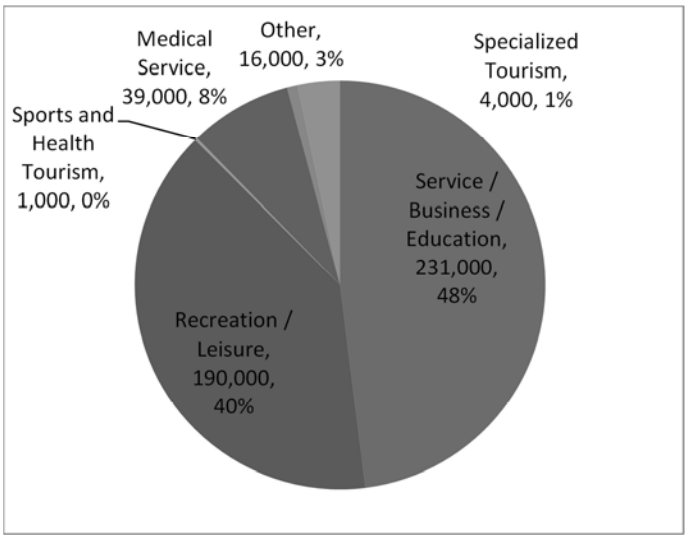
Item	Item	2006	2007	2008	2009	2010	2011
Foreigners visiting Kiev City	Service / Business / Education	71,000	90,000	105,000	92,000	79,000	116,000
	Recreation / Leisure	118,000	168,000	175,000	137,000	169,000	106,000
	Sports and Health Tourism	0	1,000	0	0	0	0
	Medical Service	1,000	8,000	19,000	23,000	23,000	9,000
	Specialized Tourism	2,000	3,000	7,000	5,000	6,000	4,000
	Other	16,000	17,000	10,000	1,000	2,000	2,000
	Sub Total	208,000	287,000	316,000	258,000	279,000	237,000
Ukrainians visiting Kiev City	Service / Business / Education	114,000	121,000	128,000	109,000	130,000	115,000
	Recreation / Leisure	217,000	189,000	160,000	129,000	133,000	84,000
	Sports and Health Tourism	5,000	31,000	3,000	4,000	1,000	1,000
	Medical Service	35,000	44,000	66,000	47,000	43,000	30,000
	Specialized Tourism	0	1,000	0	1,000	1,000	0
	Other	19,000	25,000	22,000	18,000	18,000	14,000
	Sub Total	390,000	411,000	379,000	308,000	326,000	244,000
Total Visitors to Kiev City	Service / Business / Education	185,000	211,000	233,000	201,000	209,000	231,000
	Recreation / Leisure	335,000	357,000	335,000	266,000	302,000	190,000
	Sports and Health Tourism	5,000	32,000	3,000	4,000	1,000	1,000
	Medical Service	36,000	52,000	85,000	70,000	66,000	39,000
	Specialized Tourism	2,000	4,000	7,000	6,000	7,000	4,000
	Other	35,000	42,000	32,000	19,000	20,000	16,000
	Total	598,000	698,000	695,000	566,000	605,000	481,000

Source: Main Statistics Department, Kiev City State Administration



Source: Main Statistics Department, Kiev City State Administration

Figure 3.7 Statistical Information related to Tourists



Source: Main Statistics Department, Kiev City State Administration

Figure 3.8 Proportion of Visitors to Kiev City

3.1.3 Current Situation of Water Supply System

The history of water supply in Kiev City is rooted in 1880s as the establishment of KVK as one of the oldest water suppliers in Ukraine. Currently the length of water network reaches approximately 180,000 km and supplied water is amounted at 2,8 billion m^3/year (for domestic usage, about 1.4 m^3/year). The main information regarding national water supply condition is summarized in Table 3.12.

Table 3.12 Water Supply in Ukraine

Item	Unit	2005	2006	2007	2008	2009	2010	2011	2012
Number of Water Supply Facilities	thousand unit	10.6	10.7	10.6	10.5	10.5	10.4	10.4	10.2
Number of Water Supply Network	thousand unit	2.4	2.5	2.6	2.7	2.7	2.8	2.9	3.0
Total Capacity of Facilities									
Main Pump Stations	million m^3/day	35.0	34.2	34.2	33.1	32.9	33.0	32.0	32.4
Water Supply Facilities	million m^3/day	25.3	25.2	25.1	24.8	24.5	24.1	23.7	23.6
Wastewater Treatment Facilities	million m^3/day	15.1	15.3	15.3	15.2	15.2	15.0	15.0	14.5
Total Length of Networks									
Water Supply Pipes	thousand km	57.2	54.8	53.6	53.4	51.6	51.0	50.3	50.4
Secondary Water Supply Pipes	thousand km	100.5	101.1	102.9	103.7	104.2	104.0	104.8	104.8
Connecting Pipes	thousand km	25.5	25.3	25.1	25.5	25.3	24.9	24.7	24.9
Total Water Served	billion m^3/year	3.9	3.7	3.5	3.3	3.0	3.0	2.9	2.8
To Population for Domestic Use	billion m^3/year	2.0	1.8	1.7	1.7	1.6	1.5	1.5	1.4
For Industrial and Other Purposes	billion m^3/year	0.5	0.5	0.5	0.4	0.3	0.3	0.3	0.3
Unaccounted, Leaked	billion m^3/year	1.3	1.4	1.3	1.3	1.2	1.2	1.2	1.2

Source: State Statistical Office of Ukraine

(1) Served Area

KVK is the entity operating the water supply system in Kiev City, the coverage ratio of which has reached 100% in the whole boundaries of the city.

(2) Served Population

Because of the 100% coverage ratio of water supply system in the city, the served population is equal to the general population counted by the municipality and the current served population is reaching 2,829,641 people as of 2012.

The historical profiles of water supply are summarized in Table 3.13.

Table 3.13 Historical Profiles of Water Supply in Kiev City

<table>
<tr><th colspan="5">Item</th><th>2007</th><th>2008</th><th>2009</th><th>2010</th><th>2011</th><th>2012</th><th>Remarks</th></tr>
<tr><td colspan="5">Total Population (People)</td><td>2,729,165</td><td>2,752,882</td><td>2,775,331</td><td>2,792,165</td><td>2,806,729</td><td>2,829,641</td><td>A</td></tr>
<tr><td colspan="5">Population in Supplied Area (People)</td><td>2,729,165</td><td>2,752,882</td><td>2,775,331</td><td>2,792,165</td><td>2,806,729</td><td>2,829,641</td><td>B</td></tr>
<tr><td colspan="5">Actual Supplied Population (People)</td><td>2,729,165</td><td>2,752,882</td><td>2,775,331</td><td>2,792,165</td><td>2,806,729</td><td>2,829,641</td><td>C</td></tr>
<tr><td colspan="5">Supplied Ratio (%)</td><td>100.0</td><td>100.0</td><td>100.0</td><td>100.0</td><td>100.0</td><td>100.0</td><td>D=C/B</td></tr>
<tr><td colspan="5">Supplied Households (nos)</td><td>N/A</td><td>N/A</td><td>N/A</td><td>N/A</td><td>22,700</td><td>22,810</td><td>E</td></tr>
<tr><td rowspan="6">Water Usage by Category</td><td rowspan="5">Effective Water</td><td rowspan="4">Accountable Water</td><td rowspan="2">Domestic</td><td>Daily Average Water Supply per Capita (L/People/day)</td><td>260.7</td><td>249.0</td><td>233.7</td><td>229.7</td><td>215.8</td><td>186.7</td><td>F=G/C</td></tr>
<tr><td>Daily Average Water Supply Amount (m^3/day)</td><td>711,464</td><td>685,358</td><td>648,466</td><td>641,222</td><td>605,630</td><td>528,161</td><td>G</td></tr>
<tr><td>Industrial / Office Use / Other Use</td><td>Daily Average Water Supply Amount (m^3/day)</td><td>150,870</td><td>148,548</td><td>131,784</td><td>133,924</td><td>126,397</td><td>127,052</td><td>H</td></tr>
<tr><td colspan="2">Total (m^3/day)</td><td>862,334</td><td>833,906</td><td>780,250</td><td>775,146</td><td>732,027</td><td>655,213</td><td>J=G+H</td></tr>
<tr><td colspan="3">Unaccountable Water (m^3/day)</td><td>163,239</td><td>175,914</td><td>150,258</td><td>139,642</td><td>136,323</td><td>190,819</td><td>K</td></tr>
<tr><td colspan="4">Ineffective Water (m^3/day)</td><td>N/A</td><td>N/A</td><td>N/A</td><td>N/A</td><td>N/A</td><td>N/A</td><td>L</td></tr>
<tr><td colspan="5">Total Daily Average Water Supply Amount (m^3/day)</td><td>1,025,573</td><td>1,009,820</td><td>930,508</td><td>914,788</td><td>868,350</td><td>846,032</td><td>M=J+K+L</td></tr>
<tr><td colspan="5">Total Daily Average Water Supply per Capita (L/People/day)</td><td>376</td><td>367</td><td>335</td><td>328</td><td>309</td><td>299</td><td>N=M/C</td></tr>
<tr><td colspan="5">Total Daily Peak Water Supply Amount (m^3/day)</td><td>N/A</td><td>N/A</td><td>N/A</td><td>N/A</td><td>N/A</td><td>N/A</td><td>O</td></tr>
<tr><td colspan="5">Total Daily Max Water Supply per Capita (L/People/day)</td><td>N/A</td><td>N/A</td><td>N/A</td><td>N/A</td><td>N/A</td><td>N/A</td><td>P=O/C</td></tr>
<tr><td colspan="5">Ratio of Accountable Water (%)</td><td>84.1</td><td>82.6</td><td>83.9</td><td>84.7</td><td>84.3</td><td>77.4</td><td>Q=J/M</td></tr>
<tr><td colspan="5">Ratio of Effective Water (%)</td><td>100.0</td><td>100.0</td><td>100.0</td><td>100.0</td><td>100.0</td><td>100.0</td><td>R=(J+K)/M</td></tr>
<tr><td colspan="5">Peak Factor of Peak / Average (%)</td><td>N/A</td><td>N/A</td><td>N/A</td><td>N/A</td><td>N/A</td><td>N/A</td><td>S=M/O</td></tr>
</table>

Accountable Water: Water supply for domestic, industries and factories where money can be collected
Unaccountable Water: Water usage can't be counted for money back (such as park, public utilities, etc.)
Ineffective Water: Water can't be reached for supplied utilities (due to leakage, etc.)
Source: KVK

(3) Overview of Established System

Kiev City currently relies on surface water sources for around 80% of total water sources, while the remaining part is covered by groundwater sources. Because of the introduction of water meters into the city's water supply system, water consumption has been significantly reduced contrary to the increasing trend of city's population.

The summary of water supply capacities is shown in Table 3.14.

Table 3.14 Historical and Planned Capacities for Water Supply in Kiev City

Unit: m^3/day

Item	Actual		Estimated		2021/2011 (Actual)
	2001	2011	2011	2021	
Surface Water Sourced	1,680,000	1,680,000	1,680,000	1,680,000	100.00%
Ground Water Sourced	433,900	360,000	542,700	663,300	184.25%
Total	2,113,900	2,040,000	2,222,700	2,343,300	114.87%
Total Supplied to City Network	1,394,200	1,215,000	1,585,800	1,846,000	151.93%
% of Water Supplied to City Network	65.95%	59.56%	71.35%	78.78%	132.27%

Source: Draft Updated General Planning of Kiev City, Kiev City State Administration (2013)

3.1.4 Current Situations of Sewage Treatment System

Originally the City's sewerage system was established to manage drainage system together with domestic sewage without treatment process at first place. In Ukraine, currently 1,893 wastewater treatment plants (in units) are in operation and 2.2 billion m3/year of wastewater is treated at the treatment facilities. And about 444 municipalities served sewerage networks which is mounted to 96.5% of cities and towns, but only 2.5%, 703 villages connect centralized sewerage system in Ukraine.

The main information regarding national sewage treatment is summarized in Table 3.15.

Table 3.15 Sewage Treatment in Ukraine

Item	Unit	2005	2006	2007	2008	2009	2010	2011	2012
Number of Wastewater Treatment Facilities	unit								1,893
Number of Sewerage System provided									
In Cities and Towns	nos.								444
In Villages	nos.								703
Total Capacity of Wastewater Treatment Facilities	million m^3/day	15.1	15.3	15.3	15.2	15.2	15.0	15.0	14.5
Total Treated Water at Wastewater Treatment Facilities	billion m^3/year	2.8	2.7	2.6	2.5	2.3	23.3	2.2	2.2

Source: State Statistical Office of Ukraine

(1) Served Area

The same as water supply service, the whole area of Kiev City is covered.

(2) Served Population

The number of population currently served by the sewerage system constitutes 98.85%, that is 2,795, 644 as of 2012 according to the information obtained from KVK.

(3) Overview of Established System

(A) Overview of Sewer System

The city collector system has been constructed since the end of 19th century to serve as drainage system, and the modern sewer system has been developed as separate system. Currently 2,480 km of sewer networks are in service throughout the city. The reconstruction and rehabilitation of existing collector system is also considered as one of the most urgent issue due to its aging conditions. The construction and maintenance is also managed by KVK. The sum of sewer network length is shown in Table 3.16.

Table 3.16 Length of Collector System in Kiev City (as of 2007)

Item	Length (m)	Ratio
Gravity Sewers	2,159,500	87%
Deep Gravity Sewer Mains	170,300	7%
Pressure Sewer Mains	151,500	6%
Total	2,481,300	100%

Source: Schemes of Water Supply and Sewage Systems of Kiev City by 2020, Kiev City (2007)

Intermediate pumping stations currently exist at around 30 locations and according to the existing amended infrastructure plan, rehabilitation activities for aged facilities and replacing older facilities are scheduled.

The conceptual pumping station rehabilitation plan is shown in Table 3.17.

Table 3.17 Concepts for Rehabilitation of Pumping Stations

Item	Location (nos)	Ratio
Newly Established	6	20%
Being kept as Backup	2	7%
Being Reconstructed	12	40%
Being Eliminated	10	33%
Total	30	100%

Source: Schemes of Water Supply and Sewage Systems of Kiev City by 2020, Kiev City (2007)

(B) BAS (Bortnychy WWTP)

BAS has started operation in 1964 and now has three blocks of sewage treatment lines to cover areas of both banks of Dnipro, treating incoming wastewater from all over the city as the only wastewater treatment plant in the city.

The nominal capacities of each block are shown in Table 3.18.

Table 3.18 Nominal Capacity of BAS (at the Time of Construction)

Item	Year of Commissioning	Capacity (m^3/day)
Block 1	1964	600,000
Block 2	1975	600,000
Block 3	1986	600,000
Total	-	1,800,000

Source: KVK

According to the existing plan for water supply and sewerage systems of Kiev City, the daily average inflow is estimated at around 1,000,000 m^3/day and daily sludge generation amounts to around 10,000 – 15,000 m^3/day.

The staged capacities in the existing program are shown in Table 3.19.

Table 3.19 Staged Capacities Stated in the Existing Program

Item	Unit	Initial Stage	First Phase	Second Phase
Target Year	Year	2003	2011	2012
Estimated Capacity of BAS	m^3/day	971,390	1,032,330	989,820
Hydraulic Capacity of BAS	m^3/day	1,442,900	1,645,600	2,029,000
Estimated Sludge Generation	m^3/day	10,800	12,500	15,700
Estimated Capital Investment	mil UAH	-	3,143.3	4,134.3

Source: Schemes of Water Supply and Sewage Systems of Kiev City by 2020, Kiev City (2007)

The existing wastewater treatment facilities are summarized in Table 3.20 for Block 1, Table 3.21 for Block 2 and Table 3.22 for Block 3.

Table 3.20 Existing Main Facilities for Block 1

Unit: m^3(as Construction Volume)

No.	Block	Name	Nos of Facilities	Volume of Facilities
1	Block 1Sewage Treatment	Blower House	1	18,400
2	Block 1Sewage Treatment	Pumping Station for Aeration Tanks No.1-2	2	3,000
3	Block 1Sewage Treatment	Raw Sludge Pumping Stations No.1-3	3	2,500
4	Block 1Sewage Treatment	Aeration Tanks No.1-6	6	179,400
5	Block 1Sewage Treatment	Secondary Sedimentation Tanks No.1-16	16	86,400
6	Block 1Sewage Treatment	Pre-aerator	1	11,300

Source: KVK

Table 3.21 Existing Main Facilities for Block 2

Unit: m^3(as Construction Volume)

No.	Block	Name	Nos of Facilities	Volume of Facilities
7	Block 2 Sewage Treatment	Warehouse of chlorine	1	3,300
8	Block 2 Sewage Treatment	Chlorinator room	1	3,000
9	Block 2 Sewage Treatment	Blower House	1	20,900
10	Block 2 Sewage Treatment	Bar Screen Chambers No.1-2	1	17,900
11	Block 2 Sewage Treatment	Raw Sludge Pumping Stations No.4-6	4	5,200
12	Block 2 Sewage Treatment	Pumping Station for Aeration Tanks No.3-4	2	2,600
13	Block 2 Sewage Treatment	Excess Sludge Pumping Station	1	3,000
14	Block 2 Sewage Treatment	Aeration Tanks No.7-12	6	249,000
15	Block 2 Sewage Treatment	Primary Sedimentation Tanks No.15-26	12	75,600
16	Block 2 Sewage Treatment	Secondary Sedimentation Tanks No.17	12	64,800
17	Block 2 Sewage Treatment	Sludge Thickeners No.5-7	3	15,900

Source: KVK

Table 3.22 Existing Main Facilities for Block 3

Unit: m^3(as Construction Volume)

No.	Block	Name	Nos of Facilities	Volume of Facilities
18	Block 3 Sewage Treatment	Blower House	1	23,600
19	Block 3 Sewage Treatment	Raw Sludge Pumping Stations No.7-9	3	3,900
20	Block 3 Sewage Treatment	Pumping Station for Aeration Tanks No.5-6	2	2,800
21	Block 3 Sewage Treatment	Aeration Tanks No.13-18	6	208,800
22	Block 3 Sewage Treatment	Primary Sedimentation Tanks No.27-38	12	75,600
23	Block 3 Sewage Treatment	Secondary Sedimentation Tanks No.29-42	14	75,600

Source: KVK

As for the current sludge treatment facilities, anaerobic digestion and aerobic sludge stabilization processes are used to stabilize organic compounds and reduce quantities and treated sludge which is temporally accumulated at external sludge fields.

The existing main sludge treatment facilities are summarized in Table 3.23

Table 3.23 Existing Main Sludge Treatment Facilities

Unit: m^3(as Construction Volume)

No.	Block	Name	Nos of Facilities	Volume of Facilities
24	Aerobic Sludge Stabilization	Pumping Station for Aerobic Stabilization	1	3,100
25	Aerobic Sludge Stabilization	Aerobic Reactor No.1-4	4	104,400
26	Aerobic Sludge Stabilization	Sludge Thickeners for Stabilized Sludge No.1-2	2	5,800
27	Aerobic Sludge Stabilization	Sludge Thickeners No.8-10	3	18,900
28	Sludge Treatment System	Sludge Pumping Stations No.3, 3a, 4	3	2,900
29	Sludge Treatment System	Control Buildings for Digesters	2	4,800
30	Sludge Treatment System	Anaerobic Digesters No.1-4	4	21,200
31	Sludge Treatment System	Anaerobic Digesters No.5-8	4	21,200
32	Sludge Treatment System	Gas Holders No.1-2	2	13,200
33	Boiler and Heating System	Boilers No.1-2	2	14,800
34	Boiler and Heating System	Oil Fuel Station & Storages	3	12,800

Source: KVK

The remaining associated utilities in BAS are summarized in Table 3.24

Table 3.24 Existing Main Other Facilities in BAS

Unit: m^3(as Construction Volume)

No.	Block	Name	Nos of Facilities	Volume of Facilities
35	Fist Rise Pumping Station	First Rise Pumping Station	1	12,600
36	Fist Rise Pumping Station	Bar Screen Chamber	1	5,600
37	Pozniaky Pumping Station	Pozniaky Pumping Station	1	14,000
42	Greenery and Beautification	Greenhouses No.1-2 & Warehouse	3	5,900
43	Administration Building	Administration Buildings	2	8,400
44	Administration Building	Chemical and Bacteriological Laboratory	1	2,500
45	Administration Building	Workshop & Warehouse	2	4,400
46	Pioneer Sludge Fields	Pioneer Sludge Fields	26	247,300

Source: KVK

The sludge fields were constructed to accumulate treated sludge component generated at BAS for later use as a fertilizer. Such disposal scheme was applied in the beginning of the establishment of BAS, but the use of sludge as fertilizer was banned due to high concentration of metal components contained in sludge in 1970s. The sludge fields are located 8 – 20 km away from BAS. Treated sludge is delivered to the fields using pressured pipelines, and is accumulated within their boundaries. Leachate water is collected and sent back to BAS to be treated in the general wastewater treatment process. The capacity of sludge fields are now reached to 2.5 – 3 times larger than the original capacity because the sludge fields were constructed for temporary storage.

The right bank pumping station is located on the right bank side to supplement the capacity of sending sewage generated in the right bank side. This pumping station was constructed in 1970.

The other existing main facilities outside BAS are summarized in Table 3.25

Table 3.25 Existing Other Main Facilities outside BAS

Unit: m^3(as Construction Volume)

No.	Block	Name	Nos of Facilities	Volume of Facilities
1	Right Bank Pumping Station	Right Bank Pumping Station	1	58,700
2	External Sludge Fields	Pumping Station for Sludge Field No.1	4	3,700
3	External Sludge Fields	Pumping Station for Sludge Field No.2	2	3,800
4	External Sludge Fields	Pumping Stations for Sludge Field No.3	2	1,300
5	External Sludge Fields	Sludge Fields No.1-3 (272 ha)	3	10,000,000

Source: KVK

(4) Serious Problems occurred in BAS and Sludge Fields

Because of the critical conditions of existing facilities in BAS and the sludge fields, large scaled accidents were happened in recent years.

(A) Collapse of Inlet Sewer to First Rise Pump Station

In January 2012, the inlet sewer connected to First Rise Pump Station was collapse suddenly and it caused malfunctions in distribution of collected wastewater into treatment blocks via the pump station. The reason of the accident was degradation of structural strength of the sewer due to long provisions since the original construction of this facility in early 1960s.

The blockage caused temporary reduction of capacity of wastewater treatment at BAS and instability of effluent quality. As of 2013, BAS is operated without the function of First Rise Pump Station and the distributing function is managed by existing sewer network in BAS. The pump station was officially approved to reconstruct using state fund of Ukraine and the reconstruction project has already started. Full recovery of original function is by providing new First Rise Pump Station is scheduled in 2015. Total estimated cost is 333.5 million UAH (30.7 million Euro) inclusive of construction and installation of equipment as well as commissioning works.

(B) Breach of Dyke at Sludge Field No.3

In March 2013, the dyke of sludge field No.3 was breached at around 30 m wide after the rainfall and the surface of accumulated sludge was spilled over towards nearby reservoir of storm water. The dyke is made with filled earth and the height is estimated at 4 - 5 m from the original land level. The strength of filled dyke was loosened because of infiltration of melted snow. KVK dispatched urgent recovery sources to refill the broken part of soils and the outlet to discharge supernatant storm water was reconstructed. After the accident, a part of reservoir was isolated in order not to drain out the contaminated storm water into environmental bodies and watch people is intensely allocated to observe the condition of dyke especially during the event of heavy rainfalls.

3.1.5 Relevant Plans in relation to Water Environment Protection

(1) Relevant Plans in relation to Water Environment Protection in Ukraine

(A) Amended Nationwide Program for Reforming and Development of the Utilities Sector, 2004-2010

This program was formulated in order to accelerate the improvement of infrastructure conditions in Ukraine and included such main points as quick accomplishment of reconstruction and rehabilitation works of target utilities, improvement in operation, and recovery of revenue system, reduction of energy consumption. The targeted facilities are entitled all the existing utilities including BAS and the budget allocated for the reconstruction of BAS was estimated at 3.3 billion UAH (305 million Euro) according to the program which was formulated by Kiev City based on the nationwide program.

The indicators for water supply and sewerage system are shown in Table 3.26 through Table 3.29.

Table 3.26 Stated Allocation of Budgets for Water Supply and Sewerage System

Unit: million UAH [million EUR]

Item	2010	2011	2012	2013	2014	Total
Reconstruction of Centralized Water Supply and Sewerage System	340.3	586.5	227.6	140.8	120.0	1,415.2
	[31.3]	[54.0]	[20.9]	[13.0]	[11.0]	[130.2]

Source: Amendment on Nationwide Program for Reforming and Development of the Utilities Sector, 2004-2010, the Government of Ukraine (2009)

Table 3.27 Stated Progress of Action Plans

Unit: % of Accomplishments

Item	2010	2011	2012	2013	2014
Accomplishment of Action Plans (in Particular Capital Investments)	25	70	90	100	100

Source: Amendment on Nationwide Program for Reforming and Development of the Utilities Sector, 2004-2010, the Government of Ukraine (2009)

Table 3.28 Stated Target Improvements in Recovery of Revenues

Unit: % of Revenues

Item	2010	2011	2012	2013	2014
Percentage of Recovery of Revenues	-3~0	0~3	3~5	5~7	7~12

Source: Amendment on Nationwide Program for Reforming and Development of the Utilities Sector, 2004-2010, the Government of Ukraine (2009)

Table 3.29 Stated Target Reduction of Electric Energy for Treatments

Unit: kWh/m^3

Item	2010	2011	2012	2013	2014
Reduction of Electric Energy for Water and Sewage Treatments	0.580	0.539	0.518	0.497	0.476

Source: Amendment on Nationwide Program for Reforming and Development of the Utilities Sector, 2004-2010, the Government of Ukraine (2009)

(B) Nationwide Program for Drinking Water of Ukraine, 2011-2020

In this program, allocation of budgets and prioritized activities are included to promote quick measures to recover the functions of deteriorated water supply and sewerage system infrastructures and based on this national program, action programs are formulated by city level entities. All the existing utilities are nominated to take actions for the improvements of services and condition of facilities, and BAS are one of the utilities included in the program.

Allocation of budget is shown in Table 3.30 and planned activities are shown in Table 3.31.

Table 3.30 Allocation of Budget Sources

Unit: million UAH [million EUR]

Item	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
State Budget	200.7	238.2	273.5	312.8	346.4	326.5	326.5	326.5	326.5	326.5	3,004.3
	[18.5]	[21.9]	[25.2]	[28.8]	[31.9]	[30.0]	[30.0]	[30.0]	[30.0]	[30.0]	[276.4]
Other Source	349.5	408.1	460.3	524.0	570.0	831.1	831.1	831.1	831.1	831.1	6,467.4
	[32.2]	[37.5]	[42.3]	[48.2]	[52.4]	[76.5]	[76.5]	[76.5]	[76.5]	[76.5]	[595.0]
Total	550.2	646.3	733.8	836.8	916.4	1,157.6	1,157.6	1,157.6	1,157.6	1,157.6	9,471.7
	[50.6]	[59.5]	[67.5]	[77.0]	[84.3]	[106.5]	[106.5]	[106.5]	[106.5]	[106.5]	[871.4]

Source: Nationwide Program for Drinking Water of Ukraine, 2011-2020, the Government of Ukraine (2011)

Table 3.31 Staged Target Activities

Unit: Number of Utilities

Item	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Construction and Reconstruction	6	8	10	12	15	16	16	16	16	16	131
Creation of Optimization Program	738	492									1,230
Re-equipment of Laboratories	88	88	90	90							356

Source: Nationwide Program for Drinking Water of Ukraine, 2011-2020, the Government of Ukraine (2011)

(2) Relevant Plans in relation to Water Environment Protection in Kiev City

(A) Amended Program for Reforming and Development of Utility Sector of the City of Kiev for 2010-2014

Following the "Amended Nationwide Program for Reforming and Development of the Utilities Sector, 2004-2010", a subsidized action plan of Kiev City was formulated. According to the activities listed in the program, reconstruction of sludge fields and sludge treatment facilities are the most imminent activities which have to be completed in an earlier period and the reconstruction activities for existing wastewater treatment process is also stated in the period of 2010 – 2014.

The activities stated in the program are summarized in Table 3.32.

Table 3.32 Activities included in the Program

Unit: million UAH [million EUR]

Item	2010	2011	2012	2013	2014	Total
Reconstruction of Sludge Field No.1 & 2	26.00 [2.4]	82.80 [7.6]	44.65 [4.1]			153.45 [14.1]
Screen Chamber of Block 2 & 3, Kollectorna PS	4.52 [0.4]					4.52 [0.4]
Improvement of Sludge Treatment Process	13.58 [1.2]					13.58 [1.2]
Construction of 5 Main Collectors	213.60 [19.7]	439.30 [40.4]	371.80 [34.2]	120.00 [11.0]	143.90 [13.2]	1,288.60 [118.5]
Reconstruction of Sewage & Sludge Line in BAS	129.00 [11.9]	583.00 [53.6]	800.00 [73.6]	900.00 [82.8]	900.00 [82.8]	3,312.00 [304.7]
Total	386.70 [37.8]	1,105.10 [106.1]	1,216.45 [115.4]	1,020.00 [94.9]	1,043.90 [97.3]	4,772.15 [451.4]

Source: Decision on Approval of the Program for Reforming and Development of Utility Sector of the City of Kiev for 2010-2014, Kiev City (2010)

(B) Schemes of Water Supply and Sewage Systems of Kiev City by 2020

This is the existing plan for the development of water supply and sewerage system formulated by Kiev City and contains estimated sewage amount and required capacities are stated in relation to the sewerage works.

Estimated sewage amount is shown in Table 3.33

Table 3.33 Estimated Sewage Amount by Target Stage

Items	Target Horizon	Sewage Amount (m^3/day)
Initial Stage	2003	1,077,700
First Phase	2011	1,245,600
Second Phase	2012	1,572,900

Source: Schemes of Water Supply and Sewage Systems of Kiev City by 2020, Kiev City (2007)

The amount of generated sewage by area is summarized in Table 3.34

Table 3.34 Sewage Flows including Suburb Area out of Kiev City

Unit: m^3/day

Item	Initial Stage	First Phase	Second Phase
Target Year (Year)	2003	2011	2012
Residential & Offices	971,390	1,032,330	989,820
Industries & Public Use	82,250	198,290	523,040
Sub Urban Area	24,020	24,020	60,000
Vyshneve	6,710	6,710	N/A
Irpin	9,220	9,220	N/A
Vyshgorod	3,170	3,170	N/A
Kotsyubynske	2,240	2,240	N/A
Shchaslyve	320	320	N/A
Gnidyn	210	210	N/A
Chabany	440	440	N/A
Kozyn	480	480	N/A
Koncha-Zaspa Pump Station No.1	720	720	N/A
Novoselky	510	510	N/A
Total	1,077,660	1,254,640	1,572,860

Source: Schemes of Water Supply and Sewage Systems of Kiev City by 2020, Kiev City (2007)

Estimated breakdown of sewage flows are summarized in Table 3.35

Table 3.35 Breakdown of Estimated Sewage Flows

Item	Unit	First Phase (2011)			Second Phase (2012)		
		Left Bank	Right Bank	Total	Left Bank	Right Bank	Total
Residential Wastewater	m^3/day	396,000	635,900	1,031,900	336,000	653,800	989,800
Residential Unit Wastewater	L/People/day	391.6	392.5	391.0	373.3	360.3	380.4
Wastewater from Suburb Area	m^3/day	600	23,400	24,000	-	60,000	60,000
Industrial Wastewater	m^3/day	42,100	156,200	198,300	88,200	434,800	523,000
Total Wastewater	m^3/day	438,700	815,500	1,254,200	424,200	1,148,600	1,572,800
Unit Wastewater Amount	L/People/day	434.8	501.4	475.9	454.8	668.4	593.2
Infiltration	m^3/day	-	-	390,900	-	-	456,200
Total Sewage Amount	m^3/day	-	-	1,645,100	-	-	2,029,000

Source: Schemes of Water Supply and Sewage Systems of Kiev City by 2020, Kiev City (2007)

Estimated underground water amount is shown in Table 3.36

Table 3.36 Estimated Underground Water Amount

Items	Target Horizon	Underground Water		Sewage Amount	Underground/ Sewage
		L/sec	m^3/day	m^3/day	
Initial Stage	2003	4,227.8	365,282	1,077,700	34%
First Phase	2011	4,524.4	390,908	1,254,200	31%
Second Phase	2012	5,279.7	456,166	1,572,800	29%

Source: Schemes of Water Supply and Sewage Systems of Kiev City by 2020, Kiev City (2007)

The summary of capacities in various flow conditions are shown in Table 3.37.

Table 3.37 Summary of Capacities for BAS

Item	Unit	Initial Stage	First Phase	Second Phase
Target Year	Year	2003	2011	2012
Estimated Capacity of BAS	m^3/day	971,390	1,032,330	989,820
Hydraulic Capacity of BAS	m^3/day	1,442,900	1,645,600	2,029,000
Estimated Sludge Generation	m^3/day	10,800	12,500	15,700
Estimated Capital Investment	mil UAH	-	3,143.3	4,134.3
	mil EUR	-	289.2	380.3

Source: Schemes of Water Supply and Sewage Systems of Kiev City by 2020, Kiev City (2007)

(3) Unapproved City General Plan (2013)

Kiev City is now formulating a revised city general plan which is currently waiting for final review and approval.

In relation to the sewerage system, a land use forecast, as well as water supply amount and sewerage amount forecasts are stated for the next 15 – 20 years in the future.

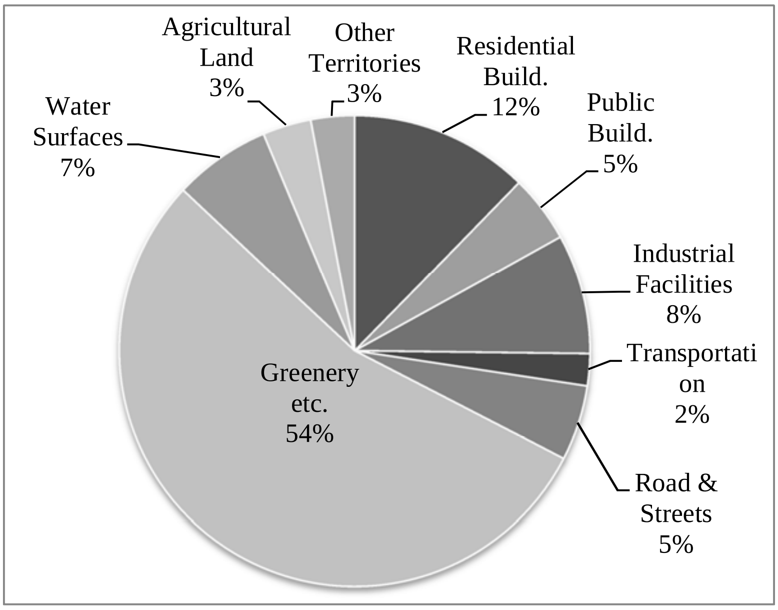
An estimate of future land use is shown in Table 3.38, Figure 3.9 and Figure 3.10.

Table 3.38 Estimated Land Use in the Future

Unit: ha

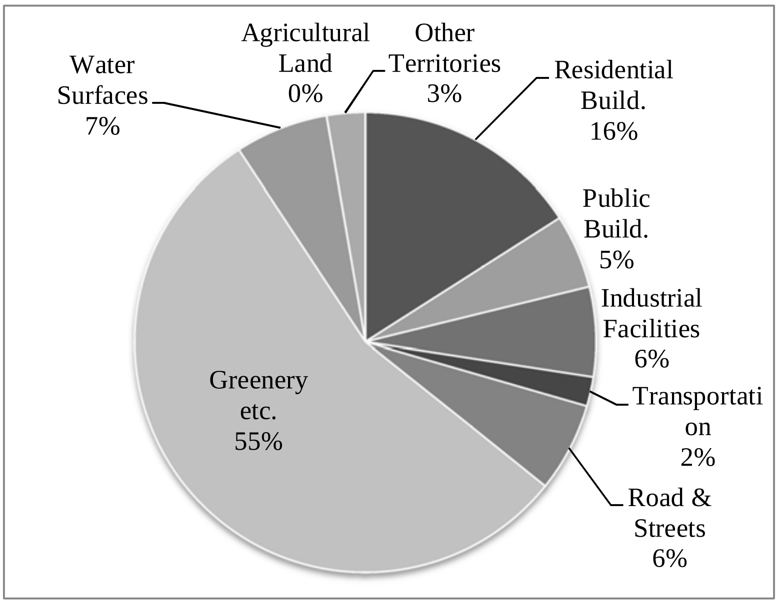
Item	Actual 2011	Next 10-15 Years (2020-2025)	Growth in %
Residential buildings, including;	10,230.5	12,944.5	26.5%
Individual Housing	*3,414.2*	*3,827.9*	12.1%
Apartment Housing	*6,816.3*	*9,116.6*	33.7%
Residential - Public Buildings	48.4	158.7	227.9%
Public Buildings	3,863.5	4,449.5	15.2%
Industrial, Research - Industrial Utility	6,912.3	5,374.0	-22.3%
Transportation Infrastructure	632.9	684.0	8.1%
Street and Road Networks	4,341.8	5,338.6	23.0%
External Transport	1,215.9	1,079.9	-11.2%
Landscape - Recreational and Green Areas, including;	45,449.2	46,880.3	3.1%
For Public Use	*5,103.0*	*7,400.0*	45.0%
Forests and Forest Parks	*33,195.0*	*31,510.0*	-5.1%
Lawns and Lawn Parks	*2,443.4*	*2,993.0*	22.5%
CountryHouse and Gardening Communities	*1,775.0*	*1,775.0*	0.0%
Recreational Facilities	*1,150.5*	*1,526.0*	32.6%
Special Purpose	*1,662.3*	*1,488.0*	-10.5%
Beaches	*120.0*	*188.3*	56.9%
Water Surfaces	5,569.3	5,569.3	0.0%
Agricultural Land	2,788.0	11.6	-99.6%
Other Territories	2,506.8	2,292.9	-8.5%
Total	83,558.6	84,783.3	1.5%

Source: Draft Updated General Planning of Kiev City, Kiev City State Administration (2013)



Source: Draft Updated General Planning of Kiev City, Kiev City State Administration (2013)

Figure 3.9 Proportion of Land Use (2011)



Source: Draft Updated General Planning of Kiev City, Kiev City State Administration (2013)

Figure 3.10 Proportion of Estimated Land Use (Next 15-20 Years)

The estimated grand total of residential population in Kiev City is projected by both permanent and living population and future population is forecasted to be 3,680,000 in living population.

The estimated population is shown in Table 3.39.

Table 3.39 Estimated Population

Unit: People

Item	Actual (2011)	Estimated (Next 15-20 Yrs)	Growth Rate	Yearly Growth Rate (Assumed Attaining Yr)	
				2026*	2031*
Permanent Population	2,757,900	3,147,300	114.12%	100.88%	100.66%
Living Population	3,144,900	3,680,000	117.01%	101.05%	100.79%

*Assumed year input by JICA Study Team according to "Next 15-20 years"
Source: Draft Updated General Planning of Kiev City, Kiev City State Administration (2013)

Water supply is forecasted using available capacities of water sources. The estimated value in 2021 is stated at 1,846,000 m^3/day as supplied amount via city's supply network.

The estimated water supply is summarized in Table 3.40.

Table 3.40 Estimated Capacities and Demands for Water Supply

Unit: m^3/day

Item	Actual		Estimated		2021/2011 (Actual)
	2001	2011	2011	2021	
Surface Water Sources	1,680,000	1,680,000	1,680,000	1,680,000	100.00%
Ground Water Sources	433,900	360,000	542,700	663,300	184.25%
Total	2,113,900	2,040,000	2,222,700	2,343,300	114.87%
Total Supplied to City Network	1,394,200	1,215,000	1,585,800	1,846,000	151.93%
% of Water Supplied to City Network	65.95%	59.56%	71.35%	78.78%	132.27%

Source: Draft Updated General Planning of Kiev City, Kiev City State Administration (2013)

The sewage amount estimated in the plan is 1,542,000 m^3/day in 2021. Estimated sewage flows are summarized in Table 3.41.

Table 3.41 Estimated Sewage Flows and Capacity of Existing BAS

Unit: m^3/day

Item	Actual		Estimated		2021 (Estimated) /2011 (Actual)
	2001	2011	2011	2021	
Total Sewage Flow to BAS	1,297,500	1,044,000	1,332,750	1,542,800	147.78%
Total Capacity of BAS	1,800,000	1,800,000	1,800,000	1,800,000	100.00%
Ratio of Sewage by Capacity	72.08%	58.00%	74.04%	85.71%	147.78%

Source: Draft Updated General Planning of Kiev City, Kiev City State Administration (2013)

As for the newest framework of effective decisions made by Ukrainian side, Resolution of the Cabinet of Ministers of Ukraine 27.02.2013 No.187 "On approval of the State program of activation of economic development for 2013-2014" and Decree of the Cabinet of Ministers of Ukraine of 17.10.2013 No.818p "On approval of the plan of priority measures to prevent manmade accidents n BAS" were announced in order to clarify the target of priority project objectives and to accelerate the reconstruction project in place.

(4) Laws and Regulations in relation to Water Environment Protection

(A) Effluent Criteria from BAS into Dnipro River (2011-2014)

Kiev city has agreed effluent criteria between State Administration for Environmental and Natural Resources Management in Kiev and currently 13 items are regulated and controlled by this agreement (this agreement is valid until December 2014).

The effluent criteria are shown in Table 3.42.

Table 3.42 Effluent Criteria for BAS

No.	Indicator	mg/L
1	Suspended solids	15.00
2	BOD_5	15.00
3	COD_{Cr}	80.00
4	Mineralization	600.00
5	Sulphates	120.00
6	Chlorides	350.00
7	Ammonia nitrogen	8.90
8	Nitrites	3.30
9	Nitrates	45.00
10	Phosphates	8.00
11	Petroleum products	0.20
12	Synthetic surface active substances (anionic)	0.50
13	Total iron	0.33

Source: State Administration for Environmental and Natural Resources Management in Kiev (2011)

(B) Discharge Criteria into Sewerage System

Discharge criteria are stated based on the regulations both Kiev City and National Committee on Construction, Architecture and Housing for households and business entities respectively.

Discharge criteria for households are shown in Table 3.43.

Table 3.43 Discharge Criteria for Households into Sewerage System

No.	Indicator	Unit	Limit
1	Suspended and floating components	mg/L	300
2	Biochemical oxygen demand (BOD5)	mg/L	200
3	Chemical oxygen demand (COD_{Cr})	mg/L	500
4	Dry particles	mg/L	1,000
5	Sulphates	mg/L	380
6	Chlorides	mg/L	240

No.	Indicator	Unit	Limit
7	Ammonium (azote ammoniacal, hydrogen nitride)	mg/L	20.0
8	Nitrites	mg/L	3.3
9	Nitrates	mg/L	45.0
10	Phosphates	mg/L	8.0
11	Oil products	mg/L	4.5
12	Synthetic surface active substances (anionic, non-ionic)	mg/L	20.0
13	Phenols	mg/L	0.14
14	Formaldehyde	mg/L	0.68
15	Cyanide	mg/L	0.5
16	Sulfides	mg/L	1.5
17	Aluminum	mg/L	2.72
18	Iron (general)	mg/L	2.0
19	Cadmium	mg/L	0.05
20	Manganese	mg/L	0.68
21	Coper (Cuprum)	mg/L	0.3
22	Nickel	mg/L	0.6
23	Lead (Plumbum)	mg/L	0.1
24	Silver	mg/L	0.05
25	Zinc	mg/L	0.9
26	Chrome 6+	mg/L	0.1
27	Chrome (general)	mg/L	2.3
28	Animal-vegetable fats	mg/L	50
29	pH	-	6.5-9.0
30	Temperature	degree C	40 or Less

Source: Kiev City State Administration Decree No. N1879 (2011)

The discharge criteria for industries are shown in Table 3.44, Table 3.45 and Table 3.46.

Table 3.44 Discharge Criteria for Industries into Sewerage (General Items)

No.	Indicator	Allowable value
1	Temperature	not above 40° C
2	pH	6.5-9.0
3	BOD, g/m^3	not more than 350
4	Suspended matter and floating components, g/m^3	not more than 500
5	Insoluble oils, resins, oil fuel	not allowed
6	Petroleum, petroleum products, g/m^3	no more than 20
7	Vegetable and animal fats, g/m^3	no more than 50
8	Chlorides, g/m^3	no more than 350
9	Sulfates, g/m^3	no more than 400
10	Sulfides, g/m^3	no more than 1.5
11	Acids, combustion mixtures, toxic and dissolved gaseous matters	not allowed
12	Concentrated mother and vat solutions	not allowed
13	Construction, industrial, utility waste, soil, abrasive matters	not allowed
14	Radioactive, epidemiologically dangerous bacterial and viral pollutants	not allowed

Source: National Committee on Construction, Architecture and Housing, No. 37 (2002)

Table 3.45 Discharge Criteria for Industries into Sewerage (Chemicals)

Description	Items	Remarks
Organic, Inorganic Chemical Substances, substituted by BOD concentration	163	Specified by the form of Chemicals

Aspects of Impacts: Toxicological, Sanitary Toxicological, Organoleptic, General Sanitary and Fishery Industrial

Source: National Committee on Construction, Architecture and Housing, No. 37 (2002)

Table 3.46 Discharge Criteria for Industries into Sewerage (Heavy Metals)

No.	Item	Concentration (g/tonDS)	Expected Ratio of Removal at WWTP
1	Strontium	300	0.1
2	Lead	750	0.5
3	Mercury	15	0.6
4	Cadmium	30	0.6
5	Nickel	200	0.5
6	Chrome (+3)	750	0.5
7	Manganese	2,000	-
8	Zinc	2,500	0.3
9	Copper	1,500	0.4
10	Cobalt	100	0.5
11	Iron	25,000	0.5

DS: Dry Solid

Source: National Committee on Construction, Architecture and Housing, No. 37 (2002)

(C) River Water Quality Criteria at the Discharge Point from BAS (Excerpt)

River water quality is periodically tested by KVK at the point of discharge into Dnipro River. In total, the criteria contain 90 detailed items based on Ukrainian standards.

River water test results are shown in Table 3.47.

Table 3.47 River Water Quality Criteria at the Discharge Point (Excerpt)

No.	Indicator	Unit	Standard*	Minimum	Maximum	Median
1	Temperature	degree.C	N/A	0.2	27.0	11.1
2	Transparency	mg/L	≤5,000	1.4	7.1	2.9
3	Color	degree	≤ 120	28	88	52
4	pH	-	6.1-8.5	7.4	8.6	8.0
5	BOD	mg/L	≤ 7.0	4.7	6.4	5.5
6	DO	mg/L	≥ 5	4.0	13.3	9.0

No.	Indicator	Unit	Standard*	Minimum	Maximum	Median
7	Ammonium Nitrogen	mg/L	≤ 1	0.17	0.62	0.31
8	Nitrite Nitrogen	mg/L	≤ 0.05	0.006	0.09	0.02
9	Nitrate Nitrogen	mg/L	≤ 1	0.05	1.45	0.50
10	Phosphate Phosphorus	mg/L	≤ 0.2	0.03	0.15	0.09
11	E.coliform	units/100mL	≤ 1,000	<9	636	32

Totally 90 indicators included in the Standard

*State's Standard DSTU4808:2007

Source: KVK

(5) Activities in Related to BAS Implemented by Aid Agencies

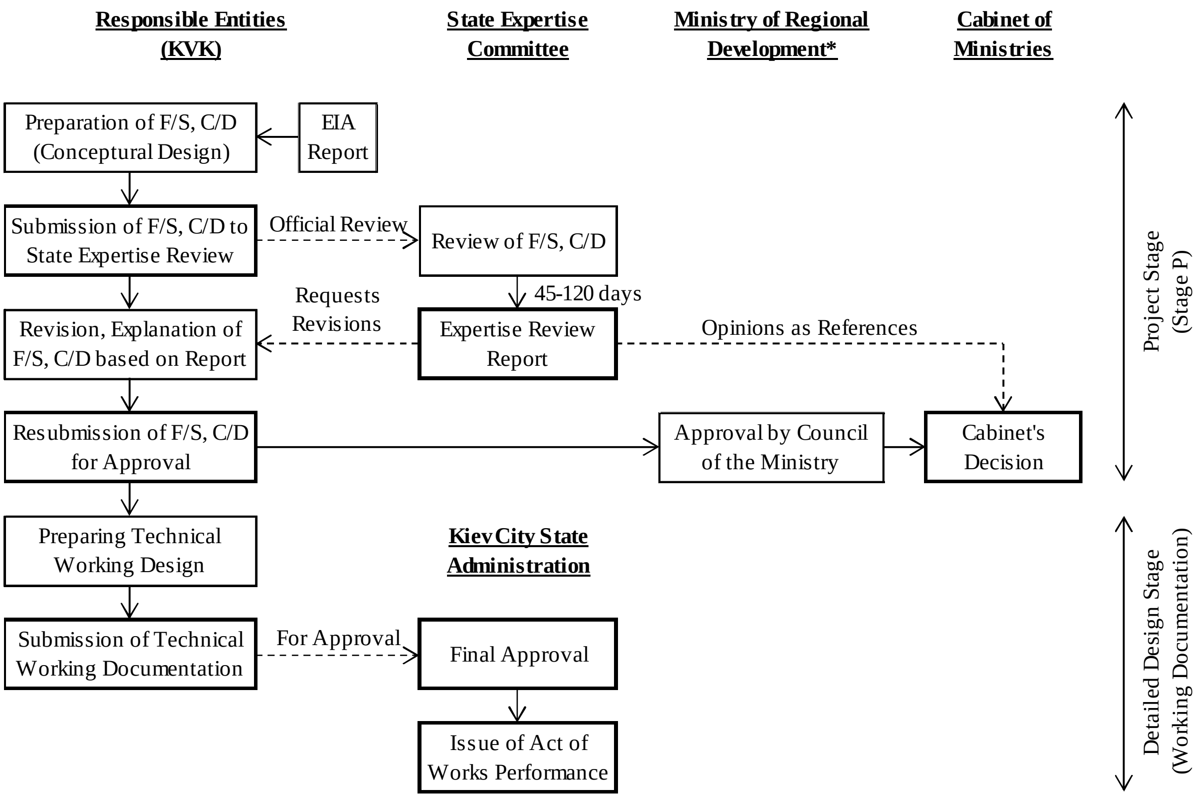
JICA Study Team inquired of KVK the activities related to BAS such as studies, designs, donations and loan projects implemented by aid agencies. KVK officially answered that KVK has never received any technical and financial assistance from any aid agencies concerning the development of BAS.

(6) Process of Preparation and Approval of the Project

The reconstruction of BAS is required to be approved by the cabinet's decisions as a large scaled project in related to infrastructures and the process consists two major parts called "Stage P (Project Stage)" and "Working Documentation (Detailed Designing Stage)". For this project, KVK has prepared draft documents for the approval of "Stage P" and the documents are to be reviewed by the members of states expertise committee and the committee will prepare "review report" requesting revisions and further clarifications with supplemental information provided with the document.

KVK will revise the documents based on this report and resubmit the final version of "Stage P" documents applying for the official approvals from the council of Ministry of Regional Development, Construction, Housing and Communal Services and followed by the final decision of the cabinet of ministers. As for the working documentation stage, latter stage of designing works is approved by Kiev City State Administration before the commencement of construction tendering for the final approval by issuing Act of Works Performance.

The simplified scheme of preparation and approval is shown in Figure 3.11.



*Ministry of Regional Development, Construction, Housing and Communal Services

Source: JICA Study Team

Figure 3.11 Scheme of Preparation and Approval of the Project

3.2 Review of the Existing Plan

3.2.1 Recent Activities for Reconstruction Planning

Followed by the requirement to formulate action plans for the reconstruction of sewerage facilities in Kiev City after the release of the Nationwide Program for Reforming and Development of the Utility Sector by Ukrainian government, Kiev City conducted feasibility studies twice targeting the reconstruction of BAS.

(1) Feasibility Study (2007, hereinafter referred to as “2007 F/S”)

The first feasibility study was conducted in 2007 to extract the necessary elements of works for the reconstruction works and a German consultant firm, i.e. Belinwasser-Ost, was engaged. As identified main activities of reconstruction works were namely equal and the total evaluated cost was 472 million Euro.

(2) Feasibility Study (2012, hereinafter referred to as “2012 F/S”)

After the five years passed, the second feasibility study was made in order to promote the reconstruction project into practice and the contents of studies have been upgraded using up to date technologies by an involvement of a French consultant firm, i.e. Sources. An Ukrainian consultant firm (called KIP) was appointed to conduct detailed documentation for approvals from Ukrainian Government through Stage P Process (application and approval stage for large scaled projects).

In this report, the review of existing plans was conducted based on "2012 F/S" in principle.

The main activities identified in the existing plantings are summarized in Table 3.48.

Table 3.48 Main Activities identified in the Existing F/Ss

Item	Description in "2007 F/S"	Description in "2012 F/S"
Wastewater Treatment	Screens and Primary Treatment Ponds Biological Nitrogen Removal Bio Filters (as Tertiary)	Screens and Primary Treatment Ponds Biological Nitrogen Removal Biological Phosphorus Removal Rapid Flocculation (as Tertiary)
Disinfection	UV Lamps	UV Lamps
Sludge Treatment	Gravity & Mechanical Thickeners Mechanical Dewatering Anaerobic Digestion (Future Stage) Fluidized Bed Incinerators	Gravity & Mechanical Thickeners Mechanical Dewatering Anaerobic Digestion Fluidized Bed Incinerators

Source: KVK

3.2.2 Design Parameters

(1) Served Area

The feasibility study does not state the served area, but it is assumed to be the same as the coverage area of current sewerage system.

(2) Design Horizon

The design horizon is set to 2021 as shown in Table 3.49.

Table 3.49 Design Horizon

Item	Value
Design Horizon	2021

Source: KVK

(3) Design Served Population

2007 F/S was formulated based on the agreed amount of sewage flow which was identified by Kiev City, while design served population is not used in the designs.

(4) Method of Collection System

2007 F/S does not state the served area, but it is assumed to be the same as the coverage area of current sewerage system.

(5) Design Wastewater Flows

Design wastewater flows are shown in Table 3.50. The most important factor is daily maximum flow and it is set at 1,573,000 m^3/day based on the city's existing plan. Distributed flows are summarized in Table 3.51.

Table 3.50 Design Wastewater Flows

Item	Unit	Value (2021)
Daily Average Flow	m^3/day	1,123,600
Daily Maximum Flow	m^3/day	1,573,000
Hourly Maximum Flow	m^3/hour	81,800
Ratio of Daily Max Flow / Daily Average Flow	-	1.40
Ratio of Hourly Maximum Flow / Daily Maximum Flow	-	1.25

Source: KVK

Table 3.51 Daily Average and Daily Maximum Flows by Block

Item	Unit	Value (2021)			
		Block 1	Block 2	Block 3	Total
Distribution Ratio	%	36.68	36.68	26.64	100.00
Ratio of Daily Max Flow / Daily Average Flow	-	1.40	1.40	1.40	1.40
Ratio of Hourly Maximum Flow / Daily Maximum Flow	-	1.25	1.25	1.25	1.25
Daily Average Flow	m^3/day	412,150	412,150	299,300	1,123,600
Daily Maximum Flow	m^3/day	577,000	577,000	419,000	1,573,000
Hourly Maximum Flow	m^3/hour	30,000	30,000	21,800	81,800

Source: KVK

(6) Design Loads, Influent and Effluent Qualities

(A) Loads and Influent Qualities

Design wastewater loads were used for dimensioning the treatment facilities.
The summary of loads and influent qualities is shown in Table 3.52, and distributed values are summarized in Table 3.53.

Table 3.52 Loads and Influent Qualities

Item	Load (kg)	Concentration (mg/L)	
		Max	Min
BOD_5	320,625	285	204
COD_{Cr}	881,289	784	560
TSS (Total Suspended Solid)	416,641	371	265
Total Kjeldahl Nitrogen (TKN)	58,810	52	37
NH_4-N	38,406	34	24
Total P (as PO_4)	20,225	18	13
VSS (Volatile Suspended Solid)	258,597	230	164
Fat, Oil & Grease (FOG)	220,322	196	140

Source: KVK

Table 3.53 Distributed Loads by Block

Item	Unit	Value (2021)			
		Block 1	Block 2	Block 3	Total*
BOD_5	kg/day	117,610	117,610	85,405	320,625
COD_{Cr}	kg/day	323,270	323,270	234,748	881,289
TSS (Total Suspended Solid)	kg/day	152,830	152,830	110,980	416,641
Total Kjeldahl Nitrogen (TKN)	kg/day	21,572	21,572	15,665	58,810
NH_4-N	kg/day	14,088	14,088	10,230	38,406
Total P (as PO_4)	kg/day	7,419	7,419	5,387	20,225
VSS (Volatile Suspended Solid)	kg/day	94,857	94,857	68,882	258,597
Fat, Oil & Grease (FOG)	kg/day	80,818	80,818	58,687	220,322

*Some of items shown inconsistent figures of totals

Source: KVK

(B) Effluent Qualities

Effluent qualities are set based on the current agreement of BAS and some additional items are added in order to satisfy the requirement of disinfection process.

Target effluent qualities are shown in Table 3.54.

Table 3.54 Target Effluent Qualities

Item	Unit	Effluent Concentration (2021)
BOD_5	mg/L	15
COD_{Cr}	mg/L	80
TSS (Total Suspended Solid)	mg/L	15
Total N	mg/L	10
NH_4-N	mg/L	Not Specified
NO_2-N	mg/L	3.3
NO_3-N	mg/L	45
Total P	mg/L	1
Dissolved Oxygen	mg/L	4 or larger
Enterococci	units/100mL	400
E. Coliform	units/100mL	1,000

Source: KVK

3.2.3 Proposed Process Flow

(1) Sewage Treatment Process

The sewage treatment process proposed by 2012 F/S employs anaerobic and aerobic bioreactors to fulfill the future demands of advanced treatment which enables biological nitrogen and phosphorus removal.

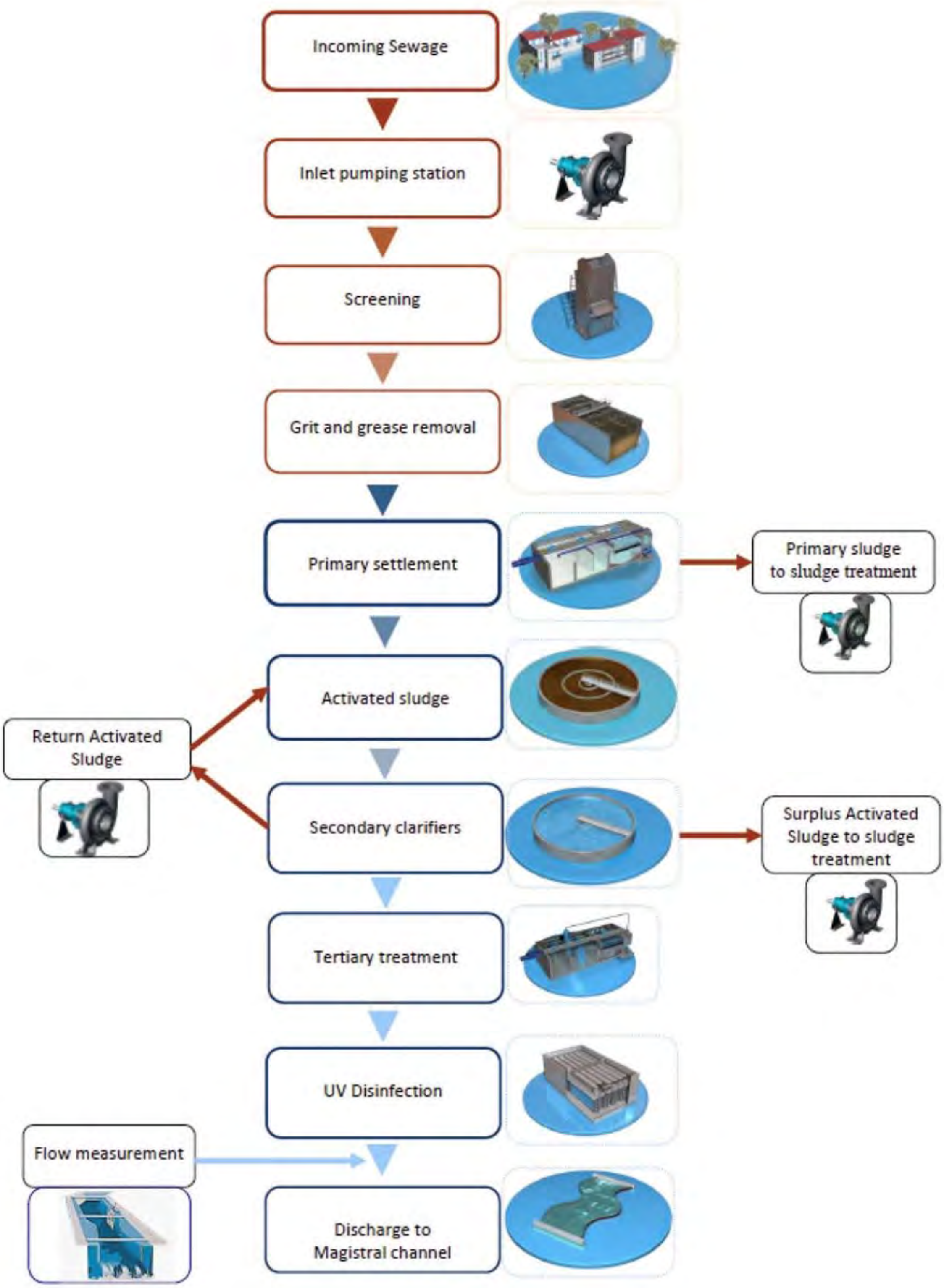
Considering the area to be used for reconstruction works, the selected method of equipment is largely efficient in space saving.

The sewage treatment process flow is shown in Figure 3.12

(2) Sludge Treatment Process

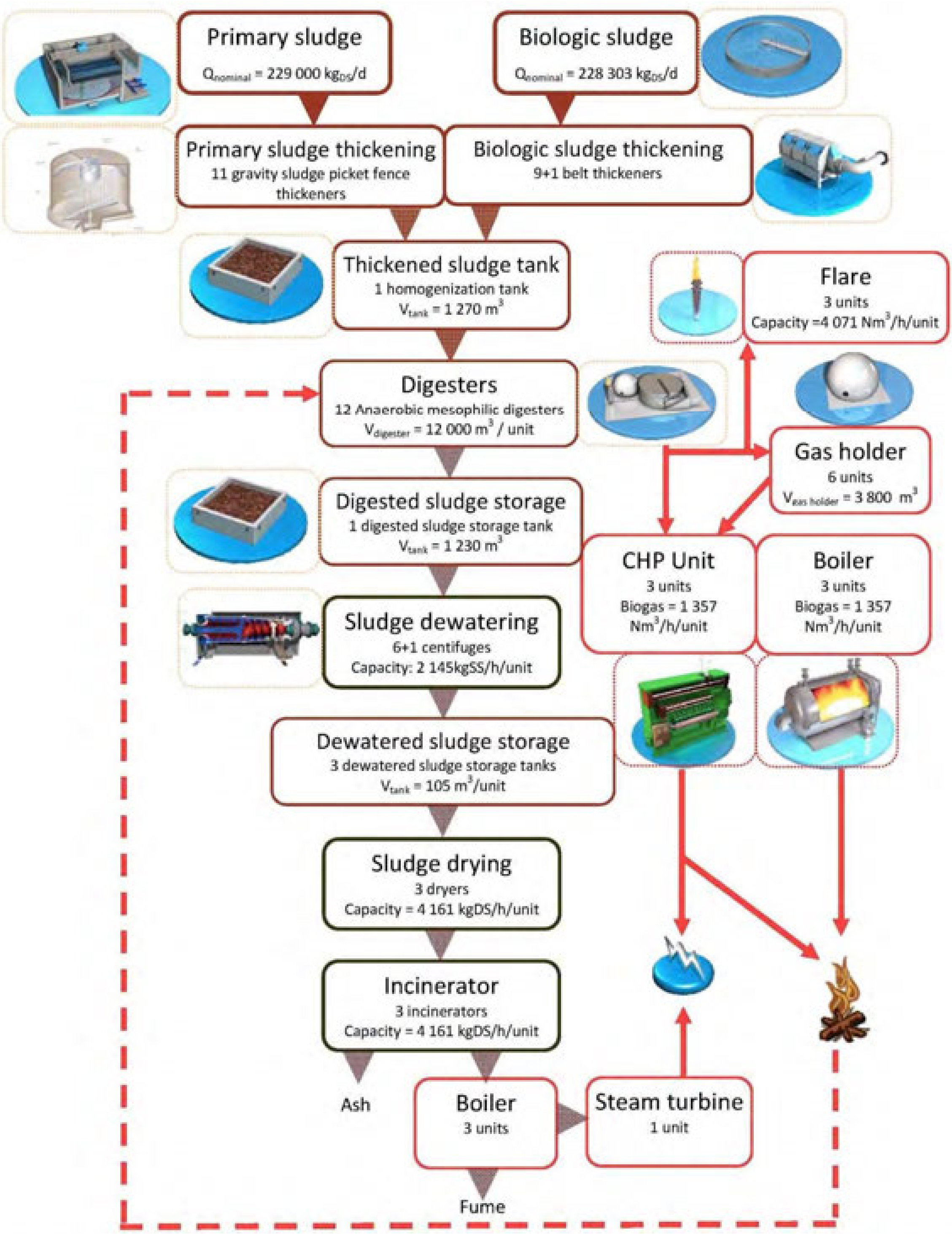
The sludge treatment process proposed by 2012 F/S newly employs mechanical thickening process for excess sludge (and also uses gravity thickening process for raw sludge component) and dewatering followed by sludge incineration. To expect recovery of electricity from ecological aspects, a biogas production flow and CHP (combined heat and power) system is also proposed.

The sludge treatment process flow is shown in Figure 3.13.



Source: KVK

Figure 3.12 Process Flow for Water Treatment



Source: KVK

Figure 3.13 Process Flow for Sludge Treatment

3.2.4 Sewerage Treatment Facilities proposed by 2012 F/S

(1) Reconstruction of Sewage Treatment Facilities

(A) Block 1

The main facilities for Block 1 sewage treatment process proposed by 2012 F/S are listed in Table 3.55.

Table 3.55 Facilities Contained in Block 1 proposed by 2012 F/S

Type	Facility	Block 1	Remarks
Preliminary Treatment	Fine Screen, 1st Stage	3 duty, 1 standby	
	Fine Screen, 2nd Stage	3 duty, 1 standby	
	Sand and Grit Removal	31 m(L) x 8 m(W) x 5 Lanes	French technology
Primary Treatment	Primary Settling Tank	16 m(L) x 16 m(W) x 8 m(D) x 14	French technology
	Raw Sludge Pump Unit	14 duty, 14 standby	
Secondary Treatment	Anaerobic - Aerobic Biological Reactor	16,000 m^3 x 4 (Anaerobic) 50,250 m^3 x 4 (Aerobic)	French technology
	Secondary Settling Tank	59 m(Dia) x 5 m(D) x 12	
	Blower Unit	10 Units	
	Return Sludge Pump Unit	12 duty, 4 standby	
	Excess Sludge Pump Unit	12 duty, 4 standby	
	Disinfection Channels	9.5 m(L) x 3 m(W) x 4, (UV lamps)	
	ACTIFLO Settler	108 m^3 x 5 (Flocculation Tank) 12.5 m(L) x 12.5 m(W) x 5 (Settling Tank)	French technology
	Disinfection Channels	9.5 m(L) x 3 m(W) x 4, (UV lamps)	
Tertiary Treatment	ACTIFLO Settler	108 m^3 x 5 (Flocculation Tank) 12.5 m(L) x 12.5 m(W) x 5 (Settling Tank)	French technology

Source: KVK

(B) Block 2

The main facilities for Block 2 sewage treatment process proposed by 2012 F/S are listed in Table 3.56

Table 3.56 Facilities Contained in Block 2 proposed by 2012 F/S

Type	Facility	Block 2	Remarks
Preliminary Treatment	Fine Screen, 1st Stage	3 duty, 1 standby	
	Fine Screen, 2nd Stage	3 duty, 1 standby	
	Sand and Grit Removal	31 m(L) x 8 m(W) x 5 Lanes	French technology
Primary Treatment	Primary Settling Tank	16 m(L) x 16 m(W) x 8 m(D) x 14	French technology
	Raw Sludge Pump Unit	14 duty, 14 standby	

Type	Facility	Block 2	Remarks
Secondary Treatment	Anaerobic - Aerobic Biological Reactor	16,000 m^3 x 4 (Anaerobic) 50,250 m^3 x 4 (Aerobic)	French technology
	Secondary Settling Tank	59 m(Dia) x 5m(D) x 12	
	Blower Unit	10 Units	
	Return Sludge Pump Unit	12 duty, 4 standby	
	Excess Sludge Pump Unit	12 duty, 4 standby	
	Disinfection Channels	9.5 m(L) x 3 m(W) x 4, (UV lamps)	
	ACTIFLO Settler	108 m^3 x 5 (Flocculation Tank) 12.5 m(L) x 12.5 m(W) x 5 (Settling Tank)	French technology
	Disinfection Channels	9.5 m(L) x 3 m(W) x 4, (UV lamps)	
Tertiary Treatment	ACTIFLO Settler	108 m^3 x 5 (Flocculation Tank) 12.5 m(L) x 12.5 m(W) x 5 (Settling Tank)	French technology

Source: KVK

(C) Block 3

The main facilities for Block 3 sewage treatment process proposed by 2012 F/S are listed in Table 3.57

Table 3.57 Facilities Contained in Block 3 proposed by 2012 F/S

Type	Facility	Block 3	Remarks
Preliminary Treatment	Fine Screen, 1st Stage	2 duty, 1 standby	
	Fine Screen, 2nd Stage	2 duty, 1 standby	
	Sand and Grit Removal	31 m(L) x 8 m(W) x 4 Lanes	French technology
Primary Treatment	Primary Settling Tank	16 m(L) x 16 m(W) x 8 m(D) x 10	French technology
	Raw Sludge Pump Unit	10 duty, 10 standby	
Secondary Treatment	Anaerobic - Aerobic Biological Reactor	7,600 m^3 x 6 (Anaerobic) 23,600 m^3 x 6 (Aerobic)	French technology
	Secondary Settling Tank	40 m(Dia) x 5 m(D) x 14 (Existing) 45 m(Dia) x 5 m(D) x 6 (Additional)	
	Blower Unit	10 Units	
	Return Sludge Pump Unit	6 duty, 2 standby (for Additional)	
	Excess Sludge Pump Unit	6 duty, 2 standby (for Additional)	
	Disinfection Channels	9.5 m(L) x 3 m(W) x 3, (UV lamps)	
Tertiary Treatment	ACTIFLO Settler	108 m^3 x 4 (Flocculation Tank) 12.5 m(L) x 12.5 m(W) x 4 (Settling Tank)	French technology

*L: Length, W: Width, D: Depth, Dia: Diameter
Source: KVK

(2) Rehabilitation of Existing Sewage Treatment Facilities

The activities of rehabilitating existing Block 2 and Block 3 facilities are included in 2012 F/S, and replacements of aged mechanical and electrical equipment and rehabilitation of civil structures are considered.

3.2.5 Sludge Treatment Facilities proposed by 2012 F/S

(1) New Construction of Sludge Treatment Facilities

Main facilities for sludge treatment proposed by 2012 F/S are shown in Table 3.58

Table 3.58 Facilities for Sludge Treatment proposed by 2012 F/S

Type	Facility	Description	Remarks
Sludge Thickening	Gravity Thickener	19.5 m(Dia) x 3.2 m(D) x 11	
	Mechanical Thickener	9 duty, 1 standby	Belt Thickener
	Thickened Sludge Tank	1,270 m^3	
Anaerobic Digestion	Anaerobic Digester	12,000 m^3 x 12 (27.5 m(Dia) x 19 m(H))	
	Sludge Recirculation Pump	12 duty, 6 standby	
	Heating Circulation Pump	12 duty, 6 standby	
	Sludge Condensate	6 Units	
	Gas Holder	3,800 m^3 x 6	
	Gas Flare Equipment	3 Units	
	Cogeneration System (CHP)	3 Units	
Sludge Dewatering	Mechanical Dewatering	6 duty, 1 standby	Centrifuge
	Dewatered Sludge Storage	105 m^3 x3	
Incinerator	Fluid Bed Incinerator	300 t/day, 3 units	
	Turbine	1 unit	

*D: Depth, Dia: Diameter
Source: KVK

(2) Measures for External Sludge Fields

According to the activities for the measures regarding sludge fields, removal of existing accumulated sludge by sending back to BAS followed by reprocessing using sludge treatment process is planned.

3.2.6 Other Facilities proposed by 2012 F/S

As for other facilities proposed by 2012 F/S, the main activities are planned as below.

- New administration building with control functions for sludge treatment
- New chemical and biological laboratory
- Other associated buildings such as greenhouse, warehouses, workshop facilities
- Land preparation works for reconstruction sites including re-cultivation of existing internal sludge fields inside BAS and earth filling works in the southernmost area
- Demolition and liquidation works for existing equipment
- Rehabilitation of existing outlet channel

3.2.7 Summary of Activities proposed by 2012 F/S

(1) Main Activities identified in 2012 F/S

By the request of nationwide program for Nationwide Program for Reforming and Development of the Utilities Sector, Kiev City identified major activities being included in the project in 2012 F/S.

According to the information provided by KVK, all the activities are sorted in 10 components and components 1 – 5 are the activities considered more important as prioritized works (and called as Stage 1) and latter activities in components 6 – 10 contains some items which will be implemented after the provisions of components 1 – 5 (called as Stage 2).

(A) Components 1 – 5 (Stage 1)

Generally, Components 1 – 5 contains activities which will recover the basic functions of BAS and rehabilitations of existing Block 2 and 3 water treatment facilities are proposed in Component 1. For Block 1, new construction using biological advanced treatment and tertiary process is planned by considering deterioration of the current facilities (in Component 4). Component 1 also contains new constructions of preliminary and primary treatment facilities in order to alleviate odors generated from existing facilities by replacing them with high efficient equipment. Sludge treatment is also contained in this group by considering its urgent necessity (in Components 2 and 3).

Component 5 originally contained rehabilitation works of river channel protection works at the beginning, but after the discussions with JICA and JST in related to the detailed activities and scope of project, river channel works were moved into Stage 2's activity (Component 10) and now Component 5 consists of general construction works such as land preparation works for the construction sites and demolition works of existing equipment and structures before the main construction works of Component 1 – 4. This component will be carried out under Ukrainian Side.

The main activities for Stage 1 proposed by 2012 F/S are contained in Table 3.59.

Table 3.59 Main Activities Contained in Stage 1 (Prioritized Activities)

Stage	Component	Main Activity	Dismantling and Land Preparation
Stage 1	Component 1 (C1)	Preliminary Treatment Facilities for Block 2 and Block 3	
		Relocation of Sand Pond	
		Primary Treatment Facilities for Block 2 and Block 3	
		Rehabilitation of existing Secondary Treatment for Block 2	Equipment and Corroded Structures (C5) Outdated Pipes, Ducts (C5)
		Rehabilitation of Part of existing Secondary Treatment for Block 3	
	Component 2	Sludge Thickening Facilities	Internal Sludge Fields

Stage	Component	Main Activity	Dismantling and Land Preparation
	(C2)	Sludge Dewatering Facilities	(covered in C5)
		Temporary Dewatered Sludge Storage Pond	
		Administration Building	Aerobic Sludge Stabilization (C5)
	Component 3 (C3)	Sludge Incinerators	Preparing Additional Site (covered in C5)
		Anaerobic Sludge Digestion Process with CHP	
		Associated Functions (Green House, etc.)	
	Component 4 (C4)	Preliminary Treatment Facilities for Block 1	Internal Sludge Fields (covered in C5) Preparing Additional Site (covered in C5)
		Primary Treatment Facilities for Block 1	
		Secondary Treatment Facilities for Block 1	
		Tertiary Treatment Facilities for Block 1	
		Disinfection Channel for Block 1	
	Component 5 (C5)*	Dismantling Existing Equipment and Corroded Structures	Related to C1
		Dismantling Existing Outdated Pipes and Ducts, etc.	Related to C1
		Dismantling Existing Aerobic Sludge Stabilization	Related to C2
		Removing Accumulated Sludge from the Internal Sludge Fields	Related to C2 and C4
		Land Preparation for Additional Site (Southernmost Property)	Related to C3 and C4

*Component 5 (C5) is to be implemented by Ukrainian Side
Source: KVK

(B) Components 6 – 10 (Stage 2)

Components 6 – 10 contain activities which are nominated secondary prioritized after Stage 1's items. The rehabilitation works of two existing main pump stations (Pozniaky Pump Station and Right Bank Pump Station, Component 6 and Component 7 respectively). According to original concept identified in 2012 F/S, constructing biological advanced treatment targeting nitrogen and phorphorus and tertiary treatment are planned in Block 2 (in Component 8). Moreover a part of secondary treatment and tertiary treatment facilities in Block 3 (in Component 9) are planned in order to complete advanced treatment in BAS after the provision of rehabilitation works contained in Component 1.

Component 10 contains river channel works and other associated facilities such as parking lots and workshops, warehouses.

The main activities proposed for Stage 2 are contained in Table 3.60.

Table 3.60 Main Activities Contained in Stage 2 (Secondary Prioritized Activities)

Stage	Component	Main Activity	Dismantling and Land Preparation
Stage 2	Component 6 (C6)	Rehabilitation of Pozniaky Pumping Station	Equipment and Corroded Structures
		Rehabilitation of Coarse Screens and Inlet Channels	
	Component 7 (C7)	Rehabilitation of Right Bank Pumping Station	Equipment and Corroded Structures
		Rehabilitation of Coarse Screens and Inlet Channels	
	Component 8 (C8)	Secondary Treatment Facilities for Block 2	Equipment (including C1's Rehabilitation) Existing Civil Structures (Tanks & Pipes)
		Tertiary Treatment Facilities for Block 2	
		Disinfection Channel for Block 2	
	Component 9 (C9)	Secondary Treatment Facilities for Part of Block 3	Equipment (including C1's Rehabilitation) Existing Civil Structures (Tanks & Pipes)
		Tertiary Treatment Facilities for Block 3	
		Disinfection Channel for Block 3	
	Component 10 (C10)	Outlet Channel from BAS to Rivermouth (9 km)	
		Warehouse and Workshop	
		Parking Lot	

Source: KVK

(2) Targeted Activities for the Project

Stage 1, or Components 1 – 5 were selected for the candidate scopes in the project among for the following reasons.

- According to the preliminary visual surveys by the JST members, reconstruction of the most deteriorated water treatment facility of Block 1 were evaluated as very urgent issue
- Block 2 and Block 3 were evaluated that the current structural conditions were manageable with renovation works and replacements of mechanical and electrical equipment, same as proposed in Component 1,
- Establishment of sludge treatment facilities is urgent because of lack of capacity in temporary sludge fields,
- Rehabilitation works of water treatment system are stringent compared to pump station by considering existing conditions, and
- All the activities identified in Stage 1 (Components 1 – 5) are also mutually approved by Kiev City and KVK as the prioritized activities.

3.3 Survey on Water Quality and Inflow of BAS

3.3.1 Analysis on Water Qualities and Sewage and Characteristics of Sludge

(1) Laboratories of Water Quality Analysis and Sludge Analysis

Analysis data are collected from the following resources:

Laboratory	Analysis data
BAS chemical and bacteriological laboratory (KVK)	Operation of treatment facilities was analyzed once a week by the department of laboratory control of water treatment by analyzing average daily samples.
Central laboratory of state enterprise “Ukrainian Geological Company”	Water quality items which could not be analyzed by BAS laboratory were analyzed at Central laboratory of state enterprise “Ukrainian Geological Company”.
Japan CCL (Japanese Laboratory)	Characteristics of sludge necessary for design of sludge treatment and incineration were analyzed by Japan CCL.

Source: JICA Study Team

(2) Sampling for Water Quality Analysis

The locations for taking samples of water quality analysis for Block 1, Block 2 and Block 3 of BAS were:

- Raw sewage (distribution channel of grit chamber)
- Primary treated water (upper distribution channel of aeration tanks)
- Treated water (branch channel of each block)

Average daily samples included snap samples taken during a day (24 hours) with an interval of every 2 hours. Complete chemical analysis of sewage was carried out in regard to the obtained average daily samples.

(3) Sampling for Sludge Analysis

Every day (24 hours), the content of sewage sludge was analyzed by the department for laboratory control of sludge treatment and the analysis was conducted according to a scheme of short analysis. The following types of sludge were analyzed:

- Raw sludge (before anaerobic digestion tanks)
- Excess sludge (after sludge thickeners)
- Digested sludge (after anaerobic digestion tanks)

Samples of raw sludge were taken from inflow and outflow of anaerobic digestion tanks while samples of excess sludge were taken from outflow of sludge thickeners. Average daily samples comprised these obtained samples and sludge was accumulated according to the scheme of complete analysis of sludge. Average samples comprised dried average daily samples.

(4) Results of Water Quality Analysis

(D) Raw Sewage

The water qualities of raw sewage analyzed by BAS chemical and bacteriological laboratory (KVK) from 2008 to 2012 are show in Table 3.61.

Table 3.61 Water Qualities of Raw Sewage (1)

(mg/l)

Year	Block	SS	VSS	BOD_5	COD_{Cr}	Mineral	Sulfate	Chloride	NH_4-N	PO_4	PP*1	SSAS*2	Total Fe
2008	1	376	273	243	778	602	65.7	83.0	26.0	20.59	1.5	2.08	2.47
	2	282	209	214	674	581	66.5	77.6	25.1	16.86	1.5	2.28	2.24
	3	279	204	215	693	596	64.7	78.0	26.5	17.92	1.5	2.33	2.19
	Ave	312	229	224	715	593	65.6	79.5	25.9	18.46	1.5	2.23	2.30
2009	1	389	288	276	832	640	52.8	84.0	27.5	20.62	1.4	1.79	1.64
	2	315	240	228	658	581	44.0	71.5	26.6	17.76	1.3	2.17	1.46
	3	327	247	240	677	597	53.1	70.7	27.4	19.59	1.3	2.15	1.53
	Ave	344	258	248	722	606	50.0	75.4	27.2	19.32	1.3	2.15	1.54
2010	1	309	237	233	655	672	58.4	83.5	29.0	16.15	1.0	1.85	1.81
	2	301	229	215	610	607	57.6	76.2	28.9	17.81	1.1	2.00	1.73
	3	325	243	231	651	602	56.2	75.6	31.0	19.26	1.1	2.02	1.74
	Ave	312	237	226	639	627	57.4	78.4	29.6	17.74	1.1	1.96	1.76
2011	1	338	254	285	652	605	60.4	80.1	33.7	15.98	1.5	1.79	1.56
	2	347	259	287	651	607	60.6	80.0	33.6	17.64	1.5	1.91	1.58
	3	373	278	317	653	594	62.0	80.2	35.4	19.66	1.5	1.85	1.63
	Ave	353	264	296	651	602	61.0	80.1	34.2	17.76	1.5	1.84	1.59
2012	1	225	166	211	495	570	42.2	86.1	33.7	11.99	1.3	1.80	1.44
	2	396	294	298	659	606	45.7	86.6	34.9	20.09	1.6	1.67	1.85
	3	367	272	283	632	570	44.9	85.9	34.8	18.36	1.5	1.67	1.77
	Ave	329	244	264	595	582	44.3	86.2	34.5	16.81	1.5	1.71	1.69
Maximum		396	294	317	832	672	66.5	86.6	35.4	20.62	1.6	2.33	2.47
Minimum		225	166	211	495	570	42.2	70.7	25.1	11.99	1.0	1.67	1.44
Average		330	246	251	668	603	56.3	79.6	30.3	18.08	1.4	1.98	1.78

PP*1: Petroleum products

SSAS*2: Synthetic surface active substances (anionic)

Source: KVK

The water qualities of raw sewage analyzed by central laboratory of state enterprise “Ukrainian Geological Company” in 2013 are shown in Table 3.62.

Table 3.62 Water Qualities of Raw Sewage (2)

Block	Total Nitrogen	Total Phosphorous
1	25.7	6.6
2	23.9	3.8
3	24.3	8.1
Average	24.6	6.2

Source: Ukrainian Geological Company

Average of water qualities of raw sewage from 2008 to 2013 in BAS are followings:

- SS: 330 mg/l
- BOD_5: 251 mg/l
- COD_{Cr}: 668 mg/l
- NH_4-N: 30.3 mg/l
- PO_4: 18.08 mg/l
- Total Nitrogen: 24.6 mg/l (1 sample)
- Total phosphorous: 6.2 mg/l (1 sample)

(E) Primary Treated Water

The water qualities of primary treated water analyzed by BAS chemical and bacteriological laboratory (KVK) from 2008 to 2012 are show in Table 3.63.

Table 3.63 Water Qualities of Primary Treated Water

(mg/l)

Year	Block	SS	BOD_5	COD_{Cr}	Mineral	Sulfate	Chloride	NH_4-N	PO_4	Total Fe
2008	1	224	179	552	597	62.0	81.7	29.5	24.96	1.79
	2	187	151	517	573	61.7	77.8	26.8	17.16	1.87
	3	171	133	521	565	60.1	76.0	27.0	19.87	1.85
	Ave	194	154	530	578	61.2	78.5	27.8	20.66	1.84
2009	1	192	199	578	605	51.9	80.8	31.3	23.68	1.25
	2	233	178	554	595	52.1	68.8	28.3	19.90	1.33
	3	175	169	474	570	53.1	69.1	27.5	20.22	1.16
	Ave	200	182	535	590	52.4	72.9	29.0	21.27	1.25
2010	1	148	182	502	612	57.4	82.1	32.0	18.85	1.33
	2	188	172	520	587	56.4	74.3	30.8	19.81	1.41
	3	191	169	511	571	55.8	75.2	30.4	20.82	1.37
	Ave	176	174	511	590	56.5	77.2	31.1	19.83	1.37
2011	1	165	209	488	602	58.9	88.1	35.8	18.52	1.08
	2	183	218	481	580	59.5	81.9	35.5	19.35	1.14
	3	201	204	487	574	59.4	81.3	35.3	20.84	1.22
	Ave	183	210	485	585	59.4	83.8	35.5	19.57	1.15
2012	1	146	173	416	537	40.7	84.4	36.5	13.24	1.20
	2	247	226	493	586	43.5	86.5	35.6	22.14	1.41
	3	184	200	432	549	45.0	85.4	34.1	19.23	1.29
	Ave	192	200	447	557	43.1	85.4	35.4	18.20	1.30
Maximum		247	226	578	612	61.8	88.1	36.5	24.96	1.87
Minimum		146	133	416	537	40.7	68.8	26.8	13.24	1.08
Average		189	184	502	580	54.5	79.6	31.8	19.91	1.38

Source: KVK

(F) Treated Water

The water qualities of treated water analyzed by BAS chemical and bacteriological laboratory (KVK) from 2008 to 2012 are show in Table 3.64.

Table 3.64 Water Qualities of Treated Water (1)

(mg/l)

Year	Block	SS	BOD_5	COD_{Cr}	Mineral	Sulfate	Chloride	NH_4-N	PO_4	PP*1	SSAS*2	Total Fe	DO
2008	1	12.0	5.0	60.7	547	59.0	78.0	7.5	2.4	0.05	0.07	0.37	3.92
	2	14.6	5.3	66.4	528	59.2	74.2	6.5	2.4	0.05	0.07	0.42	4.79
	3	12.8	4.2	59.1	537	57.2	72.9	4.9	3.4	0.05	0.06	0.37	4.95
	Ave	13.1	4.8	62.1	537	58.5	75.0	6.3	2.7	0.05	0.07	0.39	4.55
2009	1	10.2	6.6	56.7	543	49.6	75.8	5.7	2.1	0.05	0.08	0.32	4.50
	2	17.3	6.4	63.9	541	52.1	66.1	6.3	3.7	0.05	0.08	0.35	5.85
	3	13.0	4.9	57.7	533	54.3	66.2	6.1	4.9	0.05	0.08	0.33	5.76
	Ave	13.5	6.0	59.4	539	52.0	69.4	6.0	3.6	0.05	0.08	0.33	5.37
2010	1	11.0	5.3	65.8	583	54.4	79.4	5.7	2.1	0.04	0.08	0.31	4.73
	2	14.7	6.3	71.4	537	55.0	72.4	7.1	3.3	0.04	0.07	0.31	5.91
	3	15.4	6.3	71.1	530	56.9	72.8	5.9	4.2	0.04	0.07	0.32	5.50
	Ave	13.7	6.0	69.4	550	55.4	75.0	6.2	3.2	0.04	0.07	0.31	5.38
2011	1	9.9	5.5	61.5	549	56.0	85.5	4.0	3.4	0.06	0.11	0.24	4.82
	2	16.7	8.2	67.5	545	57.0	80.1	9.4	6.0	0.05	0.12	0.28	5.42
	3	16.8	8.8	66.8	556	58.0	79.4	8.0	6.5	0.05	0.13	0.28	5.54
	Ave	14.5	7.5	65.3	550	57.0	81.7	7.1	5.3	0.05	0.12	0.27	5.27
2012	1	12.1	6.7	82.8	535	51.0	81.6	5.4	2.4	0.05	0.10	0.31	5.23
	2	16.0	7.2	71.9	554	58.5	83.7	8.8	5.2	0.05	0.10	0.34	5.94
	3	16.7	7.1	67.3	521	53.6	83.1	5.8	6.0	0.05	0.09	0.33	5.68
	Ave	14.5	7.0	67.3	537	57.7	82.8	6.7	4.5	0.05	0.10	0.33	5.62
Maximum		17.3	8.8	71.9	583	61.0	85.5	9.4	6.5	0.06	0.13	0.42	5.94
Minimum		9.9	4.2	62.8	521	49.6	66.1	4.0	2.1	0.04	0.06	0.24	3.92
Average		14.0	6.3	67.3	543	59.2	76.8	6.5	3.9	0.05	0.09	0.33	5.24

PP*1: Petroleum products

SSAS*2: Synthetic surface active substances (anionic)

Source: KVK

The water qualities of treated water analyzed by central laboratory of state enterprise “Ukrainian Geological Company” in 2013 are show in Table 3.65.

Table 3.65 Water Qualities of Treated Water (2)

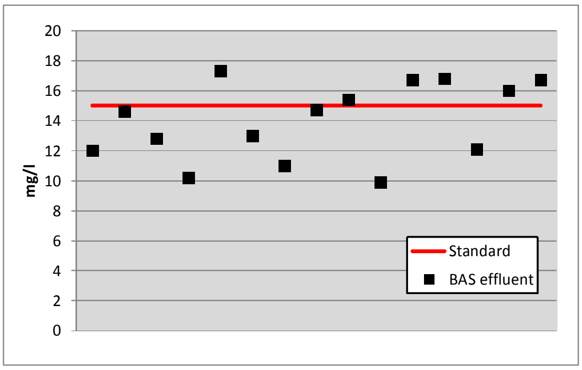
(mg/l)

Block	Total Nitrogen	Total Phosphorous
1	11.3	0.1
2	13.9	1.9
3	14.9	4.1
Average	13.4	2.0

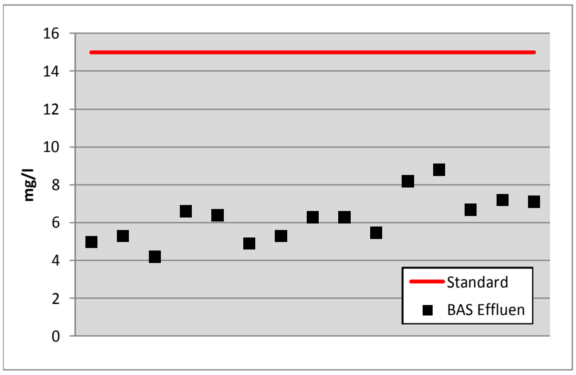
Source: Ukrainian Geological Company

The water qualities of treated water with effluent standards are shown in Figure 3.14.

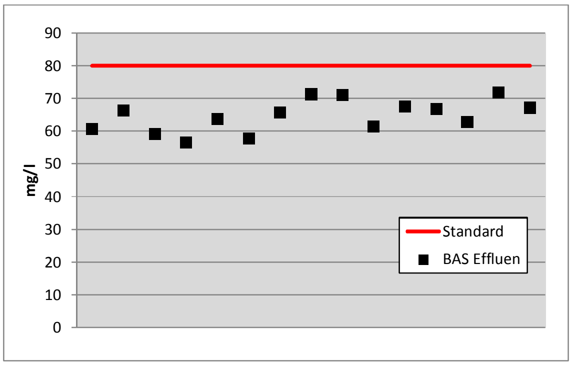
SS



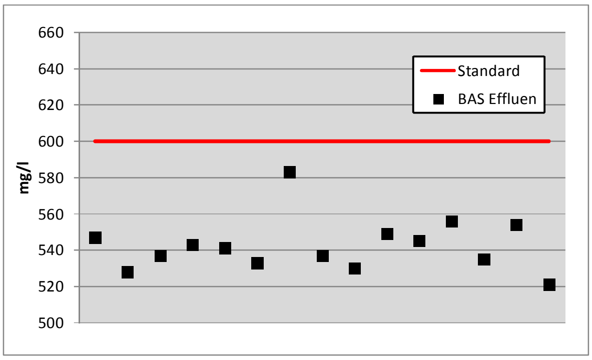
BOD_5



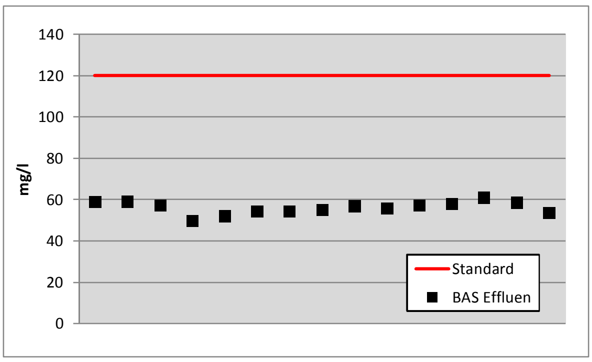
COD_{Cr}



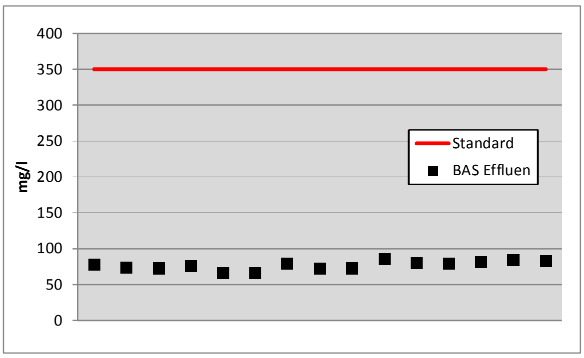
Mineral



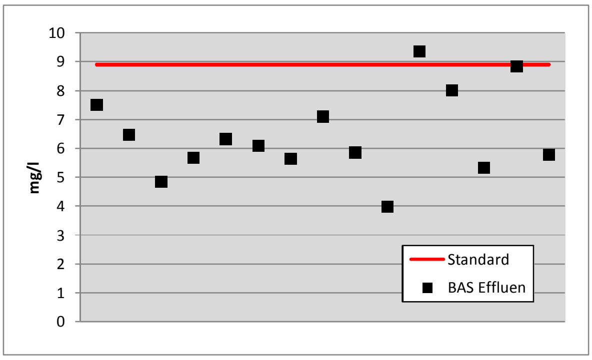
Sulfate



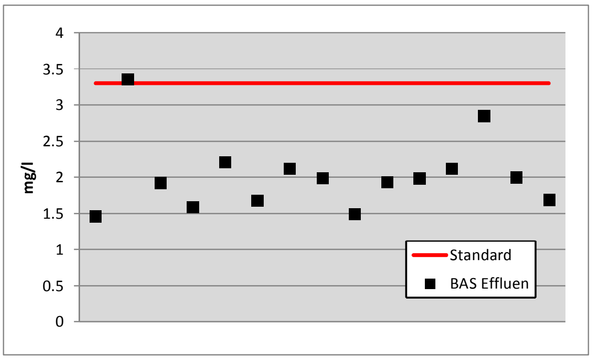
Chloride



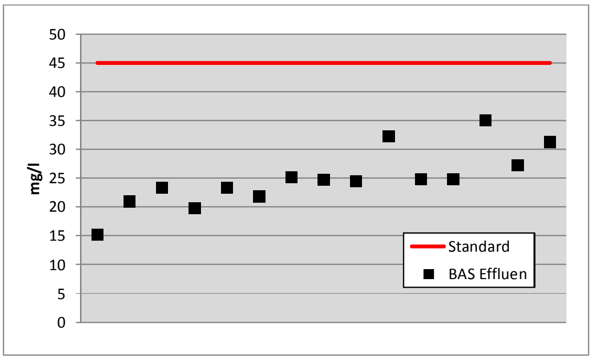
NH_4-N



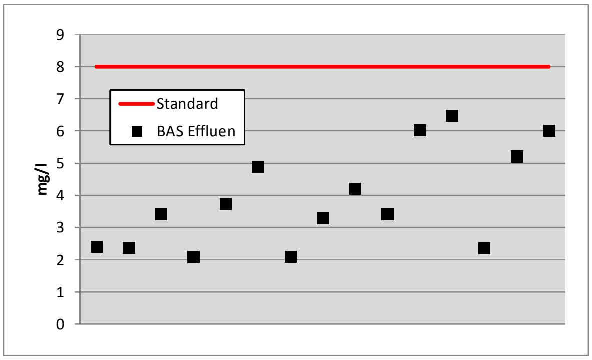
NO_2



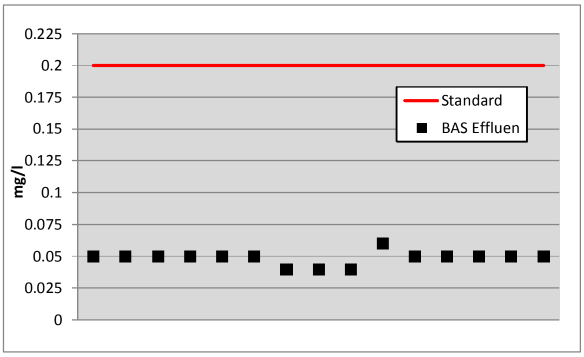
NO_3



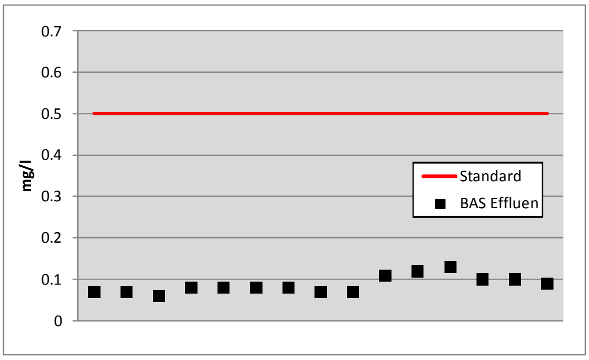
PO_4



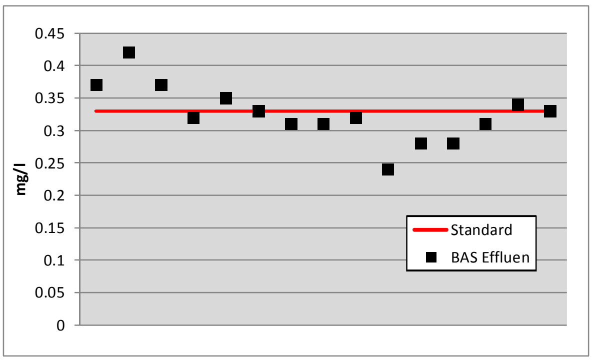
Petroleum products



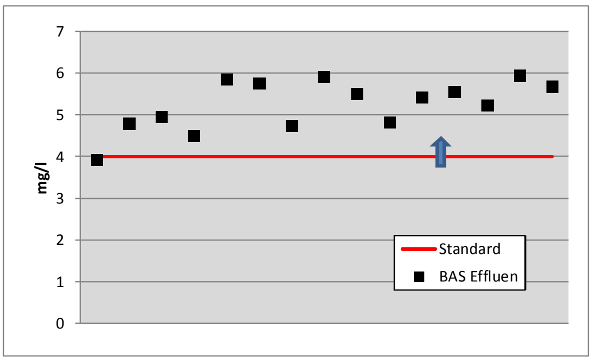
Synthetic surface active substances (anionic)



Total Fe



DO



Source: KVK

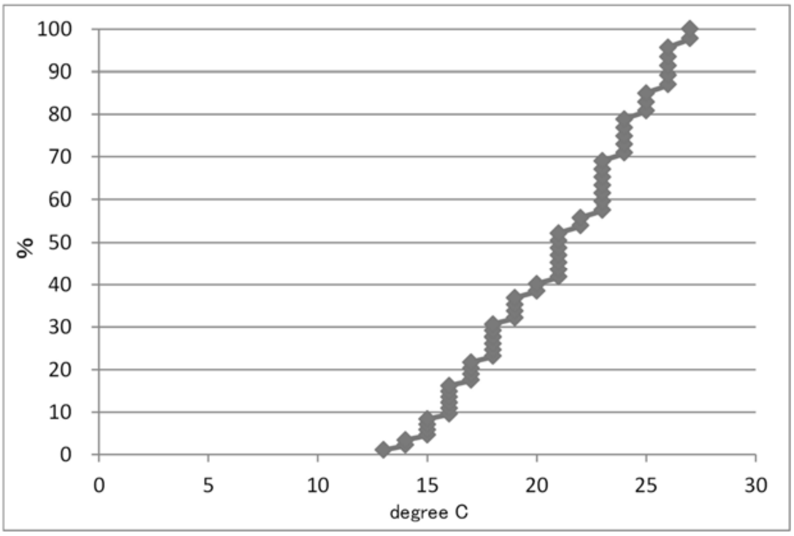
Figure 3.14 Water Qualities of Treated Water

Water quality items of SS and total Fe exceed the effluent standards in spots. Regarding SS, relatively high MLSS concentration and low surface lording of secondary settling tanks may cause the carry-over of SS. Regarding total Fe, relatively high concentration of ferrum in raw sewage results in excess of the effluent standard for total Fe.

(G) Water Temperature

The monthly average temperature in aeration tanks for Block 1 from 2008 to 2012 is shown in Figure 3.15.

- Minimum: 13 degree C
- Average: 20 degree C
- Maximum: 27 degree C



Source: KVK

Figure 3.15 Monthly Average Temperature in Aeration Tanks

(H) Boiler Water

The water qualities of boiler water analyzed by Japan CCL are shown in Table 3.66.

Table 3.66 Water Qualities of Boiler Water

Items	Unit	Values	Items	Unit	Values
pH	At 25 degree C	7.95	Hardness(Ca)	$mgCaCO_3/l$	125.5
Turbidity		1	Hardness(Mg)	$mgCaCO_3/l$	87.3
Color		2	Total Fe	mgFe/l	0.4
Evaporation Residue	mg/l	362	Total Mn	mgMn/l	0.001 or less
$KMnO_4$ Consumption	mg O/l	3.6	Chlorides	mgCl-/l	54
Electric Conductivity	μS/cm	636	Sulfates	$mgSO_4^{2-}/l$	20.8

Items	Unit	Values	Items	Unit	Values
M-Alkalinity	mg$CaCO_3$/l	254	Silica	mgSiO_2/l	9.4
Sodium	mgNa/l	46	Carbonate	mgCO_3/l	0.5 or less
Potassium	mgK/l	17	Nitrate	mgNO_3/l	1.5
Total Hardness	mg$CaCO_3$/l	212.8			

Source: Japan CCL

(5) Results of Sludge Analysis

The characteristics of sludge measured by Japan CCL are shown in Table 3.67

- Average solid contents of raw sludge and excess sludge is 2.32 % and 1.19 %, respectively
- Average ignition loss of raw sludge and excess sludge is 70.5 % and 71.9 %, respectively
- Average calorific value of raw sludge and excess sludge is 4,350 kcal/kg-dry and 3,836 kcal/kg-dry, respectively
- Sludge contains flammable sulfide from 0.40 dry-% to 0.76 dry-%
- Sludge contains flammable chlorine from 0.15 dry-% to 0.69 dry-%

Table 3.67 Characteristics of Sludge

Items / unit	Raw sludge (B1)	Raw sludge (B2)	Raw sludge (B3)	Mixture of raw sludge	Ave. of raw sludge	Excess sludge (B2)	Excess sludge (B3)	Ave. excess sludge	Digested sludge
Average water contents (%)	97.1	97.8	97.6	97.7	97.5	98.3	99.1	98.7	-
Hygroscopic moisture (%)	6.44	7.43	7.67	7.21	7.18	8.25	8.85	8.55	6.41
Solid contents (%)	2.71	2.04	2.22	2.13	2.32	1.56	0.82	1.19	-
Ignition loss (dry-%)	68.4	71.4	71.6	70.4	70.5	71.9	71.9	71.9	61.9
Ash (dry-%)	30.0	28.0	27.9	29.1	28.6	27.8	27.8	27.8	36.9
Crude fiber contents (dry-%)	8.87	7.89	8.12	8.19	8.29	5.12	4.48	4.80	9.51
Crud fat contents (dry-%)	7.49	6.32	6.45	7.64	6.75	2.40	2.44	2.42	4.48
Caloric value (kJ/kg-dry)	19,150	17,400	18,080	17,730	18,210	16,220	15,890	16,055	15,020
Caloric value (kcal/kg-dry)	4,575	4,157	4,319	4,236	4,350	3,875	3,796	3,836	3,588
Chemical element analysis									
C (dry-%)	42.4	38.2	40.1	38.9	40.2	36.8	36.2	36.5	35.5
H (dry-%)	6.77	6.11	6.46	6.15	6.45	5.85	6.02	5.94	5.73
N (dry-%)	3.40	4.67	4.79	4.49	4.29	6.45	6.33	6.39	4.86
S (dry-%)	0.67	0.69	0.76	0.66	0.71	0.40	0.54	0.47	0.62
Total S (dry-%)	0.86	0.99	1.07	0.98	0.97	0.45	0.61	0.53	0.97
Inflammable S (dry-%)	0.19	0.30	0.31	0.32	0.27	0.05	0.07	0.06	0.35
Cl (dry-%)	0.15	0.31	0.19	0.20	0.22	0.30	0.69	0.50	0.24
Total Cl (dry-%)	0.27	0.41	0.32	0.34	0.33	0.40	0.78	0.59	0.33
Inflammable Cl (dry-%)	0.12	0.10	0.13	0.14	0.12	0.10	0.09	0.10	0.09
O (dry-%)	16.61	22.02	19.80	20.50	19.48	22.40	22.42	22.41	16.15
Total florin (dry-%)	0.13	0.17	0.17	0.09	0.16	0.14	0.17	0.16	0.14

Items / unit	Raw sludge (B1)	Raw sludge (B2)	Raw sludge (B3)	Mixture of raw sludge	Ave. of raw sludge	Excess sludge (B2)	Excess sludge (B3)	Ave. excess sludge	Digested sludge
Composition analysis									
Na_2O (dry-g/kg)	4.35	5.29	4.76	5.12	4.80	5.62	10.60	8.11	5.50
MgO (dry-g/kg)	5.88	6.41	61.6	6.63	6.15	13.10	14.20	13.65	27.60
Al_2O_3 (dry-g/kg)	23.7	22.3	23.0	23.1	23.0	19.0	17.5	18.3	27.6
SiO_2 (dry-g/kg)	163	134	133	144	143	97	88	92	211
P_2O_5 (dry-g/kg)	17.9	31.4	29.2	30.0	26.2	70.6	72.8	71.7	29.7
K_2O (dry-g/kg)	5.76	5.91	5.86	6.02	5.84	12.3	13.7	13.0	6.72
CaO (dry-g/kg)	55.2	51.2	50.9	53.0	52.4	42.5	43.9	43.2	56.8
TiO_2 (dry-g/kg)	2.20	2.12	2.15	2.17	2.16	2.02	1.85	1.94	2.36
Cr_2O_3 (dry-g/kg)	0.27	0.25	0.26	0.24	0.26	0.25	0.23	0.24	0.23
MnO (dry-g/kg)	0.21	0.29	0.28	0.29	0.26	0.25	0.23	0.24	0.23
Fe_2O_3 (dry-g/kg)	18.6	16.9	16.5	17.5	17.3	14.0	13.1	13.6	18.7
NiO (dry-g/kg)	0.062	0.064	0.056	0.057	0.061	0.056	0.058	0.060	0.070
CuO (dry-g/kg)	0.221	0.233	0.221	0.229	0.225	0.232	0.223	0.230	0.255
ZnO (dry-g/kg)	0.678	0.826	0.667	0.617	0.724	0.651	0.678	0.660	0.649
Pb_2O (dry-g/kg)	0.024	0.018	0.018	0.016	0.020	0.017	0.016	0.020	0.023
SrO (dry-g/kg)	0.126	0.186	0.184	0.182	0.165	0.175	0.181	0.180	0.172
ZrO_2 (dry-g/kg)	0.132	0.109	0.115	0.104	0.119	0.092	0.080	0.090	0.133
BaO (dry-g/kg)	0.241	0.286	0.251	0.276	0.259	0.235	0.234	0.230	0.439
CdO (dry-g/kg)	ND	ND	ND	ND	-	ND	ND	-	ND
As_2O_3 (dry-g/kg)	ND	ND	ND	ND	-	ND	ND	-	ND
CoO (dry-g/kg)	ND	ND	ND	ND	-	ND	ND	-	ND
MoO_2 (dry-g/kg)	ND	ND	ND	ND	-	ND	ND	-	ND
Sb_2O_3 (dry-g/kg)	ND	ND	ND	ND	-	ND	ND	-	ND
SeO (dry-g/kg)	ND	ND	ND	ND	-	ND	ND	-	ND
SnO (dry-g/kg)	ND	ND	ND	ND	-	ND	ND	-	ND
V_2O_5 (dry-g/kg)	ND	ND	ND	ND	-	ND	ND	-	ND
WO_2 (dry-g/kg)	ND	ND	ND	ND	-	ND	ND	-	ND
Br (dry-g/kg)	ND	ND	ND	ND	-	ND	ND	-	ND
HgO (dry-g/kg)	ND	ND	ND	ND	-	ND	ND	-	ND

Source: Japan CCL

(6) Heavy Metals Contained in Sewage and Sludge

(A) Sewage

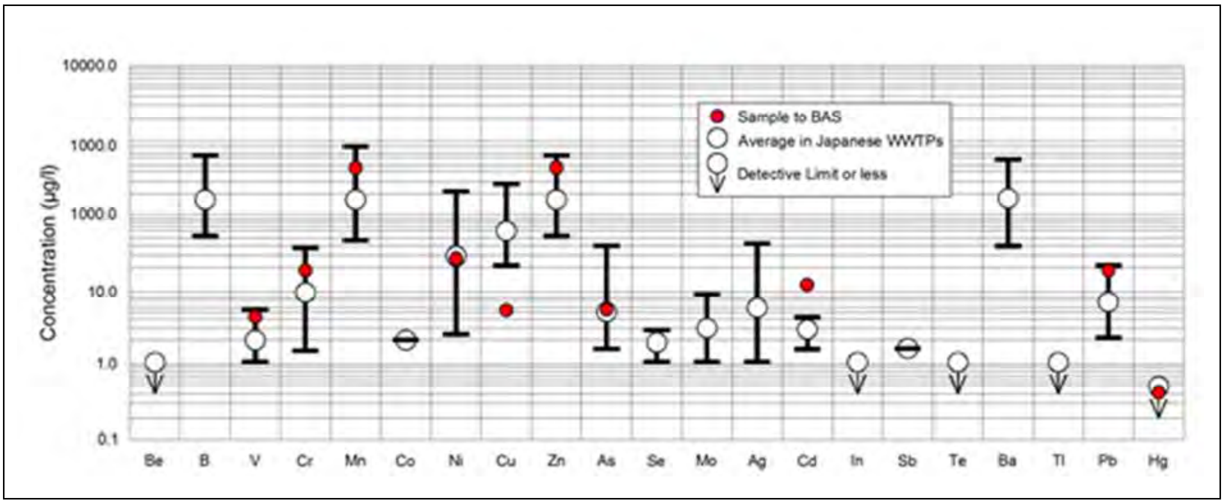
Heavy metal concentrations in BAS in Kiev and example of concentrations of heavy metals in Japan are shown in Table 3.68, Figure 3.16 and Figure 3.17, respectively. The characteristics of heavy metal concentrations in sewage in BAS and WWTPs in Japan were found to be very similar to each other.

Table 3.68 Heavy Metal Concentrations in BAS

(mg/l)

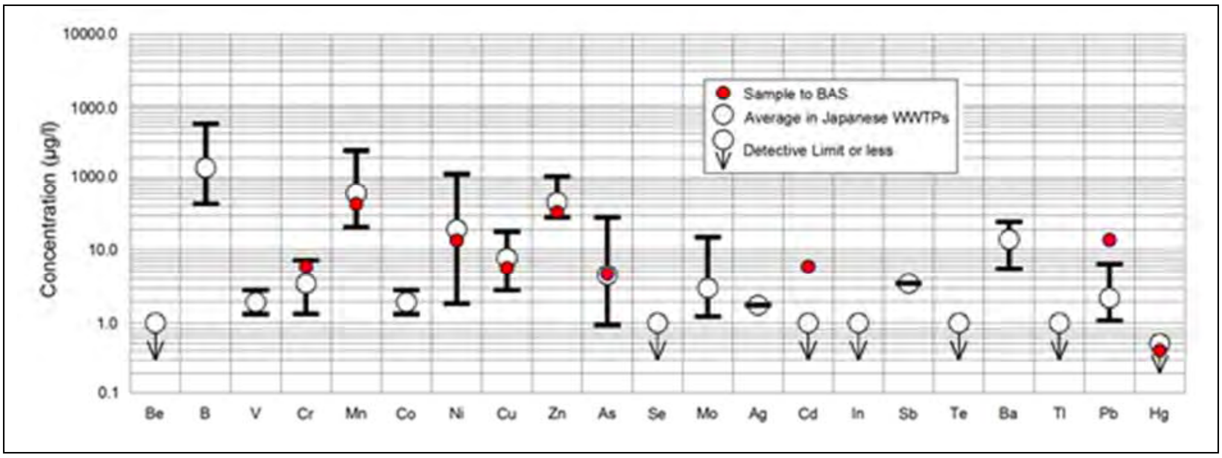
Sampling location	Al	As	Hg	Cr	Cr^{+6}	Cd	Ni	Zn	Pb	Phenolic	Cyanide	Formaldehyde	M-alkalinity
Influent (block 3)	780	<5.0	<0.5	180	18.0	<10	7.0	680	23.0	2.6	<100	<20	512.4
Effluent (block 3)	80	<5.0	<0.5	62.5	7.5	<10	5.0	30.5	15.0	1.2	<100	<20	231.8
Influent (block 2)	840	<5.0	<0.5	144	15.5	<10	6.5	360	16.0	2.5	<100	<20	402.6
Effluent (block 2)	90	<5.0	<0.5	35.0	6.5	<10	4.5	41.0	19.0	0.8	<100	<20	195.2
Influent (block 1)	520	<5.0	<0.5	190	20.5	<10	23.0	530	22.5	8.2	<100	<20	512.4
Effluent (block 1)	120	<5.0	<0.5	66.0	7.0	<10	9.5	34.5	14.5	0.9	<100	<20	219.6
Influent (average)	713	<5.0	<0.5	171	18.0	<10	20.5	523	20.5	4.4	<100	<20	475.8
Effluent (average)	97	<5.0	<0.5	54.5	7.0	<10	10.8	35.3	16.2	1.0	<100	<20	215.5

Source: Ukrainian Geological Company



Source: Study on risk assessment of sewage sludge utilization, Suzuki, MLITT, Japan

Figure 3.16 Compositions of Raw Sewage in BAS and WWTPs in Japan



Source: Study on risk assessment of sewage sludge utilization, Suzuki, MLITT, Japan

Figure 3.17 Compositions of Treated Water in BAS and WWTPs in Japan

(B) Sludge

Utilization of sewage sludge for the agricultural purposes has been banned due to the following reasons.

- High concentrations of heavy metals in sewage sludge because of acceptance of the industrial effluent which contains high concentrations of heavy metals at the time of commencing sewerage service
- Contents of the radioactive materials caused by the accident of Chernobyl power plant

While high concentrations of heavy metals in the sludge of BAS had been very significant, heavy metals such as Cd, As, Se and Hg contained in the samples of sludge were not detectable at present as shown in Table 3.67. Hence, the concentrations of heavy metals in sewage sludge produced from BAS have decreased significantly most probably owing to the relocation of the factories.

3.3.2 Analysis on Influent Flowrate

(1) Outline of Flow Measurement in BAS

Three flow measurement facilities are located in water channel between pump stations and primary settling tanks and. Each measurement facility consists of a Parshall flume flow meter, a bubble gauge and a data logger.

(2) Average Flow

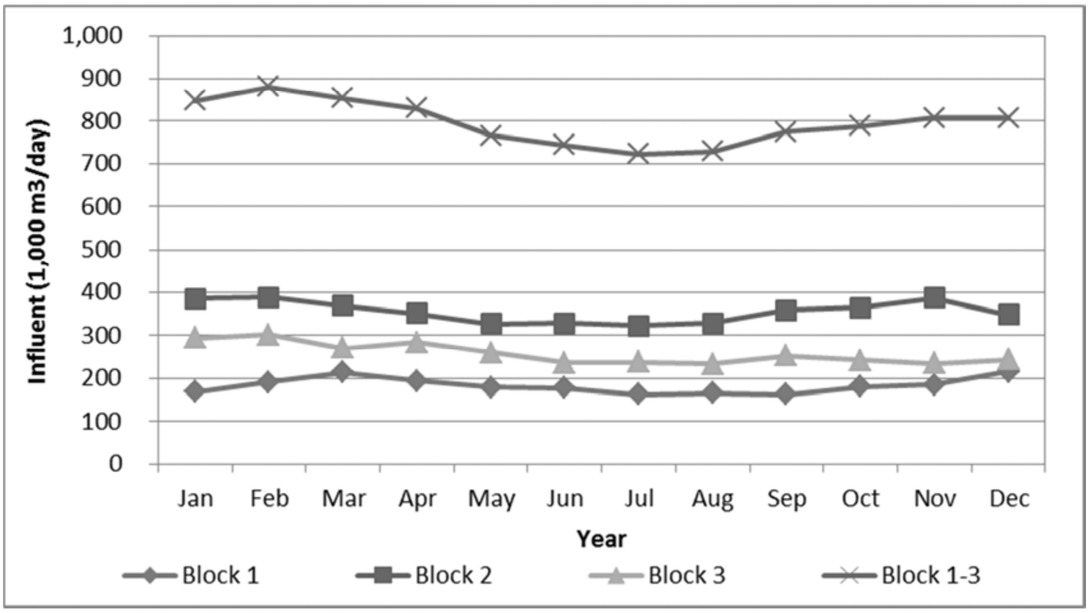
Monthly total and monthly average influent flowrates in 2012 are shown Table 3.69 and Figure 3.18.

- Influent flowrate from January to March was high
- Monthly average, maximum and minimum influent flowrates in 2012 were 796,394m^3/day, 882,121m^3/day and 722,935m^3/day, respectively

Table 3.69 Monthly Total and Monthly Average Influent Flowrates

Month	Monthly Total (m^3/month)				Monthly Average (m^3/day)			
	Block 1	Block 2	Block 3	Total	Block 1	Block 2	Block 3	Total
Jan	5,241,300	11,945,400	9,123,900	26,310,600	169,074	385,335	294,319	848,729
Feb	5,544,000	11,287,300	8,750,200	25,581,500	191,172	389,217	301,731	882,121
Mar	6,627,000	11,474,800	8,397,400	26,499,200	213,774	370,155	270.884	854,813
Apr	5,808,700	10,563,550	8,540,800	24,913,050	193,623	352,118	284,693	830,435
May	5,558,850	10,134,000	8,051,200	23,744,050	179,318	326,903	259,716	765,937
Jun	5,332,850	9,873,550	7,096,600	22,303,000	177,762	329,118	236,553	743,433
Jul	5,051,000	10,010,700	7,349,300	22,411,000	162,935	322,926	237,074	722,935
Aug	5,152,450	10,213,150	7,233,700	22,599,300	166,208	329,456	233,345	729,010
Sep	4,897,500	10,763,400	7,593,500	23,254,400	163,250	358,780	253,117	775,147
Oct	5,621,500	11,314,850	7,497,000	24,247,300	181,339	364,995	241,839	788,173
Nov	5,570,000	11,626,500	7,050,800	25,040,300	185,667	387,550	235,027	808,243
Dec	6,670,950	10,817,750	7,551,600	25,040,300	215,192	348,960	243,600	807,752
Total	67,076,100	130,024,950	94,236,000	291,337,,050	2,199,314	4,265,515	3,091,898	9,556,727
Average	5,589,675	10,835,413	7,853,000	24,278,088	183,276	355,460	257,658	796,394
Maximum	6,670,950	11,945,400	9,123,900	26,499,200	215,192	389,217	301,731	882,121
Minimum	4,897,500	9,873,550	7,050,800	22,303,000	162,935	322,926	233,345	722,935

Source: KVK



Source: JICA Study Team

Figure 3.18 Monthly Total and Monthly Average Influent Flowrates

(3) Daily Maximum Flow

Daily influent flowrate in 2012 is shown in Table 3.70.

- Daily maximum flow was observed on 25 Feb 2012 at 1,015,100m^3/day
- Ratio of daily maximum flow and daily mean flow was calculated at 1.30

Table 3.70 Daily Influent Flowrates

Rank	Date	Day	Daily flow (m^3/day)				Remark
			Block 1	Block 2	Block 3	Total	
1	2012/02/25	Sat	213,800	475,300	326,000	1,015,100	(1)
2	2012/01/13	Fri	174,700	508,700	323,900	1,007,300	
3	2012/08/14	Tue	196,350	464,600	326,700	987,650	
4	2012/08/13	Mon	170,450	487,750	328,800	987,000	
5	2012/04/09	Mon	221,700	432,000	332,700	986,400	
6	2012/02/24	Fri	220,950	424,750	322,600	968,300	
7	2012/11/06	Tue	216,450	439,400	291,100	946,950	
8	2012/02/26	Sun	201,700	426,500	310,400	938,600	
9	2012/01/30	Mon	177,700	449,700	304,700	932,100	
10	2012/04/18	Wed	198,600	411,500	320,900	931,000	
Daily maximum flow (m^3/day)						1,015,100	(2)=(1)
Daily mean flow (m^3/day)						796,394	(3)
Ratio of daily maximum flow and daily mean flow					Calculated	1.27	(4)=(2)/(3)
					Rounded	1.30	

Source: JICA Study Team

(4) Hourly Maximum Flow

Hourly influent flow on 25th February 2012 is shown in Table 3.71.

- Hourly maximum flow was observed from 16:00 to 19:00 at 52,700m^3/hour
- Ratio of daily maximum flow and daily mean flow was calculated at 1.25

Table 3.71 Hourly Influent Flowrates

Date	Time	Daily flow (m^3/hour)				Remark
		Block 1	Block 2	Block 3	Total	
2012/02/25	00:00	10,150	20,250	13,700	44,100	
2012/02/25	01:00	8,850	19,800	13,700	42,350	
2012/02/25	02:00	6,800	17,500	13,400	37,700	
2012/02/25	03:00	6,800	16,250	11,200	34,050	
2012/02/25	04:00	6,800	14,100	11,200	32,100	
2012/02/25	05:00	6,800	14,100	9,200	30,100	
2012/02/25	06:00	6,800	14,100	9,200	30,100	
2012/02/25	07:00	6,800	13,250	9,200	29,250	
2012/02/25	08:00	7,300	12,500	9,200	29,000	
2012/02/25	09:00	7,500	14,500	9,200	31,200	
2012/02/25	10:00	8,850	16,250	10,600	35,700	
2012/02/25	11:00	10,150	18,850	12,500	41,500	
2012/02/25	12:00	10,300	20,250	13,700	44,250	
2012/02/25	13:00	10,300	21,100	13,700	45,100	

Date	Time	Daily flow (m^3/hour)				Remark
		Block 1	Block 2	Block 3	Total	
2012/02/25	14:00	10,300	21,500	14,400	46,200	
2012/02/25	15:00	10,300	24,650	15,600	50,550	
2012/02/25	16:00	10,300	25,100	17,300	52,700	(1)
2012/02/25	17:00	10,300	25,100	17,300	52,700	
2012/02/25	18:00	10,300	25,100	17,300	52,700	
2012/02/25	19:00	10,300	25,100	17,300	52,700	
2012/02/25	20:00	10,150	25,100	17,300	52,550	
2012/02/25	21:00	8,850	23,750	17,300	49,900	
2012/02/25	22:00	8,850	23,350	16,900	49,100	
2012/02/25	23:00	10,150	23,750	15,600	49,500	
Total					1,015,100	(2)
Hourly maximum flow (m^3/hour)					52,700	(3)=(1)
Daily maximum flow (m^3/hour)					42,296	(4)=(2)/24
Ratio of hourly maximum flow and daily maximum flow					1.25	(5)=(3)/(4)

Source: JICA Study Team

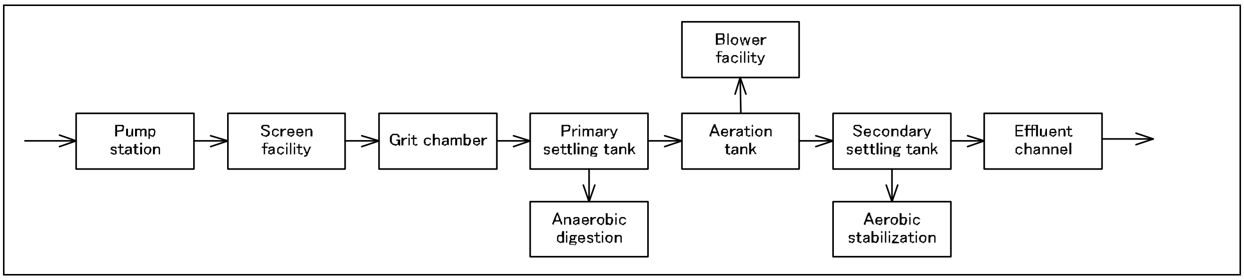
3.4 Evaluation of the Existing Conditions of BAS

3.4.1 Method of Evaluation of the Existing Conditions

The following inspections were conducted in order to evaluate the existing conditions of the facilities of BAS.

- Visual inspection
- Operating condition of equipment
- Hammer tests for concrete
- Interviewing operating personnel
- Analysis of documents and working records
- Availability of spare parts

The treatment process of BAS is shown in Figure 3.19 together with photographs of each process.



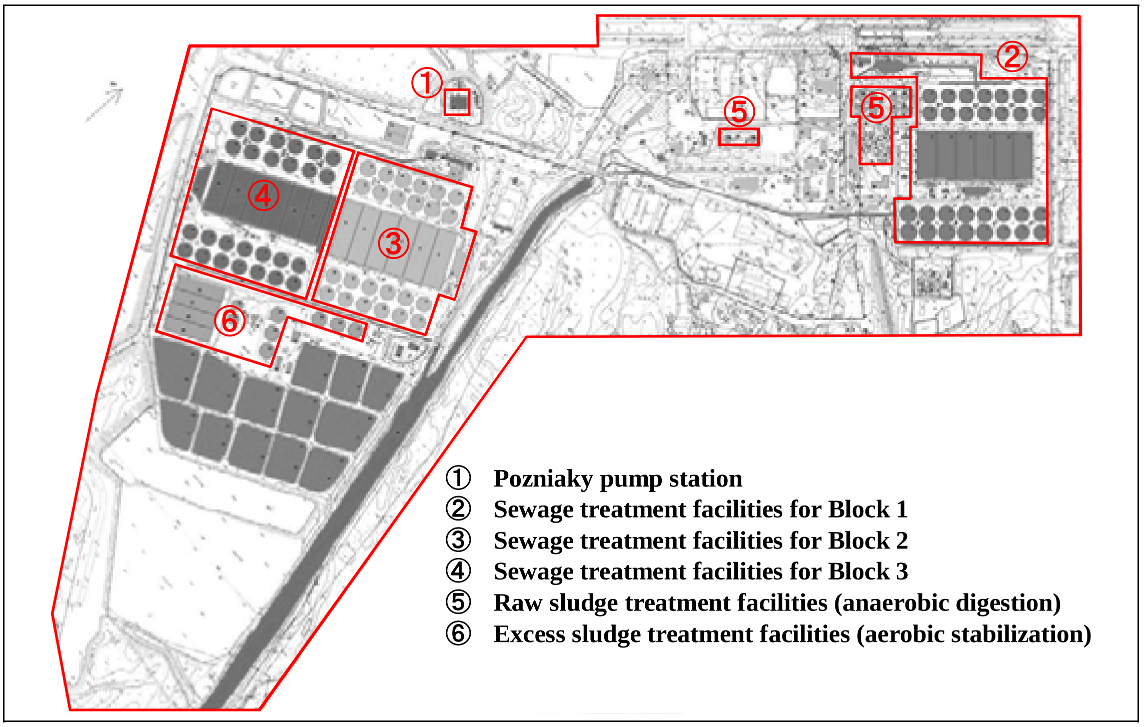
Source: JICA Study Team

Figure 3.19 Treatment Process of BAS

The facilities, the existing conditions of which are evaluated by the inspections, are categorized into the following groups considering their function and location of the facilities. These groups of facilities are shown in Figure 3.20.

- Pozniaky pump station
- Sewage treatment facilities for Block 1
- Sewage treatment facilities for Block 2
- Sewage treatment facilities for Block 3
- Raw sludge treatment facilities (anaerobic digestion)
- Excess sludge treatment facilities (aerobic stabilization)
- Electrical facilities

No.1 pump station (first rise pump station) is excluded from the inspections since the reconstruction plan of No.1 pump station has been already approved by Ukrainian government and the reconstruction is planned to be implemented by KVK after receiving budget from Kiev City State Administration.



Source: JICA Study Team

Figure 3.20 Groups of Evaluated Facilities

Pump station 	Screen facility 
Girt chamber 	Primary settling tank 
Aeration tank 	Blower facility 

Secondary settling tank	Effluent channel
	
Anaerobic digestion	Aerobic stabilization
	

Figure 3.21 Photograph of Each Process

3.4.2 Pozniaky Pump Station

General explanation and evaluation of Pozniaky pump station are summarized in Table 3.72. The results of inspections conducted to evaluate the existing conditions are shown in Chapter 1.1 of Appendix.

Table 3.72 Evaluation of Pozniaky Pump Station

	Evaluation
General explanation	Operation of Pozniaky pump station started its operation in 1994. Structure of the pump station is constructed by caisson method. Pozniaky pump station is comprised of screen section and pump section divided by cut off walls. 4 screens and 7 gates are installed in the screen section. 7 lift pump units are installed in the pump section, of which 2 or 3 pump units are usually operated to lift sewage collected in the left bank.
Civil and architectural works	Generally, deterioration is not so critical in the underground and aboveground parts of the building frame. The underground part is a circular caisson structure; no water leakages from the outside wall could be found. Rebar corrosion can be seen in some parts of the inner walls on the third ground floor. It is expected that corrosion can be caused by lack of concrete covers during the construction. It is considered that there is no other considerable damage which can influence structural strength.
Mechanical and electrical works	Screens are severely corroded due to the effect of corrosive gas generated from incoming sewage. Screening system is not automated. Hence, screenings, which flow to the pump station with sewage, are captured by screen bars, manually removed and conveyed to the ground floor by a hoist. 6 pump units out of 7 units are operational while 1 unit is under maintenance. Condition of lift pumps is relatively good owing to periodical maintenance. Inner surface of casing of the pump under maintenance is rusted. However, rust is not severe. Replacement of packing of discharge valves is needed since some valves have minor leakage from the shafts. Proper function of lift pumps can be maintained by keeping regular maintenance while automation of screening system is recommend in order to facilitate operation of the pump station.

Source: JICA Study Team

3.4.3 Sewage Treatment Facilities for Block 1

General explanation and evaluation of sewage treatment facilities for Block 1 are summarized in Table 3.73. The results of inspections conducted to evaluate the existing conditions are shown in Chapter 1.2 of Appendix.

Table 3.73 Evaluation of Sewage Treatment Facilities for Block 1

	Evaluation
General explanation	The operation of sewage treatment facilities for Block 1started in 1965. The sewage treatment process is comprised of screening, grit chamber, primary settling tank, aeration tank and secondary settling tank. Operation rate of Block 1 is relatively low because of the oldest facilities. On average, 35% (4.2 units out of 12 units) of primary settling tanks, 66% (4.0 units out of 6 units) of aeration tanks and 41% (4.9 units out of 12 units) of secondary settling tanks were operated in 2012. Kiev City administration instructed not to operate sewage treatment facilities for Block 1. However, operation of Block 1 is not able to be suspended completely due to the shortage of treatment capacity.
Civil and architectural works	In general, scaling (concrete surface peeling) caused by frost is occasionally visible on any facility. Although the concrete deterioration in underground part is not considerable, there is concrete scaling and rebar exposure on some water accumulated places of the floor surface of aeration tanks and trough walls of secondary settling tanks due to the lack of concrete cover. Hence, it is necessary to conduct repair works as soon as possible.
Mechanical and electrical works	Screens are severely corroded due to the effect of corrosive gas generated from incoming sewage. Screenings captured by screen bars are manually removed since automatic scratching system is not operational. Grit collectors are also severely corroded. 5 units of primary settling tanks are operational while 7 units have been abandoned and 2 units are waiting for major repair works. 4 units of aeration tanks are operational while 2 units have been abandoned. 7 units of secondary settling tanks are operational while 5 units have been abandoned and 2 units are waiting for major repair works. Sludge collectors for primary settling tanks and secondary settling tanks are severely deteriorated due to corrosion and abrasion. Aeration in aeration tanks is not efficient due to inefficient diffusers and air leakages. There are many air leakages from air pipes and riser pipes of diffusers due to corrosion. Aeration tanks are excessively aerated since the existing blower system cannot adjust air flow. Major replacement works are necessary taking deterioration and ineffectiveness of equipment into consideration to ensure the operation of the facilities in the long term.

Source: JICA Study Team

3.4.4 Sewage Treatment Facilities for Block 2

General explanation and evaluation of sewage treatment facilities for Block 2 are summarized in Table 3.74. The results of inspections conducted to evaluate the existing conditions are shown in Chapter 1.3 of Appendix.

Table 3.74 Evaluation of Sewage Treatment Facilities for Block 2

	Evaluation
General explanation	Operation of sewage treatment facilities for Block 2 started in 1975. The sewage treatment process is comprised of automatic screening, aerated grit chamber, primary settling tank, aeration tank and secondary settling tank. On average, 73% (8.8 units out of 12 units) of primary settling tanks, 95% (5.7 units out of 6 units) of aeration tanks and 87% (10.4 units out of 12 units) of secondary settling tanks were operated in 2012.
Civil and architectural works	Compared to Block 1, the deterioration is not considerable. However, exposure of rebar, lack of concrete cover, concrete peeling and rock pockets (asymmetry of aggregates) are visible because of poor construction. The cracks on the inside wall of aeration tanks and secondary settling tanks are not considerable, thus it seems that there is no damage which can cause problems for stable operation. Therefore, operation may continue for at least 10 years with partial repair works.
Mechanical and electrical works	Screen facility has been replaced with automatic screening system consisting of automatic screens, screw conveyers and a hopper by using budget from Kiev City administration. Hence, the screening system is automatically operated in better condition. Sludge collectors for primary settling tanks and secondary settling tanks are periodically repaired in order to maintain their proper function. Aeration in aeration tanks is maintained effective by periodical replacement of diffusers every 8 years on average. Owing to replacement of the diffusers, proper function of aeration tanks is restored. However, the existing blower system cannot adjust air flow. Generally, the equipment of Block 2 is in better condition and operationa1 compared to that of Block 1. It is recommended to continue the current maintenance work such as repair of sludge collectors and replacement of diffusers in order to keep proper function of equipment and maintain the performance of the facilities.

Source: JICA Study Team

3.4.5 Sewage Treatment Facilities for Block 3

General explanation and evaluation of sewage treatment facilities for Block 3 are summarized in Table 3.75. The results of inspections conducted to evaluate the existing conditions are shown in Chapter 1.4 of Appendix.

Table 3.75 Evaluation of Sewage Treatment Facilities for Block 3

	Evaluation
General explanation	Operation of sewage treatment facilities for Block 3 started in 1985. Sewage treatment process is comprised of the same facilities as sewage treatment facilities for Block 2. 2 aeration tanks have been renovated by recreating the existing structures from plug flow tanks to oxidation ditches and replacing equipment such as diffusers and agitators. Operation of renovated aeration tanks started in 2010. 2 aeration tanks are under renovation, however, the works are suspended due to the shortage of budget from Kiev City administration. 2 aeration tanks still use the old system. On average, 52% (6.2 units out of 12 units) of primary settling tanks, 67% (4.0 units out of 6 units) of aeration tanks and 67% (8.0 units out of 12 units) of secondary settling tanks were operated in 2012.
Civil and architectural works	As well as Block 2, exposure of rebar, lack of concrete cover, concrete peeling and rock pocket (asymmetry of aggregates) are visible because of poor construction. The supports of outflow troughs of primary and secondary settling tanks for Block 2 and Bock 3 are made of steel. The supports of the Block 3 collapsed, thus, it is considered that the quality of materials and construction works of the Block 3 are worse than those of the Block 2. Hence, periodic inspections and repair works are required.
Mechanical and electrical works	Screen facility has been replaced with automatic screening system together with Block 2. Sludge collectors for primary settling tanks and secondary settling tanks are periodically repaired and periodical replacement of diffusers are conducted in order to maintain proper function as the same as Block 2. 6 units out of 10 blowers are operational owing to periodical overhaul even though flow control is not possible. However, the other 4 units have never been operational since the panels for these blowers were not completed in the construction. It is recommended to complete renovation of 2 aeration tanks as soon as possible to restore the full treatment capacity of Block 3 before losing the treatment capacity of Block 1 due to deterioration caused by corrosion and abrasion. And also, it is required to continue the current maintenance work such as repair of sludge collectors and replacement of diffusers in order to keep proper function of equipment and maintain the performance of the facilities.

Source: JICA Study Team

3.4.6 Raw Sludge Treatment Facilities (Anaerobic Digestion)

General explanation and evaluation of raw sludge treatment facilities (anaerobic digestion) are summarized in Table 3.76. The results of inspections conducted to evaluate the existing conditions are shown in Chapter 1.5 of Appendix.

Table 3.76 Evaluation of Raw Sludge Treatment Facilities

	Evaluation
General explanation	Regarding raw sludge treatment facilities, the operation of 4 anaerobic digesters started in 1966 while operation of other 4 digesters started in 1975. Operation of 2 gas holders started in 1966 together with first 4 digesters. The raw sludge treatment process is comprised of sludge feeding system, anaerobic digesters, gas holders, a heating system including boilers, and sludge transfer pumps to sludge fields. 4 digesters which started its operation in 1975, have been abandoned due to digestion gas leaks out from the joints of precast concrete on top slab of the digesters. Currently, the first 4 digesters are operated.
Civil and architectural works	Although the buildings and structures of boiler house, pumping room of return sludge and distribution chamber are old, they have been repaired by painting and were properly maintained. Leakage from structures digesters was found, caused by poor construction in the new tanks and concrete deterioration in the old tanks. Hence, it is necessary to renovate or reconstruct the structures of digesters.
Mechanical and electrical works	The performance of digestion process is deteriorated since blowers which agitate sludge by injecting digestion gas are not operational. Furthermore, grit contained in raw sludge has settled in the bottom of the digesters and results in reducing the capacity of tanks. Both gas holders are not operational at full capacity due to leakage from holes on piston wall. Generally, the equipment of anaerobic digestion is severely deteriorated. Deterioration is accelerated because the hydrogen sulfide contained in digestion gas is not removed. The boilers which supply steam for heating digesters and hot water for air-conditioning of the buildings in the plant are periodically overhauled in order to maintain function and efficiency. In order to treat raw sludge properly in the long term, reconstruction of the process is recommended taking deterioration and ineffectiveness of the process into consideration.

Source: JICA Study Team

3.4.7 Excess Sludge Treatment Facilities (Aerobic Stabilization)

General explanation and evaluation of excess sludge treatment facilities (aerobic stabilization) are summarized in Table 3.77. The results of inspections conducted to evaluate the existing conditions are shown in Chapter 1.6 of Appendix.

Table 3.77 Evaluation of Excess Sludge Treatment Facilities

	Evaluation
General explanation	Regarding excess sludge treatment facilities, the operation of 4 aerobic stabilization tanks started in 1987-1991 together with sewage treatment facilities for Block 3. Excess sludge treatment process is comprised of gravity thickeners for excess sludge, aerobic stabilization tanks, gravity thickeners with coagulant dosing equipment for stabilized sludge and sludge transfer pumps to sludge fields. Currently, 4 aerobic stabilization tanks are in operation. Gravity thickeners of Block 1 and Block 3 for excess sludge are bypassed. Hence, excess sludge from these blocks is transferred to aerobic stabilization directly from secondary settling tanks.
Civil and architectural works	Treatment facility consists of comparatively small buildings. Despite some tile deterioration and peeling in some areas, no significant damage was found. Despite the fact that sludge thickeners require partial repairs, there is significant exposure of rebar, concrete peeling, rock pockets and lack of concrete cover because of poor construction of aerobic stabilization tanks. Hence, repair seems necessary as soon as possible.
Mechanical and electrical works	Aeration of aerobic stabilization tanks is not effective due to inefficient diffusers. It is highly expected that insufficient aeration causes the deterioration of performance of the process. The performance of solid-liquid separation in thickening process after aerobic stabilization is also not effective even though polymer is added by newly installed coagulant dosing equipment. The separated liquid which contains high pollution load, is transferred to the beginning of sewage treatment process of Block 2/3, which causes deterioration of performance of sewage treatment process. In order to treat excess sludge properly in the long term, reconstruction of the process is recommended taking deterioration and ineffectiveness of the process into consideration.

Source: JICA Study Team

3.4.8 Electrical Facilities

Evaluation of electrical facilities is summarized in Table 3.78. The results of inspections conducted to evaluate the existing conditions are shown in Chapter 1.7 of Appendix..

Table 3.78 Evaluation of Electrical Facilities

	Evaluation
Power receiving facilities	The operation of Bortnytska substation, which has two 25MVA transformers, started in 1964. Electric power from the substation is fed to sewage treatment facilities for Block 1. The operation of Lugova substation, which has two 31.5MVA transformers, started in 1975 and the facilities were modified in 1985. The electric power from this substation is fed to Pozniaky pump station and sewage treatment facilities for Block 2/3. These two substations are operated by the electrical distribution company (Kyivoblenergo). Hence, renovation and reconstruction plan of these substations will be managed by the company, considering the electrical distribution system of the city. The distribution voltage for BAS is 6kV. BAS has 6kV high tension motors for pumps/blowers and low tension motors which are supplied from step-down transformers of 6kV/0.4kV.
Electrical panels	Electrical panels and control boxes of all facilities have been continuously used since the beginning of operation. Rust, paint peeling and dents due to aged deterioration are found. However, critical damage and leakages are not observed. Hence, fundamental functions of the panels are maintained by proper maintenance, accommodating spare parts and substituting general parts. Moreover, the decline of influent sewage results in an increase of the number of standby machines. Hence, the risks to influence the whole process caused by breakdown of the panels are minimized.
Control system and instrumentation	It is possible to perform the same operation as the existing conditions by maintaining the present O&M organization structure of operators. However, the present operating method is manual operation with switching on/off according to the limited indices such as levels and flows. Hence, it is difficult to optimize operation according to rapid change in terms of flow and pollution load. An introduction of a SCADA system with automatic control and IT application requires the application of motor driven equipment, input/output signal from/to electrical circuits and malfunction indication. Hence, it is impossible to utilize the existing panels for application of automation. All electrical facilities should be renewed and instrumentation system should also be reconstructed for automation. Automation with SCADA system requires continuous measurement of not only levels and flows but also water quality. Measured values are utilized as indices for automatic control and evaluation of the performances of treatment.

Source: JICA Study Team

3.4.9 Priority of the Facilities to Be Reconstructed

The reconstruction order of the evaluated facilities was prioritized taking the urgency and importance of the facilities into consideration. The priorities of reconstruction are proposed as shown in Table 3.79.

Table 3.79 Priority of the Reconstruction of the Facilities

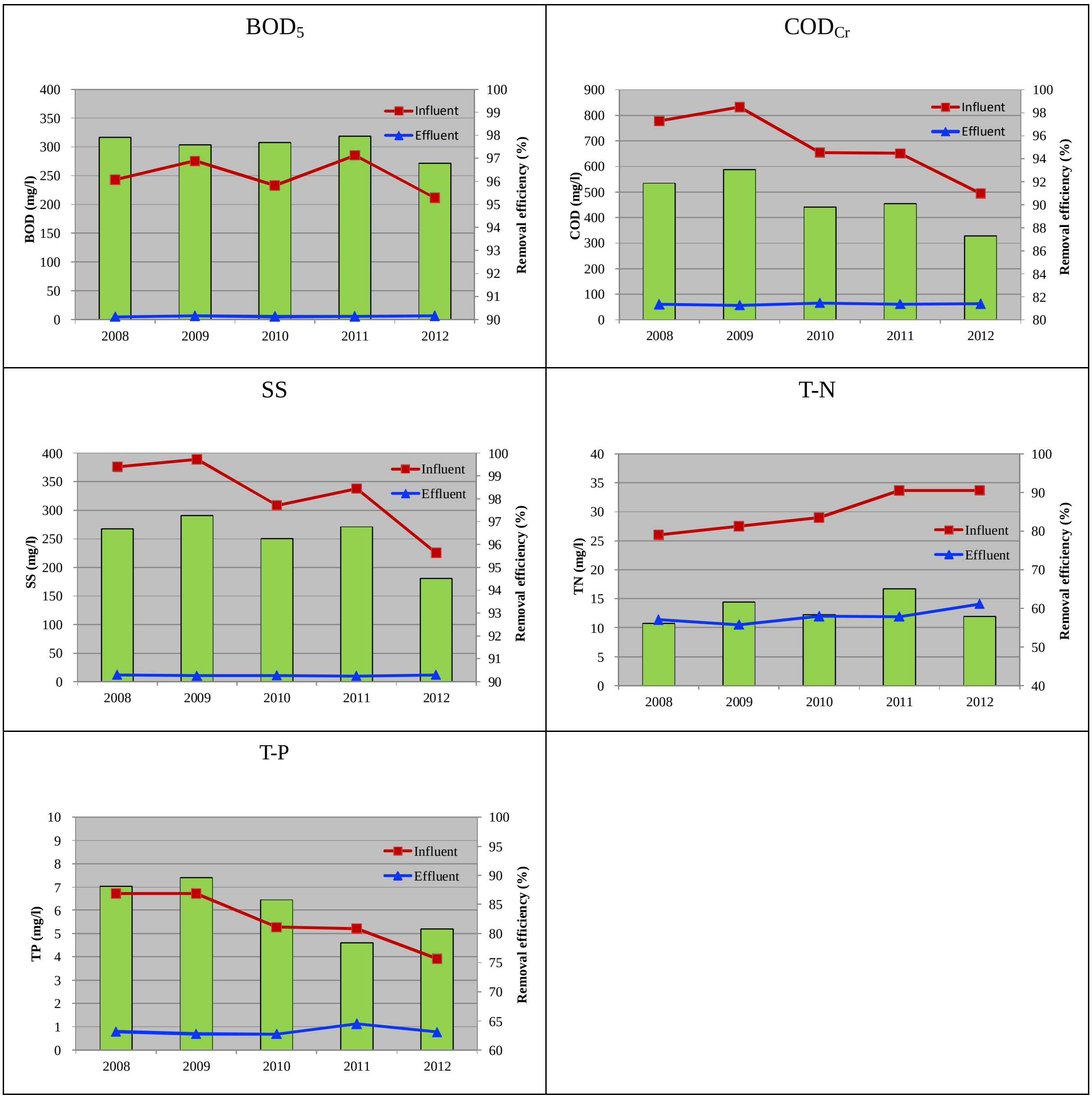
Facilities	Priority
Pozniaky pump station	C
Sewage treatment facilities for Block 1	A
Sewage treatment facilities for Block 2	B*1
Sewage treatment facilities for Block 3	B*1
Raw sludge treatment facilities	A
Excess sludge treatment facilities	A
Electrical facilities	B

Remark: A: high, B: middle, C: low
Remark *1: Overall priority is middle, but rehabilitation of the facilities is given high priority.
Source: JICA Study Team

3.5 Evaluation of the Performances of BAS

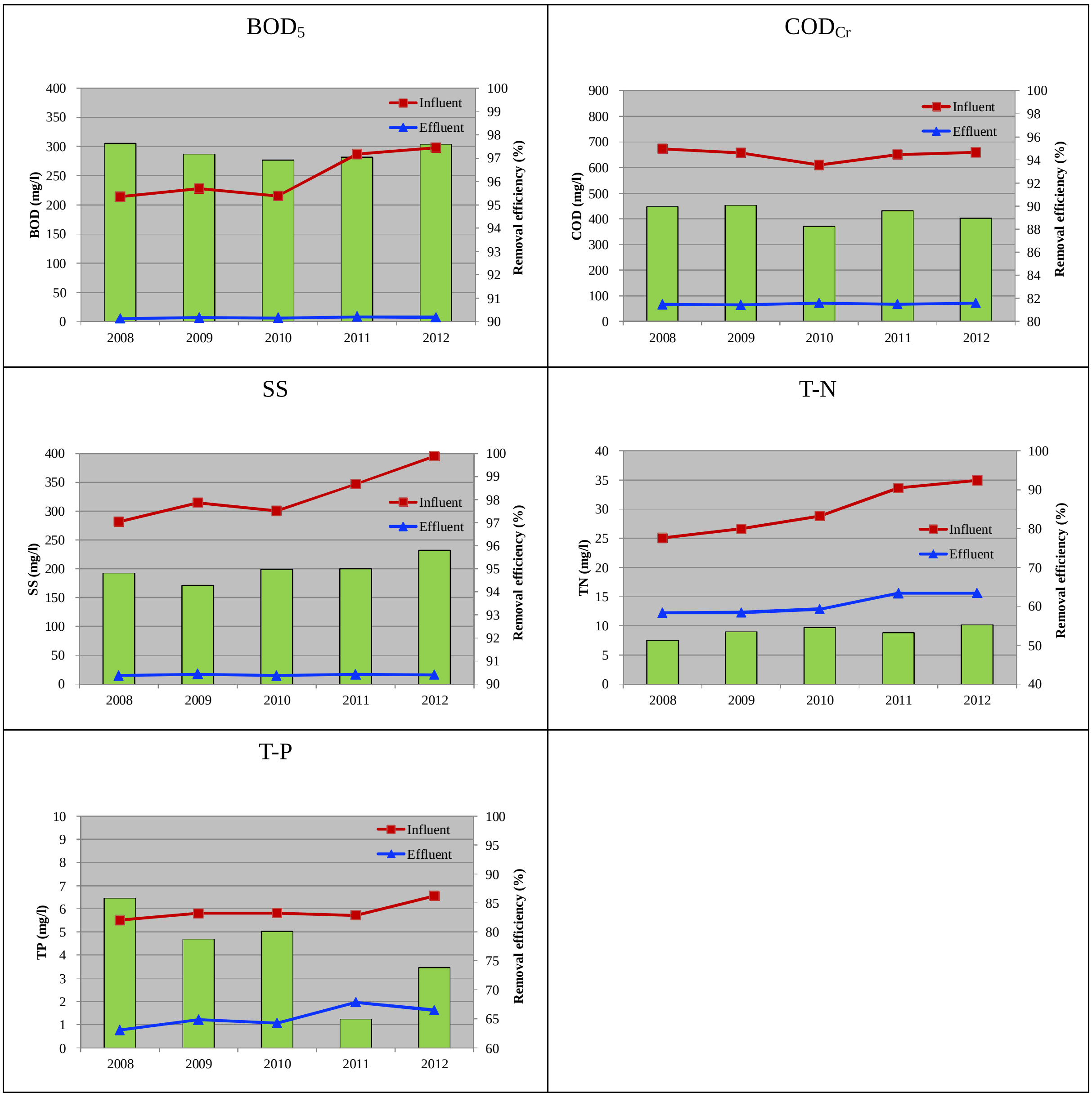
3.5.1 Performances of Sewage Treatment Facilities

The performance of sewage treatment of each block during the recent 5 years was analyzed and summarized in Figure 3.22, Figure 3.23 and Figure 3.24, respectively.



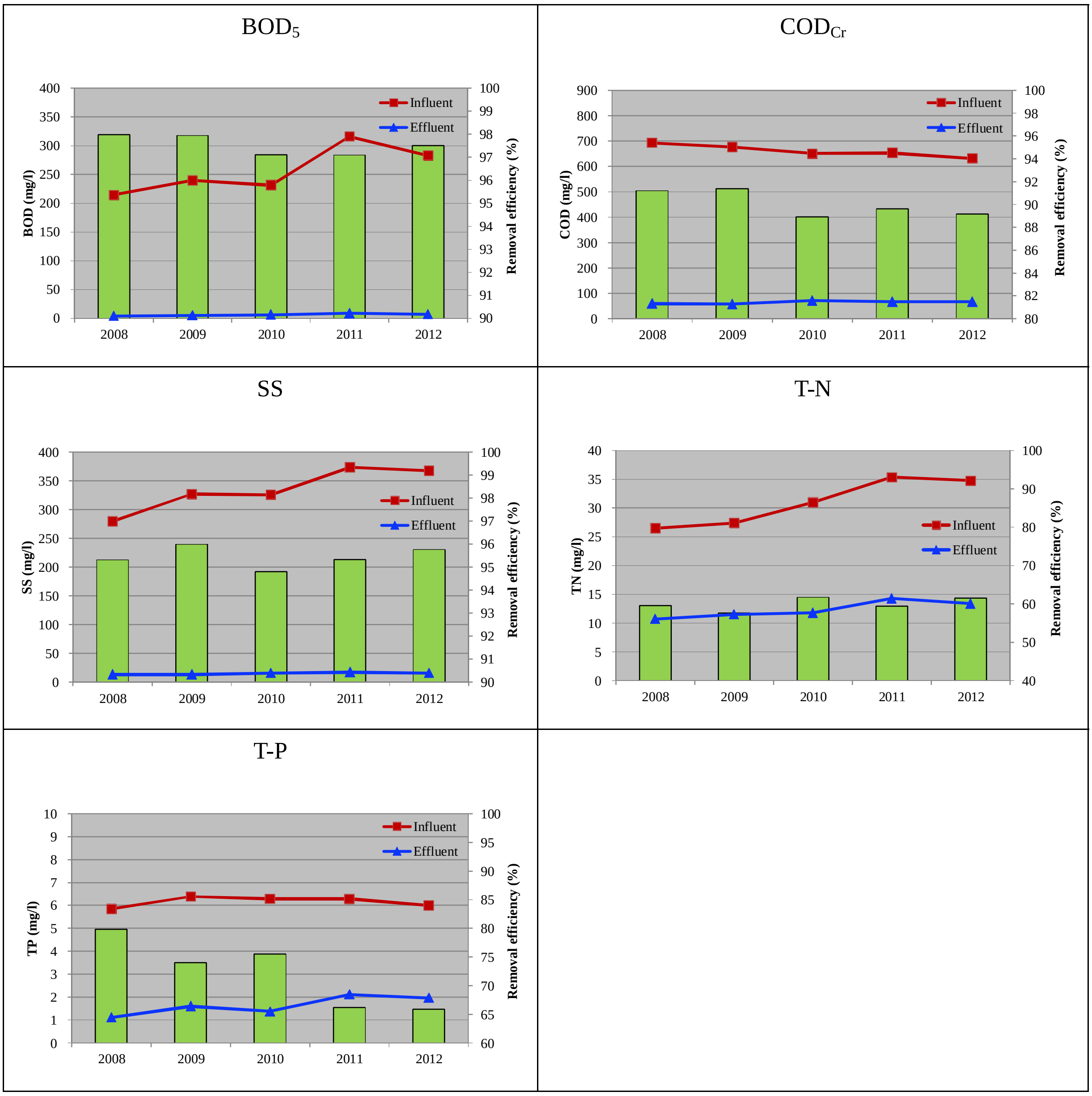
Source: JICA Study Team

Figure 3.22 Water Quality and Removal Efficiency (Block 1)



Source: JICA Study Team

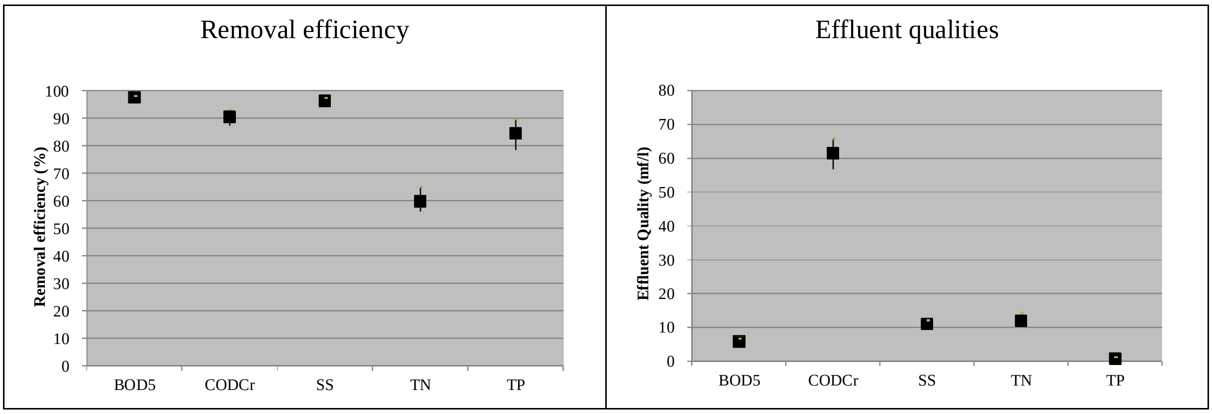
Figure 3.23 Water Quality and Removal Efficiency (Block 2)



Source: JICA Study Team

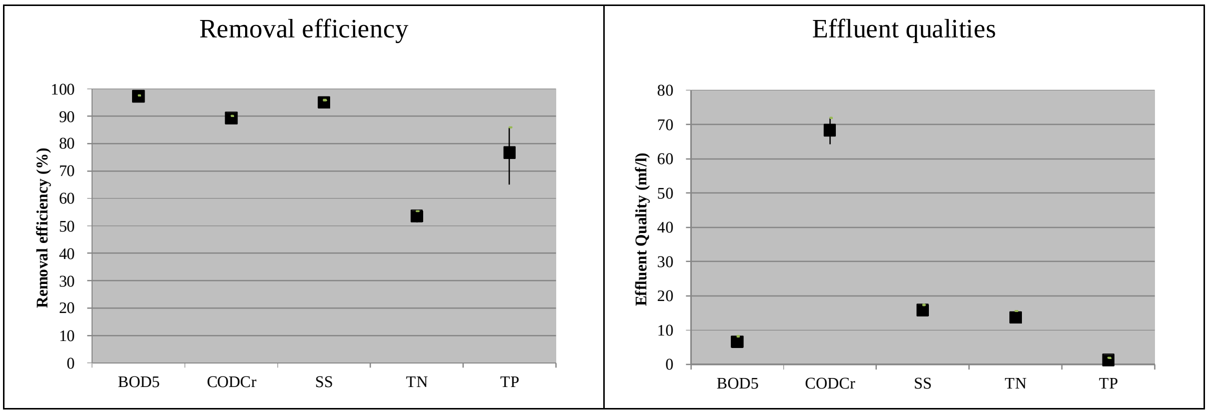
Figure 3.24 Water Quality and Removal Efficiency (Block 3)

The averages of removal efficiency and effluent quality for each block during the recent 5 years were calculated and summarized in Figure 3.25, Figure 3.26 and Figure 3.27, respectively.



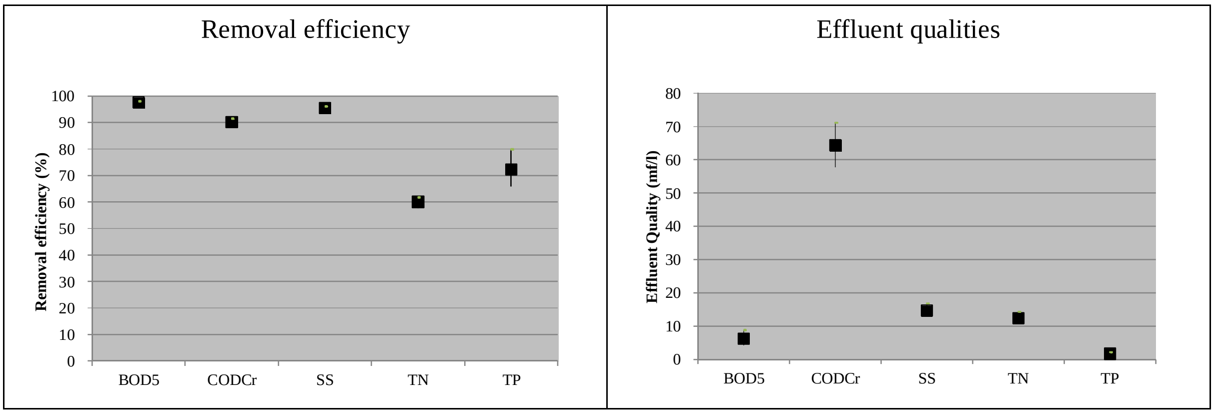
Source: JICA Study Team

Figure 3.25 Removal Efficiency and Effluent Qualities (Block 1)



Source: JICA Study Team

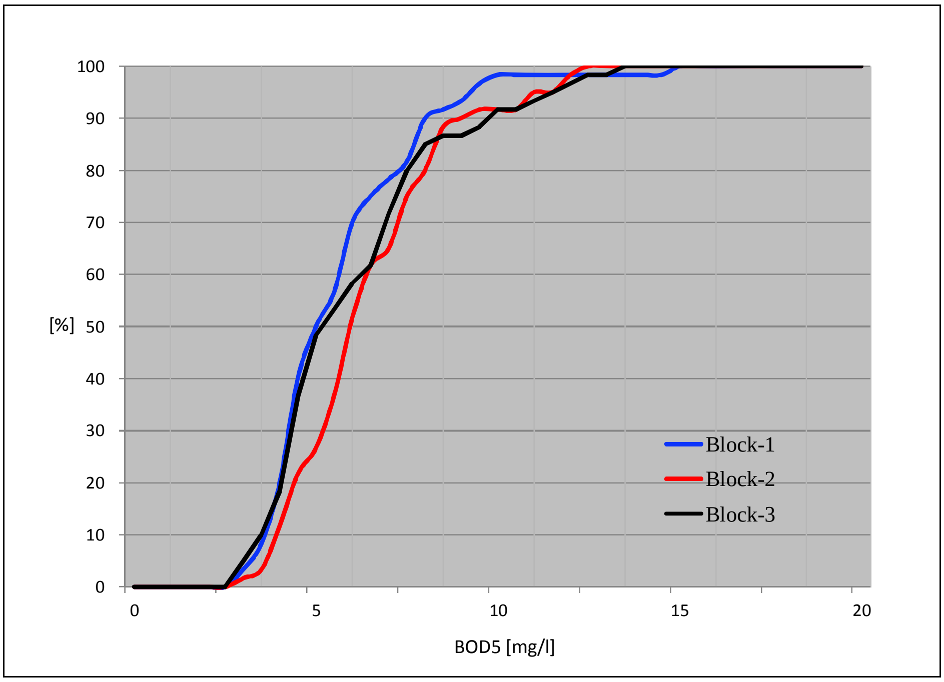
Figure 3.26 Removal efficiency and Effluent Qualities (Block 2)



Source: JICA Study Team

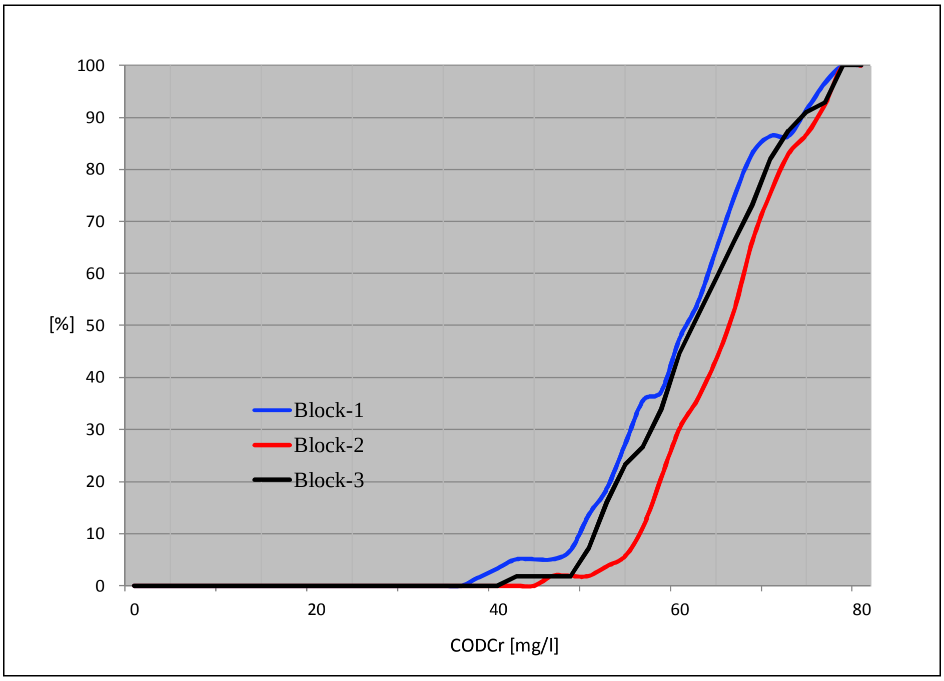
Figure 3.27 Effluent Qualities and Removal efficiency (Block 3)

Cumulative distribution curves of monthly averages for each block during the recent 5 years were analyzed and summarized in Figure 3.28, Figure 3.29, Figure 3.30, Figure 3.31 and Figure 3.32, with respect to each effluent quality item.



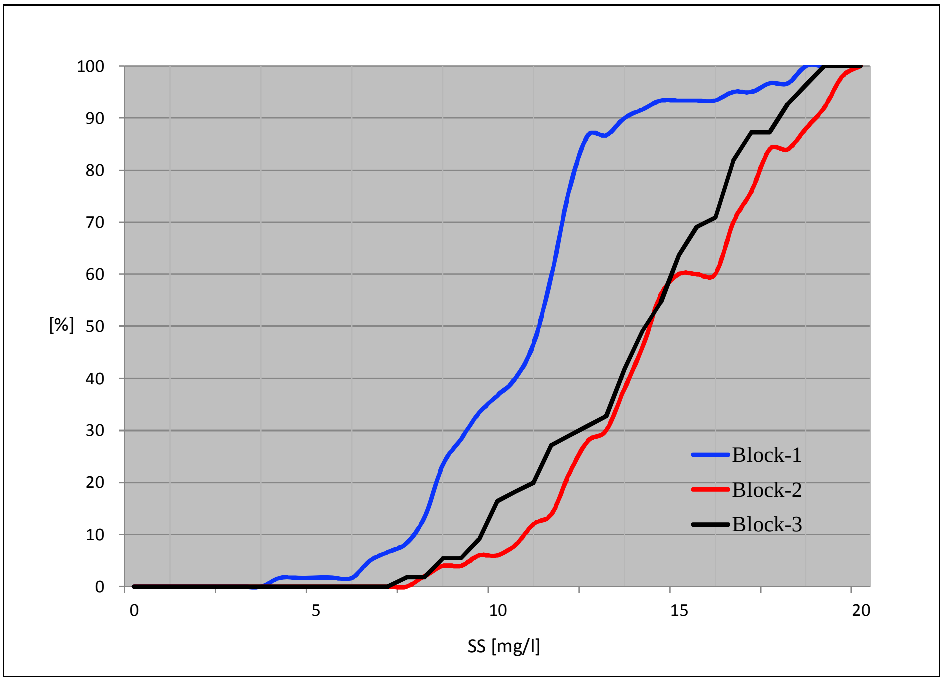
Source: JICA Study Team

Figure 3.28 Cumulative Distribution Curve of BOD_5



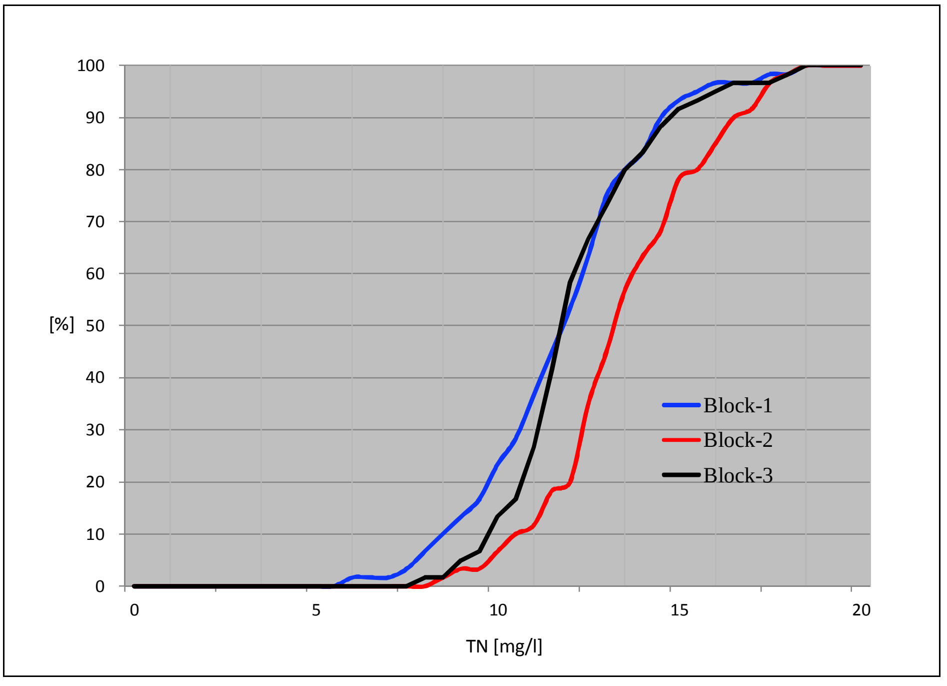
Source: JICA Study Team

Figure 3.29 Cumulative Distribution Curve of COD_{Cr}



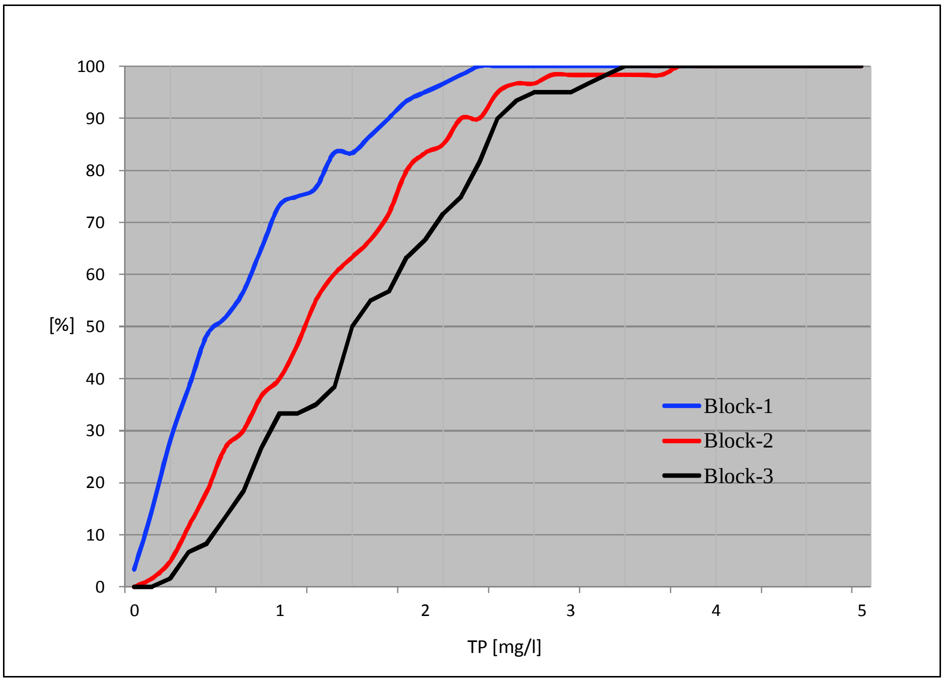
Source: JICA Study Team

Figure 3.30 Cumulative Distribution Curve of SS



Source: JICA Study Team

Figure 3.31 Cumulative Distribution Curve of T-N



Source: JICA Study Team

Figure 3.32 Cumulative Distribution Curve of T-P

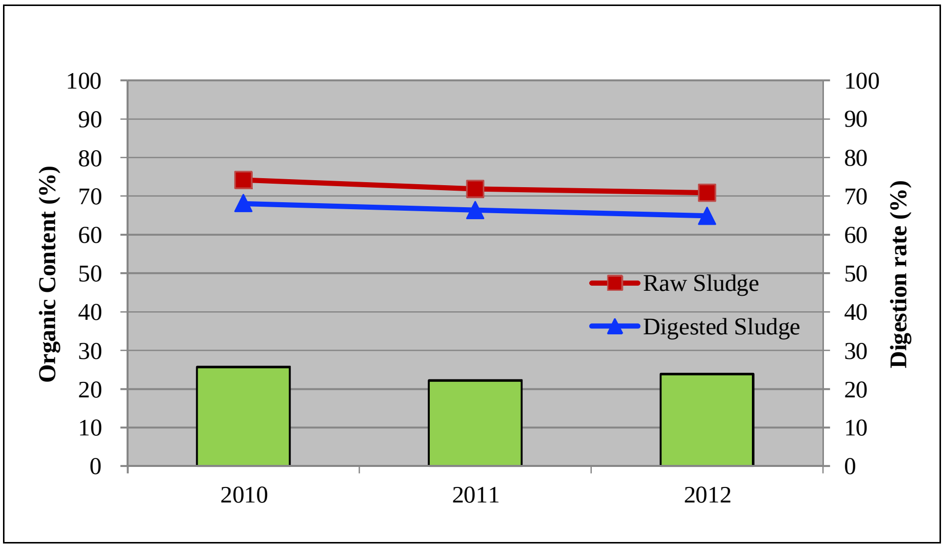
The following was found as a result of the performance analysis of operation experience in terms of sewage treatment.

- 100% of monthly average of all blocks satisfy effluent standard for BOD_5 (15 mg/l)
- 100% of monthly average of all blocks satisfy effluent standard for COD_{Cr} (80 mg/l)
- 93% of monthly average of Block 1, 60% of Block 2 and 60% of Block 3 satisfy effluent standard for SS (15 mg/l)
- 23% of monthly average of Block 1, 7% of Block 2 and 13% of Block 3 satisfy effluent standard for total nitrogen (10 mg/l) even though removal efficacy is approximately 58% on average and considerably high for conventional treatment
- 73% of monthly average of Block 1, 40% of Block 2 and 30% of Block 3 satisfy effluent standard for total phosphorus (1 mg/l) since removal efficacy is approximately 66% on average and considerably high for conventional treatment
- Negative influence on effluent qualities caused by side stream from sludge treatment process is acknowledged since effluent qualities (SS and T-P) of Block 2 and Block 3 are worse than Block 1
- Superiority of renovation of Block 3 is not acknowledged from the view point of nutrient removal (effluent of Block 3 is mixture of renovated system and old system and facilities are not adequately operated since no control system has been installed)

3.5.2 Performance of Sludge Treatment Facilities

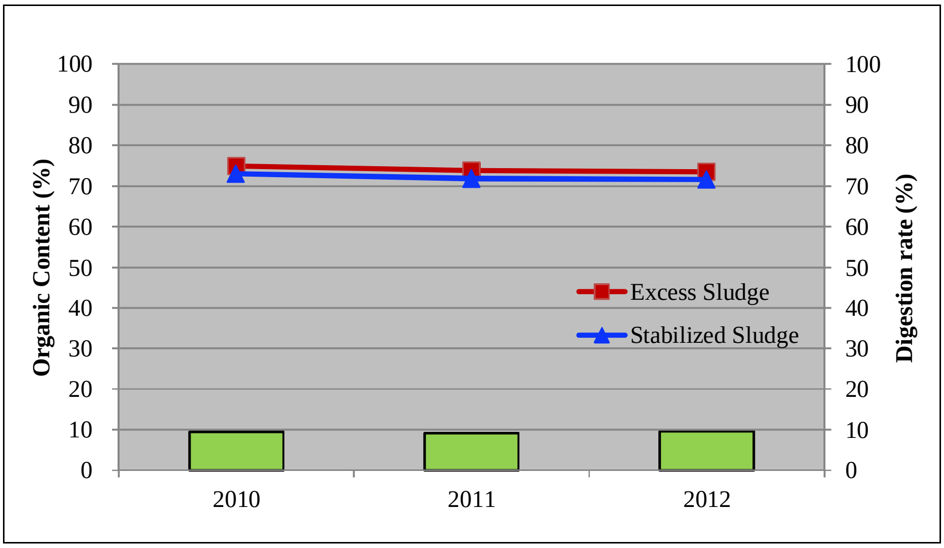
The performance of sludge treatment in anaerobic digestion and aerobic stabilization during the recent

3 years were analyzed and summarized in Figure 3.33 and Figure 3.34, respectively.



Source: JICA Study Team

Figure 3.33 Digestion Rate of Anaerobic Digestion



Source: JICA Study Team

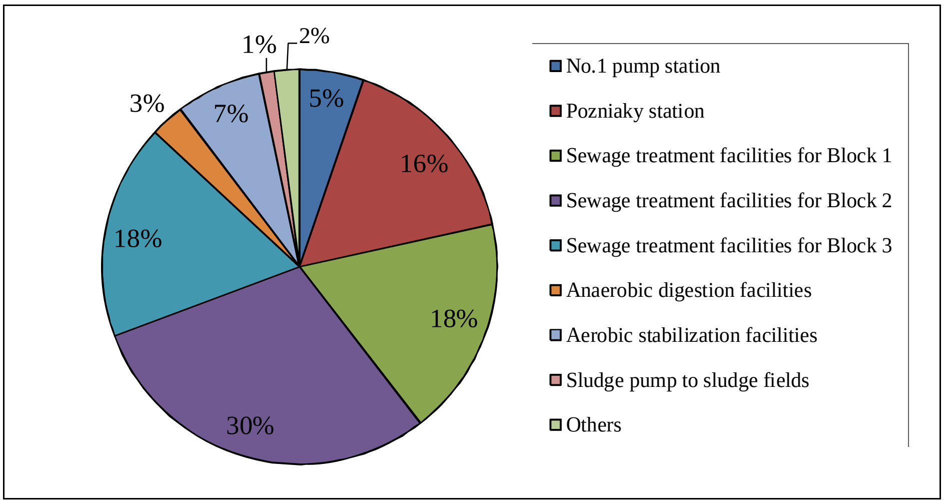
Figure 3.34 Digestion Rate of Aerobic Stabilization

The following are evaluated from the results of the performance analysis of operation experiences in terms of sludge treatment.

- Digestion rate of anaerobic digestion is calculated as 24% on average and rather low since 50% is generally expected
- Digestion rate of aerobic stabilization is calculated as 9% on average and rather low since 40-50% is generally expected
- Both anaerobic digestion and aerobic stabilization are not effective according to the evaluation of performance from operation experiences

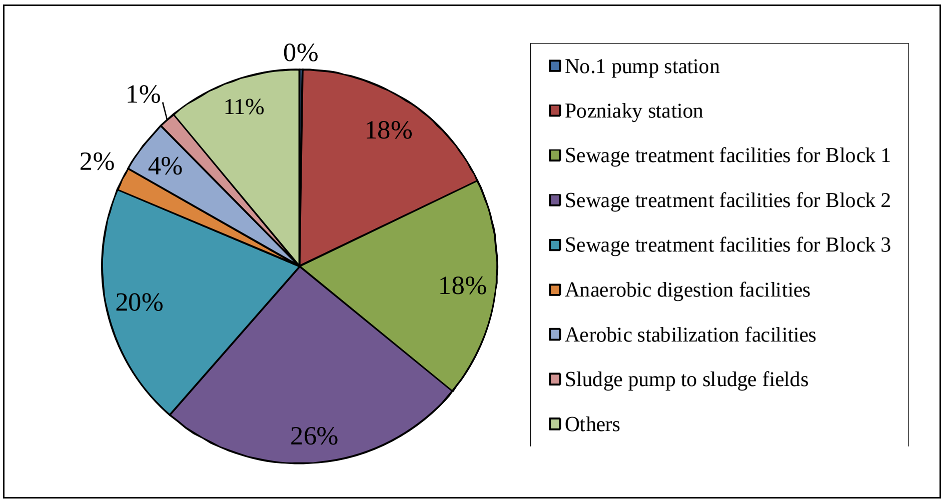
3.5.3 Evaluation of Power Consumption

The total power consumption of BAS is 112 MWh in 2011 and 118 MWh in 2012, respectively. The percentages of power consumption of each facility during the recent 2 years are calculated and shown in Figure 3.35 and Figure 3.36, respectively.



Source: JICA Study Team

Figure 3.35 Distribution of Power Consumption in 2011

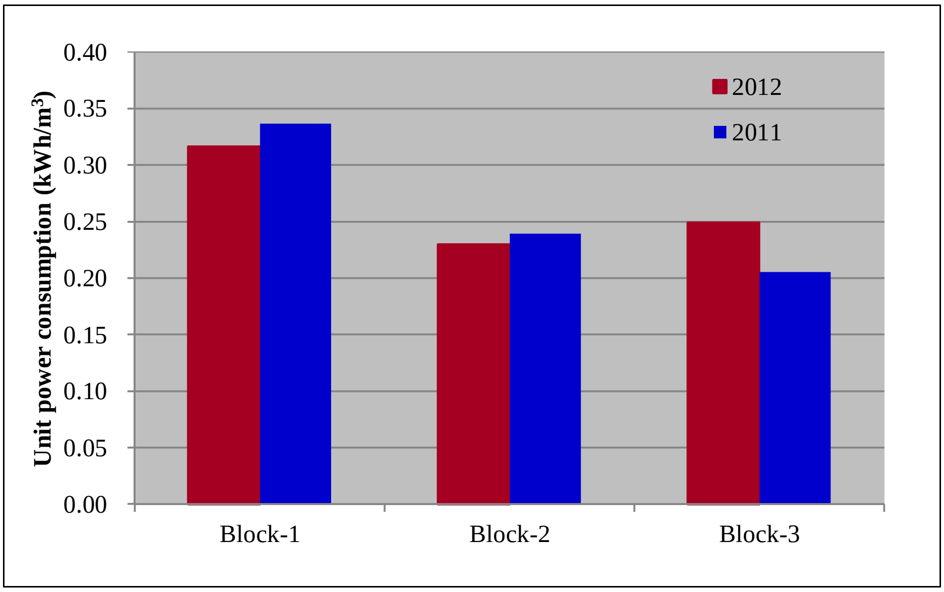


Source: JICA Study Team

Figure 3.36 Distribution of Power Consumption in 2012

Operation of No.1 pump station was suspended in 2012. During this period, operation of Pravobrezhna pump station was increased in order to lift influent sewage generated from the right bank to BAS and additional power consumption of Pravobrezhna pump station was included in the category of the others. Hence, No.1 pump station accounts for 0 % of total power consumption while the others account for 11 % in 2012.

The efficiencies of sewage treatment of each block during the latest 2 years are analyzed and summarized in Figure 3.37.



Source: JICA Study Team

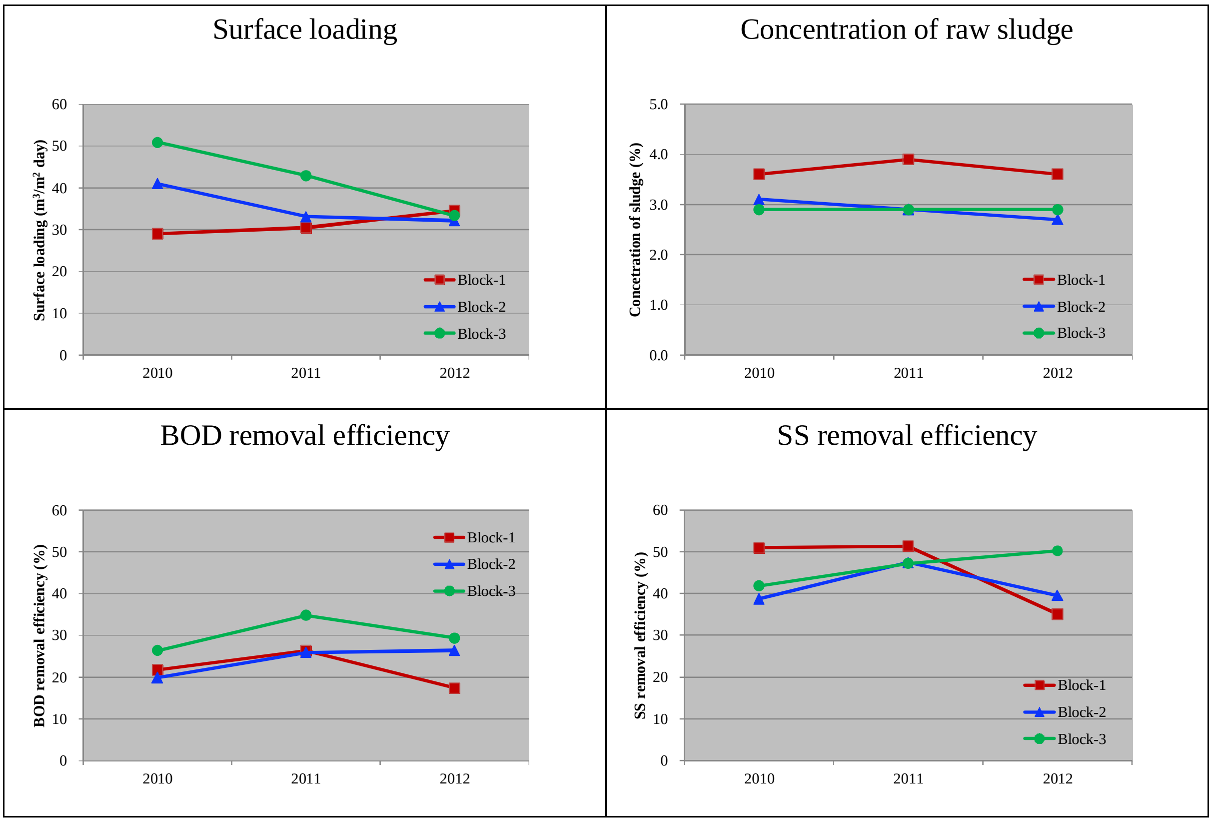
Figure 3.37 Unit Power Consumption

The following are evaluated from the results of the efficiency analysis of operation experiences in terms of power consumption.

- Percentage of power consumption of the WWTP in 2011 is 21%: pump stations, 66%: sewage treatment facilities, 11% sludge treatment facilities and 2% others
- Percentage of power consumption of the WWTP in 2012 is 18%: pump stations, 64%: sewage treatment facilities, 7% sludge treatment facilities and 11% others
- Unit power consumption of sewage treatment facilities for Block 1 is 40% higher than those for Block 2 and Block 3 due to several reasons such as the deterioration of the facilities, enhancing nitrogen removal, no aeration control with the existing blowers, etc.

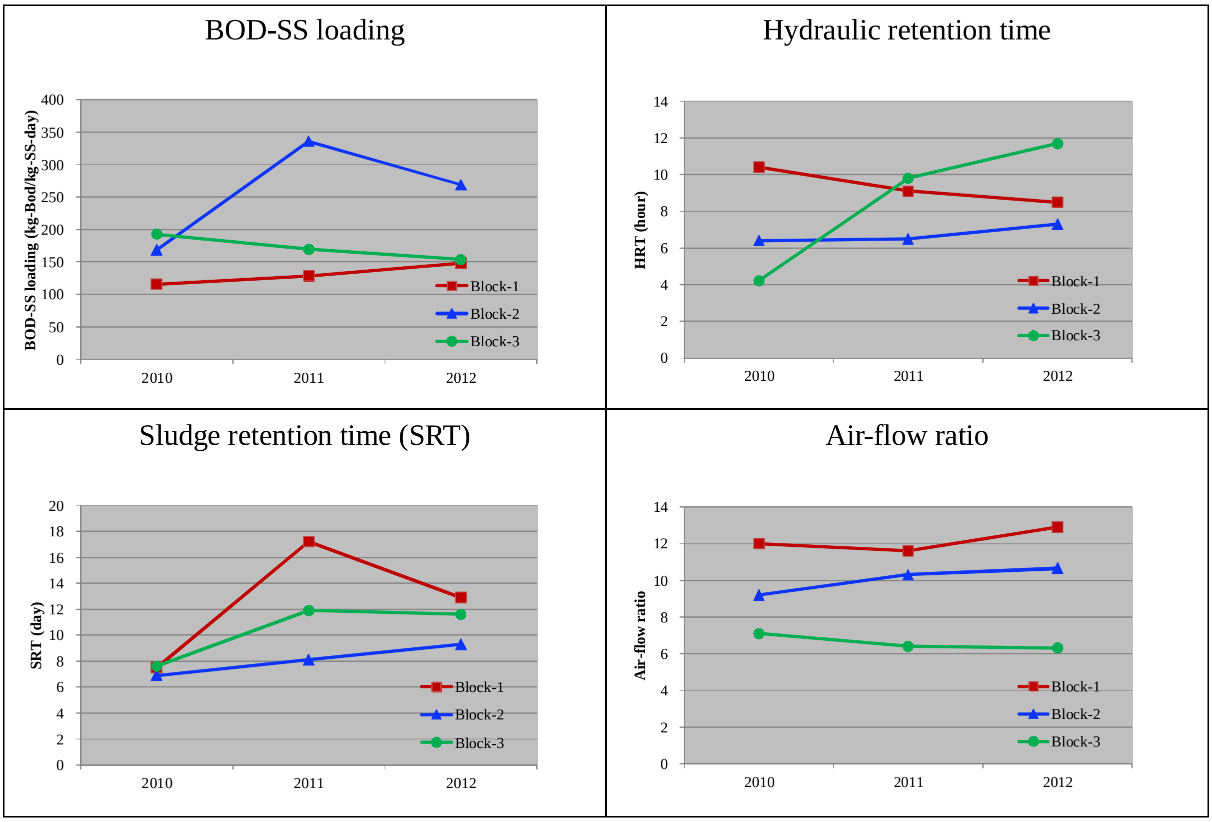
3.5.4 Evaluation of Operation Indicators

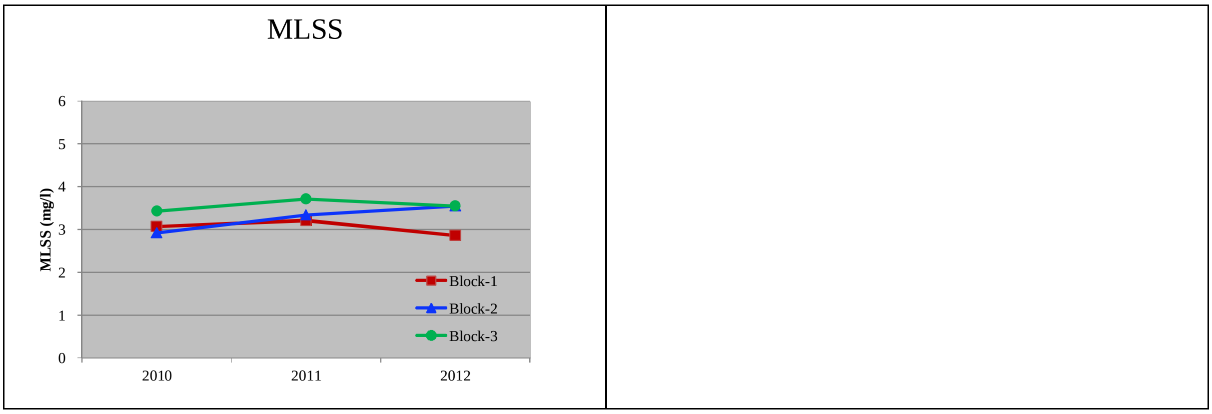
The operation indicators of sewage treatment process during the recent 3 years are analyzed and summarized in Figure 3.38, Figure 3.39 and Figure 3.40, respectively.



Source: JICA Study Team

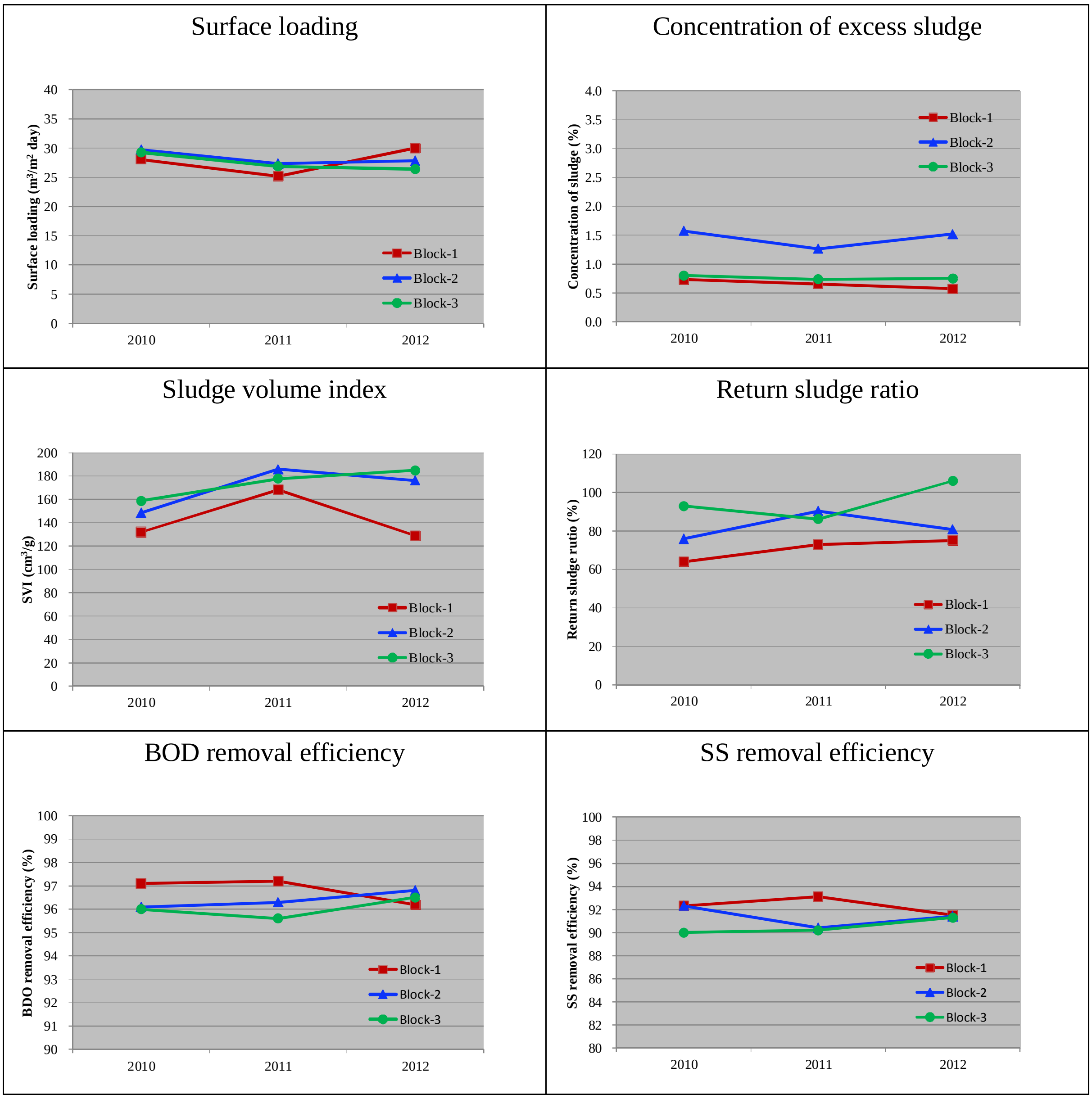
Figure 3.38 Operation Indicators of Primary Settling Tanks





Source: JICA Study Team

Figure 3.39 Operation Indicators of Aeration Tanks



Source: JICA Study Team

Figure 3.40 Operation Indicators of Secondary Settling Tanks

The following are evaluated from the results of the analysis of operation experiences in terms of operation indicators.

- Surface loading of primary settling tanks is maintained 30-50 m^3/m^2day
- Unit air flow per sewage of Block 1 and Block 2 is considerably high while that of Block 3 is seemed to be reasonable
- Solid retention time (SRT) is 8-10 days on average and enough to retain nitrifying bacteria for nitrification of ammonium nitrogen
- Mixed liquor suspended solid (MLSS) of aeration tanks is maintained more than 3,000 mg/l
- Surface loading of secondary settling tanks is maintained 25-30 m^3/m^2day and lower surface loading is preferable in case to keep current high MLSS
- Sedimentation of activated sludge in secondary settling tanks is relatively good condition since sludge volume index (SVI) is kept less than 200 cm^3/g on average

3.5.5 Recommendations on Operation

The following are the recommendations to improve operation of BAS considering the results of evaluation of operation experiences.

(1) Anaerobic-Oxic Operation

In anaerobic-oxic operation, an anaerobic condition is maintained in the front stage of aeration tanks while an aerobic condition is maintained in the latter stage. In the anaerobic zone, agitation is required in order to mix sewage and return sludge and prevent activated sludge from settling down. Hence, installation of agitators in anaerobic zones is preferable in order to create a complete anaerobic condition. However, it is also beneficial to reduce air flow amount so as to create pseudo anaerobic condition by utilizing the existing facilities. Further study and trial operation with the pilot-scale application are recommended before the full-scale application since effectiveness varies depending on actual operation conditions for every WWTP. The following improvements are expected by applying anaerobic-oxic operation.

- Improvement of removal efficiency of nitrogen and phosphorus
- Improvement of sedimentation of activated sludge in secondary settling tanks
- Prevention of filamentous bulking
- Prevention of destruction of activated sludge caused by excess aeration
- Reduction of power consumption of the blowers

(2) Aeration Control System

Adjustment of aeration supplied to aeration tanks is important in order to improve the performance and efficiency of biological treatment. Optimization of aeration is possible by introducing blowers with flow control function, panels with control sequence of the blowers and instrumentation. There are following two control methods for optimization of aeration. The constant air capacity control method is a kind of control logic to adjust air flow so as to keep constant capacity of air against sewage amount. The DO control method is a kind of control logic to adjust air flow so as to keep designated dissolved oxygen in aeration tanks. The following improvements are expected from introducing an aeration control system.

- Reduction of power consumption of the blowers
- Prevention of destruction of activated sludge caused by excess aeration
- Prevention of flotation of activated sludge in secondary settling tanks

(3) Optimization of Sludge Treatment Process

The performance of the existing sludge treatment facilities is deteriorated considering a rather low digestion rate. The limitation to continue the current sludge treatment from the viewpoint of sustainability is realized since sludge fields are almost full. The existing sludge treatment process also gives negative influence on sewage treatment process due to a side stream containing high secondary pollution load from sludge treatment facilities and inadequate sludge withdrawal from sewage treatment facilities. Those result from inadequate performance and capacity shortage of sludge treatment process. Hence, reconstruction of the entire sludge treatment process is inevitable. The following improvements are expected by optimizing the sludge treatment process.

- Securing the sustainability of sludge disposal
- Improvement of effluent quality by avoiding negative influences caused by sludge treatment process
- Reduction of emission of unpleasant odorous compounds and greenhouse gases

4. Facility Planning of BAS

4.1 Basics for Planning

4.1.1 Basic Conditions

(1) Served Area

Same as the existing condition, the entire boundaries of Kiev City are covered and the surrounding satellite towns which will be possibly connected within the target horizon are also included.

(2) Design Horizon

The design horizon is set based on the expected year of commissioning of newly constructed facilities with the aspect of looking at the prospect of longer period. The final target is proposed to be 2030. The intermediate year is proposed to be 2021.

The design horizon is summarized in Table 4.1

Table 4.1 Design Horizon

Item	Value	
	Intermediate	Final Target
Design Horizon	2021	2030

Source: JICA Study Team

(3) Method of Collection System

Same as the existing condition, separate sewerage system is continuously used and the facility designs are based on this method.

4.1.2 Design Population

(1) Projection of Future Residential Population

(A) Residential Population in Kiev City

According to the statistical records, the total population of Kiev City shows a stable increasing trend and its growth rate is between 0.5 – 1.0% per year.

The historical population profiles for the recent 10 years are shown in Table 4.2

Table 4.2 Historical Population Profiles for the Recent 10 Years

Unit: People

Year	Living Population		Permanent Population	
	Population	Growth Rate	Population	Growth Rate
2003	2,621,700	100.00%	2,577,300	100.00%
2004	2,639,000	100.66%	2,597,700	100.79%
2005	2,666,400	101.04%	2,625,100	101.05%
2006	2,693,200	101.01%	2,651,900	101.02%
2007	2,718,100	100.92%	2,676,800	100.94%
2008	2,740,200	100.81%	2,698,900	100.83%
2009	2,765,500	100.92%	2,724,200	100.94%
2010	2,785,100	100.71%	2,743,800	100.72%
2011	2,799,200	100.51%	2,757,900	100.51%
2012	2,814,300	100.54%	2,773,000	100.55%

Source: Main Statistics Department, Kiev City State Administration

Using historical population profiles, future values were forecasted by using a mathematical method. To cover the actual circumstance in Kiev City, living population which contains unregistered population such as temporary workers and school students should be considered. The period of data used as basic input was chosen at recent ten years and five different types of equations were used to compare the trends of future changes until 2050.

The results showed that all of five curves turned out increasing trends and comparably higher reliabilities because of the stable profile in actual growth rate of the population.

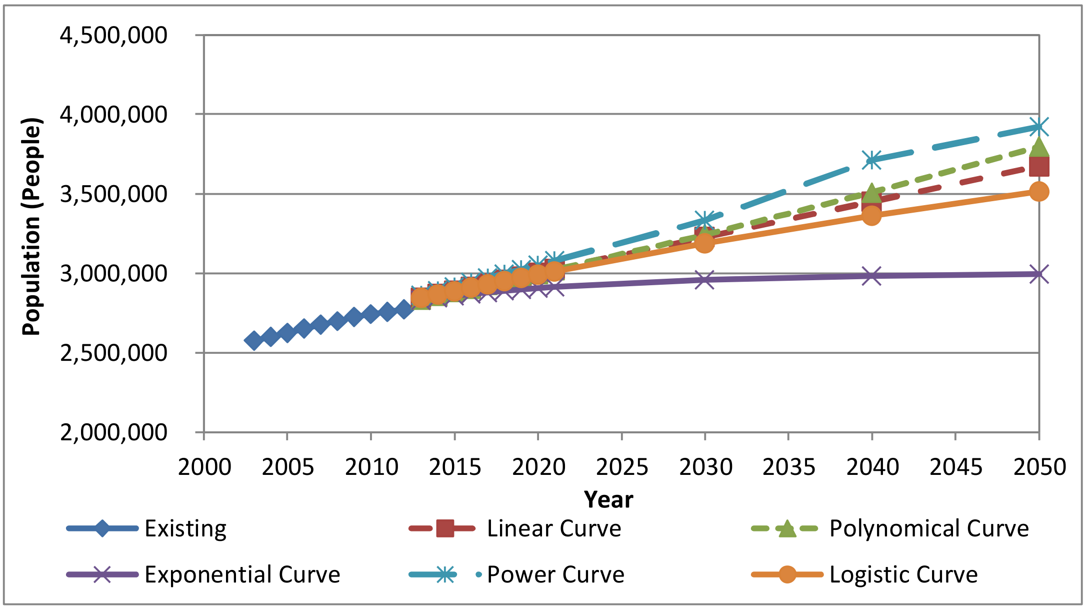
The results of mathematical projections are summarized in Table 4.3 and Figure 4.1.

Table 4.3 Results of Projections for Future Living Population

Unit: People

No.	Item	2013	2015	2021	2030	2040	2050	R
1	Linear Curve	2,847,180	2,891,875	3,025,958	3,227,084	3,450,556	3,674,029	0.996
2	Polynomial Curve	2,836,555	2,881,594	3,021,049	3,242,987	3,508,758	3,796,310	0.995
3	Exponential Curve	2,831,343	2,857,804	2,914,972	2,961,098	2,984,203	2,994,133	1.000
4	Power Curve	2,863,207	2,916,165	3,079,337	3,332,926	3,712,206	3,921,238	0.994
5	Logistic Curve	2,845,532	2,888,292	3,012,556	3,186,592	3,361,090	3,514,977	0.997

Source: JICA Study Team



Source: JICA Study Team

Figure 4.1 Results of Projections for Future Living Population

The study finally chose the "Linear Curve" which indicated a high R value and the simplest projection among other equations.

The summary of proposed design population is presented in Table 4.4.

Table 4.4 Proposed Design Population in Kiev City

Unit: People

Year	Projected Population (Linear Curve)	Design Population (Rounded Value)	Remarks
2012	2,814,300	2,814,300	Historical Value
2013	2,847,180	2,847,200	
2014	2,869,527	2,869,500	
2015	2,891,875	2,891,900	
2016	2,914,222	2,914,200	
2017	2,936,569	2,936,600	
2018	2,958,916	2,958,900	
2019	2,981,264	2,981,300	
2020	3,003,611	3,003,600	
2021	3,025,958	3,026,000	
2030	3,227,084	3,227,100	
2040	3,450,556	3,450,600	
2050	3,674,029	3,674,000	

Source: JICA Study Team

(B) Population of Satellite Towns

According to the obtained information from the existing plans and unapproved city general plan, some of the surrounding towns have been served with sewers to connect to BAS. The existing plan "Schemes of Water Supply and Sewage Systems of Kiev City by 2020, Kiev City (2007)" introduces that currently ten of towns, villages and private industries have serviced sewer networks and around 24,000 m^3/day of sewage was treated at BAS as of 2003. In addition, the draft document of unapproved city general plan (2013) indicates that currently 53% of townships are receiving sewerage services from facilities connected to BAS.

The study estimated the possible current sewerage served population by utilizing the following ideas;

- All towns, villages and industries will continue to expand their services
- 53% of coverage ratio can be entitled to these entities
- The current served population will be represented by 53% of total population in these areas

The calculation shows that the assumed current served population is approximately 80,000 people. The results of calculations are shown in Table 4.5.

Table 4.5 Estimation of Current Served Population from Satellite Towns

Unit: People

No.	Name	Category	Population (2013)	Served Population	Remarks
1	Vyshgorod	Town	32,000	Coverage Ratio* 53%	
2	Irpin	Town	76,900		
3	Vyshneve	Town	26,536		
4	Petropavlivska Borshchagivka (Svyatoshynsky District)	Village	6,125		
5	Sofiivska Borshchagivka (Svyatoshynsky District)	Village	6,571		
6	Novosilky (Svyatoshynsky District)	Village	941		
7	Bortnychi (Darnytsky District)	Village	2,000		
8	Horenka - Recreation (Svyatoshynsky District)	Utility	N/A		Industry
9	Koncha Zaspa	Utility	N/A		Industry
10	Poultry Factory	Utility	N/A		Industry
-	Total	-	151,073	80,069	

*Information from Draft Updated General Planning of Kiev City, Kiev City State Administration (2013)

Source: Statistical Office of Kiev Region, KVK

For an estimation of future possible served population from satellite towns and villages, the following procedures were taken and future values were calculated for 2021 and 2020 at 169,000 and 257,900 respectively.

- Other satellite towns are added to the possible areas being covered with sewer networks based on the map of unapproved city general plan, which indicates the locations of unconstructed pumping stations that will accept incoming sewers
- The towns and villages which currently started to be served will expand their areas and will attain 100% of coverage ratio in the future (2030)
- By considering the time period for laying new sewer system in the other satellite towns, 20% of coverage ratio was assumed until 2020 and intermediate rate was given
- Future population was calculated using current population and ratio of coverage
- The impact of incoming sewage from three currently served industries is deemed to be negligible

The results of calculation are presented in Table 4.6.

Table 4.6 Estimation of Future Served Population from Satellite Towns

Unit: People

No.	Name	Category	Population	Assumed Ownership			Served Population		
			2013	2013	2021	2030	2013	2021	2030
1	Vyshgorod	Town	32,000	53%	77%	100%	16,960	24,500	32,000
2	Irpin	Town	76,900	53%	77%	100%	40,757	58,800	76,900
3	Vyshneve	Town	26,536	53%	77%	100%	14,064	20,300	26,500
4	Boryspil	Town	59,545	0%	10%	20%	0	6,000	11,900
5	Brovary	Town	98,250	0%	10%	20%	0	9,800	19,700
6	Bucha	Town	28,483	0%	10%	20%	0	2,800	5,700
7	Vasylkiv	Town	36,672	0%	10%	20%	0	3,700	7,300
8	Bila Tserkva	Town	210,919	0%	10%	20%	0	21,100	42,200
9	Berezan	Town	16,543	0%	10%	20%	0	1,700	3,300
10	Obykhiv	Town	33,102	0%	10%	20%	0	3,300	6,600
11	Boyarka	Town	35,320	0%	10%	20%	0	3,500	7,100
12	Ukrainka	Town	15,644	0%	10%	20%	0	1,600	3,100
13	Petropavlivska Borshchagivka	Village	6,125	53%	77%	100%	3,246	4,700	6,100
14	Sofiivska Borshchagivka	Village	6,571	53%	77%	100%	3,483	5,000	6,600
15	Novosilky	Village	941	53%	77%	100%	499	700	900
16	Bortnychi	Village	2,000	53%	77%	100%	1,060	1,500	2,000
-	Total	-	685,551	12%	25%	38%	80,069	169,000	257,900

Source: JICA Study Team

(2) Policies for Other Components of Population

(A) Tourist Population

As introduced, the tourists and visitors of Kiev City have very limited impact compared to the scale of the total population of the city and the tourist population was deemed as not considered (for example, 481,000 people per year in 2011 according to the city's statistical record, hence 1,318 people as per daily basis). The policy is mentioned in Table 4.7

Table 4.7 Tourist Population for the Proposed Population

Item	Description	Remarks
Tourist Population	Not considered	Because of small impact

Source: JICA Study Team

(B) Unregistered Population in Kiev City

The unregistered population is makes a considerable part of the total actual population of Kiev City, however there are no official records available to incorporate with more reliable number but the contained population in the living population which is officially in public.

The study deemed that the unregistered population was not considered separately.

The policy is mentioned in Table 4.8

Table 4.8 Unregistered for the Proposed Population

Item	Description	Remarks
Unregistered Population	Not considered	Partly included in Living Population

Source: JICA Study Team

(3) Population Projections Conducted in Other Plans

(A) Unapproved City General Plan (2013)

The unapproved city general plan (2013) introduces the future population in next 15 – 20 years and it will grow to 3,680,000 people as living population.

(B) Feasibility Study (2012)

The feasibility study doesn't mention to the design population because the study was conducted based on the existing sewage amount which was decided and stated in the official plan that was formulated by the Kiev City State Administration.

(4) Summary of Proposed Design Population

The summary of proposed design population is shown in Table 4.9.

Table 4.9 Summary of Proposed Design Population

Unit: People

Item	Description	Present	Estimated	
		2012	2021	2030
Proposed Served Population	Population in Kiev City	2,814,300	3,026,000	3,227,100
	Population in Satellite Towns	80,069	169,000	257,900
	Total	2,894,369	3,195,000	3,485,000
Feasibility Study	Sewerage Served Population	Not Specified		
Existing Sewerage Plan	Sewerage Served Population	Not Specified		
Unapproved General Plan	Population in Kiev City	3,144,900	-	3,680,000

Source: JICA Study Team

4.1.3 Design Wastewater Flows

(1) Domestic Wastewater Flow

Domestic wastewater flow is usually determined by design population and its potential consumption of water which is drained into sewerage system. The consumption of water is estimated by the historical water supply by considering future trend of usage.

(A) Projection of Future Unit Water Supply per Capita

The consumed water amount for domestic use is represented by the water supply amount per capita (per single person of population) and the study estimated the future amount of usage by mathematical projections as same as the estimation for the population living in Kiev City.

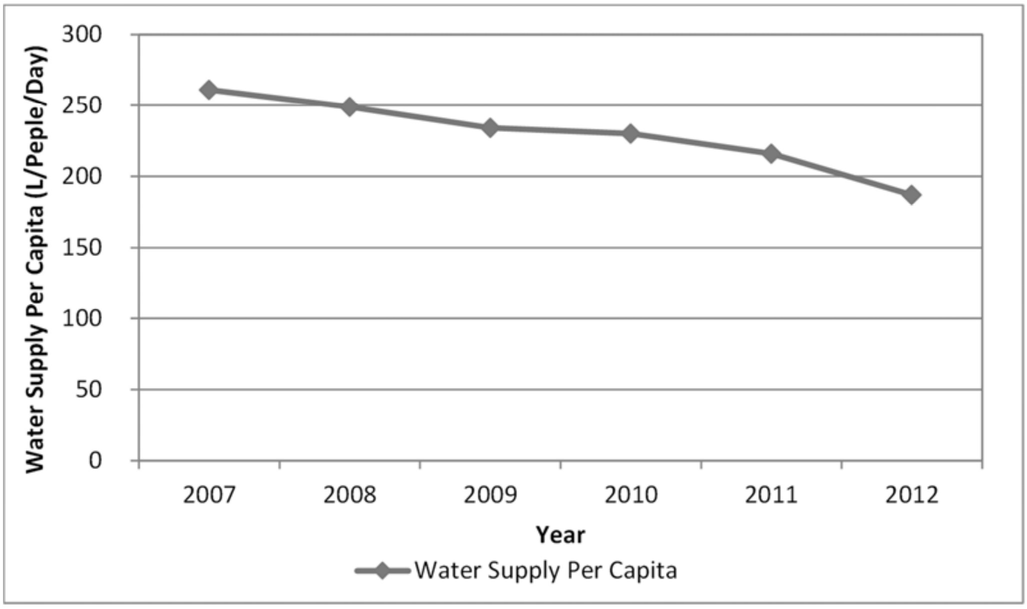
When the historical profiles are converted to per capita amount using water-supplied population, per capita amounts show a decreasing trend because of significant drops of entire use in the supplied water due to the introduction and the endeavors of progressive water tariff system with water meters in the city.

The historical profiles of per capita domestic water supply are presented in Table 4.10 and Figure 4.2.

Table 4.10 Historical Profiles of Domestic Water Flow per Capita

Year	Served Population	Domestic Water Flow	
		(m3/day)	(L/People/day)
	A	B	C=A/B
2007	2,729,165	711,464	261
2008	2,752,882	685,358	249
2009	2,775,331	648,466	234
2010	2,792,165	641,222	230
2011	2,806,729	605,630	216
2012	2,829,641	528,161	187

Source: KVK



Source: JICA Study Team

Figure 4.2 Historical Profiles of Domestic Water Flow per Capita

Similar to the future projection applied to the living population, per capita water amount was calculated by using five equations. However due to a decreasing trend, one equation, Logistic Curve, was inapplicable and the remaining other four data have turned out not usable for a practical study, except the result of Power Curve.

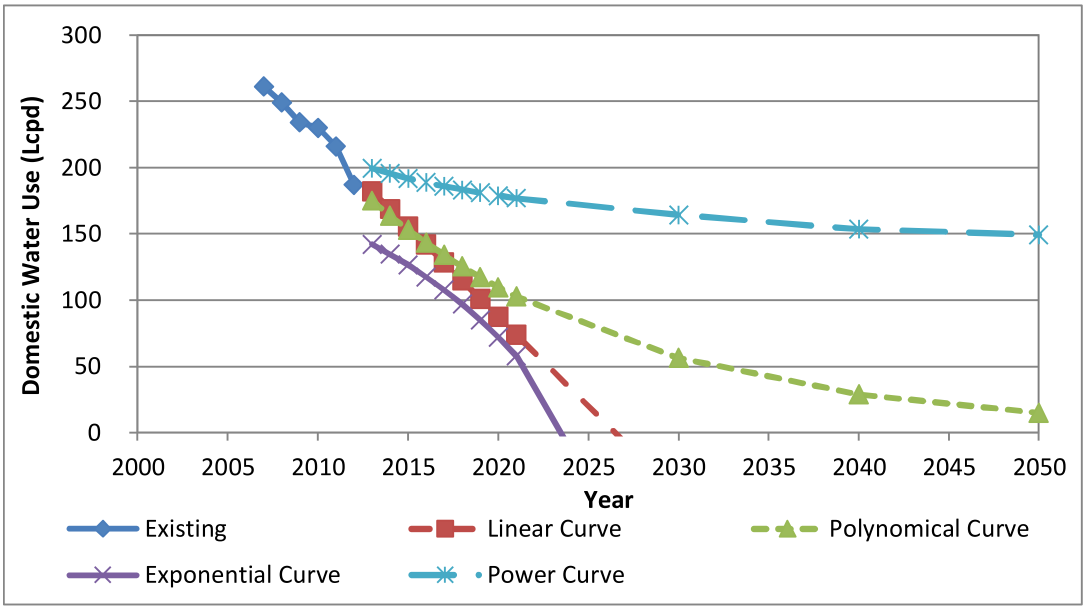
The results are shown in Table 4.11 and Figure 4.3

Table 4.11 Results of Projections for Future Domestic Water Flow for Capita

Unit: People

No.	Item	2013	2015	2021	2030	2040	2050	R
1	Linear Curve	182	155	74	-48	-183	-318	0.972
2	Polynomial Curve	175	153	103	56	29	15	0.964
3	Exponential Curve	142	126	58	-154	-735	-2,221	0.981
4	Power Curve	200	192	177	164	153	149	0.899
5	Logistic Curve	Inapplicable						

Source: JICA Study Team



Source: JICA Study Team

Figure 4.3 Results of Projections for Future Domestic Water Flow for Capita

It is practically difficult to predict when the decrease of unit water use is to become stable in the future, but the typical domestic water use is maintained between 180 - 200 L/person/day according to the similar practices, and the study chose the daily average water amount at 200 L/person/day according to the profiles of recent two years.

The future trend was set with keeping the same degree until 2030 in the study. The proposed design per capita flow amount is presented in Table 4.12.

Table 4.12 Proposed Design Domestic Wastewater Flow per Capita

Unit: L/People/day

Year	Projected Water Use (Power Curve)	Design Domestic Wastewater per Capita	Remarks
2012	187	187	Historical Value
2013	200	200	
2014	195	200	
2015	192	200	
2016	189	200	
2017	186	200	
2018	183	200	
2019	181	200	
2020	179	200	
2021	177	200	
2030	164	200	
2040	153	200	
2050	149	200	

Source: JICA Study Team

(B) Proposed Design Domestic Wastewater Flow (Daily Mean)

Daily mean domestic wastewater flow was identified by multiplying the design population with the unit water supply amount per capita and the figures were given 639,000 m^3/day to 2021 and 697,000 m^3/day in 2030. The proposed domestic wastewater flow (daily mean) is shown in Table 4.13

Table 4.13 Proposed Domestic Wastewater Flow (Daily Mean)

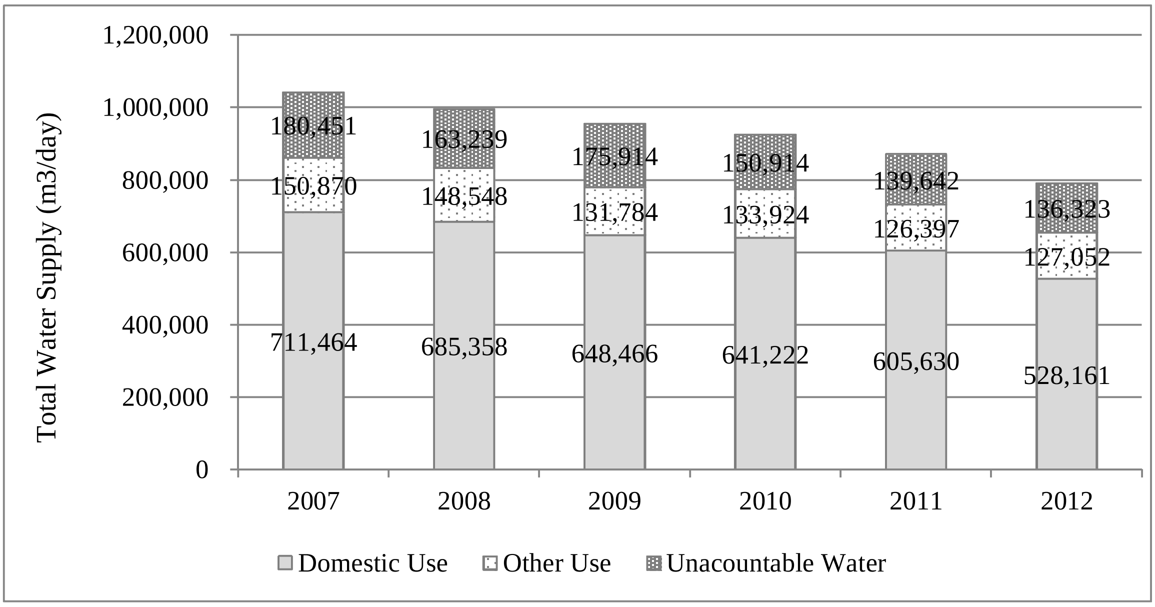
Item	Unit	Present	Estimated	
		2012	2021	2030
Served Population	People	2,894,369	3,195,000	3,485,000
Unit Domestic Water Flow	L/People/day	187	200	200
Domestic Wastewater Flow	m^3/day	541,247	639,000	697,000

Source: JICA Study Team

(2) Industrial Wastewater Flow

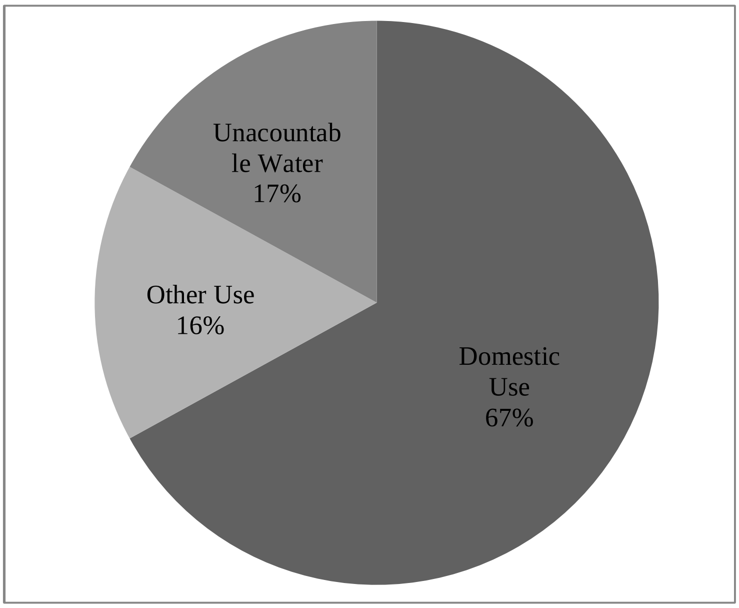
Beside the domestic use of water, the usage for industrial activities and other purposed water amount is also counted as wastewater which flows to BAS.

According to the statistical records, other use of supplied water which potentially contains industrial use and other use such as used water in the public functions and other commercial activities occupies 20 – 25% versus total domestic water use (unaccountable water is mainly caused by leakage and this amount of water will not be considered as sewage). The historical proportions of purpose of water uses are assembled in Figure 4.4, Figure 4.5 and Table 4.14.



Source: KVK

Figure 4.4 Proportion of Historical Water Flow by Category



Source: KVK

Figure 4.5 Proportion of Historical Water Use (2012)

Table 4.14 Percentage of Industrial and Other Use of Water

Unit: m^3/day

Item	2007	2008	2009	2010	2011	2012	Average
Domestic Use	711,464	685,358	648,466	641,222	605,630	528,161	636,717
Industries & Other Use	150,870	148,548	131,784	133,924	126,397	127,052	136,429
Ratio of Industrial & Other Use	21.21%	21.67%	20.32%	20.89%	20.87%	24.06%	21.50%

Source: KVK

As for the officially estimated figures, the existing plan has future targets which were formulated in 2007 by Kiev City and it indicates that industrial water flow, or usage would increasingly grow and reach as much as 50% of total domestic use in the future.

The estimate is summarized in Table 4.15.

Table 4.15 Industrial Wastewater Flow in the Existing Plan

Unit: m^3/day

Items	Target Horizon	Domestic Flow			Industrial Flow	Ratio of Industrial Water Flow
		Kiev	Suburb	Total		
Initial Stage	2003	971,400	24,000	995,400	82,300	8.47%
First Phase	2011	1,031,900	24,000	1,055,900	198,300	19.22%
Second Phase	2012	989,800	60,000	1,049,800	523,000	52.84%
Average	-	-	-	-	-	27.00%

Source: Flows are considered as the capacity of BAS (Daily Maximum Flow Condition)

Source: Schemes of Water Supply and Sewage Systems of Kiev City by 2020, Kiev City (2007)

(C) Proposed Design Industrial Wastewater Flow (Daily Mean)

The study finally proposes that the future industrial water demand will maintain the current proportion at 21.50% in connection with the growth of residential population in Kiev City and the expansion of the development expected in the satellite towns and the estimation was made using the design population and fixed proportion ratio of industrial wastewater flow.

The results show the identified future industrial wastewater flow to 2021 and 2030 is 137,000 m^3/day and 150,000 m^3/day respectively.

Proposed design industrial wastewater flow (daily mean) and its calculation are shown in Table 4.16.

Table 4.16 Proposed Design Industrial Wastewater Flow (Daily Mean)

Item		Unit	Present	Estimated	
			2012	2021	2030
Domestic Wastewater Flow		m^3/day	541,247	639,000	697,000
% of Industrial Wastewater		%	-	21.50%	21.50%
Industrial Wastewater Flow	Raw	m^3/day	127,052	137,385	149,855
	Rounded	m^3/day	-	137,000	150,000
Total		m^3/day	668,299	776,000	847,000

Source: JICA Study Team

(3) Wastewater Flow Ratios

In respect of designing justified amount of wastewater flow and proper facility designs, the following variations of wastewater flow are used for the reasons listed in the table below.

The narratives of purposes of using daily mean, daily maximum and hourly maximum wastewater flows are shown in Table 4.17.

Table 4.17 Purpose of Use for Various Wastewater Flows

Item	Description
Daily Mean Wastewater Flow	Mainly used as a baseline of daily operation and maintenance as well as evaluating treatment costs
Daily Maximum Wastewater Flow	Determining technical specifications for water and sludge treatment processes and dimensioning facilities and equipment
Hourly Maximum Wastewater Flow	Hydraulic calculations mainly at inlet pump stations and preliminary treatment processes

Source: JICA Study Team

The study sets the ratios for wastewater flows based on the actual variations of inflows to BAS and these figures are to be used for dimensioning treatment facilities.

The proposed ratios of wastewater flows are shown in Table 4.18

Table 4.18 Proposed Ratios of Wastewater Flows

Item	Daily Mean Water Flow	Daily Maximum Water Flow	Hourly Maximum Water Flow
Wastewater Flow Ratio	0.70	1.00	1.25

Source: JICA Study Team

(4) Proposed Design Domestic and Industrial Wastewater Flows

Using the determined ratios, respective flows were calculated to represent the future domestic and industrial wastewater flows in daily mean, daily maximum and hourly maximum conditions.

Summarized design domestic and industrial wastewater flows are shown in Table 4.19 and converted per capita domestic wastewater flow is also attached for reference in Table 4.20.

Table 4.19 Summary of Design Domestic and Industrial Wastewater Flows

Item		Ratio	Unit	Present	Estimated (Rounded)	
				2012	2021	2030
Daily Mean Wastewater Flow	Domestic	0.70	m^3/day	541,247	639,000	697,000
	Industrial		m^3/day	127,052	137,000	150,000
	Total		m^3/day	668,299	776,000	847,000
Daily Maximum Wastewater Flow	Domestic	1.00	m^3/day	773,210	913,000	996,000
	Industrial		m^3/day	181,503	196,000	214,000
	Total		m^3/day	954,713	1,109,000	1,210,000
Hourly Maximum Wastewater Flow	Domestic	1.25	m^3/day	966,513	1,141,000	1,245,000
	Industrial		m^3/day	226,879	245,000	268,000
	Total		m^3/day	1,193,391	1,386,000	1,513,000

Source: JICA Study Team

Table 4.20 Converted Domestic Wastewater Flows in per Capita (Reference)

Unit: Liter/Person/day

Item	Ratio	Present	Estimated (Rounded)	
		2012	2021	2030
Daily Mean Wastewater Flow	0.70	187	200	200
Daily Maximum Wastewater Flow	1.00	267	285	285
Hourly Maximum Wastewater Flow	1.25	334	355	355

Source: JICA Study Team

(5) Underground Water Flows

Underground water flow is incorporated in the design flow. It usually consists of infiltration of external fresh water contained in the soil into the sewerage system. The occurrence of infiltration is highly influenced by the soil condition around the sewer networks and also by age or deterioration of existing sewer pipes.

(A) Comparison using Historical Water Supply Records

For the preliminary assumption, the balance of water amount between supplied water and sewerage was compared using historical data and the results implied that possible underground water flow is ranged between 8 – 13 % of total wastewater amount measured in BAS.
The results are summarized in Table 4.21.

Table 4.21 Possible Underground Water Flow from Historical Records

Unit: m^3/day

Item	2007	2008	2009	2010	2011	Average	Remarks
Daily Mean Influent to BAS	932,301	933,852	881,726	853,808	798,986	880,135	(1)
Supplied Water Flow (Domestic + Industrial)	862,334	833,906	780,250	775,146	732,027	796,733	(2)
Underground Water (and Other Components)	69,967	99,946	101,476	78,662	66,959	83,402	(3)=(1)-(2)
Ratio of Underground Water	8.11%	11.99%	13.01%	10.15%	9.15%	10.47%	(4)=(3)/(2)

Source: KVK

(B) Identified Values in the Existing Plan

The existing plan indicates that the estimated underground water is ancillary 30% of total of domestic and industrial wastewater components.
The estimated values and ratios are shown in Table 4.22.

Table 4.22 Estimated Underground Water in the Existing Plan

Unit: m^3/day

Items	Target Horizon	Wastewater Flow	Underground Water	Ratio of Underground Water
Initial Stage	2003	1,077,700.0	365,282	33.89%
First Phase	2011	1,254,200.0	390,908	31.17%
Second Phase	2012	1,572,800.0	456,166	29.00%
Average	-	-	-	31.50%

Source: Schemes of Water Supply and Sewage Systems of Kiev City by 2020, Kiev City (2007)

(C) Proposed Design Underground Water Flows

The sewer system in Kiev City has an over 100-year long history and the pipes laid in the earliest periods must have heavily deteriorated and substantial amount of infiltration is easily seen in the event of rain falls according to the information provided from BAS engineers and the specialists of chemical laboratory who are in charge of periodic water testing.

Therefore it is recommended to consider large proportion of underground water component in order to satisfy the requirement of capacities not only for the daily services for dry conditions but also in the rainy events on account of protecting from hindrances of local inundations in terms of hydraulic capacity.

The study chose the ratio of underground water at 30% unanimously applicable to the respective conditions of wastewater flows and this ratio was verified by the calculation of influent quality which is almost fit to the actual situation when the calculation was made using proposed parameters.
The proposed ratio of underground water is indicated in Table 4.23.

Table 4.23 Proposed Ratio of Underground Water

Item	Daily Mean Water Flow	Daily Maximum Water Flow	Hourly Maximum Water Flow
Underground Water Ratio	30.00%	30.00%	30.00%

Source: JICA Study Team

Proposed design underground water flows are calculated as shown in Table 4.24.

Table 4.24 Proposed Design Underground Water Flows

Item		Unit	Present	Estimated (Rounded)	
			2012	2021	2030
Daily Mean Wastewater Flow	Domestic & Industrial Wastewater	m^3/day	668,299	776,000	847,000
	Ratio of Underground Water	%	30.00%		
	Underground Water	m^3/day	200,490	233,000	254,000
Daily Maximum Wastewater Flow	Domestic & Industrial Wastewater	m^3/day	954,713	1,109,000	1,210,000
	Ratio of Underground Water	%	30.00%		
	Underground Water	m^3/day	286,414	333,000	363,000
Hourly Maximum Wastewater Flow	Domestic & Industrial Wastewater	m^3/day	1,193,391	1,386,000	1,513,000
	Ratio of Underground Water	%	30.00%		
	Underground Water	m^3/day	358,017	416,000	454,000

Source: JICA Study Team

(6) Summary of Design Wastewater Flows

The summary of design wastewater flows shows that the estimated future wastewater flow in daily maximum wastewater condition in 2030 coincides with the design flow of the feasibility study which targets to 2021.

The detailed design wastewater flows are listed in Table 4.25, and converted hourly rate in hourly maximum conditions are shown in Table 4.26.

Table 4.25 Summary of Design Wastewater Flows

Item		Unit	Present	Estimated (Rounded)	
			2012	2021	2030
Daily Mean Wastewater Flow	Domestic Wastewater	m^3/day	541,247	639,000	697,000
	Industrial Wastewater	m^3/day	127,052	137,000	150,000
	Underground Water	m^3/day	200,490	233,000	254,000
	Total	m^3/day	868,789	1,009,000	1,101,000
Daily Maximum Wastewater Flow	Domestic Wastewater	m^3/day	773,210	913,000	996,000
	Industrial Wastewater	m^3/day	181,503	196,000	214,000
	Underground Water	m^3/day	286,414	333,000	363,000
	Total	m^3/day	1,241,127	1,442,000	1,573,000
Hourly Maximum Wastewater Flow	Domestic Wastewater	m^3/day	966,513	1,141,000	1,245,000
	Industrial Wastewater	m^3/day	226,879	245,000	268,000
	Underground Water	m^3/day	358,017	416,000	454,000
	Total	m^3/day	1,551,408	1,802,000	1,967,000

Source: JICA Study Team

Table 4.26 Converted Hourly Maximum Wastewater Flow

Item		**Unit**	**Present**	**Estimated (Rounded)**	
			2012	**2021**	**2030**
Hourly Maximum Wastewater Flow (Hourly Rate)	Domestic Wastewater	m^3/hour	966,513	1,141,000	1,245,000
	Industrial Wastewater	m^3/hour	226,879	245,000	268,000
	Underground Water	m^3/hour	358,017	416,000	454,000
	Total	m^3/hour	1,551,408	1,802,000	1,967,000

Source: JICA Study Team

For reference purposes, the comparison of proposed design flow and other available figures is shown in Table 4.27.

Table 4.27 Comparison of Proposed Design Flow (Daily Maximum)

Item	Unit	Present	Estimated	
		2012	2021	2030
Proposed Wastewater Flow	m^3/day	1,241,127	1,442,000	1,573,000
Feasibility Study	m^3/day	-	1,573,000	-
Existing Sewerage Plan	m^3/day	1,572,800	-	-
Unapproved General Plan	m^3/day	1,332,750	1,542,800	-

Source: JICA Study Team

4.1.4 Design Loads and Effluent Qualities

(1) Historical Influent Qualities at BAS

From the archives of periodic water testing results, historical profiles of influent qualities were summarized. In accordance with the reductions of water flow into BAS on the contrary to the increasing trend in population, each of the indicators shows an increase in concentration except COD_{Cr} and Phosphorus.

The summary of historical profiles of influent qualities is listed in Table 4.28.

Table 4.28 Historical Profiles of Influent Qualities at BAS

Unit: mg/L

Item	2008	2009	2010	2011	2012	Average	Median
BOD_5	224	248	226	296	264	251.6	248
COD_{Cr}	715	722	639	651	595	664.4	651
SS	312	344	312	312	327	321.3	312
T-N	28	27	30	34	35	30.7	30
T-P	5.9	6.2	5.9	5.9	5.5	5.88	5.9

Source: KVK

(2) Design Loads, Influent and Effluent Qualities in Feasibility Study

(A) Design Loads and Influent Qualities

The design loads and influent qualities set in the feasibility study are based on the recent profiles of water indicators stipulated to the regulation to BAS.

The design values in the feasibility study are shown in Table 4.29 and Table 4.30.

Table 4.29 Design Loads and Influent Qualities in Feasibility Study

Item	Load (kg)	Concentration (mg/L)	
		Max	Min
BOD_5	320,625	285	204
COD_{Cr}	881,289	784	560
TSS (Total Suspended Solid)	416,641	371	265
Total Kjeldahl Nitrogen (TKN)	58,810	52	37
NH_4-N	38,406	34	24
Total P	20,225	18	13
VSS (Volatile Suspended Solid)	258,597	230	164
Fat, Oil & Grease (FOG)	220,322	196	140

Source: KVK

Table 4.30 Distributed Design Loads in Feasibility Study

Item	Unit	Value (2021)			
		Block 1	Block 2	Block 3	Total*
BOD_5	kg/day	117,610	117,610	85,405	320,625
COD_{Cr}	kg/day	323,270	323,270	234,748	881,289
TSS (Total Suspended Solid)	kg/day	152,830	152,830	110,980	416,641
Total Kjeldahl Nitrogen (TKN)	kg/day	21,572	21,572	15,665	58,810
NH_4-N	kg/day	14,088	14,088	10,230	38,406
Total P	kg/day	7,419	7,419	5,387	20,225
VSS (Volatile Suspended Solid)	kg/day	94,857	94,857	68,882	258,597
Fat, Oil & Grease (FOG)	kg/day	80,818	80,818	58,687	220,322

*Some of items shown inconsistent figures of totals

Source: KVK

(B) Effluent Qualities

The design target of effluent qualities in the feasibility study was also determined by the requirements for the demands of future trends, as well as compulsory levels of treatment quality being levied on the agreement with the state entities in the future.

The target effluent qualities is shown in Table 4.31

Table 4.31 Target Effluent Quality in Feasibility Study

Item	Unit	Effluent Concentration (2021)
BOD_5	mg/L	15
COD_{Cr}	mg/L	80
TSS (Total Suspended Solid)	mg/L	15
Total Kjeldahl Nitrogen (TKN)	mg/L	10
NH_4-N	mg/L	Not Specified
NO_2-N	mg/L	3.3
NO_3-N	mg/L	45
Total P	mg/L	1
Dissolved Oxygen	mg/L	4 or larger
Enterococci	units/100mL	400
E. Coliform	units/100mL	1,000

Source: KVK

(3) Proposed Design Loads and Influent Qualities

(A) Procedures for Calculations

The study determined the proposed design loads and water qualities using the following procedures.

- Assume levels of influent qualities from the recent trends of historical profiles
- Input assumed values as the daily mean wastewater conditions in the future qualities to 2021 and 2030 based on the scenario that the values are remaining in the same range as seen in current standard (therefore input will be considered as the recent trends)
- Discharge of wastewater from domestic and industrial uses is assumed at the same quality because of no available justified basis for setting practical values for industrial wastewater profiles
- As difference in loads for daily maximum condition, industrial loads consider the increase by the amount of water released to the sewerage system based on the assumption that same quality of wastewater is generated during the increase of business productions
- No additional loads are considered for domestic loads in the daily maximum flow condition because of no change in design population even in the peak period
- Influent qualities in the daily maximum condition are calculated by increased loads with design wastewater flows

Assumed influent qualities based on the recent trends were set according to the following reasons indicated in Table 4.32.

Table 4.32 Assumed Influent Qualities

Unit: mg/L

Item	Assumed Quality	Remarks
BOD_5	270	Considering higher trend in recent years
COD_{Cr}	730	Using maximum value to consider higher trends seen in other items
SS	350	Considering higher trend in recent years
T-N*	50	Considering higher trend in recent years
T-P (as PO_4)	18	Using average value

*Multiplied with 1.5 from measured values considering organic compounds to formulate Total Nitrogen

Source: JICA Study Team

(B) Proposed Design Loads and Influent Qualities

Following the procedures, the distributed loads for domestic and industrial wastewater generations in daily mean conditions were calculated to use them as basis for estimating daily maximum conditions. The results of distributions for 2021 and 2030 are shown in Table 4.33 and Table 4.34 respectively.

Table 4.33 Distributed Domestic and Industrial Loads (2021)

Item	Influent Quality (mg/L)	Daily Mean Wastewater Flow (m^3/day)	Load to BAS (kg/day)	Ratio of Distribution in Volume of Wastewater		Distributed Load (kg/day)	
				Domestic	Industrial	Domestic	Industrial
	(1)	(2)	(3)=(1)x(2)/1,000	(4)	(5)	(6)=(3)*(4)	(7)=(3)*(5)
BOD_5	270	1,009,000	272,430	82.35%	17.65%	224,333	48,097
COD_{Cr}	730	1,009,000	736,570	82.35%	17.65%	606,531	130,039
SS	350	1,009,000	353,150	82.35%	17.65%	290,803	62,347
T-N	50	1,009,000	50,450	82.35%	17.65%	41,543	8,907
T-P(as PO_4)	18	1,009,000	18,162	82.35%	17.65%	14,956	3,206

Source: JICA Study Team

Table 4.34 Distributed Domestic and Industrial Loads (2030)

Item	Influent Quality (mg/L)	Daily Mean Wastewater Flow (m^3/day)	Load to BAS (kg/day)	Ratio of Distribution in Volume of Wastewater		Distributed Load (kg/day)	
				Domestic	Industrial	Domestic	Industrial
	(1)	(2)	(3)=(1)x(2)/1,000	(4)	(5)	(6)=(3)*(4)	(7)=(3)*(5)
BOD_5	270	1,101,000	297,270	82.29%	17.71%	244,625	52,645
COD_{Cr}	730	1,101,000	803,730	82.29%	17.71%	661,393	142,337
SS	350	1,101,000	385,350	82.29%	17.71%	317,106	68,244
T-N	50	1,101,000	55,050	82.29%	17.71%	45,301	9,749
T-P(as PO_4)	18	1,101,000	19,818	82.29%	17.71%	16,308	3,510

Source: JICA Study Team

Increased values in industrial wastewater loads were calculated and total of loads in the daily maximum conditions were identified.

The proposed design loads in the daily maximum conditions in 2021 and 2030 are shown in Table 4.35 and Table 4.36 respectively.

Table 4.35 Proposed Design Loads in Daily Maximum Flow Condition (2021)

Item	Load (kg/day)	Industrial Flow (m^3/day)		Ratio of D. Max /D. Mean	Load (kg/day) Industrial		Total Load (kg/day)	Daily Max Flow (m^3/day)	Influent Quality (mg/L)
	Domestic	D. Mean	D. Max		D. Mean	D. Max			
	(1)	(2)	(3)	(4)=(3)/(2)	(5)	(6)=(5)x(4)	(7)=(1)+(6)	(8)	(9)=(7)/(8)
BOD_5	224,333	137,000	196,000	1.43	48,097	68,810	293,143	1,442,000	203
COD_{Cr}	606,531	137,000	196,000	1.43	130,039	186,041	792,572	1,442,000	550
SS	290,803	137,000	196,000	1.43	62,347	89,198	380,000	1,442,000	264
T-N	41,543	137,000	196,000	1.43	8,907	12,743	54,286	1,442,000	38
T-P(as PO_4)	14,956	137,000	196,000	1.43	3,206	4,587	19,543	1,442,000	14

Source: JICA Study Team

Table 4.36 Proposed Design Loads in Daily Maximum Flow Condition (2030)

Item	Load (kg/day)	Industrial Flow (m^3/day)		Ratio of D. Max /D. Mean	Load (kg/day) Industrial		Total Load (kg/day)	Daily Max Flow (m^3/day)	Influent Quality (mg/L)
	Domestic	D. Mean	D. Max		D. Mean	D. Max			
	(1)	(2)	(3)	(4)=(3)/(2)	(5)	(6)=(5)x(4)	(7)=(1)+(6)	(8)	(9)=(7)/(8)
BOD_5	224,333	150,000	214,000	1.43	52,645	75,107	319,732	1,573,000	203
COD_{Cr}	606,531	150,000	214,000	1.43	142,337	203,068	864,460	1,573,000	550
SS	290,803	150,000	214,000	1.43	68,244	97,361	414,467	1,573,000	263
T-N	41,543	150,000	214,000	1.43	9,749	13,909	59,210	1,573,000	38
T-P(as PO_4)	14,956	150,000	214,000	1.43	3,510	5,007	21,315	1,573,000	14

Source: JICA Study Team

Design loads are summarized in Table 4.37.

Table 4.37 Summary of Design Loads

Unit: kg/day

Item	Load (2021)		Load (2030)	
	Daily Mean	Daily Max	Daily Mean	Daily Max
BOD_5	272,430	293,143	297,270	319,732
COD_{Cr}	736,570	792,572	803,730	864,460
SS	353,150	380,000	385,350	414,467
T-N	50,450	54,286	55,050	59,210
T-P (as PO_4)	18,162	19,543	19,818	21,315

Source: JICA Study Team

Based on the identified values of loads contained in influent wastewater, design influent quality in the daily maximum conditions were finally determined. These parameters are used in the designing process of water treatment facilities and followed by sludge treatment facilities by dimensioning and determining basic specifications for equipment.

The summary of design influent qualities is shown in Table 4.38.

Table 4.38 Summary of Design Influent Qualities

Unit: mg/L

Item	Influent Quality (2021)		Influent Quality (2030)	
	Daily Mean	Daily Max	Daily Mean	Daily Max
BOD_5	270	203	270	203
COD_{Cr}	730	550	730	550
SS	350	264	350	263
T-N	50	38	50	38
T-P	18	14	18	14

Source: JICA Study Team

(4) Target Effluent Qualities

The target effluent qualities were deemed the same as proposed levels of standard by following the reasons of requirements and improvements in the effluent standard in the future.
The target effluent qualities are presented in Table 4.39.

Table 4.39 Target Effluent Qualities

mg/L

Item	Target Effluent Quality	
	2021	2030
BOD_5	15	15
COD_{Cr}	80	80
SS	15	15
T-N	10	10
T-P	1	1

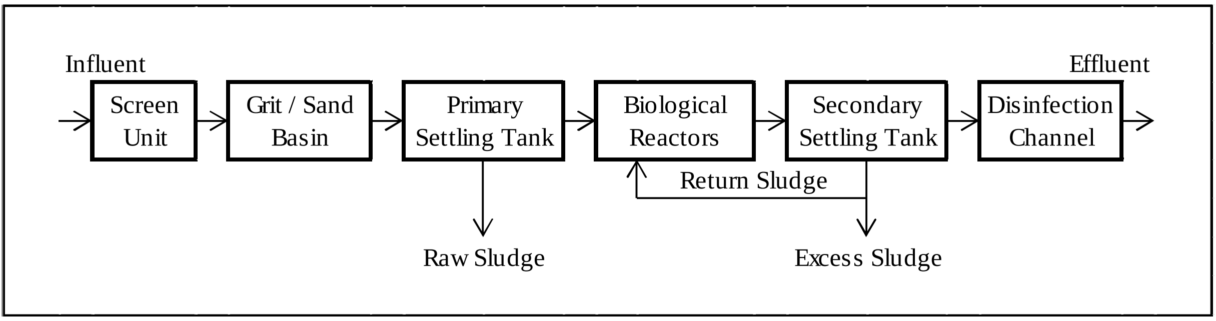
Source: JICA Study Team

4.2 Wastewater Treatment Process

It is important that the proper sewage treatment process is selected in order to fulfill the target effluent criteria and the selection was made based on the characteristics of influent sewage, as well as the scale of wastewater coming into BAS, the aspects of economic efficiency and operability.

In the 2012 F/S, Kiev City has identified that the process of wastewater treatment containing preliminary treatment and primary treatment process on account of removing sand and grits from incoming sewage, followed by secondary treatment process consisting of biological reactors, secondary settling tanks and disinfection using ultraviolet lamps, and tertiary treatment process in order to ensure removal of suspended substances to meet strict requirements being imposed in the future on Kiev City.

The proposed wastewater treatment process is shown in Figure 4.6.



Source: JICA Study Team

Figure 4.6 Proposed Wastewater Treatment Process in 2012 F/S

This study reviewed the wastewater treatment method and processes from viewpoints such as efficiency, sustainability, fulfillment of required effluent standards, etc.

- Secondary Treatment Process
- Tertiary Treatment Process

4.2.1 Secondary Treatment Process

(1) Second Treatment Processes in Comparison

The study proposed three different methods of treatment processes using activated sludge because BAS is loaded at nearly full capacity with generated sewage from the city and the treatment is conducted using conventional activated sludge process. Hence, rehabilitated and reconstructed trains will be reasonable to use activated sludge based process;

- Suitable treatment method for large scaled sewerage entities more than three million people in covered population
- Existing characteristics, such as historical influent volume and water qualities, are available and future behaviors are comparably easier to estimate future profiles for BAS
- Any treatment process which enables reconstruction within the territories of existing BAS and comparably less electric energy consumption which will not cause significant changes in the operation cost expenditures
- Currently, the operation and maintenance team in BAS maintains capacities enough to conduct daily operations for wastewater treatment techniques using activated sludge

process

- Enough to fulfill the water quality indices which have been requested by Kiev City eligible in the future

From the viewpoints shown above, the study conducted comparisons among Activated Sludge Process, Anaerobic – Anoxic – Oxic Process (A2O Process) and Advanced Oxidation Ditch Process.

(2) Comparisons of Secondary Treatment Processes

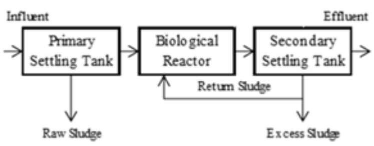
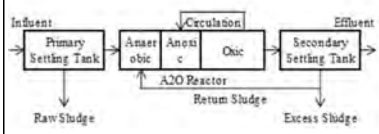
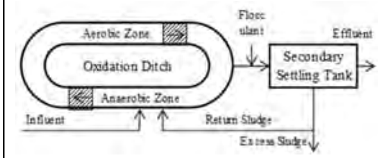
Among these three candidate processes for comparisons of Activated Sludge Process, Anaerobic – Anoxic – Oxic Process (A2O Process) and Advanced Oxidation Ditch Process, outlines and information are summarized as listed below.

- Outlines of treatment process
- Required treatment capacity (for a single treatment train based on 2012 F/S) for comparisons
- Aspect of fulfillment of effluent criteria
- Aspect of initial investment
- Aspect of operability (including energy consumption and stability in operation and maintenance)

According to the results of the comparisons, Anaerobic – Anoxic – Oxic Process (A2O Process) has shown its space saving characteristics and the process can fulfill the required effluent criteria. The study proposes this process.

The table shown below summarizes the comparisons of candidate processes as Table 4.40.

Table 4.40 Comparisons of Secondary Treatment Processes

Item	Description		
Method	Conventional Activated Sludge Process (CAS Process)	Anaerobic-Anoxic-Oxic Process (A2O Process)	Advanced Oxidation Ditch Process
Simplified Flow Sheet			
Principles	Same treatment process as established at BAS, being remodeled using advanced equipment to reduce energy consumption. No specific functions installed for biological treatment for Nitrogen and Phosphorus.	Modified from CAS Process and biological treatment units for nitrogen and phosphorus are installed by combining anaerobic and anoxic zones to control specific micro organisms to grow and enhance reactions.	Endless circulating ditch allocated both anaerobic zone and aerobic zone, nitrification and denitrification are expected to fulfill at the stable conditions. To add phosphorus removals, dosing coagulant at the effluent channel.
	Retention Time: 6-8 hours in reactors	Retention Time: 12+ hours in reactors	Retention Time: 24 hours in reactors
Treatability	BOD & SS: In principle same as existing tank T-N: Difficult to meet at design flow condition T-P: No specific treatment done	BOD & SS: Almost same as existing tank T-N: Biological treatment carried out T-P: Biological treatment carried out	BOD & SS: Almost same as existing tank T-N: Biological treatment carried out T-P: Fulfills requirement with coagulant
Footprint of Reactors	Smallest among these alternatives 50 - 70 % of A2O Process	Smallest among these alternatives 50 - 70 % of A2O Process	Largest among these alternatives Requires 2+ times space as A2O Process
O&M	Energy: Smallest among these alternatives Operation: Same range of existing system	Energy: In principle, the most expensive Operation: Most complicated among these options	Energy: Slightly higher than CAS Process Operation: Easier to gain stabilized operations
Overall Evaluation	Treatment for nutrients is not enough to fulfill the demand in the future at design flow	Most possible option in terms of land constraint and fulfillment of effluent criteria. Proper training and monitoring required to maintain	Requires large scale of land for establishment and will cause escalation of construction and management costs

*Reactors for biological treatment in Block 3 is implemented by other scheme
Source: JICA Study Team

In 2012 F/S, the Anaerobic – Anoxic – Oxic Process using endless tanks was proposed as the secondary treatment process, since and the process reduces volume of tanks by introducing deep water depth at 8 m and it highly contributes to downsizing and fits the limited layout conditions.

Actual examples of this process in Europe Area are summarized in Table 4.41 and Figure 4.7 regarding examples of City A, Table 4.42 and Figure 4.8 regarding examples of City B.

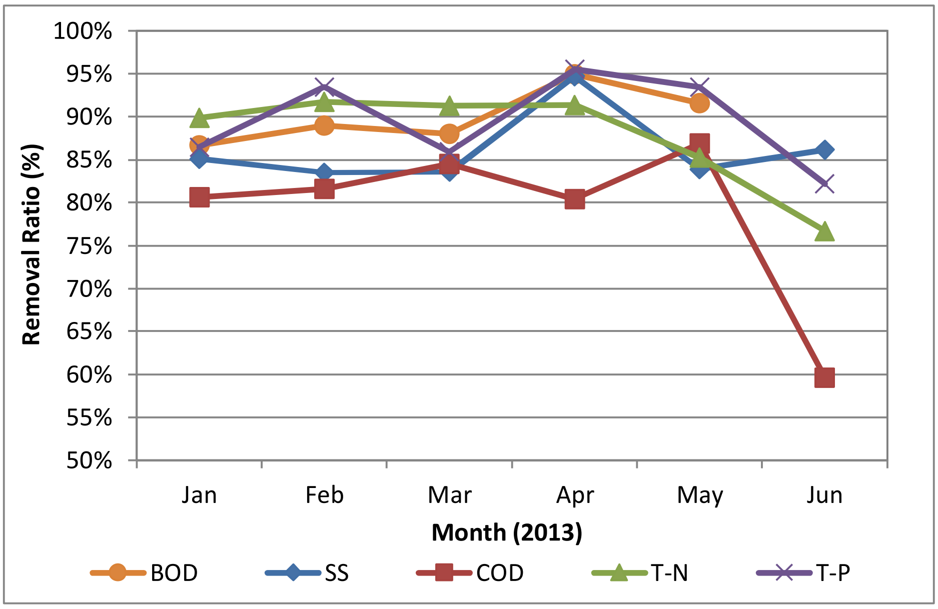
Table 4.41 Examples of Actual Performances of Endless A2O Process (City A)

Unit: %

Month	Removal Ratio (Secondary Treatment)				
	BOD	SS	COD	T-N*	T-P
January	86.7%	85.1%	80.6%	89.9%	86.5%
February	89.0%	83.5%	81.6%	91.7%	93.4%
March	88.0%	83.6%	84.5%	91.3%	85.9%
April	95.0%	94.7%	80.4%	91.4%	95.5%
May	91.6%	83.9%	86.9%	85.3%	93.5%
June		86.2%	59.6%	76.7%	82.2%
Average	89.7%	86.2%	80.6%	89.0%	89.9%
Median	97.2%	93.6%	91.5%	90.0%	92.8%
Maximum	100.0%	100.0%	100.0%	100.0%	100.0%
Minimum	45.4%	7.4%	1.6%	64.0%	27.6%

*T-N used overall removal ratio due to lacking data

Source: KVK



Source: KVK

Figure 4.7 Examples of Actual Performances of Endless A2O Process (City A)

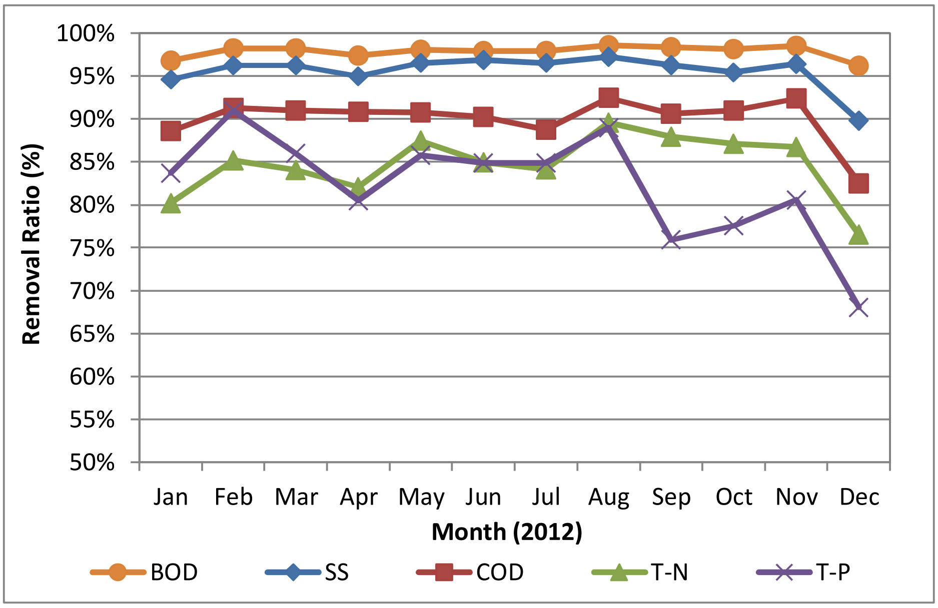
Table 4.42 Examples of Actual Performances of Endless A2O Process (City B)

Unit: %

Month	Removal Ratio (Overall Treatment*)				
	BOD	SS	COD	T-N	T-P
January	96.8%	94.6%	88.6%	80.2%	83.7%
February	98.3%	96.2%	91.3%	85.2%	90.9%
March	98.3%	96.3%	91.0%	84.1%	86.0%
April	97.4%	95.0%	90.8%	82.1%	80.5%
May	98.1%	96.6%	90.8%	87.4%	85.8%
June	97.9%	96.9%	90.2%	84.9%	84.9%
July	98.0%	96.5%	88.8%	84.2%	84.9%
August	98.6%	97.2%	92.4%	89.5%	89.0%
September	98.4%	96.3%	90.6%	87.9%	75.9%
October	98.2%	95.4%	91.0%	87.1%	77.5%
November	98.6%	96.4%	92.3%	86.7%	80.6%
December	96.2%	89.8%	82.5%	76.5%	68.0%
Average	97.9%	95.6%	90.0%	84.6%	82.3%
Median	98.4%	96.7%	91.1%	85.9%	84.8%
Maximum	99.1%	99.1%	95.2%	92.7%	95.3%
Minimum	84.1%	62.9%	51.5%	55.9%	14.7%

All data represented overall removal ratios due to lacking information

Source: KVK



Source: KVK

Figure 4.8 Examples of Actual Performances of Endless A2O Process (City B)

According to historical information, a relatively high range of removal ratios was achieved in other applications (City B didn't calculate removal ratios for secondary treatment). According to the anticipated removal ratios for pollutant indices including BOD, SS and COD, the proposed ratios in

2012 F/S are 94.7%, 96.0% and 89.8% respectively as overall removal ratios. To achieve these higher standards of treatment required by the city, tertiary treatment process is necessary to be installed.

For reference, qualities of indices identified by 2012 F/S is shown in Table 4.43, anticipated removal ratios are shown in Table 4.44.

Table 4.43 Qualities at Primary Treatment Process in 2012 F/S

Unit: mg/L

Item	BOD	SS	COD	T-N	T-P
Influent	285	371	784	35	6
After Primary Treatment Process	200	178	502	31	5
Effluent	15	15	80	10	1

Source: KVK

Table 4.44 Removal Ratio at Different Treatment Processes in 2012 F/S

Unit: %

Item	BOD	SS	COD	T-N	T-P
Primary Treatment Process	30.0%	52.0%	36.0%	12.0%	12.0%
Secondary Treatment Process	92.5%	91.6%	84.1%	67.5%	81.1%
Overall Treatment Processes	94.7%	96.0%	89.8%	71.4%	83.3%

Source: KVK

From the comparisons and additional information shown above, the selection of secondary treatment process has adopted the technology proposed in 2012 F/S. However it is recommended to take additional considerations at the detailed design stage in order to supplement the efficacy of using this process for the reconstruction of BAS.

- ➢ The retention time of reactors specified in 2012 F/S is less than nine hours and it is recommended to confirm sufficiency of the capacities for de-nitrification in lower water temperature conditions in winter time
- ➢ Proposed concentration of MLSS, or mixed liquor suspended solid is set at 4,500 mg/L and it is recommended to consider the stability of retaining thicker content throughout the year in order to retain higher treatment functions

(3) Secondary Treatment Process for Rehabilitation Works

Rehabilitation works for existing wastewater treatment facilities of Block 2 and Block 3 are proposed in the project prior to the reconstruction period and these activities are included in Component 1. Through the rehabilitation works which include replacement of equipment which has been operated as conventional activated sludge process and will maintain the current treatment capacities and prolong the life of existing treatment lines in the both blocks.

The study reviewed that the contents and technologies are properly referred from existing facilities and concluded that there are no technical problems in this activities.

(4) Construction of Advanced Treatment Facilities in Block 3

The existing treatment process of Block 3 which was once constructed as conventional sludge treatment process using standardized design like other treatment blocks has been upgraded into advanced treatment facilities that uses technologies introduced from Denmark. The reactors shaped as endless oxidation ditches and the reconstruction of 1/3 of the reactors (two tanks out of six in Bock 3) has been finished, while the other 1/3 (two tanks) are under construction under a state budget financed scheme and the remaining 1/3 are proposed to be done in the future. These remodeling activities of reactors have been already sanctioned and started individually and are considered to be out of the scope of the project for the study.

(5) Disinfection Facilities

Formerly, a disinfection process using hypochlorite was introduced the existing BAS at the beginning of the operation in 1960s. However, because of the lack of chemicals and budgetary issues, disinfection is no longer conducted. 2012 F/S proposes disinfection using ultraviolet lamps which are substituted by existing treatment philosophy because the use of chloride agents is restricted in order to prevent the possibility of generating trihalomethane in the discharged water bodies, in order to comply with the directives of the EU. The study has found that the use of ultraviolet lamps is a quite proper solution for this treatment.

4.2.2 Tertiary Treatment Process

(1) Tertiary Treatment Processes being Compared

2012 F/S proposed to add tertiary treatment process in order to take terminal removals of suspended substances and phosphorus contained in the secondary treated wastewater to meet the standard which is required by Kiev City. As a result, the ACTIFLO Process is introduced in the selections. The study proposed candidate processes for comparisons based on the viewpoints shown below;

- Suitable for treating larger amount of wastewater
- Smaller footprint because of limited available land
- Not complicating necessary operations
- Effective for targeted indices required by advanced standards

In the study, ACTIFLO and Discfilter processes are listed for comparison based on the criteria listed above.

(2) Comparisons of Secondary Treatment Processes

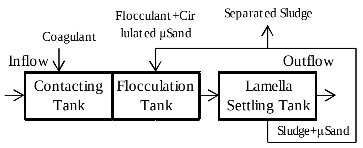
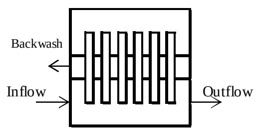
Among these candidate processes for comparisons, various characteristics were summarized about ACTIFLO Process and Discfilter, and the points of comparison are shown as below.

- Outlines of treatment process
- Required treatment capacity (for a single treatment train based on 2012 F/S) for comparisons
- Aspect of fulfillment of effluent criteria
- Aspect of initial investment
- Aspect of operability (including energy consumption and stability in O&M)

According to the results, ACTIFLO Process was found to have a smaller footprint and to enable an efficient layout in the limited space allowed for the tertiary treatment plan and therefore as mentioned in 2012 F/S, ACTIFLO is recommended to the project.

The comparisons of tertiary treatment processes are summarized in Table 4.45.

Table 4.45 Comparisons of Tertiary Treatment Processes

Item	Description	Description
Method	ACTIFLO Process	Discfilter
Simplified Flow Sheet		
Principles	Combination of flocculation technology using micro sand and rapid lamella settling tank enables to treat water in a shorter period of time (generally 10-15 minutes). Flocculation is processed by use of micro sand as a core media and flocculant and coagulant are used to agitate flocculation	Filtration of water using a number of disc-like media with a very small head loss and can be applied under gravity flow conditions. The principles and structures behind this system are very simple. Maintenance can be carried out even during operation
Treatability	SS and other components, especially Phosphorus, which are contained in sludge can be removed with the help of coagulation in the process	SS and other contained components captured in the suspended substances can be removed. Phosphorus removal is less effective than using ACTIFLO Process
Footprint of Reactors	Smaller than discfilter because the unit capacity is larger as per the characteristics of this method	Becomes larger because many units have to be established because due to massive flow amount
O&M	Energy: Use more electricity than discfilter Operation: Maintaining chemical agents and micro sand constitute a considerable difference in comparison with the discfilter	Energy: Less than ACTIFLO Process Operation: Comparably easier than ACTIFLO because of its simple structures
Overall Evaluation	A smaller footprint, and effective removal of phosphorus and suspended matter are requisite points. Therefore, this method is chosen	ACTIFLO Process can be installed using less land and coagulation process can help remove phosphorus and SS to make it more fitting to fulfill the set requirements

Source: JICA Study Team

4.3 Selection of Sewage Treatment Equipment

4.3.1 Alternatives of Aeration Equipment

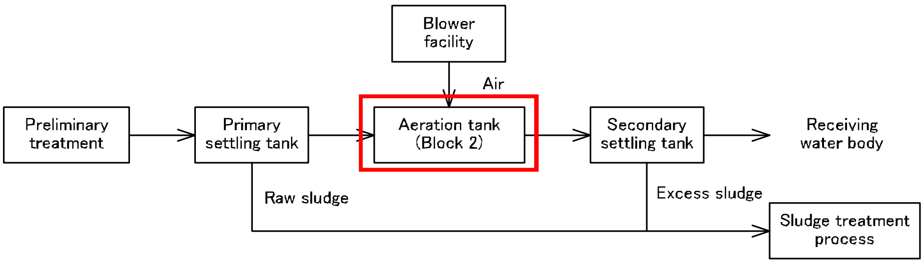
Aeration equipment consumes a significant portion (usually 30-60%) of total electricity used in the sewage treatment process. In addition, its role is vital in the activated sludge process. Therefore, aeration equipment should be selected considering all factors regarding the efficiency of dissolving oxygen, economical aspect, operation and maintenance, etc.

Fine bubble diffusers are installed in the existing aeration tanks except for two aeration tanks for Block 3, which have been renovated to the endless flow tanks. Ultrafine bubble diffusers are installed in these renovated aeration tanks. Also, other two aeration tanks are waiting for replacement with the same equipment which is already procured. Hence, it is expected that the same type of diffuser, ultrafine bubble diffuser, will be installed in all aeration tanks for Block 3.

For the rehabilitation of aeration thanks for Block 2, the newly developed aeration equipment which can be potential alternatives for BAS, is listed below together with the conventional type of equipment. A brief explanation of the newly developed technologies is shown in Table 4.46.

- Fine bubble diffuser
- Ultrafine bubble diffuser
- Submersible aeration device (Japanese product)

Table 4.46 Explanation of Newly Developed Technology

Explanation		
 Aeration equipment is installed in aeration tanks. Aeration equipment supplies oxygen which is required by activated sludge to remove pollutant load. Additionally, aeration mixes sewage and activated sludge.		
Ultrafine bubble diffuser	The ultrafine bubble diffuser is the latest energy saving technology. This diffuser has high oxygen transfer efficiency owing to producing ultrafine bubbles which are smaller than fine bubbles produced from the conventional diffusers by using membranes with fine slips.	
Submersible aeration device (Japanese product)	The submersible aeration device can produce fine bubbles by mechanically mixing air supplied from blowers using impellers. This device can be operated as a mixer by stopping air supply, which makes it capable of operating in both aerobic and anaerobic conditions.	

Source: JICA Study Team

4.3.2 Comparison of Aeration Equipment

The comparison of alternatives is summarized in Table 4.47, Table 4.48 and Table 4.49. As a result of comparison, the ultrafine bubble diffuser is recommended for aeration tanks for Block 2 due to the following advantages.

- It is most effective in terms of energy saving due to its high efficiency of dissolving oxygen.
- It can be utilized for a relatively longer time period due to its non-clogging feature in case of adequate operation.
- It has a high level of flexibility for various operations due to its feature of wide operational range of air flow.
- It is the most economical in terms of life cycle cost since it requires the lowest O&M cost due to its high efficiency.

Table 4.47 Comparison of Aeration Equipment (1)

	Fine bubble diffuser
Explanation of equipment	The fine bubble diffuser is comprised of diffusers made of ceramic or synthetic resin and holders made of stainless or synthetic resin. This diffuser produces fine bubbles from small opening on diffusers.
Efficiency	Oxygen transfer efficiency is generally 20-32%. The diffusers do not consume electricity. Hence, total energy consumption is less than that of submersible aeration devices.
Operation	Adjustable range of air flow amount is relatively narrow because of limitations on minimum flow. The minimum flow is required to be maintained in order to avoid clogging of diffusers.
Maintenance	The fine bubble diffuser requires periodical replacement of diffusers within 5-10 years due to clogging of diffusers caused by aging deterioration. Without replacement, the efficiency decreases due to clogging.
Intermittent operation	Intermittent aeration is impossible since infiltration of sewage occurs and results in clogging without air supply. It is required to remove diffusers from sewage for suspension of operation.
Air flow resistance	Less than 2.4 kPa (Increase of 0.3-0.8kPa/year is expected due to aging)
Aeration requirement (Block 2)	3,673 m^3/min (189 %)
Power consumption (Block 2)	24,209 MWh/year (160 %)
Environmental and social considerations	Emission of greenhouse gas is more than ultrafine bubble diffuser because of lower efficiency.
Outlines of equipment	Fine bubble diffuser: 6 tanks Turbo blower: 750 m^3/min x 57 kPa x 910 kW x 7 nos. (1 standby)
Initial investment	Aeration equipment: 4.26 Million Euro Blower: 9.89 Million Euro Electrical cost: 5.05 Million Euro Total: 19.19 Million Euro (122 %)
O&M cost	Electricity: 2.91 Million Euro/ year Maintenance: 0.27 Million Euro/ year Total: 3.18 Million Euro/ year (156 %)
Net present value	60.41 Million Euro (141 %)
Selection	-

Net present value: Discount rate = 7.8% / period = 30year

Source: JICA Study Team

Table 4.48 Comparison of Aeration Equipment (2)

	Ultrafine bubble diffuser
Explanation of equipment	The ultrafine bubble diffuser is comprised of membranes, baseplates, fixing frames and air supply openings. This diffuser produces ultrafine bubbles from fine slips by supplying air between membranes and baseplates.
Efficiency	Oxygen transfer efficiency is generally 28-35%. The diffusers do not consume electricity. Hence, total energy consumption is the least and its energy saving effect is considerable.
Operation	Adjustable range of air flow amount is wider compared to conventional fine bubble diffuser since infiltration of sewage is prevented due to higher internal pressure of diffusers.
Maintenance	The ultrafine bubble diffuser does not require periodical replacement of diffusers in the event of conducting appropriate operation due to its non-clogging feature.
Intermittent operation	Intermittent aeration and suspension of operation is possible since the infiltration of sewage is prevented by closing slips. Membranes cohere to baseplates by water pressure when air supply is stopped.
Air flow resistance	Less than 11 kPa (Increase of resistance is not expected due to aging)
Aeration requirement (Block 2)	1,946 m^3/min (100 %)
Power consumption (Block 2)	15,099 MWh/year (100 %)
Environmental and social considerations	Emission of greenhouse gas is the least since energy consumption is the least owing to high oxygen transfer efficiency.
Outlines of equipment	Ultrafine bubble diffuser: 6 tanks Turbo blower: 750 m^3/min x 67 kPa x 1,070 kW x 4 nos. (1 standby)
Initial investment	Aeration equipment: 6.40 Million Euro Blower: 5.99 Million Euro Electrical cost: 3.39 Million Euro Total: 15.78 Million Euro (100 %)
O&M cost	Electricity: 1.81 Million Euro/ year Maintenance: 0.22 Million Euro/ year Total: 2.03 Million Euro/ year (100 %)
Net present value	42.97 Million Euro (100 %)
Selection	Selected by advantages mentioned in 4.3.2

Net present value: Discount rate = 7.8% / period = 30year

Source: JICA Study Team

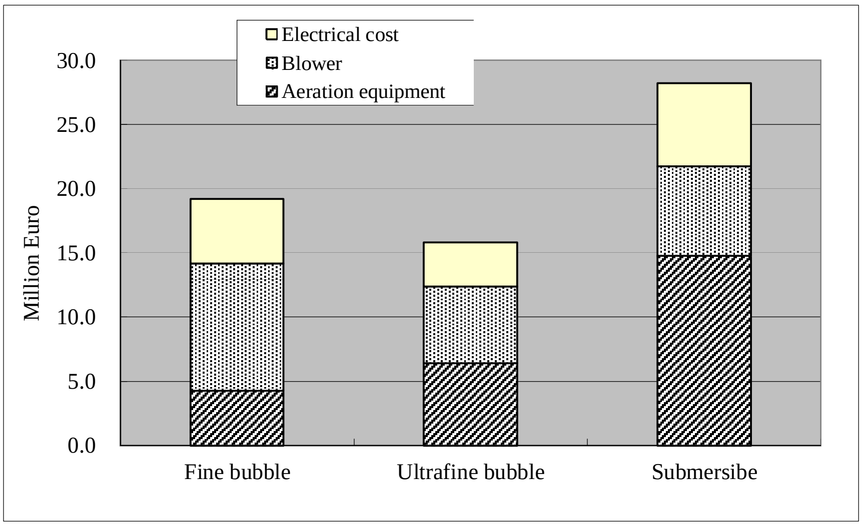
Table 4.49 Comparison of Aeration Equipment (3)

	Submersible aeration device (Japanese product)
Explanation of equipment	The submersible aeration device is comprised of motors, reduction gears, impellers and casings. This device produces fine bubbles by mechanically mixing air supplied from the blowers with impellers.
Efficiency	Oxygen transfer efficiency is generally 20-30%. The submersible aeration device itself also consumes electricity. Considering power consumption of aeration devices, an energy saving effect is not to be expected.
Operation	There is no limitation on air flow amount. Hence, adjustable range of air flow amount is the widest. Adjustment by speed of rotating impellers is also possible adopting VVVF control.
Maintenance	Submersible aeration device requires periodical overhaul of reduction gears, greasing of submerged aerator/rotating impellers and replacement of spare parts such as mechanical seals.
Intermittent operation	Intermittent aeration and suspension of operation are possible since there is no limitation on air supply. This device is also capable of mixing operation without air supply.
Air flow resistance	Less than 1.0 kPa (Increase of resistance is not expected due to aging)
Aeration requirement (Block 2)	2,520 m^3/min (129 %)
Electricity consumption (Block 2)	31,431 MWh/year (208 %)
Environmental and social considerations	Emission of greenhouse gas is the highest since total energy consumption including blowers and aeration devices is the highest.
Outlines of equipment	Submersible aeration device: 15 kW x 168 nos. Turbo blower: 750 m^3/min x 55 kPa x 880 kW x 5 nos. (1 standby)
Initial investment	Aeration equipment: 14.78 Million Euro Blower: 6.97 Million Euro Electrical cost: 6.42 Million Euro Total: 28.18 Million Euro (188 %)
O&M cost	Electricity: 3.77 Million Euro/ year Maintenance: 0.41 Million Euro/ year Total: 4.18 Million Euro/ year (206 %)
Net present value	83.42 Million Euro (194 %)
Selection	-

Net present value: Discount rate = 7.8% / period = 30year

Source: JICA Study Team

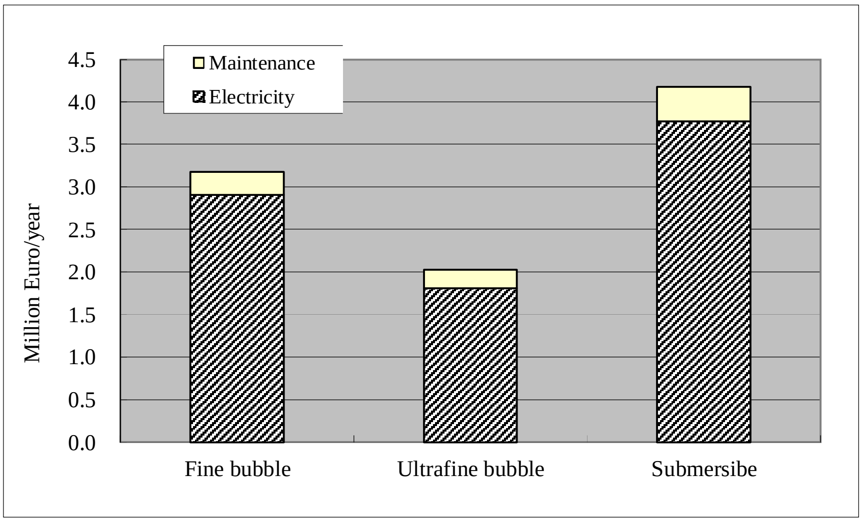
The initial investment of alternatives is analyzed as shown in Figure 4.9. The Initial investment of aeration system of ultrafine bubble diffuser is the lowest owing to smaller capacity of blower facility.



Source: JICA Study Team

Figure 4.9 Initial Investment

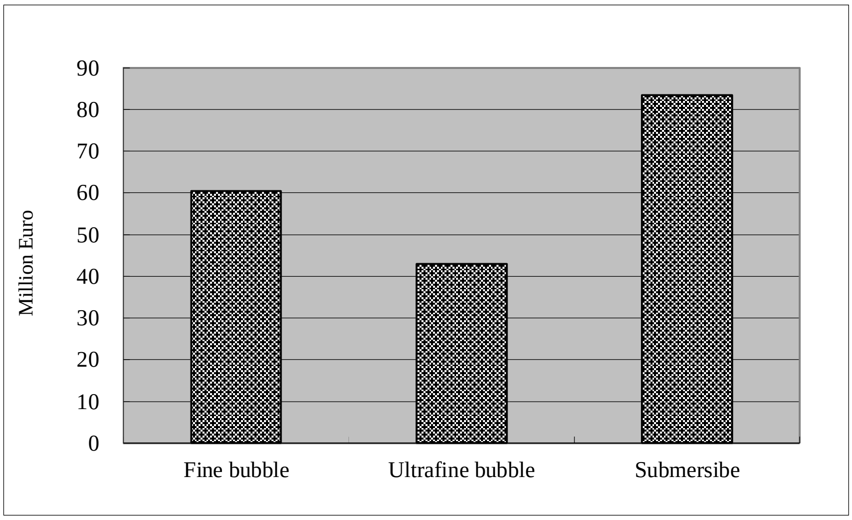
The O&M cost of alternatives is analyzed as shown in Figure 4.10. Electricity expenses of ultrafine bubble diffuser are the lowest owing to the highest efficiency of oxygen transfer.



Source: JICA Study Team

Figure 4.10 O&M Cost

The net present value of alternatives is analyzed as shown in Figure 4.11. The ultrafine bubble diffuser is the most economical in terms of net present value.



Source: JICA Study Team

Figure 4.11 Net Present Value

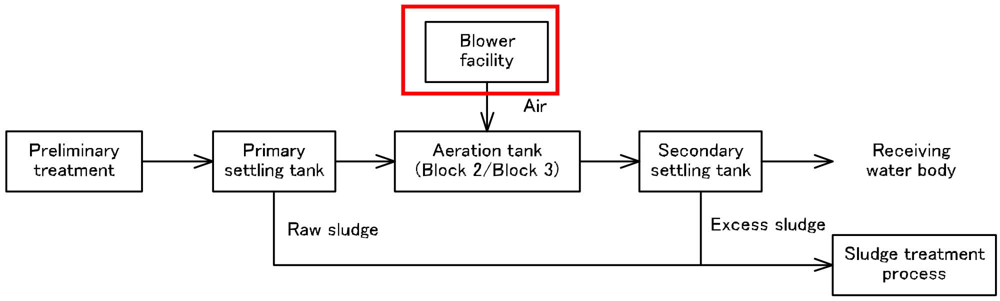
4.3.3 Alternatives of Blower

The existing blowers of sewage treatment facilities for Block 2 and Block 3 are planned to be replaced since the blowers cannot adjust aeration amount. The adjustment of aeration is important in order to improve the performance and efficiency of biological treatment. Optimization of aeration is possible by introducing blowers with a flow control system and instrumentation.

For the replacement of the blowers, newly developed blowers which can be potential alternatives for BAS, are listed below together with the conventional types of blowers. A brief explanation for newly developed technologies is shown in Table 4.50.

- Gear-drive single stage turbo blower (Japanese product)
- Direct-coupling single stage turbo blower (Japanese product)
- Multistage turbo blower (Japanese product)

Table 4.50 Explanation of Newly Developed Technology

<table>
<tr><th colspan="3">Explanation</th></tr>
<tr><td colspan="3">

The blower facility supplies air to aeration tanks in order to enhance purification by activated sludge. Adjustment of aeration is necessary to improve the performance and efficiency of biological treatment</td></tr>
<tr><td>Direct-coupling single stage turbo blower (Japanese product)</td><td>Impellers which are connected to main shafts of motors are contactless by magnetic bearings. Wide range of flow control with high efficiency is achieved by combining frequency control and inlet vane control. Increase of rotation of impellers is conducted by frequency control of motors.</td><td></td></tr>
</table>

Source: JICA Study Team

4.3.4 Comparison of Blower

The comparison of alternatives is summarized in Table 4.51, Table 4.52 and Table 4.53. As a result of comparison, gear-drive single stage turbo bower (Japanese product) is recommended for replacement of the blowers for Block 2 and Block 3 due to the following advantages.

- Operation and maintenance are easier since the type of blower is the same as the existing blowers.
- Replacement of blowers is easily conducted in the same position owing to the same type and capacity as the existing blowers while multistage turbo blower requires modification of structures for installation.
- The number of blowers is minimized since larger capacity blowers can be manufactured.
- Efficiency is higher than that of multistage turbo blower in wide range of operation.
- It is the most economical option in terms of net present value.

Table 4.51 Comparison of Blower (1)

	Gear-drive single stage turbo blower (Japanese product)
Description of blower	Impellers are connected to main shafts of motors via speed up gears. Increase of rotation of impellers is conducted by speed up gears since the revolution of motors is constant.
Flow control	Flow control is conducted by inlet vane control. Range of flow control from 55% to 100% of the rated capacity is expected.
Driving system	Speed increase by speed up gear
Lubrication method	Individual lubrication method.
Cooling method	Water-cooling method by circulating potable water
Noise and vibration	Noise is expected due to high velocity revolution.
Efficiency	Range of flow control is narrow compared to that of multistage turbo blower. However, efficiency is higher than that of multistage turbo blower in wide range of operation.
Reliability	Accurate clearance is kept owing to shorter main shaft since impeller has a single stage. Reliability is high owing to forced lubrication despite of high velocity revolution.
Operation and maintenance	Operation is easy since protective devices prevent surging, monitor abnormal vibration and detect thrust. Inspection and maintenance is easy since the blowers have a single open impeller.
Replacement of the existing blowers	It is possible to replace the existing blowers since the blower is the same type as the existing blowers
Power consumption (Block 2 and Block 3)	26,834 MWh/year (100 %)
Environmental and social considerations	Noise is the largest because of high velocity revolution. However, noise is easily mitigated by covers since the frequency of noise is high.
Outlines of equipment	Block 2: 750 m^3/min x 67 kPa x 1,070 kW x 4 nos. (1 standby) Block 3: 750 m^3/min x 67 kPa x 1,070 kW x 4 nos. (1 standby)
Initial investment	Blower for Block 2: 8.53 Million Euro Blower for Block 3: 8.53 Million Euro Total: 17.06 Million Euro (100 %)
O&M cost	Electricity: 3.22 Million Euro/ year Maintenance: 0.27 Million Euro/ year Total: 3.49 Million Euro/ year (100 %)
Net present value	61.91 Million Euro (100 %)
Selection	Selected by advantages mentioned in 4.3.4

Net present value: Discount rate = 7.8% / period = 30year

Source: JICA Study Team

Table 4.52 Comparison of Blower (2)

	Direct-coupling single stage turbo blower (Japanese product)
Explanation of blower	Impellers which are connected to main shafts of motors are contactless by magnetic bearings. Increase of rotation of impellers is conducted by frequency control of the motors.
Flow control	Flow control is conducted by frequency control and inlet vane control. Range of flow control from 45% to 100% of the rated capacity is expected.
Driving system	Direct coupling to high revolution motor (VVVF)
Lubrication method	Not necessary
Cooling method	Air-cooling method
Noise and vibration	Least noise and vibration is expected owing to contactless bearings.
Efficiency	Efficiency is slightly higher owing to magnetic bearings. Flow control with keeping high efficiency is possible by combining frequency control and inlet vane control.
Reliability	Larger clearance is kept owing to magnetic bearings. Hence, troubles caused by fraction and foreign material are less. Reliability is high since magnetic bearings do not wear out.
Operation and maintenance	Operation is easy since protective devices detect many kinds of abnormal operating conditions. Maintenance costs less since the blowers do not require lubrication devices and cooling devices.
Replacement of the existing blowers	It is possible to replace the existing blowers since size of blower is smaller than gear-drive single stage turbo blower.
Power consumption (Block 2 and Block 3)	28,565 MWh/year (106 %)
Environmental and social considerations	Noise and vibration is the least owing to contactless bearings.
Outlines of equipment	Block 2: 300 m^3/min x 67 kPa x 400 kW x 9 nos. (1 standby) Block 3: 300 m^3/min x 67 kPa x 400 kW x 9 nos. (1 standby)
Initial investment	Blower for Block 2: 10.41 Million Euro Blower for Block 3: 10.41 Million Euro Total: 20.83 Million Euro (122 %)
O&M cost	Electricity: 3.43 Million Euro/ year Maintenance: 0.33 Million Euro/ year Total: 3.76 Million Euro/ year (108 %)
Net present value	69.85 Million Euro (113 %)
Selection	-

Net present value: Discount rate = 7.8% / period = 30year

Source: JICA Study Team

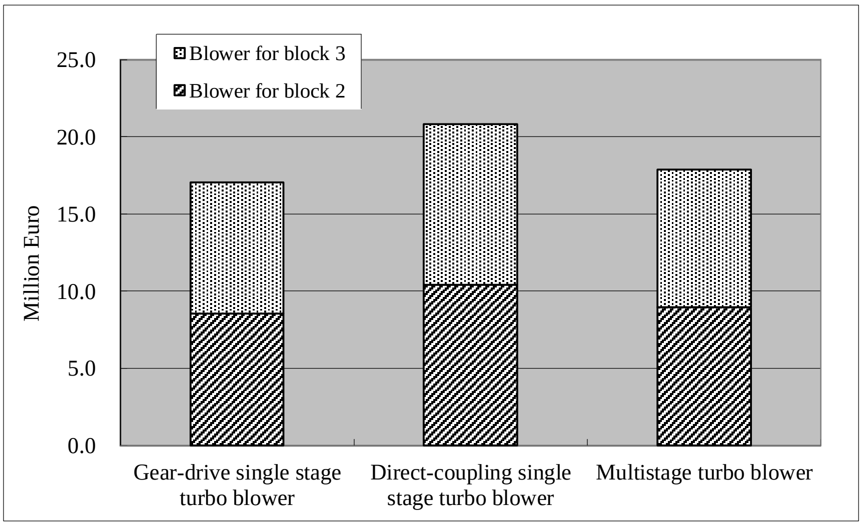
Table 4.53 Comparison of Blower (3)

	Multistage turbo blower (Japanese product)
Explanation of equipment	Impellers are directly connected to main shafts of motors without speed up gears. Hence, rotation of impellers is the same as the revolution of motors. Multiple stages of impellers are required so as to gain high pressure.
Flow control	Flow control is conducted by inlet vane control. Range of flow control from 30% to 100% of the rated capacity is expected.
Driving system	Direct coupling to general motor
Lubrication method	Centralized lubrication method
Cooling method	Water-cooling method by circulating potable water
Noise and vibration	Less noise is expected comparing to gear-drive single stage turbo blower.
Efficiency	Range of flow control is large compared to that of single stage turbo blower. However, efficiency is lower than that of single stage turbo blower in wide range of operation.
Reliability	Larger clearance is necessary because of deflection caused by longer main shaft since the impeller is multistage. Many labyrinth seal increases risk of fraction and performance decrement.
Operation and maintenance	Regular recoding of temperature and pressure is necessary since protective device is not equipped. More maintenance work is required due to multiple stages of closed impeller.
Replacement of the existing blowers	It is difficult to replace the existing blowers since multistage turbo blower is larger and heavier than the existing blowers.
Power consumption (Block 2 and Block 3)	26,834 MWh/year (100 %)
Environmental and social considerations	Noise is less than single stage turbo blower. However, attention not to cause sympathetic vibration with the buildings is necessary.
Outlines of equipment	Block 2: 750 m^3/min x 67 kPa x 1,070 kW x 4 nos. (1 standby) Block 3: 750 m^3/min x 67 kPa x 1,070kW x 4 nos. (1 standby)
Initial investment	Blower for Block 2: 8.94 Million Euro Blower for Block 3: 8.94 Million Euro Total: 17.88 Million Euro (105 %)
O&M cost	Electricity: 3.22 Million Euro/ year Maintenance: 0.29 Million Euro/ year Total: 3.51 Million Euro/ year (100 %)
Net present value	63.12 Million Euro (102 %)
Selection	-

Net present value: Discount rate = 7.8% / period = 30year

Source: JICA Study Team

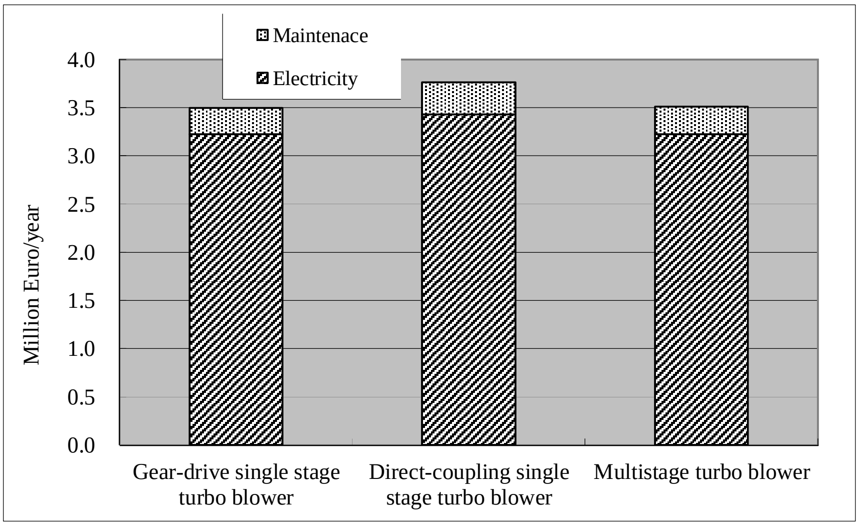
The initial investment of alternatives is analyzed as shown in Figure 4.12. The largest capacity of direct-coupling single stage blower is 300m^3/min. Hence, this type of blower requires 18 nos. in total, while the other types of blower require 8 nos. in total since larger capacity can be manufactured. Therefore, initial investment of direct-coupling single stage blower is the lowest due to the number of blowers.



Source: JICA Study Team

Figure 4.12 Initial Investment

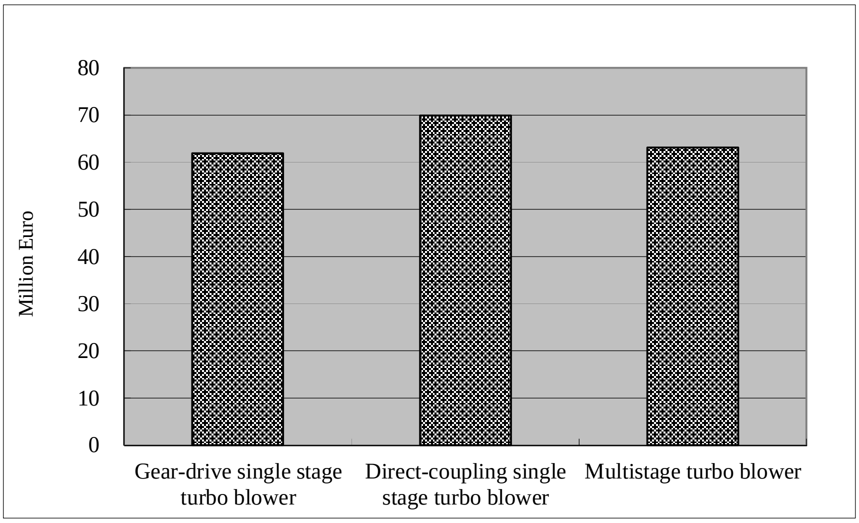
The O&M cost of alternatives was analyzed as shown in Figure 4.13. Electricity expenses of gear-drive single stage turbo blower and multistage blower is lower than that of direct-coupling single stage blower owing to slightly better efficiency resulting from larger capacity.



Source: JICA Study Team

Figure 4.13 O&M Cost

The net present value of alternatives is analyzed as shown in Figure 4.14. Gear-drive single stage turbo blower is the most economical in terms of net present value.

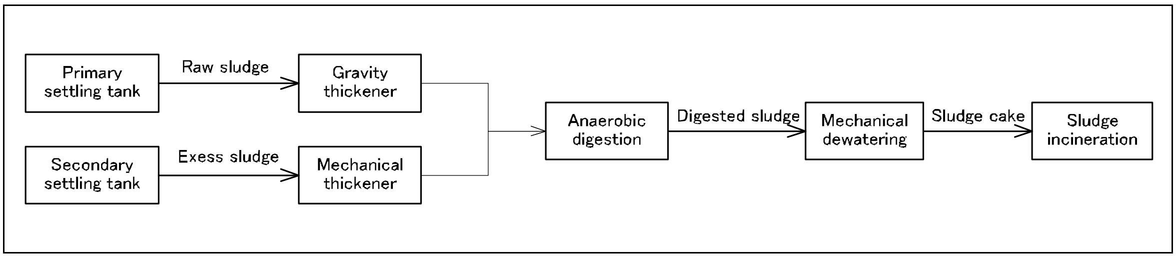


Source: JICA Study Team

Figure 4.14 Net Present Value

4.4 Selection of Sludge Treatment Process

One of the principles of sewage treatment is to treat sludge produced from sewage treatment stably and efficiently on a permanent basis. As for 2012 F/S, a process comprised of thickening, anaerobic digestion with biogas utilization, mechanical dewatering and incineration is adopted for sludge treatment process of Bortnychy WWTP. The sludge treatment process chosen in 2012 F/S is shown in Figure 4.15.



Source: JICA Study Team

Figure 4.15 Sludge Treatment Process of 2012 F/S

In this Study, the following studies are conducted in order to optimize sewage treatment process from the viewpoints of efficiency, sustainability and environmental aspect.

- Study of with/without anaerobic digestion processes
- Study of options for final disposal of sewage sludge

4.4.1 With/Without Anaerobic Digestion Process

Currently, BAS operates sludge treatment facilities for the purpose of transporting thickened and stabilized sludge to the external sludge fields. However, due to a lack of sludge field capacities and a need for additional reduction of volume, 2012 F/S proposes a comprehensive change of sludge treatment process including a new sludge thickening process and introductions of sludge dehydration and incineration.

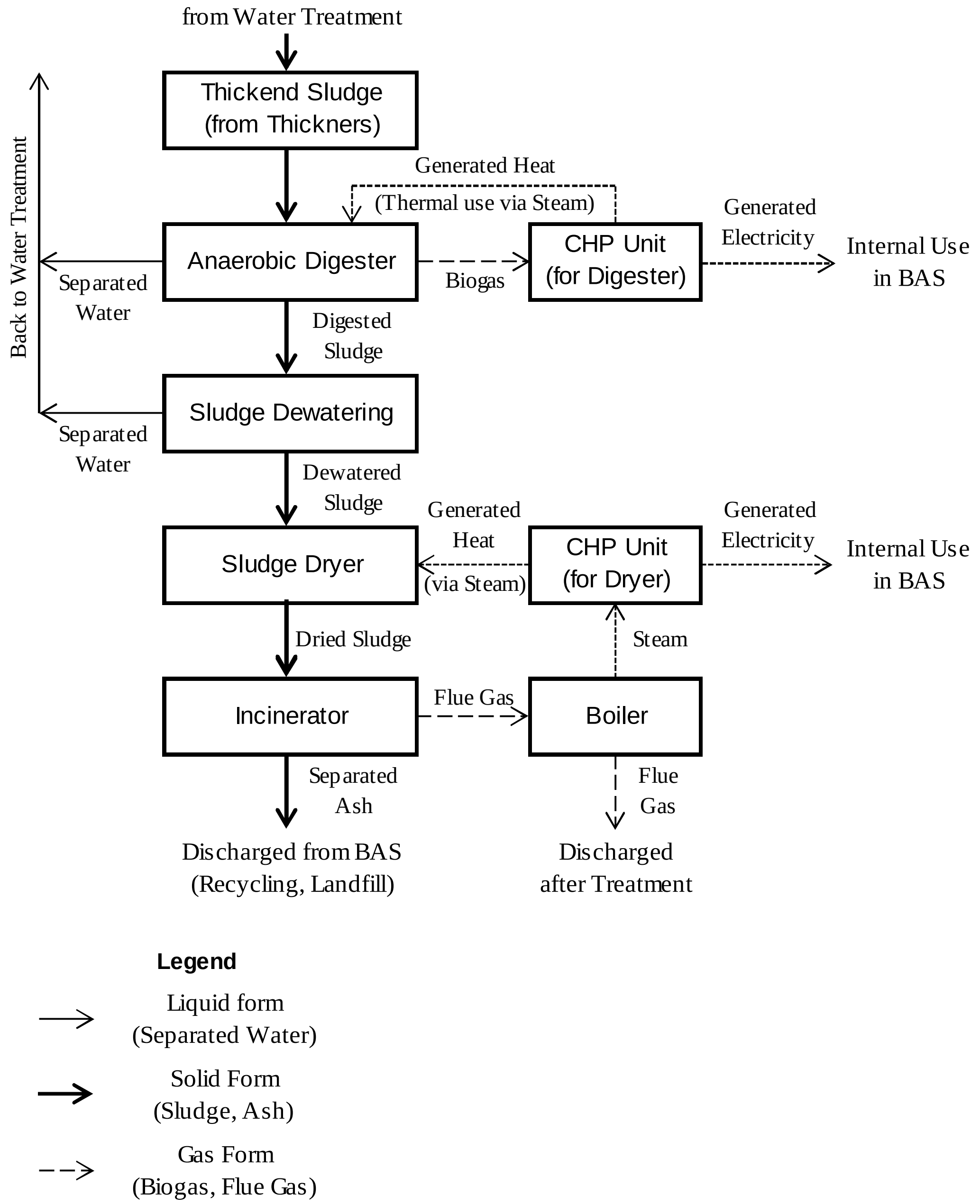
In the study, comparisons were taken into account in relation to anaerobic digestion process followed by cogeneration system equipped with generators using produced digested gas with the viewpoints of effectiveness and sustainability in daily operation. The combinations of compared treatment processes are listed below.

- Anaerobic digestion with cogeneration (CHP, Combined Heat and Power) system and sludge incineration
- Advanced incineration with generator, without digestion system

Additionally the comparison also considered the differences in the system flows after sludge thickening process, sludge dewatering processes were also compared simultaneously.

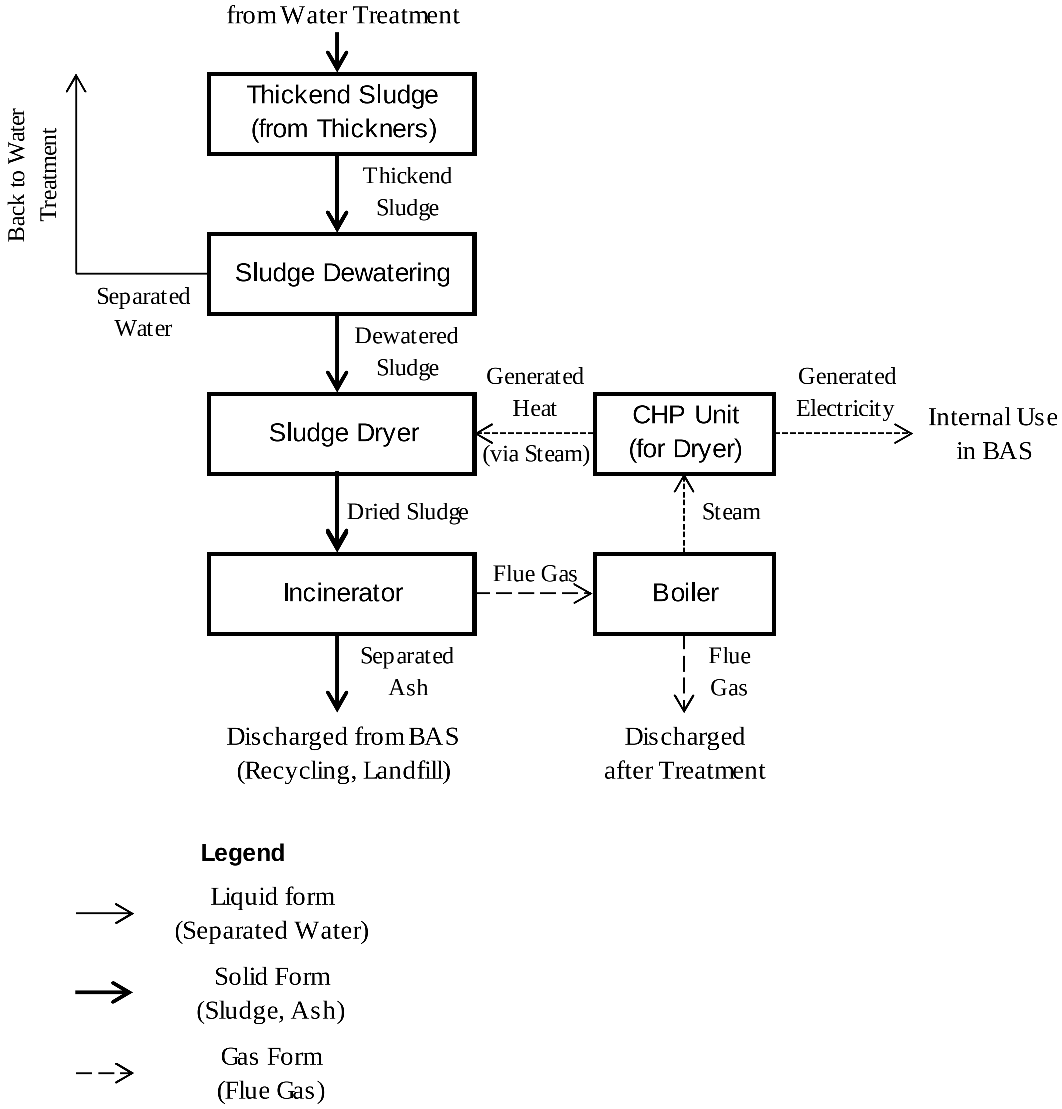
(1) Treatment Processes

The technical outlines of “anaerobic digestion with cogeneration system and sludge incineration” and “advanced incineration with generator” were summarized and shown in Figure 4.16 and Figure 4.17.



Source: KVK

Figure 4.16 Anaerobic Digestion with Cogeneration and Sludge Incineration



Source: JICA Study Team

Figure 4.17 Advanced Incineration with Generator

(2) Conditions for Comparisons

The viewpoints for comparison are selected as shown below.

- Comparing at the design capacity to 2030, without considering the transitions in population and water usage (generation of sewage)
- Initial investments are assumed in Japanese standard costs in order to compare system wide
- The main specifications and design standards are also based on Japanese technologies because of assumption that the project is to be covered under STEP (Special Terms for Economic Partnership) conditions

(3) Results of Comparison

(A) Difference in Solid Component in Dimensioning Equipment

In order to compare the efficiency of treatment processes, it is necessary to determine the differences of solid weights of sludge being applied into respective processes. The system without anaerobic digestion process receives sludge directly from thickening process into latter stage of treatment processes. Then, the solid weight becomes larger and the ancillary ratio preliminarily reaches up to 1.5 times compared to the system using digestion units according to the calculation.

Comparisons of energy balance for both of cases showed that the generated energy in the case of “Anaerobic digestion with cogeneration system and sludge incineration” turned out predominant in terms of the volume of generated heat/electricity from the system because of relatively higher organic content anticipated after the chemical analysis of existing sewage compositions in the design flow condition. The comparisons of solid weight for sludge treatment processes are summarized in Table 4.54

Table 4.54 Comparisons of Solid Weight for Sludge Treatment Processes

Unit: kgDS/day

Item	Incineration With Digestion	Incineration Without Digestion	Ratio
	(1)	(2)	(3)=(2)/(1)
Solid Weight for Thickening Process	424,451	425,256	100.2%
Solid Weight for Dewatering Process	280,307	429,509	153.2%
Solid Weight for Incineration	260,686	408,034	156.5%

Weight of Thickening Process differed because of considering return loads through the process

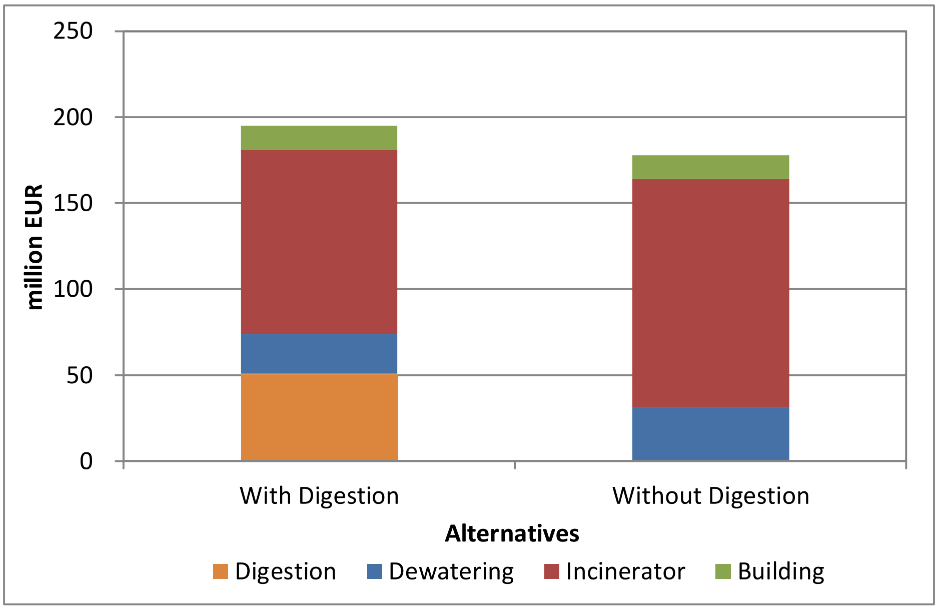
Source: JICA Study Team

(B) Initial and O&M Costs

Comparison of costs was performed under the assumption that the project is implemented under STEP (Special Terms for Economic Partnership) conditions and the calculations were considered employing Japanese technologies and specifications, and initial cost, operation and maintenance cost and net present values in total costs were compared respectively.

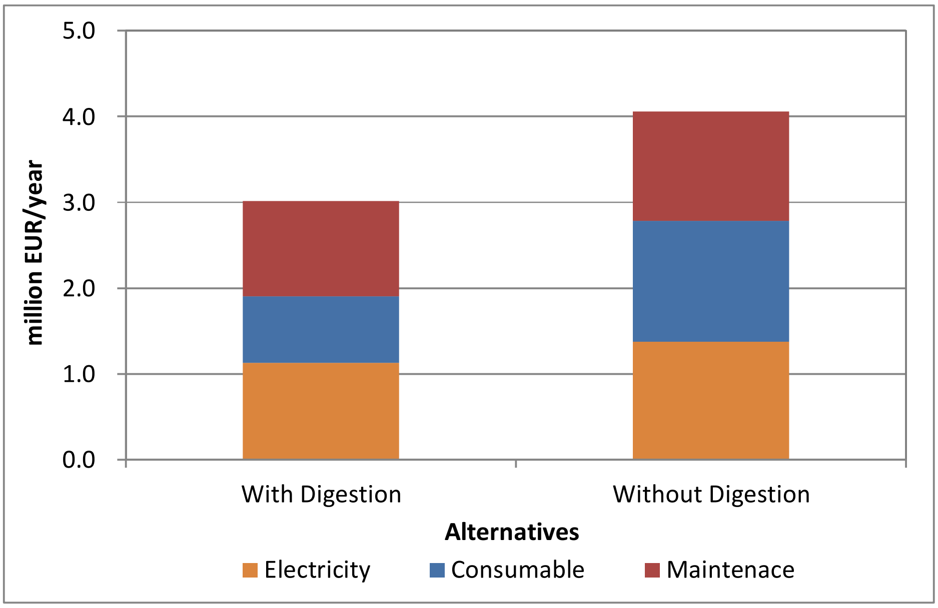
The results turned out that the case of “advanced incineration with generator” showed its predominance in higher energy saving characteristics.

The results of comparison in construction cost, operation and maintenance cost, net present value (period for 30 years) are shown in Figure 4.18, Figure 4.19, Figure 4.20 respectively.



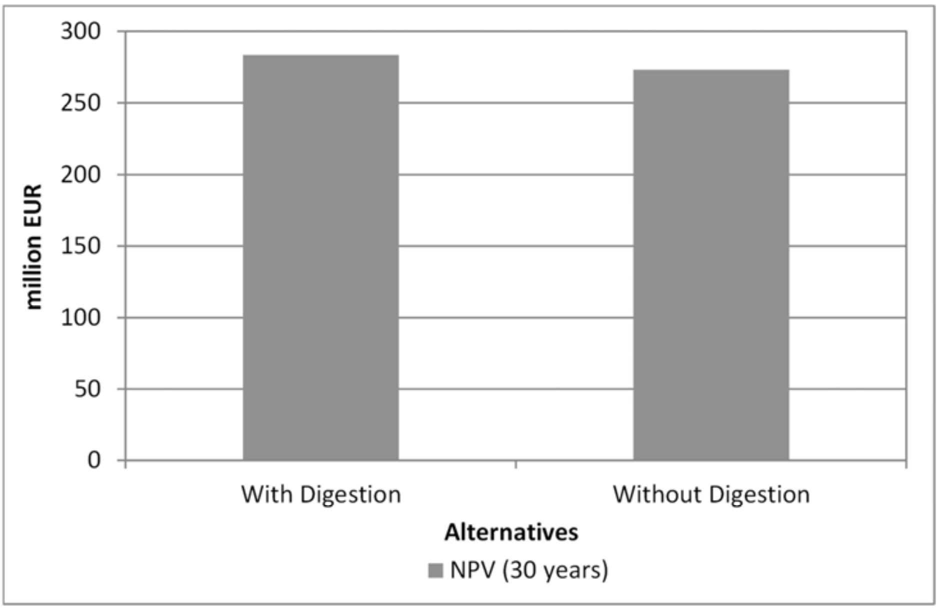
Source: JICA Study Team

Figure 4.18 Comparisons of Construction Costs



Source: JICA Study Team

Figure 4.19 Comparisons of Operation and Maintenance Costs



Source: JICA Study Team

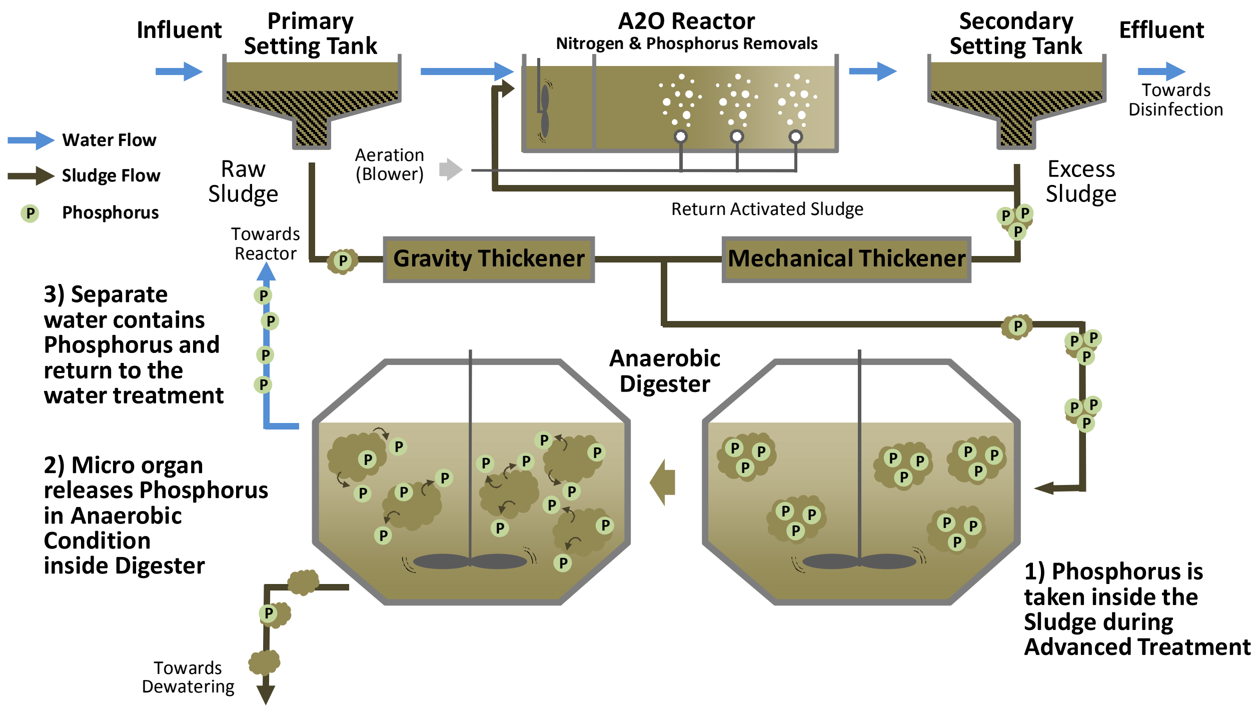
Figure 4.20 Comparisons of Net Present Values

(C) Impact on Phosphorus Removals in Treated Water

As for the design effluent criteria in the project, total phosphorus is targeted at 1 mg/L. In recent years phosphorus has transited relatively stable compared to other main indices for sewage treatment, but instead, the trend of decreasing unit water consumption is affecting increase of concentration of sewage components and therefore the removal of phosphorus is stated as one of the most pressing problems by BAS.

In the wastewater treatment process, phosphorus is generally removed by the phenomenon of uptake by microorganisms contained in sludge component and separated by settling process. The biological treatment process employed by the Anaerobic–Anoxic–Oxic Process (A2O Process) treats phosphorus by excessive uptake phenomenon of microorganisms in aerobic conditions, however the release of phosphorus into liquid phase occurs in anaerobic conditions. Therefore, in terms of the removal by the help of biological treatment process, the presence of anaerobic digestion process will have an adverse effect.

The general behavior of phosphorus component in anaerobic digestion is narrated in Figure 4.21.



Source: JICA Study Team

Figure 4.21 General Behavior of Phosphorus in Anaerobic Digestion Process

(D) Summary of Comparisons

The study eventually proposes "advanced incineration with generator" based on the following reasons.

- The said combination has shown best results in terms of project cost
- Possibility of interference of anaerobic digestion process with biological phosphorus removal
- Some of equipment proposed in 2012 F/S for anaerobic digestion is not commonly applied in Japanese practices and it cannot be contained in the process flow using Japanese products when the STEP (Special Terms for Economic Partnership) conditions are deemed as prerequisite
- The system using digestion process requires complicated procedures to maintain the system fully functional throughout the season as well as a commencement period of the system which needs to consider lower productivity until the time when design flow comes to BAS

4.4.2 Final Disposal of Sewage Sludge

Disposal of sewage sludge produced from sewage treatment continues on a permanent basis and amount of sewage sludge will increase along with the development of sewer system. Final disposal of sewage sludge should be considered mainly from the viewpoints of sustainability and mitigation of environmental impact. Nowadays, utilization of sewage sludge is encouraged so as to assist the establishment of material recycling society.

(1) Final Form of Sewage Sludge

The final form of sewage sludge is ash since the sludge treatment process includes incineration. Ash is utilized as construction material since ash is composed of inorganic materials after incineration. Those construction materials are usually used in urban construction works. Hence, use as construction materials is a desirable method of utilization in which the location of production matches the location of consumption.

Ash is classified into two types by chemicals used for mechanical dewatering process. One is ash containing polymer and the other is ash containing coagulant such as calcium hydroxide and ferric chloride. Sludge is planned to be dewatered by adding polymer to flocculate sludge prior to supply to mechanical dewatering machines. Hence, ash containing polymer is subject to utilization. The chemical composition of ash, which is assumed based on analysis on characteristics of sludge from BAS, are shown in Table 4.55.

Table 4.55 Chemical Compositions of Ash

(Dry-%)

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	TiO_2	P_2O_5	Cl
41.73	7.25	5.45	16.86	3.45	2.27	3.23	0.72	17.23	0.41
CrO_3	MnO	NiO	CuO	ZnO	Pb_2O	SrO	ZrO	BaO	S
0.08	0.10	0.02	0.08	0.22	0.01	0.06	0.03	0.09	0.69

Source: JICA Study Team

(2) Utilization of Sewage Sludge

Utilization of ash containing polymer is classified into two methods. One is utilization to use ash as ingredient and the other is utilization to use ash as raw material to produce the products. Utilization methods using ash as ingredient of cement and asphalt mixture are summarized in Table 4.56 and Table 4.57, respectively.

Table 4.56 Ingredient of Cement

<table>
<tr><th>Explanation of utilization as ingredient of cement</th></tr>
<tr><td>The chemical components of ash are generally similar to those of clay ingredient for cement. Hence, ash is utilized to produce cement as a substitute of clay. Cement is mainly made from limestone ($CaCO_3$), clay (SiO_2, Al_2O_3, Fe_2O_3), silica (SiO_2) and ferric oxide (Fe_2O_3). Cement is produced by mixing those ingredients in a prescribed proportion, drying and clashing, burning at approximately 1,450 degree C and mixing calcium sulfate. Utilization of ash may cause negative influence on the quality of cement. The components which may cause deterioration of cement are shown below.
<table>
<tr><th colspan="2">Components negatively influence to quality of cement</th></tr>
<tr><td>Phosphorus (P_2O_2)</td><td>Cause deterioration of strength if content of phosphorus exceeds 0.5 %</td></tr>
<tr><td>Chlorine (Cl)</td><td>Cause corrosion of re-bar if considerable amount of chlorine is contained</td></tr>
<tr><td>Alkalinity (R_2O)</td><td>Cause caustic erosion of aggregates if alkalinity is considerably high</td></tr>
<tr><td>Heavy metals</td><td>Do not cause negative influence on general composition of ash</td></tr>
<tr><td>Component fluctuation</td><td>Cause flocculation of cement quality due to flocculation of components</td></tr>
</table>
Ash is transported from the wastewater treatment plant to cement factories by dump trucks in wet condition or tank trucks in dry condition.</td></tr>
</table>

Source: JICA Study Team

Table 4.57 Ingredient of Asphalt Mixture

<table>
<tr><th>Explanation of utilization as ingredient of asphalt filler</th></tr>
<tr><td>Ash is utilized as an asphalt filler. The asphalt mixture which is used for base layer and surface layer of asphalt pavement, is made from bituminous materials, aggregates and asphalt fillers and is produced by heating and mixing those ingredients. The asphalt filler fills empty space between coarse aggregates and fine aggregates and enhances stability of asphalt mixture. The asphalt filler is a powder of mineral substance, 90 % of which passes through 0.075mm mesh and limestone powder is usually used. Preferable conditions to use ash as asphalt filler are shown below.
<table>
<tr><th>Item</th><th>Condition</th><th>Item</th><th>Condition</th></tr>
<tr><td>Plastic index</td><td>Less than 4</td><td>Flow</td><td>Less than 50 %</td></tr>
<tr><td>Swelling rate</td><td>Less than 3 %</td><td>Exfoliation</td><td>Less than 1/4</td></tr>
</table>
Asphalt mixture is in constant demand due to new installation, replacement and repair of asphalt pavement. Hence, use as asphalt filler is a method of utilization that ensures stable demand for a long period of time.</td></tr>
</table>

Source: JICA Study Team

Options for utilization of ash as raw material for concrete products and calcination products are summarized in Table 4.58 and Table 4.59, respectively.

Table 4.58 Concrete Products

<table>
<tr><th colspan="2">Explanation of utilization as concrete products</th></tr>
<tr><td colspan="2">Ash is utilized to produce concrete products such as interlocking blocks, reinforced concrete pipes, street gully, concrete curb and system manhole. Those concrete products are produced by mixing ingredients including ash, forming of the products and aging. The concrete products which are produced utilizing ash are shown below. Interlocking blocks have several types including normal interlocking blocks, interlocking blocks with water permeability, interlocking blocks for vegetation and warming interlocking blocks for visually disabled persons.</td></tr>
<tr><td>
Interlocking block</td><td>
Reinforced concrete pipe</td></tr>
<tr><td>
Street gully</td><td>
System manhole</td></tr>
</table>

Source: JICA Study Team

Table 4.59 Calcination Products

Explanation of utilization as calcination products	
Ash is utilized to produce calcination products such as tiles, bricks, clay pipes, aggregate and soil improvement material. Calcination products which are produced utilizing ash are shown below. Bricks have several types including normal bricks, interlocking bricks and bricks having water permeability. Aggregates have several types including lightweight aggregates and paving aggregates.	
 Tile	 Brick
 Soil improvement material	 Aggregate

Source: JICA Study Team

It is recommended to consider multiple options of utilization in order to ensure sustainable and stable disposal of sewage sludge.

(3) Market Research

In order to ensure sustainable utilizations of sewage sludge as construction materials, it is inevitable to find utilization options showing stable demand for a long period of time. Hence, it is important to conduct market research to understand the possibility of utilization, market scale, demand estimates, willingness to pay for the products, marketing routes and so forth.

Therefore, KVK is required to conduct market research to assess which kind of utilization is suitable for the local market before the implementation of the project. Viewpoints of market research are summarized in Table 4.60.

Table 4.60 Viewpoints of Market Research

	Research contents
Analysis of demand	Understanding scale and environment of the market ➢ Quantity demanded (scale of market, forecasting, etc.) ➢ Users (buying motivation, etc.) ➢ Compatibility with requirement of users ➢ Others
Analysis of sales efficiency	Understanding marketing method and routes of the products ➢ Marketing routes (channel of distribution, etc.) ➢ Marketing methods (business activities, ordering, after service, etc.) ➢ Users (buying motivation, etc.) ➢ Sales promotion (advertising, sale promotion, etc.) ➢ Necessity and selection of channel of distribution ➢ Others
Analysis of business environment	Understanding the business environment ➢ Socio-economic environment (economic conditions, industry forecasting, future prospect of industries, etc.) ➢ Sales competition ➢ Trend of business conditions ➢ Influences of other markets ➢ Influences of politics, legislation, etc. ➢ Others

Source: JICA Study Team

The results of interviews conducted by KVK are summarized in Chapter 3 of Appendix.

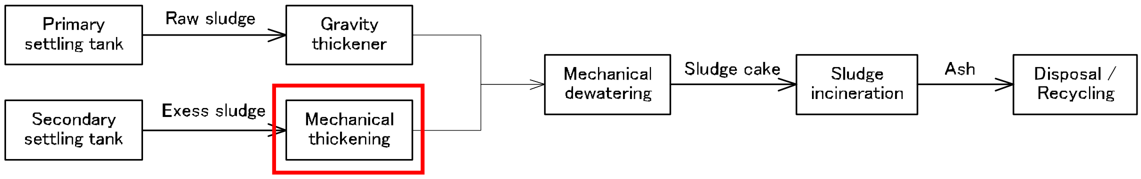
4.5 Selection of Sludge Treatment Equipment

4.5.1 Alternatives of Mechanical Thickener

The F/S recommends belt type thickeners as the mechanical thickeners for BAS. There are other types of mechanical thickeners which can be potential alternatives for BAS. Alternatives including newly developed technology of screw type thickener and conventional types of mechanical thickener are listed below. A brief explanation of newly developed technology is shown in Table 4.61.

- ➢ Belt type thickener (Japanese product)
- ➢ Centrifugal type thickener
- ➢ Screw type thickener (Japanese product)

Table 4.61 Explanation of Newly Developed Technology

<table>
<tr><th colspan="3">Explanation</th></tr>
<tr><td colspan="3">
Mechanical thickener thickens excess sludge, which is low concentration sludge generated from secondary settling tanks, by lowering water content (removing water) in order to carry out following process efficiently.</td></tr>
<tr><td>Screw type thickener (Japanese product)</td><td>Screw type thickener requires less energy compared to other conventional mechanical thickeners. This machine can thicken by low-speed rotation so that the sludge can be thickened using low energy and in an efficient way.</td><td></td></tr>
</table>

Source: JICA Study Team

4.5.2 Comparison of Mechanical Thickeners

The comparison of alternatives is summarized in Table 4.62, Table 4.63 and Table 4.64. As a result of comparison, belt type thickener (Japanese product) is recommended due to the following advantages.

- Operation and maintenance cost is the least owing to lowest energy consumption and maintenance cost.
- Initial investment is the lowest.
- Maintenance is relatively easy and is handled at the site by maintenance staff.
- Belt type thickener can achieve stable operation by adjusting running speed of belts, dosing rate of coagulant and feeding amount of sludge according to characteristics of excess sludge.
- It is the most economical option in terms of net present value.

Table 4.62 Comparison of Mechanical Thickener (1)

	Belt type thickener (Japanese product)
Thickening mechanism	Belt type thickeners thicken flocculated excess sludge using reticulated belts by gravity. Belt type thickeners are comprised of filtration devices, flocculation devices and control panels.
Outline of design criteria	Concentration of thickened sludge: 4.0-5.0 % Recovery rate of sludge: 95 % Dosing rate of coagulant: 0.3 %
Outline of mechanical thickener	Thickening capacity: 150 m^3/hour Number: 9 nos. (1 standby)
Required space	952 m^2 (Mechanical thickener only)
Operation	Belt type thickeners can adjust running speed of belts, dosing rate of coagulant, feeding amount of sludge according to the characteristics of excess sludge.
Maintenance	Belt type thickeners require replacement of belts every 12,000 of operation hours. The replacement of belts can be carried out at the site by the maintenance staffs.
Washing water	Belt type thickeners require washing belts continuously during the operation.
Noise and vibration	Belt type thickeners do not cause noise or vibration owing to slow speed movement.
Environmental and social considerations	Emission of greenhouse gas is least since energy consumption is least. Odor problem is mitigated by attaching covers.
Initial investment	Equipment: 5.83 Million Euro Building: 1.05 Million Euro Total: 6.88 Million Euro (100 %)
O&M cost	Electricity: 0.04 Million Euro/ year Coagulant: 1.34 Million Euro/ year Maintenance: 0.08 Million Euro/ year Total: 1.46 Million Euro/ year (100 %)
Net present value	25.23 Million Euro (100 %)
Selection	Selected by advantages mentioned in 4.5.2

Net present value: Discount rate = 7.8% / period = 30year

Source: JICA Study Team

Table 4.63 Comparison of Mechanical Thickener (2)

	Centrifugal type thickener
Thickening mechanism	Centrifugal type thickeners thicken excess sludge using a centrifugal force which is generated by rotating external cylinders without dosing of coagulant. Centrifugal type thickeners are comprised of external cylinders, screws, differential driving devices and control panels.
Outline of design criteria	Concentration of thickened sludge: 4.0 % Recovery rate of sludge: 90 % Dosing rate of coagulant: 0 %
Outline of mechanical thickener	Thickening capacity: 150 m^3/hour Number: 9 nos. (1 standby)
Required space	1,080 m^2 (Mechanical thickener only)
Operation	Centrifugal type thickeners can adjust rotating speed of cylinders, differential rate, height of weir, feeding amount of sludge according to the characteristics of excess sludge.
Maintenance	Centrifugal type thickeners require replacement of edges every 12,000 of operation hours. The machines need to be taken to the manufacturer factories for replacement of edges.
Washing water	Centrifugal type thickeners require washing inside of cylinders once a day. Washing time is around ten minutes. Therefore, centrifugal type thickeners consume little water.
Noise and vibration	Centrifugal type thickeners require preventive measures for noise and vibration because of high speed of cylinder rotation.
Environmental and social considerations	Emission of greenhouse gas is the highest since energy consumption is high comparing the other machines. Noise problem is more considerable than in other solutions.
Initial investment	Equipment: 6.08 Million Euro Building: 1.19 Million Euro Total: 7.26 Million Euro (106 %)
O&M cost	Electricity: 1.49 Million Euro/ year Coagulant: 0.00 Million Euro/ year Maintenance: 0.19 Million Euro/ year Total: 1.68 Million Euro/ year (115 %)
Net present value	28.21 Million Euro (112 %)
Selection	-

Net present value: Discount rate = 7.8% / period = 30year

Source: JICA Study Team

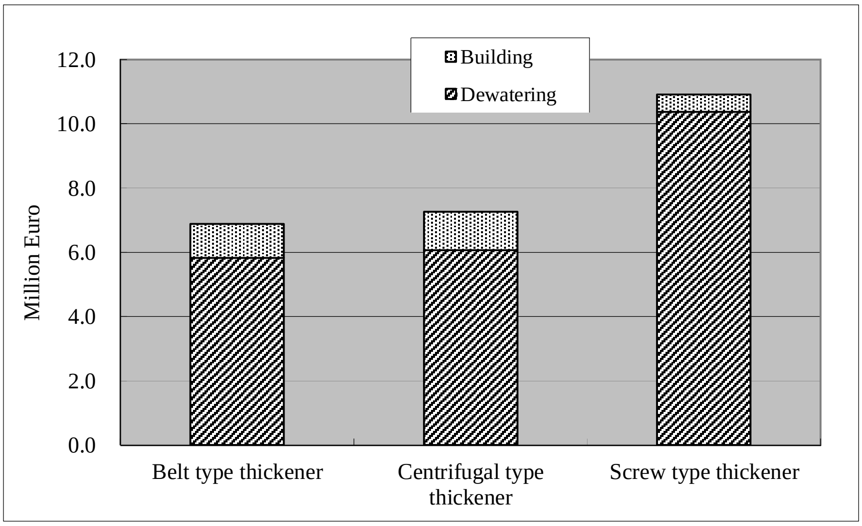
Table 4.64 Comparison of Mechanical Thickener (3)

	Screw type thickener (Japanese product)
Thickening mechanism	Screw type thickeners thicken by filtering flocculated excess sludge with screws and perforated metal screens. Screw type thickeners are comprised of screws, outer screens, washing devices, driving devices, flocculation devices and control panels.
Outline of design criteria	Concentration of thickened sludge: 4.0 % Recovery rate of sludge: 95 % Dosing rate of coagulant: 0.3 %
Outline of mechanical thickener	Thickening capacity: 180 m^3/hour Number: 8 nos. (1 standby)
Required space	490 m^2 (Mechanical thickener only)
Operation	Screw type thickeners can adjust the rotating speed of screws and screens, dosing rate of coagulant and feeding amount of sludge according to characteristics of excess sludge.
Maintenance	Screw type thickeners require replacement of screens every 40,000 of operation hours. The replacement of screens can be carried out at the site but requires supervision of the manufacturer.
Washing water	Screw type thickeners require washing screens continuously or intermittently during the operation. Screw type thickeners require less washing water but better water quality than filtrate is required.
Noise and vibration	Screw type thickeners do not cause noise and vibration owing to slow speed movement.
Environmental and social considerations	Emission of greenhouse gas is less since energy consumption is low.
Initial investment	Equipment: 10.37 Million Euro Building: 0.54 Million Euro Total: 10.91 Million Euro (159 %)
O&M cost	Electricity: 0.07 Million Euro/ year Coagulant: 1.34 Million Euro/ year Maintenance: 0.09 Million Euro/ year Total: 1.50 Million Euro/ year (103 %)
Net present value	31.05 Million Euro (123 %)
Selection	-

Net present value: Discount rate = 7.8% / period = 30year

Source: JICA Study Team

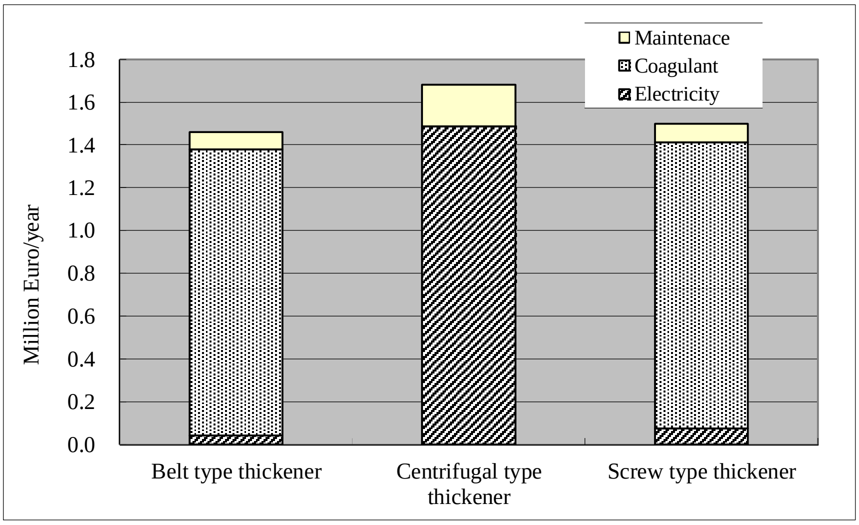
The initial investment of alternatives is analyzed as shown in Figure 4.22. The initial investment of belt type thickener is the lowest.



Source: JICA Study Team

Figure 4.22   Initial Investment

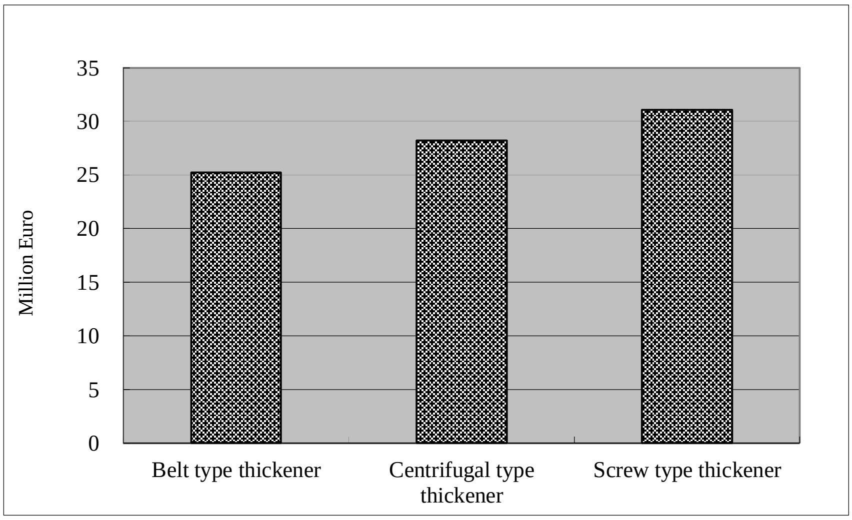
O&M cost of alternatives is analyzed as shown in Figure 4.23. O&M cost of belt type thickener is the lowest owing to the least electricity and maintenance expenses.



Source: JICA Study Team

Figure 4.23   O&M Cost

Net present value of alternatives is analyzed as shown in Figure 4.24. Belt type thickener is the most economical in terms of net present value.



Source: JICA Study Team

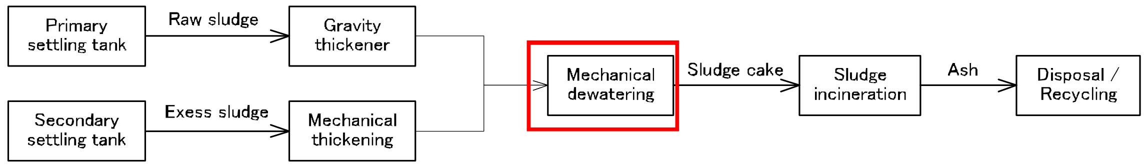
Figure 4.24 Net Present Value

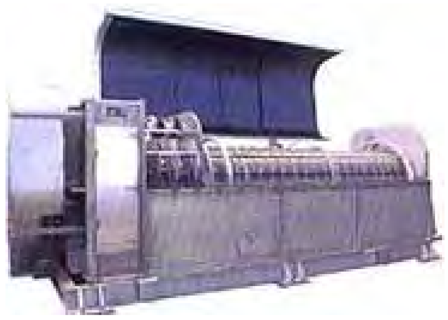
4.5.3 Alternatives of Mechanical Dewatering Machine

The F/S recommends centrifugal dewatering machines as the mechanical dewatering machine for BAS. There are other types of mechanical dewatering machines which can be potential alternatives for BAS. Alternatives including the newly developed technology of screw press dewatering machine and the conventional types of dewatering machine are listed below. A brief explanation of newly developed technology is shown in Table 4.65.

- Belt press dewatering machine
- Centrifugal dewatering machine
- Screw press dewatering machine (Japanese product)

Table 4.65 Explanation of Newly Developed Technology

<table>
<tr><th colspan="3">Explanation</th></tr>
<tr><td colspan="3">

A dewatering machine produces sludge cake by removing water contents contained in liquid sludge from thickening process in order to carry out incineration of sludge efficiently.</td></tr>
<tr><td>Screw press dewatering machine (Japanese product)</td><td>The screw press dewatering machine requires less energy compared to other conventional dewatering machines. This machine can thicken, filter and compress the conveyed sludge by low-speed rotation so that the sludge can be dewatered using low energy and in an efficient way.</td><td></td></tr>
</table>

Source: JICA Study Team

4.5.4 Comparison of Mechanical Dewatering Machine

The comparison of alternatives is summarized in Table 4.66, Table 4.67 and Table 4.68. As a result of comparison, the screw press dewatering machine (Japanese product) is recommended due to the following advantages.

- Operation and maintenance cost is the least due to lowest energy consumption and maintenance cost.
- Maintenance is relatively easy since belt press requires periodical replacement of belts and centrifugal dewatering machine requires to be taken to factories to replace edges.
- Screw press can optimize the operation by adjusting screw rotation speed, dosing rate of coagulant, mixing speed of flocculation devices, feeding pressure, pressure of presser and feeding amount of sludge according to fluctuation of sludge characteristics.
- It is the most economical option in terms of net present value.

Table 4.66 Comparison of Mechanical Dewatering Machines (1)

	Belt press dewatering machine
Dewatering mechanism	Belt press dewatering machines dewater sludge by squeezing and shearing flocculated sludge with two belts, which are pressurized by rollers. Belt press dewatering machines are comprised of filtration devices, flocculation devices and control panels.
Outline of design criteria	Moisture content of sludge cake: 76 % Filtration ratio: 140 kg Dry Solid /m hour Recovery rate of sludge: 93 % Dosing rate of coagulant: 1.0 %
Outline of dewatering machine	Wide of belt 3.0 m Number: 48 nos. (5 standby)
Required space	4,493 m^2 (Dewatering machine only)
Operation	Belt press dewatering machines can adjust speed of belts, dosing rate of coagulant, feeding amount of sludge according to fluctuation of sludge characteristics.
Maintenance	Belt press dewatering machines require replacement of belts every 8,000 of operation hours. The replacement of belts can be carried out at the site by the maintenance staff.
Washing water	Belt press dewatering machines require washing belts continuously during the operation. Therefore, belt press dewatering machines consume much more water compared to the other machines.
Noise and vibration	Belt press dewatering machines do not cause noise and vibration owing to slow speed movement.
Environmental and social considerations	Emission of greenhouse gas is less since energy consumption is low. Odor problem is more considerable than with other options.
Initial investment	Equipment: 9.68 Million Euro Building: 4.49 Million Euro Total: 14.62 Million Euro (117 %)
O&M cost	Electricity: 0.32 Million Euro/ year Coagulant: 8.56 Million Euro/ year Maintenance: 0.69 Million Euro/ year Total: 9.57 Million Euro/ year (109 %)
Net present value	126.30 Million Euro (109 %)
Selection	-

Net present value: Discount rate = 7.8% / period = 30year

Source: JICA Study Team

Table 4.67 Comparison of Mechanical Dewatering Machine (2)

	Centrifugal dewatering machine
Dewatering mechanism	Centrifugal dewatering machines dewater sludge by centrifugal force which is generated by rotating external cylinders at a high speed. Centrifugal dewatering machines are comprised of external cylinders, screws, differential driving devices and control panels.
Outline of design criteria	Moisture content of sludge cake: 76 % Dewatering capacity: 56 (79*0.8) m^3/hour Recovery rate of sludge: 95 % Dosing rate of coagulant: 1.0 %
Outline of dewatering machine	Dewatering capacity: 70 m^3/h Number: 9 nos. (1 standby)
Required space	1,416 m^2 (Dewatering machine only)
Operation	Centrifugal dewatering machines can adjust rotating speed of cylinders, dosing rate of coagulant, pressure of presser, feeding amount of sludge according to fluctuation of sludge characteristics.
Maintenance	Centrifugal dewatering machines require replacement of edges every 12,000 hours of operation. The machines need to be taken to factories for replacement of edges.
Washing water	Centrifugal dewatering machines require washing inside of cylinders once a day. Washing time is around ten minutes. Therefore, centrifugal dewatering machines consume little water.
Noise and vibration	Centrifugal dewatering machines require preventive measures for noise and vibration due to a high speed rotation of cylinders.
Environmental and social considerations	Emission of greenhouse gas is the most since energy consumption is high compared to the other machines. Noise problem is more considerable than with other options.
Initial investment	Equipment: 7.84 Million Euro Building: 1.56 Million Euro Total: 9.40 Million Euro (75 %)
O&M cost	Electricity: 1.46 Million Euro/ year Coagulant: 8.56 Million Euro/ year Maintenance: 0.33 Million Euro/ year Total: 10.35 Million Euro/ year (117 %)
Net present value	129.37 Million Euro (111 %)
Selection	-

Net present value: Discount rate = 7.8% / period = 30year

Source: JICA Study Team

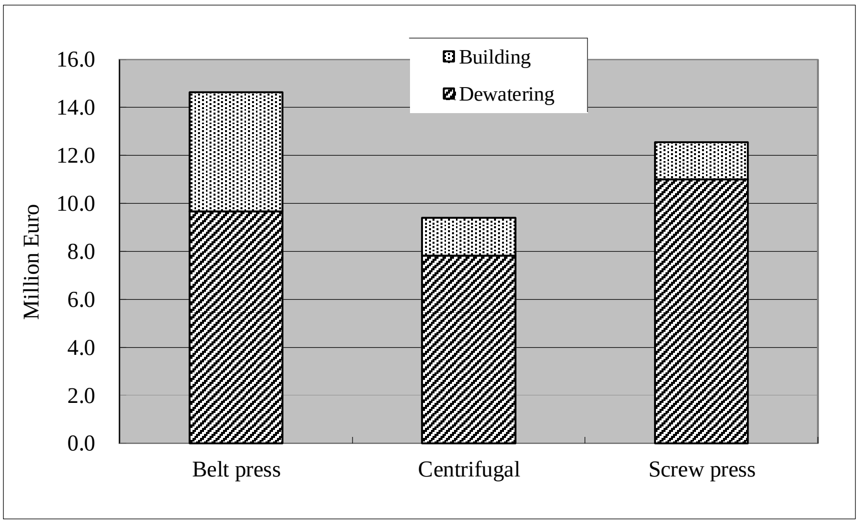
Table 4.68 Comparison of Mechanical Dewatering Machine (3)

	Screw press dewatering machine (Japanese product)
Dewatering mechanism	Screw press dewatering machines dewater sludge by squeezing flocculated sludge with screws and perforated metal screens. Screw press dewatering machines are comprised of screws, outer screens, pressers, driving devices, flocculation devices and control panels.
Outline of design criteria	Moisture content of sludge cake: 76 % Filtration ratio: 2,140 kg Dry Solid /hour Recovery rate of sludge: 95 % Dosing rate of coagulant: 1.0 %
Outline of dewatering machine	Diameter of screw: 1200 mm * 2 screws Number: 10 nos. (1 standby)
Required space	1,402 m^2 (Dewatering machine only)
Operation	Screw press dewatering machines can adjust rotating speed of screws, dosing rate of coagulant, mixing speed of flocculation devices, feeding pressure, pressure of presser and feeding amount of sludge according to fluctuation of sludge characteristics.
Maintenance	Screw press dewatering machines require replacement of screens every 30,000 of operation hours. The replacement of screens can be carried out at the site but require supervision of the manufacturer.
Washing water	Screw press dewatering machines require washing screens every 6-8 hours of operation. Washing time is around thirty minutes. Therefore, screw press dewatering machines consume little water.
Noise and vibration	Screw press dewatering machines do not cause noise and vibration owing to slow speed of movement.
Environmental and social considerations	Emission of greenhouse gas is the least since energy consumption is the least.
Initial investment	Equipment: 11.00 Million Euro Building: 1.54 Million Euro Total: 12.96 Million Euro (100 %)
O&M cost	Electricity: 0.12 Million Euro/ year Coagulant: 8.56 Million Euro/ year Maintenance: 0.14 Million Euro/ year Total: 8.82 Million Euro/ year (100 %)
Net present value	116.10 Million Euro (100 %)
Selection	Selected by advantages mentioned in 4.5.4

Net present value: Discount rate = 7.8% / period = 30year

Source: JICA Study Team

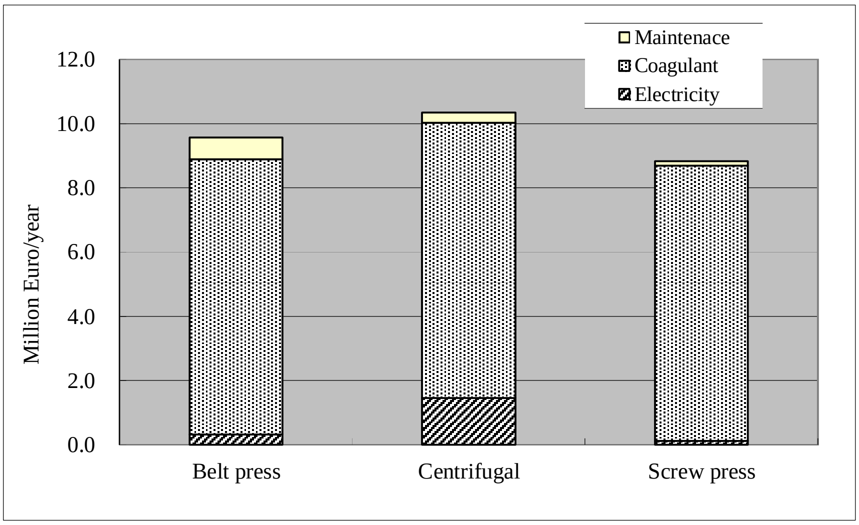
The initial investment of alternatives is analyzed as shown in Figure 4.25. The initial investment of centrifugal dewatering machine is the lowest.



Source: JICA Study Team

Figure 4.25 Initial Investment

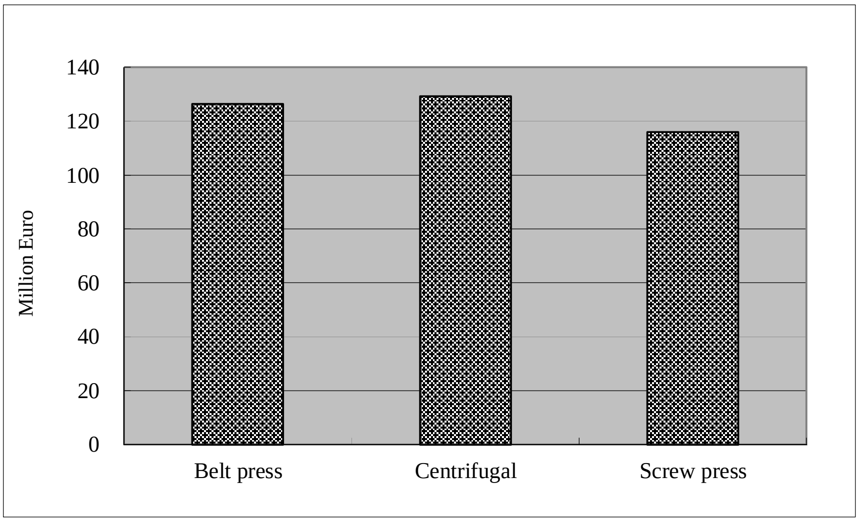
The O&M cost of alternatives is analyzed as shown in Figure 4.26. The O&M cost of screw press dewatering machine is the lowest owing to the least electricity and maintenance expenses. The screw press dewatering machine has longer operating life than the other options.



Source: JICA Study Team

Figure 4.26 O&M Cost

The net present value of alternatives is analyzed as shown in Figure 4.27. The screw press dewatering machine is the most economical in terms of net present value.



Source: JICA Study Team

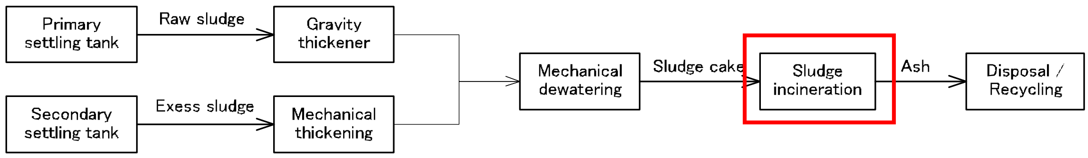
Figure 4.27 Net Present Value

4.5.5 Alternatives of Sludge Incinerator

The F/S recommends conventional fluidized bed incinerator (FBI) as sludge incinerator for BAS. There is a new type of sludge incinerator which can be potential alternatives for BAS. Alternatives including the newly developed technology of pressurized fluidized bed incinerator (PFBI) and the conventional type of sludge incinerator are listed below. A brief explanation of newly developed technology is shown in Table 4.69.

- Conventional fluidized bed incinerator (Japanese product)
- Pressurized fluidized bed incinerator (Japanese product)

Table 4.69 Explanation of Newly Developed Technology

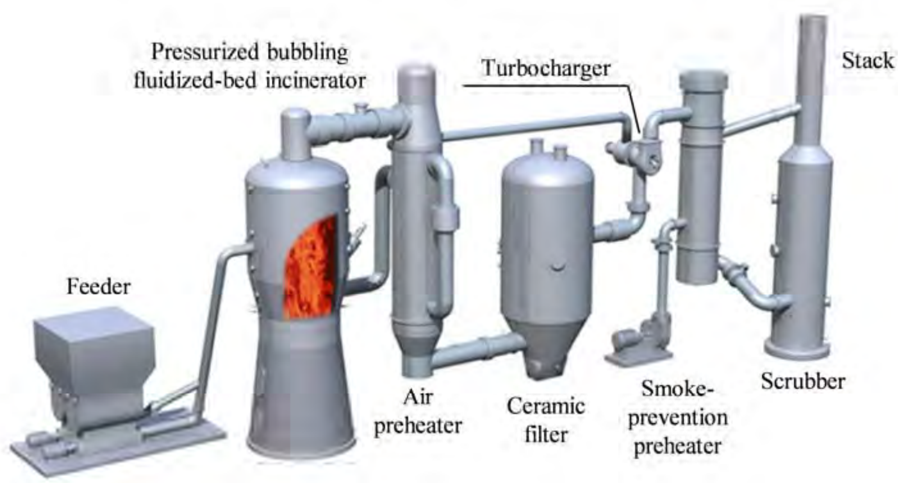
<table>
<tr><th colspan="3">Explanation</th></tr>
<tr><td colspan="3">

The sludge incinerator reduces volume of sludge by evaporating water contents contained in sludge cake and stabilizes characteristics of sludge by burning organic components contained in sludge cake.</td></tr>
<tr><td>Pressurized fluid bed incinerator (Japanese product)</td><td>PFBI is a newly developed sludge incinerator which combines a pressurized fluidized bed incinerator and a turbocharger driven by flue gas. Sludge cake is incinerated under positive pressure which is created by a turbocharger using flue gas from incinerator.</td><td></td></tr>
</table>

Source: JICA Study Team

4.5.6 Explanation of Pressurized Fluid Bed Incinerator

A schematic diagram of the PFBI is shown in Figure 4.28. The major characteristics of PFBI are pressurized combustion and utilization of turbocharger.



Source: JICA Study Team

Figure 4.28 Schematic Diagram of Pressurized Fluidized Bed Incinerator

The main advantages of the PFBI are summarized in Table 4.70.

Table 4.70 Advantages of Pressurized Fluidized Bed Incinerator

Advantage	Explanation
Compact facility	The sludge combustion reaction is improved since the partial pressure of oxygen in the incinerator is increased by the pressurization. Hence, the volume of the incinerator is substantially smaller than that of an FBI with the same incineration capacity. The volume of flue gas duct, air preheater and bag filter is reduced owing to reduction of flue gas volume. The inner diameter of the furnace is also reduced by 40% compared to that of the FBI.
Saving fuel consumption	The heat loss from surface of equipment is reduced owing to the compactness of the facility. Hence, consumption of supplementary fuel is reduced by 10% compared to that of FBI in the startup of operation.
Saving power consumption	Fluidized air blower is not required in steady operation since compressed air is supplied to the incinerator by using a turbocharger which is driven by flue gas. Induced draft fan is also not required since flue gas has positive pressure. Hence, consumption of electricity is reduced by 60% owing to omission of fluidized air blower and induced draft fan which consumes considerable amount of electricity.
Reduction of N_2O emission	Oxidation reaction is very active and combustion speed is fast owing to pressurized combustion and higher partial pressure of oxygen. Then, a high temperature combustion zone is formed. N_2O is decomposed owing to combustion in the higher temperature. As the result, emission of N_2O is reduced by 50% compared to that of FBI.

Source: JICA Study Team

4.5.7 Comparison of Sludge Incinerator

The comparison of alternatives is summarized in Table 4.71 and Table 4.72. As a result of comparison, pressurized fluidized bed incinerator (Japanese product) is recommended due to the following advantages.

- Operation and maintenance cost is less owing to lower energy consumption and maintenance cost.
- Initial investment is less owing to the compact facilities.
- Total emission of greenhouse gas is less owing to pressurized combustion, higher partial pressure of oxygen and decomposition of N_2O.
- Operation under low loading condition is easier since PFBI can be operated efficiently with less combustion air.
- It is the most economical option in terms of net present value.

Table 4.71 Comparison of Sludge Incinerator (1)

	Conventional fluidized bed incinerator (Japanese product)
Structure of furnace	Furnaces are comprised of free boards, fluidized bed zones and shells covered internally with refractory. Diffuser pipes are inserted horizontally at fluidized bed zones. Combustion air for fluidizing is supplied through diffuse pipes to fluidized bed zones. Silica sand is used as fluidizing mediums. Silica sand and non-combustibles can be easily discharged from the bottom of the incinerators.
Combustion	Fluidized sand forms vigorous fluidization in furnaces. Sludge fed from side shells is mixed with combustion air. Sludge is dried, incinerated and decomposed completely. Ash powder is discharged from the top of furnaces with exhaust gas. Combustion air is supplied to furnaces by fluidizing blowers. Air is heated by air heater which exchanges heat from exhaust gas to fluidizing air and supplied to furnaces as combustion air. Sludge is dried and crushed by fluidizing sand owing to activeness of mixing sludge and combustion air. Combustion effect is higher than multiple hearth furnaces.
Operation and maintenance	Temperature drop is low after stopping operation owing to large quantity of heat mediums. However, it takes long time to startup from cooled condition. FBI has relatively long operating life owing to no moving part in furnaces. However, periodical repair of refractory inside furnaces is required.
Required space	1,300 m^2 (425 t/day *1 nos.)
Temperature	800-850 degree C
Operation pressure	minus 0.5 kPa
Combustion air ratio	Approximately 1.3
Environmental and social considerations	Total emission of GHG: 111,200 kg-CO_2/day (425 t/day*1 nos.) (fuel: 14,900 kg-CO_2/d, power: 12,300 kg-CO_2/d, N_2O: 84,000 kg-CO_2/d)
Initial investment (425 t/day *4 nos.)	Incinerator: 139.47 Million Euro Building: 18.72 Million Euro Total: 158.19 Million Euro (108 %)
O&M cost (425 t/day *4 nos.)	Electricity: 2.79 Million Euro/ year Consumable: 1.42 Million Euro/ year Maintenance: 1.39 Million Euro/ year Total: 5.60 Million Euro/ year (138 %)
Net present value (425 t/day *4 nos.)	263.75 Million Euro (113 %)
Selection	-

Net present value: Discount rate = 7.8% / period = 30year

Source: JICA Study Team

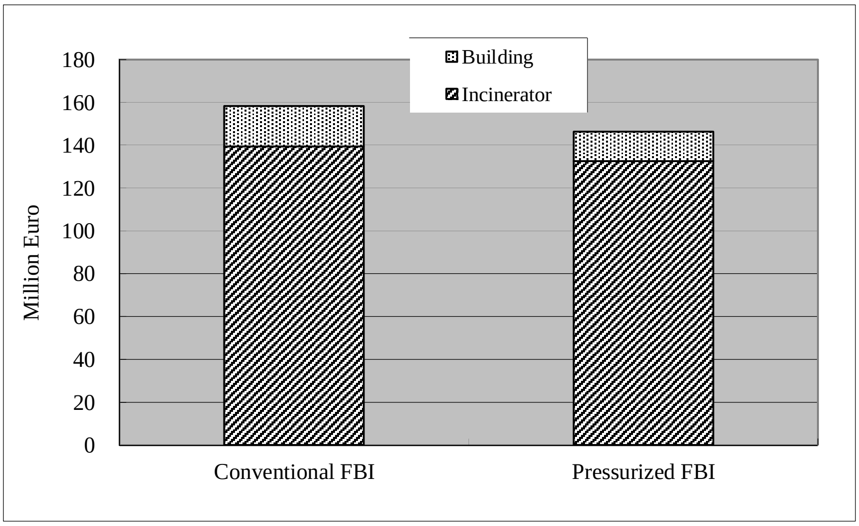
Table 4.72　Comparison of Sludge Incinerator (2)

	Pressurized fluidized bed incinerator (Japanese product)
Structure of furnace	Furnaces are comprised of free boards, fluidized bed zones and shells covered internally with refractory material. While the conventional FBI is operated under negative pressure, the PFBI is operated under positive pressure. Combustion air for fluidizing generated by turbochargers is supplied through diffuser pipes to fluidized bed zones.
Combustion	Fluidized sand forms vigorous fluidization in furnaces. Sludge fed from side shells is mixed with combustion air. Sludge is dried, incinerated and decomposed completely. Combustion air is supplied by turbochargers driven by exhaust gas. Exhaust gas is utilized to rotate turbine wheels of the turbochargers. As a result, compressor wheels attached to the same shafts as the turbine wheels rotate and generate pressurized air. Ash is discharged from the top of furnaces with exhaust gas. Combustion speed is higher than FBI since reaction between organic material in sludge and oxygen in air is more effective under pressured atmosphere due to high O_2 partial pressure.
Operation and maintenance	Operation under low load condition is easy since PFBI can be operated with less combustion air. Hence, PFBI can be operated continuously. PFBI has relatively long operating life owing to absence of moving part in furnaces. However, periodical repairs of refractory layer inside furnaces is required.
Required space	960 m^2 (425 t/day *1 nos.)
Temperature	800-850 degree C
Operation pressure	plus 150 kPa
Combustion air ratio	Approximately 1.3
Environmental and social considerations	Total emission of GHG: 62,300 kg-CO_2/day (425 t/day*1 nos.) (fuel: 14,100 kg-CO_2/d, power: 6,000 kg-CO_2/d, N_2O: 42,000 kg-CO_2/d)
Initial investment (425 t/day *4 nos.)	Incinerator: 132.65 Million Euro Building: 13.82 Million Euro Total: 146.47 Million Euro (100 %)
O&M cost (425 t/day *4 nos.)	Electricity: 1.37 Million Euro/ year Consumable: 1.42 Million Euro/ year Maintenance: 1.27 Million Euro/ year Total: 4.06 Million Euro/ year (100 %)
Net present value (425 t/day *4 nos.)	232.48 Million Euro (100 %)
Selection	Selected by advantages mentioned in 4.5.7

Net present value: Discount rate = 7.8% / period = 30year

Source: JICA Study Team

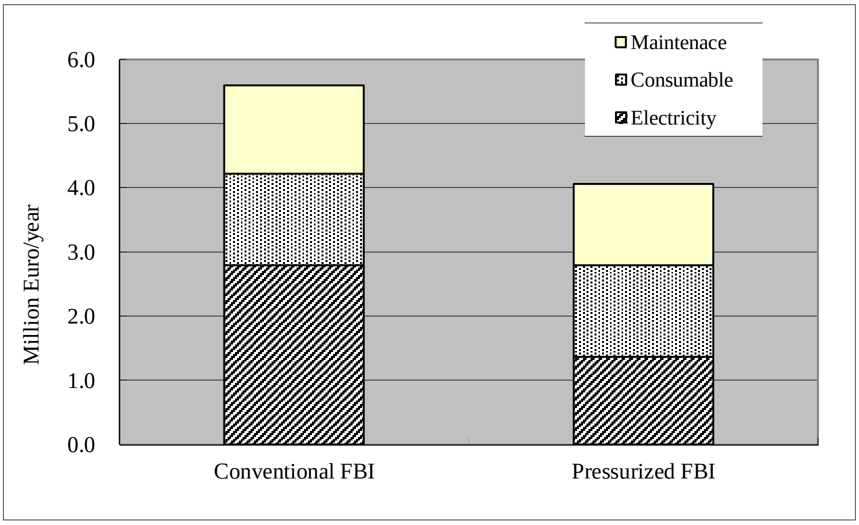
The initial investment of alternatives is analyzed as shown in Figure 4.25. The initial investment of pressurized fluidized bed incinerator is found to be lower.



Source: JICA Study Team

Figure 4.29 Initial Investment

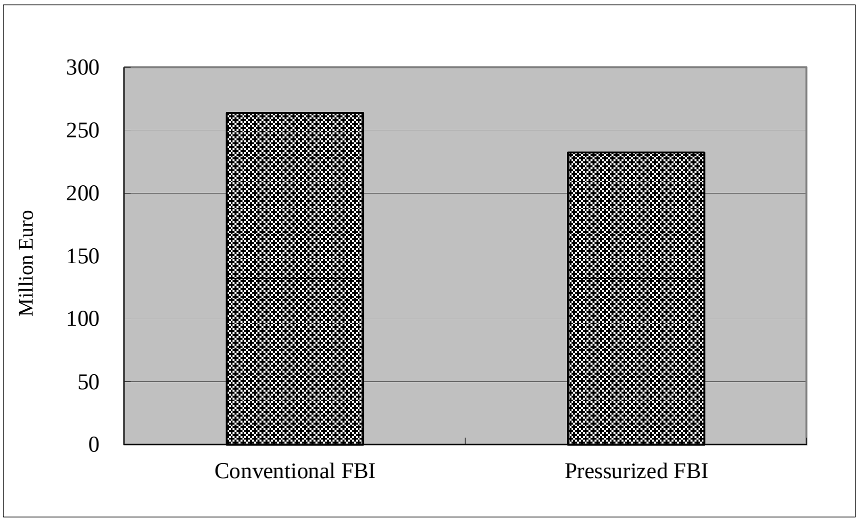
The O&M cost of alternatives is analyzed as shown in Figure 4.26. The O&M cost of pressurized fluidized bed incinerator is found to be lower owing to lower electricity and maintenance expenses.



Source: JICA Study Team

Figure 4.30 O&M Cost

The net present value of alternatives is analyzed as shown in Figure 4.27. The pressurized fluidized bed incinerator is more economical in terms of net present value.

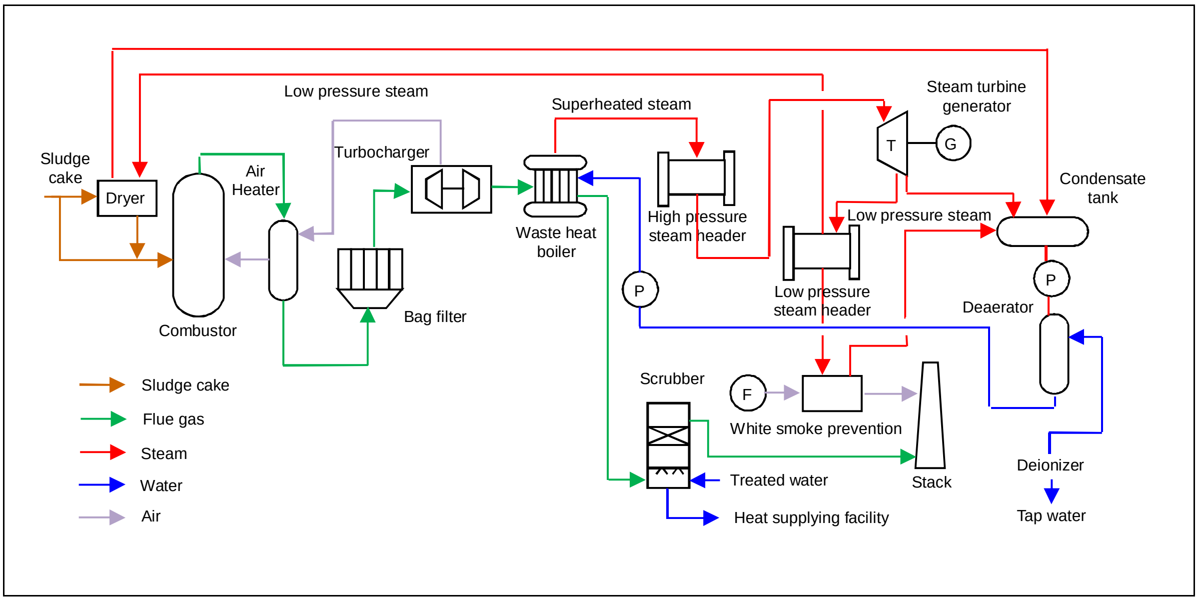


Source: JICA Study Team

Figure 4.31 Net Present Value

4.5.8 Energy Utilization of Flue Gas from Incinerator

In the past, sludge incinerators utilized waste heat recovered from flue gas for heat resources of preheating of combustion air and preventing white smoke from the stacks. Furthermore, self-sustained combustion by adapting pre-drying process of sludge cake utilizing waste heat and power generation by introducing steam power generation system utilizing waste heat energy is recommended for this project. A schematic flow and configuration of heat recovery system is shown in Figure 4.32 and Table 4.73.



Source: JICA Study Team

Figure 4.32 Schematic Flow of Heat Recovery System

Table 4.73 Configuration of Heat Recovery System

Equipment	Explanation
Air preheater	The temperature of flue gas from the incinerators is approximately 850 degrees C. The air preheater preheats air up to 650 degree C by exchanging heat between flue gas and air. The efficiency of the incinerators is improved by utilizing preheated air for fluidizing air and combustion air.
Waste heat recovery system	Waste heat recovery system with waste heat boilers recovers waste heat possessed by flue gas after the air preheaters, and produce superheated steam (pressure: 3.0MPa, temperature: 350 degree C). A waste heat recovery system is installed for each incinerator. Superheated steam is supplied to steam power generation system. Low pressure steam extracted from the steam turbine generator is utilized for heat resources of drying of sludge cake and preventing white smoke from the stacks. Hot water utilizing heat recovered from high temperature drain water from the scrubbers is supplied as heat resources for air-conditioning.
Dryer	The pre-drying process which dries sludge cake prior to combustion, is adapted in order to achieve self-sustained combustion without supplementary fuel. Some portion of sludge cake (water content: 76%) is dried until 40% of water content and mixed with sludge cake in order to produce sludge (water content: less than 72%) which makes self-sustained combustion possible. An inclined disc type dryer which dries sludge cake indirectly utilizes low pressure steam extracted from the steam turbine generator, is installed.
Steam power generation system	Steam power generation system generates electric power by rotating a turbine driven by superheated steam produced from the waste heat recovery system. One unit of steam power generation system is installed for four incinerators and generates approximately 1.2MW. A portion of low pressure steam extracted from the steam turbine generator is utilized for heat resources of drying of sludge cake and preventing white smoke from the stacks. Remaining low pressure steam and drain steam from driers and smoke prevention heaters is condensed in the condensate tank. Effluent is utilized for cooling water. Condensed water is recycled to boilers.
Smoke prevention preheater	Smoke prevention preheater preheats air supplied by fans up to the designated temperature by exchanging heat between low pressure steam and air. Preheated air is mixed with flue gas in order to reheat flue gas. Reheat of flue gas prevents water contained in flue gas from condensation at the exits of stacks and producing white smoke at atmospheric discharge.

Source: JICA Study Team

The following benefits are expected by introducing the heat recovery system of flue gas from the incinerators.

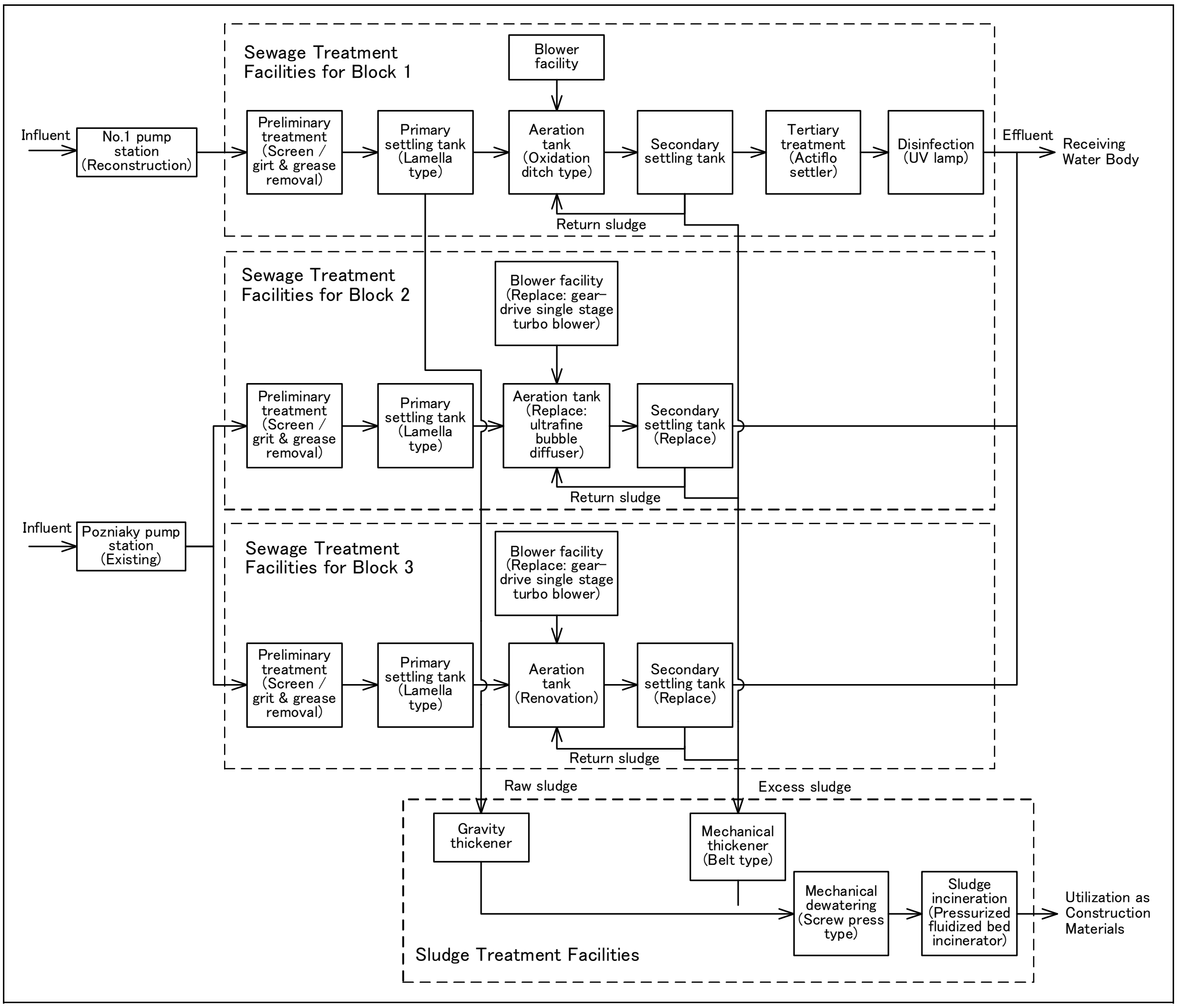
- Accomplishment of self-sustained combustion (stable operation condition of sludge incineration without supplementary fuel)
- Reduction of 60% of power consumption of sludge incineration facilities by power generation utilizing waste heat
- Reduction of greenhouse gas emissions (5,200 ton-CO_2/year) by substituting electricity

supplied from power company

- ➢ Supply of hot water (120,000 MJ/h) for air-conditioning of the buildings in the plant by recovering heat energy from waste water from flue gas treatment

4.6 Proposed Optimum Plan

The schematic flow of the optimized treatment process recommended for BAS is shown in Figure 4.33.



Source: JICA Study Team

Figure 4.33 Schematic Flow of Treatment Process

4.7 Reconstruction Plan of Sewage Treatment Facilities for Block 2 and Block 3

4.7.1 Reconstruction Plan of Concrete Structures

(1) Evaluation of the Existing Concrete Structures

Firstly, the deterioration of concrete structures of the existing facilities was investigated visually. As a result, the surface delamination caused by scaling is generally visible. The damage of sewage treatment facilities for block 1 is especially prominent (Refer to 3.4).

In addition, 49 years have passed since the operation of Block 1 started. Thus, deterioration of sewage treatment facilities for block 1 is severe. According to the existing plan of reconstructing BAS, sewage treatment facilities for block 1 are planned to be dismantled due to degradation of the whole system and reconstructed in another location while sewage treatment facilities of Block 2 and Block 3 are planned to be utilized after renovation of the facilities.

In order to determine the scope of repair works considering expected life extension period of the existing sewage treatment facilities for Block 2 and Block 3, the following detailed surveys presented in Table 4.61 and Table 4.75 were conducted.

Table 4.74 Schmidt Hammer Test

Concrete Compressive Strength		
Schmidt hammer tests were conducted at 20 sample locations after concrete surfaces for testing were made as smooth as possible using metal brush and whetstone.		
		

Source: JICA Study Team

Table 4.75 Neutralization Test by Scraping

Concrete Neutralization Depth		
Depths of concrete surface, which of color was changed to violet, were measured by a caliper after scraping concrete by a pick hammer and spraying phenolphthalein liquid.		
		

Source: JICA Study Team

Measured values of concrete compressive strength and neutralization depth (average value) are shown on Table 4.76.

Table 4.76 Results of Concrete Compressive Strength and Neutralization Depth

Facility	Block 1		Block 2		Block 3	
	Outside	Inside	Outside	Inside	Outside	Inside
Primary settling tank	50.8 (7.0)		39.2 (70.8[*1])	30.5 (12.5)	27.9 (11.9)	35.2 (3.0)
Aeration tank			27.0 (13.3)	37.9 (3.0)	36.7 (14.0)	34.6 (9.7)
Secondary settling tank			20.5 (15.3)	31.3 (2.0)	26.3 (16.3)	30.4 (5.0)
Grit chamber				27.5 (9.5)		
Distribution tank						33.5 (6.0)
Sludge thickener						23.2 (4.0)
Commencement of operation, (age)	1964 (49)		1976 (37)		1987 (26)	
Neutralization depth, theoretical value (mm)	28.0		24.4		20.4	

Upper value: compressive strength (Nmm^2)
Lower value: neutralization depth (mm) / *1: mark includes the mortar (thickness: 30mm)
Source: JICA Study Team

The reference of design strength is 21N/mm^2 (estimate value). Only the value of compressive strength of secondary settling tanks for Block 2 was found to be lower than the reference of design strength while the others are higher than the reference.

In addition, it is observed that the values of neutralization depth of the facilities except for primary settling tanks (outside) for Block 2 are considerably lower than the theoretical values. Hence, it is confirmed that deterioration of concrete is not critical.

(2) Proposed Repair Works for Concrete Structures

The results of neutralization tests, show that the progress of neutralization of concrete structures of sewage treatment facilities is considerably slow despite of severe environmental conditions owing to mortar covering on concrete structures and periodical repairing works of mortar finishing.

The measured values of Schmidt hammer tests are not conclusive evidence due to the fact the boundary of mortar and concrete structure is unclear. Hence, coring tests are recommended in case more definitive evidence is required. Based on the comparison of compressive strength of primary settling tanks, the concrete structures of the facilities for Block 1 appears to be the strongest despite of the oldest age. Hence, it is assumed that the quality of concrete for Block 1 is better than that for Block 2 and Block 3.

Considering the results of detailed surveys, the following are recommended for the reconstruction plan of BAS:

- Repair work for Block 1, which is planned to be dismantled and reconstructed, is not required until the end of its operation
- Repair works including intensive repair at the places where re-bar is exposed and periodical mortar finishing in the same way for Block 2 and Block 3, which are planned to be utilized, are required in order to extent its operation

4.7.2 Outline of Civil and Architectural Works of Reconstruction Plan

Outlines of civil and architectural works for reconstruction plan of sewage treatment facilities for Block 2 and Block 3 are summarized in Table 4.77. The drawings of the facilities, which are rehabilitated under this Project, are presented in Appendix-Drawings.

Table 4.77 Outlines of Civil and Architectural Works of Reconstruction Plan

No	Facilities / Dimension / Specification	Quantity	Statues
1.	Secondary treatment facilities for Block 2		
1-1	Removing degraded concrete surface by 10mm thickness and refilling with mortar by 30mm thickness for aeration tank	6 tanks	Repair
1-2	Painting for blower building	-	Repair
1-3	Reconstruction of trough supports for secondary settling tank	12 tanks	Repair
1-4	Laying bypass pipes from primary treatment to aeration tank	1 set	New installation
2.	Secondary treatment facilities for Block 3		
2-1	Removing degraded concrete surface by 10mm thickness and refilling with mortar by 30mm thickness for aeration tank	2 tanks	Renovation

No	Facilities / Dimension / Specification	Quantity	Statues
	Constructing dividing walls and corner walls to renovate as endless ditch type aeration tank		
2-2	Painting for blower building	-	Repair
2-3	Removing degraded concrete surface by 10mm thickness and refilling with mortar by 20mm thickness for secondary settling tank	14 tanks	Repair
2-4	Laying bypass pipes from primary treatment to aeration tank	1 set	New installation

Source: JICA Study Team

4.7.3 Outline of Mechanical and Electrical Works of Reconstruction Plan

Outlines of mechanical and electrical works for reconstruction plan of sewage treatment facilities for Block 2 and Block 3 are summarized in Table 4.78. The drawings of the facilities, which are rehabilitated under this Project, are presented in Appendix-Drawings.

Table 4.78 Outlines of Mechanical and Electrical Works of Reconstruction Plan

No	Equipment / Specification	Quantity	Status
1.	Secondary treatment facilities for Block 2		
1-1	Air diffuser for aeration tanks (ultrafine bubble diffuser)	6 tanks	Replacement
1-2	Blower with filter (750m^3/min × 70kPa × 1,070kW)	4 nos.	Replacement
1-3	Traveling crane for blower building	1 nos.	Replacement
1-4	Sludge collector for secondary settling tank (diameter: 40m)	12 nos.	Replacement
1-5	Gate for secondary settling tank (Size: W1.2m*H2.3m)	12 nos.	Replacement
1-6	Gate for secondary settling tank (Size: W1.5m*H3.6m)	12 nos.	Replacement
1-7	Electrical panel (PLC, APP, etc.)	1 set	Replacement
1-8	Instrumentation (flow meter, DO sensor, etc.)	1 set	New installation
2.	Secondary treatment facilities for Block 3		
2-1	Gate for aeration tank (Size: W5.0m*H0.5m)	6 nos.	New installation
2-2	Mixer for aeration tank	2 nos.	New installation
2-3	Air diffuser for aeration tanks (ultrafine bubble diffuser)	2 tanks	Replacement
2-4	Blower with filter (750m^3/min × 70kPa × 1,070kW)	4 nos.	Replacement
2-5	Traveling crane for blower building	1 nos.	Replacement
2-6	Sludge collector for secondary settling tank (diameter: 40m)	14 nos.	Replacement
2-7	Gate for secondary settling tank (Size: W1.2m*H2.3m)	14 nos.	Replacement
2-8	Gate for secondary settling tank (Size: W1.5m*H3.6m)	14 nos.	Replacement
2-9	Electrical panel (PLC, APP, etc.)	1 set	Replacement
2-10	Instrumentation (flow meter, DO sensor, etc.)	1 set	New installation

Source: JICA Study Team

4.8 Facility Planning

4.8.1 Design Criteria

The design criteria which are applied for facility planning of BAS are summarized in Table 4.79. Design criteria applied for facility planning of sewage treatment facilities are European standards including German standards (ATV), manufacture standards, etc. since the same treatment process in the F/S is adopted as the results of comparisons in 0. At the same time, those applied for facility planning of sludge treatment facilities are Japanese standards since the main equipment which is planned to be introduced in sludge treatment process are Japanese products.

Table 4.79 Design Criteria

No	Item	Design Criteria	
1.	Preliminary treatment facilities		
1-1	Flow velocity in the channel (screen)	0.3	m/second
1-2	Maximum upflow velocity (grit and grease removal)	25	m^3/hour
1-3	Minimum retention time (grit and grease removal)	8	minute
2.	Primary treatment facilities		
2-1	Lamella plates inclination angle	60	degree
2-2	Minimum spacing between plates	75	mm
2-3	Minimum plate length (inclined)	1.5	m
2-4	Depth of water underneath the plates	2.0	m
2-5	Max upflow velocity	15	m/hour
2-6	Max Hazen velocity	1.4	m/hour
3	Aeration tanks for block 1		
3-1	Minimum contact and anaerobic HRT (at maximum flow)	2.5	Hour
3-2	Maximum f/m ratio	0.10	Kg-BOD_5/kg-TSS/day
3-3	Minimum sludge age	13	day
3-4	Maximum MLSS concentration	4.5	g/l
3-5	Return activated sludge rate (at peak hourly flow)	100	%
3-6	Maximum water depth	8	m
3-7	Maximum oxygen efficiency transfer coefficient	0.55	
3-8	Flow velocity in the ditch (mixers requirement)	0.3	m/s
3-9	Minimum temperature of raw sewage	14	degree Celsius
4.	Secondary settling tanks for block 1		
4-1	Maximum hydraulic loading	0.9	m/hour
4-2	Maximum sludge load at peak flow	8	kg/m^2/hour
4-3	Minimum water depth	4.5	m
5.	Tertiary treatment facilities for block 1		

No	Item	Design Criteria	
5-1	Coagulation contact time (ferric chloride)	1.0	minute
5-2	Required ferric chloride concentration	50	mg/l
5-3	Flocculation contact time (polymer)	1.0	minute
5-4	Required polymer concentration	1	mg/l
5-5	Maturation contact time	2.0	minute
5-6	Apparent flow velocity	55	m/hour
6.	UV disinfection facilities for block 1		
6-1	Enterococci	400	units/100ml
6-2	E. Coli	1,000	units/100ml
7.	Gravity thickeners		
7-1	Solid surface loading	75	$kg/m^2/day$
7-2	Solid concentration of thicken sludge	4.0	%
7-3	Solid recovery rate	85	%
7-4	Effective depth	4.0	m
8.	Mechanical thickening facilities		
8-1	Solid concentration of thicken sludge	4.0	%
8-2	Solid recovery rate	95	%
8-3	Polymer dosing rate	0.3	%
9.	Mechanical dewatering facilities		
9-1	Operation hours	24	hour
9-2	Moisture content of sludge cake	76	%
9-3	Solid recovery rate	95	%
9-4	Polymer dosing rate	1.0	%
10.	Sludge incineration facilities		
10-1	Operation hours	24	hour
10-2	Rate of operating	100	%

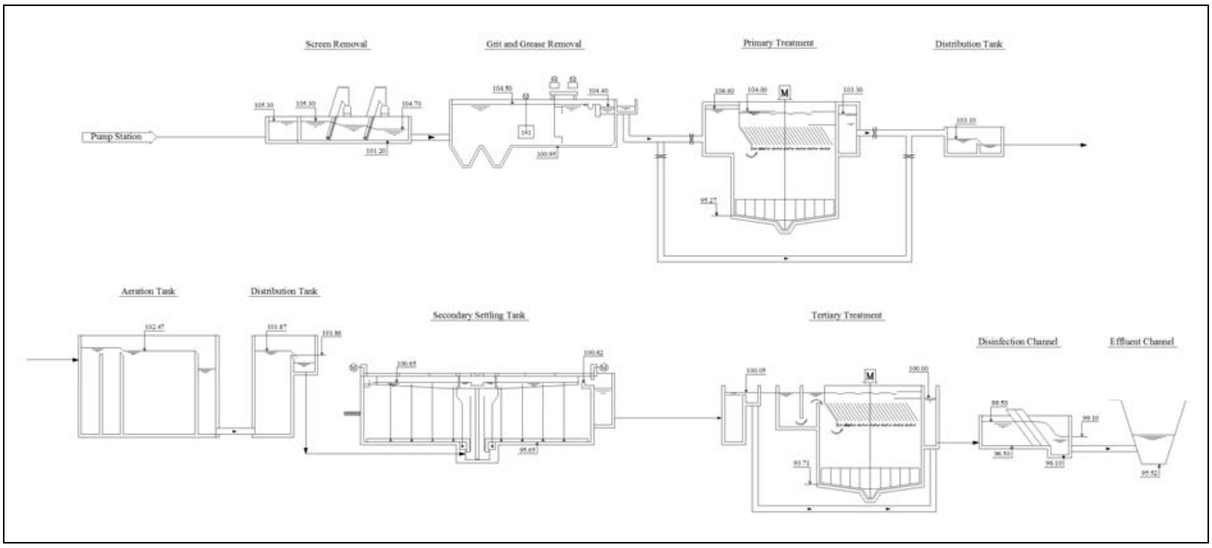
Source: JICA Study Team

4.8.2 Hydraulic Profile Planning

(1) Hydraulic Profile after Reconstruction of Sewage Treatment Facilities

Sewage treatment facilities for Block 1 are planned to be reconstructed in the same area as the existing sewage treatment facilities for Block 2 and Block 3. Hence, the distance from the pump station is significantly shortened. It results in an increase of available hydraulic head of sewage treatment facilities for Block 1 after reconstruction.

Sewage treatment facilities for Block 2 and Block 3 are planned to be utilized after renovation. According to the reconstruction plan, preliminary and primary treatment facilities will be newly constructed while the existing secondary treatment facilities are planned to be rehabilitated. Hence, hydraulic conditions between the planned primary treatment facilities and the existing aeration tanks should be confirmed. Hydraulic profile of planned sewage treatment facilities after reconstruction is shown in Figure 4.34.



Source: JICA Study Team

Figure 4.34 Hydraulic Profile of Sewage Treatment Facilities after Reconstruction

The following are hydraulic conditions:

- Water level at the planned primary treatment (+ 103.10m)
- Water level at the existing primary settling tanks (+ 101.86m)

It is confirmed that effluent from the planned primary treatment facilities flows by gravity to the existing aeration tanks since the water level of the planned primary treatment facilities is higher than the water level of the existing primary settling tanks.

(2) Planning of Effluent Channel

Snow melting causes damage to the embankment of effluent channel every spring since the existing embankment of effluent channel is natural levee which is made of sand and easy to erode. The planned improvement area of effluent channel embankment of and photographs of the current conditions are shown in Figure 4.35.

Source: JICA Study Team

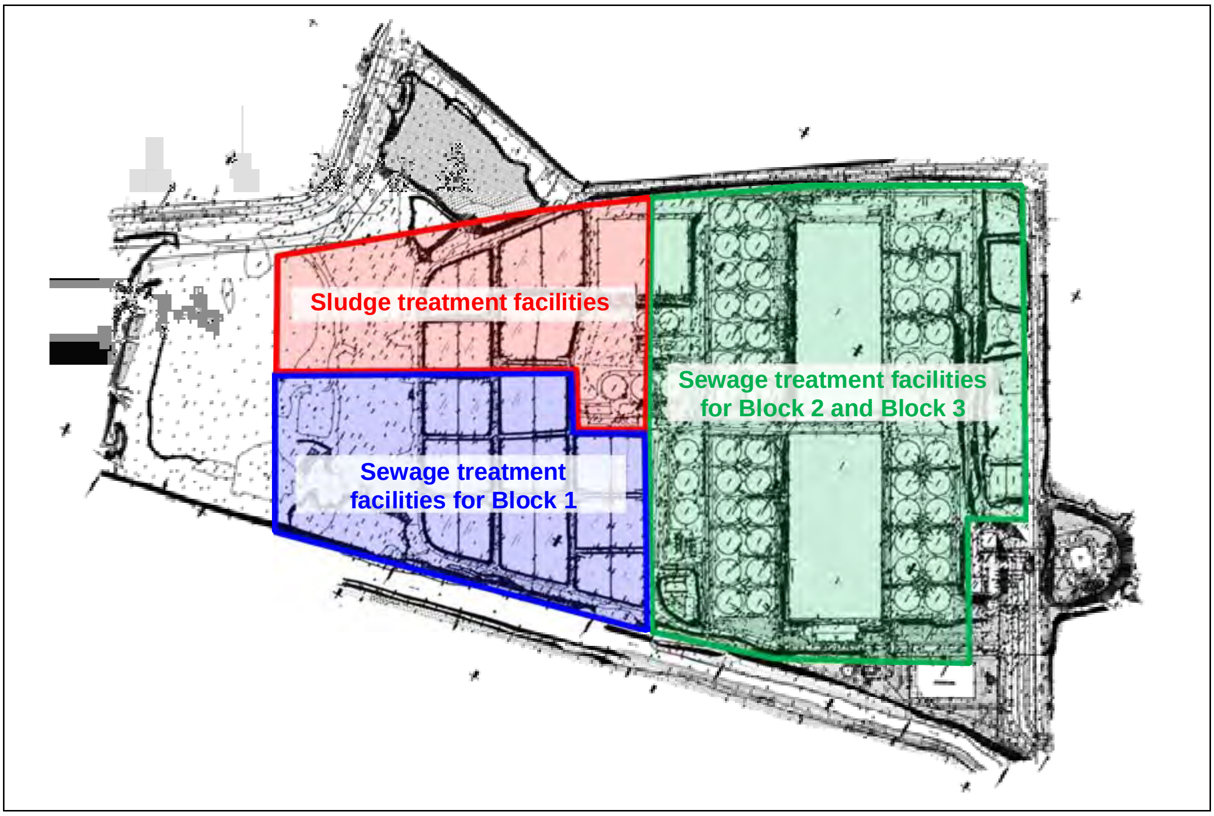
Figure 4.35 Embankment of Effluent Channel

KVK is planning to improve embankment of effluent channel by installing concrete sheet piles (percussion method) in order to prevent embankment from erosion. This measure is the most economical construction method. At present, planting on either bank is thought to have preferable influence in terms of scenery and water quality. Hence, it is desirable to consider hydrophobicity to have water permeability in the future.

4.8.3 General Layout Planning

As for F/S, the facilities are designated in the WWTP site according to the following groups of the facilities as shown in Figure 4.36.

- Sewage treatment facilities for Block 1
- Sewage treatment facilities for Block 2 and Block 3
- Sludge treatment facilities



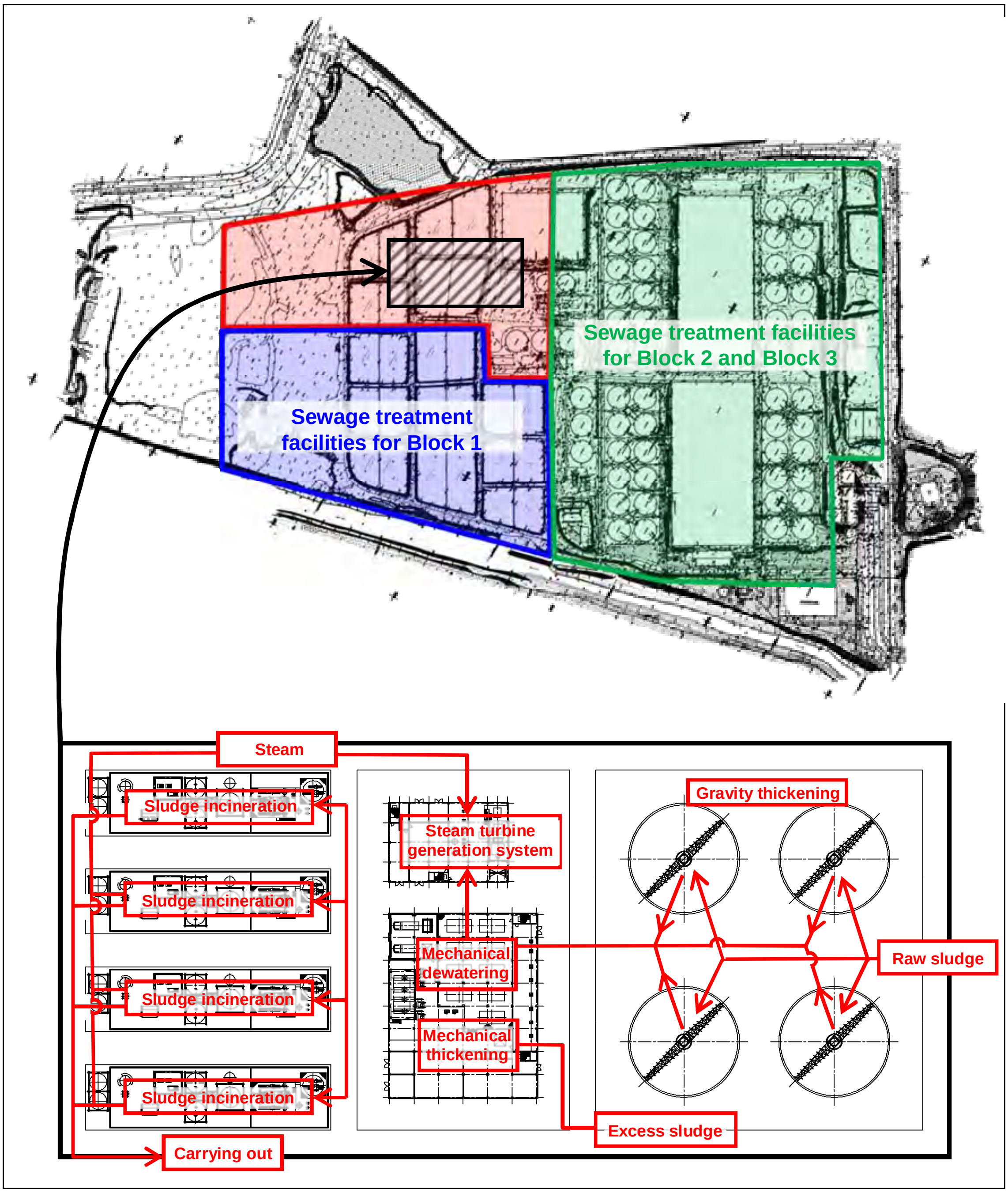
Source: JICA Study Team

Figure 4.36 Planed General Layout of BAS

A general layout of sludge treatment facilities, which are newly introduced, has been arranged considering the following conditions and concepts.

- The sludge treatment facilities are located within the area designated for sludge treatment facilities in F/S.
- The facilities are placed so that sludge flow line during treatment is optimized and length of sludge transfer is shortened.
- The facilities are placed so that efficient working line and necessary spaces are secured for the workability of daily operation and maintenance of the facilities

A general layout of sludge treatment facilities and sludge flow line are shown in Figure 4.37.



Source: JICA Study Team

Figure 4.37 General Layout of Sludge Treatment Facilities and Sludge Flow Line

4.8.4 Electrical System Planning

The electrical system at BAS, consuming approximately 15,000kW electric power, shall be designed carefully with high reliability, high efficiency, operational flexibility and reasonable construction/operational costs. The design concept of the electrical system is the following;

- Efficient power distribution to all WWTP including pump stations, sewage treatment facilities for Blocks 1/2/3, sludge treatment facilities and sludge incineration facilities located in a wide area

- Implementation of 6kV large capacity motors for blowers and lift pumps, and 400V motors for other loads
- Two bank system of transformer, having 100% standby capacity in each
- Parallel line network system for 6kV power distribution feeder
- Introduction of steam turbine generator system at the incineration process, utilizing high temperature exhaust gas

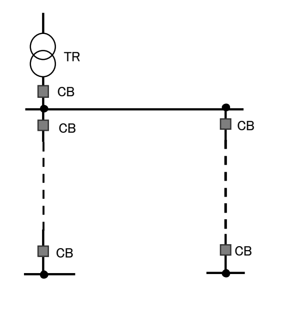
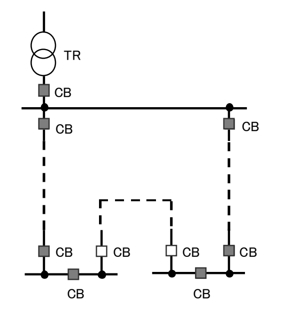
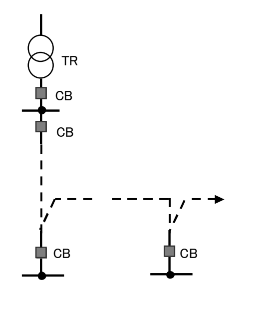
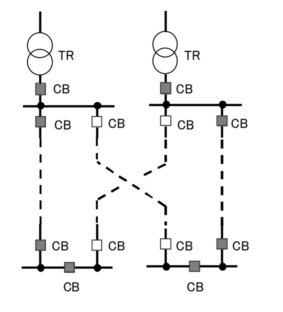
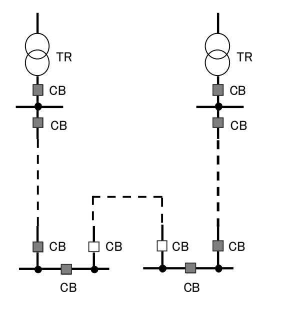
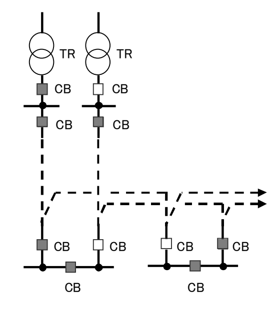
The existing two power stations, receiving 100kV from the city line, have main step-down transformers and supply 6kV electric power to all facilities in the WWTP premises. According to the reconstruction schedule of BAS, the electrical distribution systems shall be updated one by one. The two above-mentioned 100kV power stations will be renewed by the electric distribution company.

The three electrical distribution systems as explained in Table 4.80 can be considered, and each system has two options i.e. single system and modified parallel system as shown in Figure 4.38. It is also necessary to obtain agreement from the electric distribution company.

Table 4.80 Brief Explanations of Electrical Distribution System

System	Brief explanation
Radial system	The radial-type 6kV feeders from 100kV power station supply electrical power to every treatment facility and building. The radial system is the simplest and requires the lowest cost. Therefore, it is common system for the small/medium scale WWTPs. The existing 6kV distribution system is based on radial-type with two individual 100kV power stations. However, each power station has its own load area. Hence, the advantage of having two non-related power stations is not utilized.
Loop system	The 6kV feeder from the 100kV power station loops through several treatment facilities and buildings and returns back to the same power station. In either case, the loop can function with the tie switches normally open or normally closed. In case of fault, both incoming breakers are open so that the fault area is isolated from both directions. Since a 6kV fault causes a temporary power breakdown of all feeding area, operation is difficult.
Network system	The 6kV feeder from 100kV power station can be tapped off to all facilities and buildings. The network lines are passed in several directions according to the treatment blocks or the load area. The reliability and the quality of service of the network arrangement is much higher than the radial and loop arrangement. In the case of network lines from two individual 100kV power stations, it is easier to design and operate than a multiple source network system.

Source: JICA Study Team

	Radial system	Loop system	Network system
Single system			
Modified parallel system			

Source: JICA Study Team

Figure 4.38 Diagram of Options for 6KV Electrical Distribution System

A modified parallel network system is selected for 6kV power distribution system due to the following advantages:

- High reliability
- Easy and flexible operation
- Lower construction cost

Moreover, the termination of 6kV network line shall have tie connection circuit, which circuit is normally open, to other network lines for higher reliability.

4.8.5 SCADA and Control System Planning

(1) Introduction

BAS is a very important infrastructure facility in Kiev City. It is imperative that pump stations, sewage treatment facilities and sludge treatment facilities run efficiently and economically in an optimized manner conserving energy so as to ensure sustainability of the operation.

In the existing WWTP, operations by valve open/close and drive start/stop are being done manually. All operators shall have enough experiences for operational protocol in respect of the daily operation. However, in case of rapid changes in the influent quantity/quality, the operators have difficulties to maintain the stable quality of treated water. A stable quality of effluent requires proper and continuous control of treatment facilities. Therefore, automatic monitoring and control of parameters is essential for obtaining consistent levels of effluent quality.

(2) Purpose of SCADA System

For the purposes mentioned above, it is imperative that the necessary data is collected and stored, and the required information is provided to the engineers. This is a first step of information utilization for effective and efficient operation. Therefore, it is essential that all data become accessible information beyond the narrow borders of the operating personnel. This also provide an opportunity for the engineers/operators/chemists to share the information. It also facilitate mining of the historical data for reference and overall improvement.

In case of WWTP operation, operation cycle of "collection of information – analysis of the information – operation of the facilities – evaluation of the operation result" is important. The first two steps can be realized by the data acquisition system. The next step, in which the engineer operates the facilities and determines the control parameters according to his/her judgment immediately, calls for automatic control system wherein the remote control of drives and valves by electric actuation is possible.

Normal operation is ensured by automatic control by analog calculation logic or sequential operation. The PLC (programmable logic controller) which is a component of SCADA system has these control functions programmed into it. With supervisory control and above-mentioned data acquisition system, the original feature of the SCADA system can be fully realized. Further advantages of the system include:

- Improving public service as a result of real time information and capability
- Meeting contemporary performance expectations
- Minimizing risks by avoiding/managing incidents
- Energy saving by appropriate automatic control
- Utilizing the operating personnel effectively and improving productivity

In this project, the SCADA system will be surely designed not only with basic functions, but also with attempts to introduce more advanced technology.

(3) Data Acquisition

Information required for plant operation is both operation status (on/off/failure) of the equipment and analog measuring values proportional to flow, level, turbidity, etc. These signals are sent to signal input unit of PLC. After screening abnormal data, all signals are recorded as operation information in the server computer. According to the data formats of information, a database is created in the server computer. As for the analog measuring values, databases are built with time frames in minutes, hours and days. As for the other information, the status data is stored as events. These data are provided for the engineers as the status indication on a graphic screen, a trend graph in the display, as well as report generation for the printer.

(4) Control and Operation

The collected and stored information is used in the automatic control or the remote operation which operates through interfacing relays. For such automatic control or remote operation through the SCADA system, equipment must be electrically actuated or motor driven machine. The control system and control logic is to be designed carefully so as to include all relevant parameters and enough information which should be provided for the engineers who decide the operation and the adjustment of control at the central control room. The same concepts apply for the operation of sludge treatment and incineration with an additional sub-control room.

(5) Web Based SCADA System

A conventional SCADA system with centralized control room would enable the monitoring of all relevant parameters only in the concerned central control room or in the concerned sub-control room. This may inhibit the retrieval of data for proper analysis for the top officials since the data is available only for the officials stationed in central control rooms. Additionally, this puts a constraint in the overall objective of pooling the resources and infrastructure in respect of WWTP management.

A web based SCADA system is the application of web-based technologies, and this can communicate with each component through a LAN/VPN line. Authorized engineers with access rights can access the SCADA information through client PCs. This interactive monitoring system makes the information more transparent and accessible, which is not possible with a conventional SCADA system. This system supports the engineers to conduct appropriate analysis and judgment. Moreover, a web-based SCADA system has flexibility and an open architecture so that easy extensions are possible in the future.

(6) Video Monitoring System

Image data contains various information such as shape, color, motion, surroundings, sound, unusual state and uninvited persons/animals. Prices of cameras and peripherals has become inexpensive owing to the benefit of IT evolution. Moreover, the performance of CPU is increasing at a rapid rate. Therefore, a VMS (video monitoring system) or CCTV (closed circuit TV) has wide fields of application, not only for watching purposes.

Active introduction of VMS improves the potential function of SCADA system of BAS. When considering newly developed technology, it is important not to focus on current needs but to look at the plans for the future. The purposes of VMS are WWTP's security system, visual monitoring at control rooms and virtual site tour for visitors. Each network camera has control function. "Virtual site tour" function can implement walk through inspection or patrol without leaving control rooms. For this purpose, cameras are controlled one by one from start point, and selected consecutively along with the inspection way. The cameras can be controlled to focus on objectives by preset function. When the camera reaches goal point, "Virtual site tour" of about 3km is completed. Using this function, the visitors can be safely guided through the WWTP.

(7) Automatic Control

The main purpose of the automatic control is ensuring stable quality of effluent water and managing WWTP operation properly. A 24-hour automatic control and monitoring system is an essential technology for the automated WWTP. Meanwhile, a well-experienced engineer's judgment is also necessary for WWTP operation. For the efficient operation of WWTP, it is necessary to assess quantity and quality of sewage and sludge daily basis. The electric power parameters are also monitored for the purpose of energy conservation. The automation of WWTPs has become common practice. Rather than simply following prevailing trends, it is important to analyze the following objectives of automation.

- Improving operating conditions (The primary function of an automated system is to remove the need for repetitive tasks by installing actuators on frequently used valves, motorized equipment, etc.)
- Improving plant performance (The aim is to optimize treatment by adjusting internal procedures and regulations concerning the process. Since, automation also reduces the risk of human error, reliability and operational safety increases.)
- Assisting supervision (Assistance includes the installation of sensors, alarm detectors, etc. Automation should be regarded as a management tool of WWTP.)

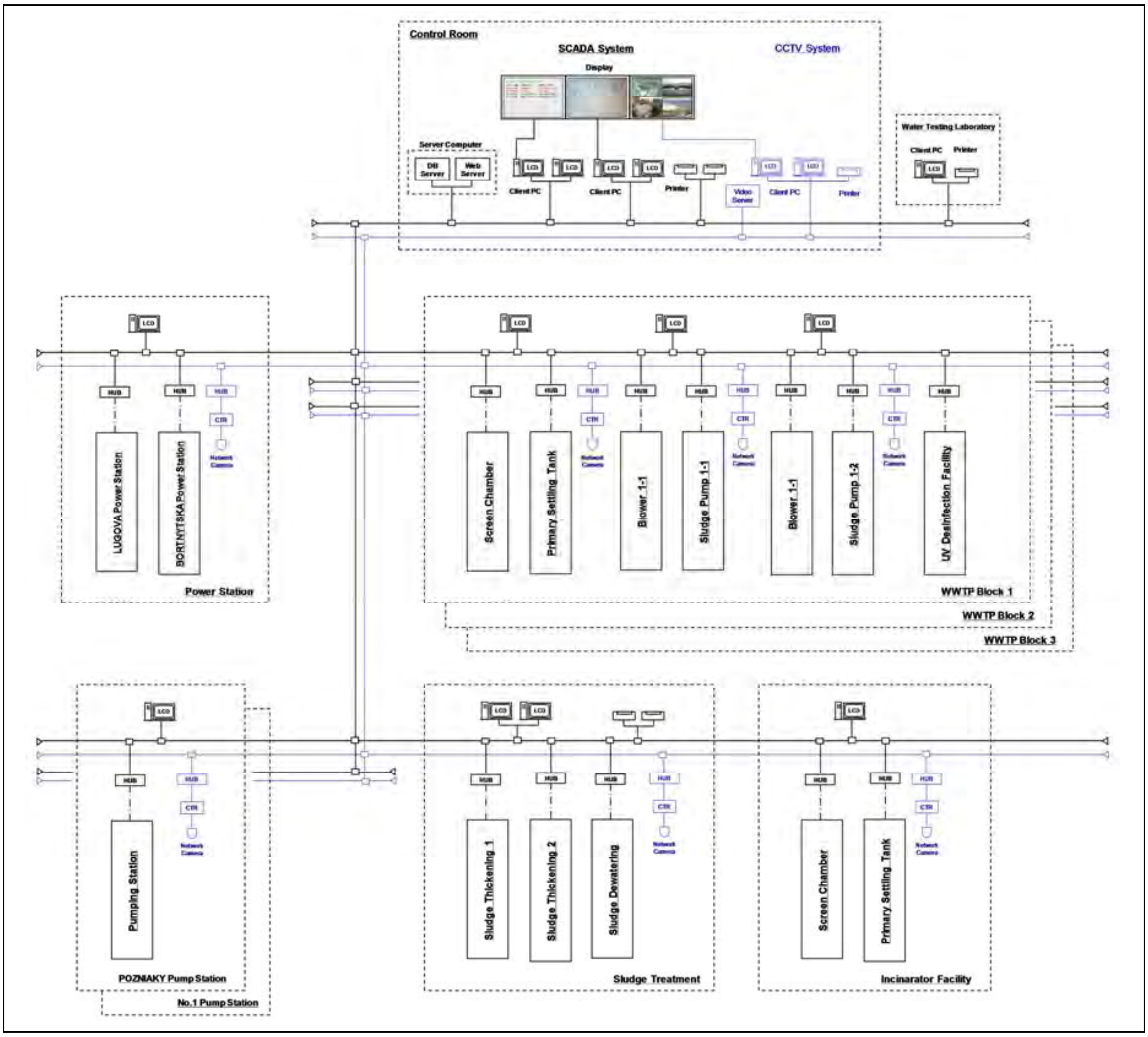
The fluctuation in terms of quality of influent sewage is generally small. However, the fluctuation in terms of quantity of influent sewage is large. Hence, flow rate is an essential factor on introducing automation of plants.

(8) Instrumentation

Flow sensing is important to manage the WWTP operation. Three types of flow meters are often used. Ultrasonic type flow meter can be selected for large size of pipe diameter. Electromagnetic type flow meter can be selected for sludge and coagulant measurement tasks. The Parshall flume can be selected for flow measurement at channels. Level sensing is also important to manage the WWTP operation. For level sensing, ultrasonic type and microwave type sensors are used. These types have the advantage not to require actual contact with sewage/sludge or chemicals. The laser beam type sludge density meter is used for measuring sludge turbidity owing to the simplicity of measurement method without moving parts.

The influent sewage temperature and pH, DO and SS in aeration tanks and other indices are measured for the purpose to judge the condition for activated sludge. Measuring temperature, pH and turbidity of effluent water is useful to confirm effluent quality for observing environmental protection measures. A water sampling system is necessary for water quality measurement at each sampling point.

(9) SCADA System Configuration



Source: JICA Study Team

Figure 4.39 SCADA System Configuration

(10) Operational Methods

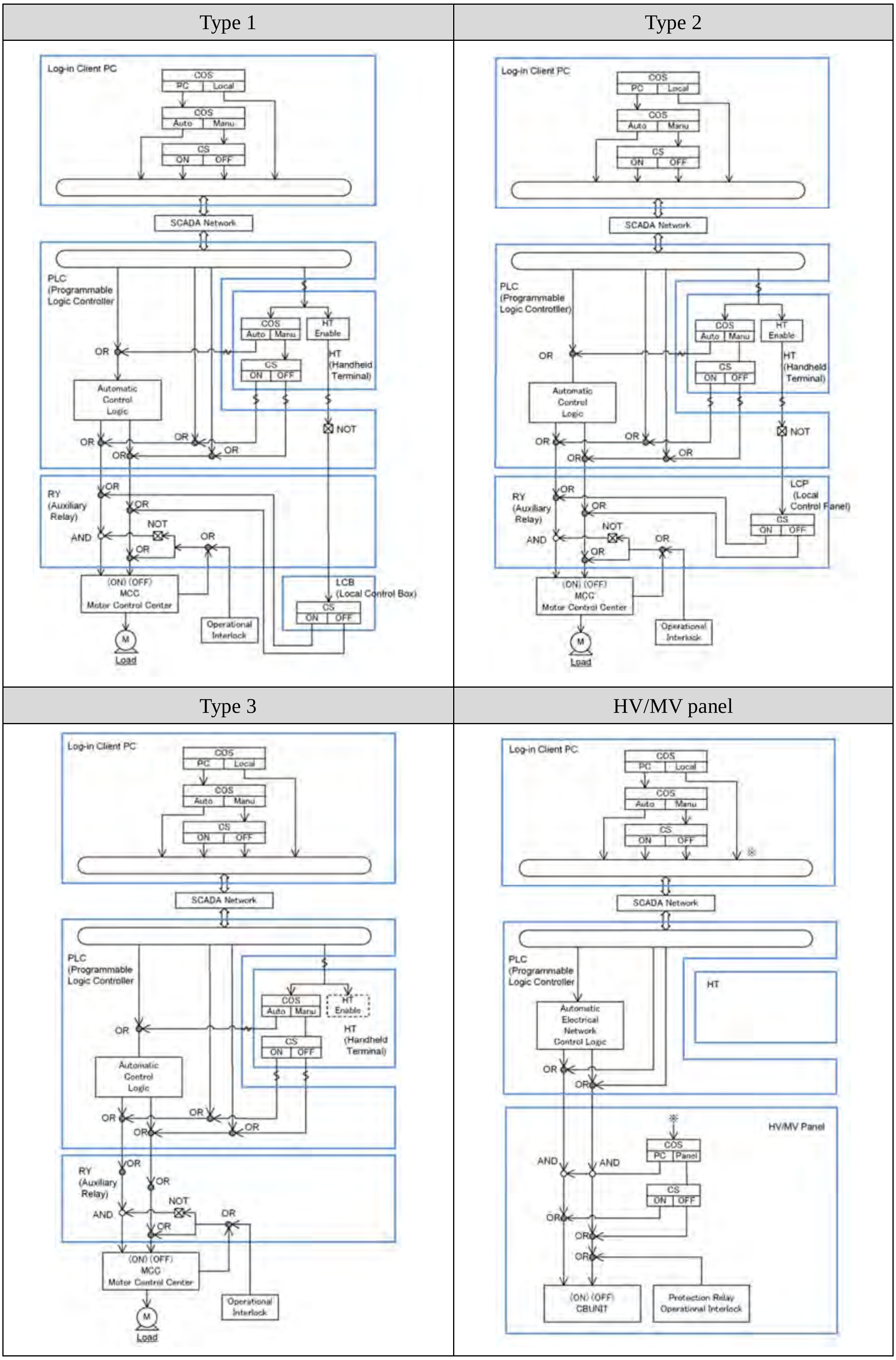
The operational priority is decided hierarchically. The operational policy is always decided by the technological leader at the central control room or sub-control room (electrical room). PC-Local change over switch is installed at the log-in client PC. The switch is shown in LCD of the client PC that is activated for the operation. The operational parameter and command are set through the log-in client PC, HT (wireless handheld terminal) or LCB (local control box) / LCP (local control panel at auxiliary relay cubicle) which are selected for operational position. At the local site, the indicator shows the operating position, and the switch is installed in LCB or LCP. It is possible to stop urgently at the local site for safety purposes. It is necessary for all operators in the WWTP to understand the operational rules. Each PLC works for automatic control as a distributed control system. Therefore, automatic control by PLC might continue in case of problems with the server computer, client PCs or communication networks. It is switched to local operation mode by the PLC software logic. HT is used for the site operation. The installation and wiring of the local control box are minimized for the HT operation system.

Classification and configuration of operational methods are shown in Table 4.81 and Figure 4.40, respectively.

Table 4.81 Classification of Operational Methods

Operational methods	PC	HT	LCB	LCB (RY)	Load / Facility
Type 1	✓	✓	✓		Inlet gate, drainage pump, blower
Type 2	✓	✓		✓	Preliminary treatment facility, disinfection facility, sludge dewatering facility
Type 3	✓	✓		(✓)	Sludge collector, scum skimmer, thickened sludge pump
HV/MV panel				HV/MV	Power station equipment

Source: JICA Study Team



Source: JICA Study Team

Figure 4.40 Configuration of Operational Methods

4.8.6 Odor Control Planning

Sewerage facilities such as WWTPs and pump stations may cause odor problems at the same time that those contribute environmental protection. Hence, order control is important form the following reasons;

- Mitigate negative influence to residents living in the vicinity of the WWTPs
- Ensuring the working conditions inside the WWTP
- Prevent the facilities from corrosion

In general, the major constituents of odorous gas produced from sewerage facilities are the following;

- Hydrogen sulfide
- Methylmercaptan
- Methyl sulfide
- Methyl disulfide
- Ammonia

Deodorization methods should be selected considering all factors regarding regulatory standards, surrounding environment, amount and density of odorous gases, economical aspect, operation and maintenance, etc. The F/S adopted the chemical deodorization method for the sewage treatment facilities of BAS. For the sludge treatment and incineration facilities, the combustion deodorization method is recommended since sludge incineration is planned to be introduced. Outlines of these deodorization methods are shown in Table 4.82.

Table 4.82 Outlines of Deodorization Methods

Chemical deodorization method
The air treatment technology consists of scrubbing odorous gas with a chemical solution. The odorous molecules are transferred from gas phase to liquid phase. The mass transfer is amplified by the large contact surface of the packing inside the scrubber tower. After the gas is physically absorbed into the liquid phase, a chemical reaction takes place. Polluted air pass through a series of scrubbing towers. A scrubbing tower is a kind of chemical reactor tower where air is flowing from bottom to top, whereas a liquid is sprayed from the top of the tower, flowing down by gravity.
Combustion deodorization method
The air treatment technology consists of combusting odorous gas by the combustors. Sludge incinerators can be utilized as the combustors to burn odorous gas by supplying odorous gas as substitute for ordinary air.. Since sludge incinerators are planned to introduced in this Project, additional initial cost and operating cost for deodorization equipment is basically free of charge. The amount of odorous gas, which can be treated by the incinerators, has limitation depending on the capacity and is about the amount generated from sludge treatment and incineration facilities for |BAS.

Source: JICA Study Team

4.8.7 Mitigation of Climate Change

Certain human activities have been identified as significant causes of recent climate change, often reefed to as global warming. Most of global warming has been caused by increasing concentrations of greenhouse gases produced by human activities.

It is inevitable that wastewater treatment plants produce greenhouse gases since they consume energy to treat sewage. Hence, it is important to reduce emission of greenhouse gases in order to mitigate climate change by optimizing the treatment processes for sewage and sludge. Effects on climate change caused by BAS at the present condition and after the reconstruction of facilities are presented as shown in Table 4.83.

Table 4.83 Effects on Climate Change

The current situation of BAS	
Sewage treatment facilities	At present, the blower system, which supplies air for biological treatment, does not have flow control function. Hence, excess aeration in aeration tanks is inevitable since adjustment of aeration is not possible with the existing system. Furthermore, aeration is not effective because of inefficient diffusers and air leakage from pipes. Aeration consumes a significant portion of total electricity used in the sewage treatment process. Hence, excess and inefficient aeration cause increase of CO_2 emission by increasing power consumption and is identified as significant causes of global warming. Especially, unit power consumption of sewage treatment facilities for Block 1 is higher than those of Block 2 and Block 3 because of the severe deterioration of whole facilities.
Sludge treatment facilities	At present, raw sludge is treated by anaerobic digestion whereas excess sludge is treated by aerobic stabilization. Sludge in about 15,000m^3/day is then conveyed to the sludge fields covering area of 272 ha. Sludge in the sludge fields is accumulated and kept in anaerobic condition generating odious smell and methane (CH_4), which has 21 times as effect to global warming as CO_2. Methane produced from the sludge fields is identified as significant causes of global warming. Furthermore, the performance of anaerobic digestion is considerably low and supplementary fuel is required to keep temperature for digestion since production of digestion gas is not enough. Hence, the existing digestion process is contributing global warming by consuming fossil fuel, but not preventing by utilizing biomass energy.
After the reconstruction of BAS	
Sewage treatment facilities	After the reconstruction of BAS, optimization of aeration will be possible by introducing blowers with flow control function, panels with control sequence of the blowers and instrumentation. Furthermore, fine bubble diffuser, i.e. the conventional type of diffuser, is planned to be replaced with ultrafine bubble diffuser, which is the latest energy saving technology, to improve oxygen transfer efficiency. Aeration system is important in order to improve the performance of biological treatment. Renovation of aeration system contributes to reduce emission of CO_2 by reducing power consumption owing to improvement of efficiency of aeration system.

Sludge treatment facilities	After the reconstruction of BAS, sludge will be treated by the process comprised of gravity thickening, mechanical thickening, mechanical dewatering and incineration. Final form of sludge disposal is ash, which does not contain organic substances after combustion. Hence, ash itself does not produce greenhouse gases in any case of recycling and disposal. Furthermore, pressurized fluid bed incineration, which is newly developed technology in Japan, is planned to be introduced and results in reducing power consumption and N_2O emission. Steam power generation system is also planned to be introduced to generate electricity by recovering waste heat possessed by flue gas. This contributes to reduce emission of CO_2 by substituting biomass energy for electricity supplied by the national grid.

Source: JICA Study Team

As shown above, the reconstruction of BAS contributes mitigation of climate change by reducing emission of greenhouse gases during the treatment facilities.

4.8.8 Outline of Facility Planning

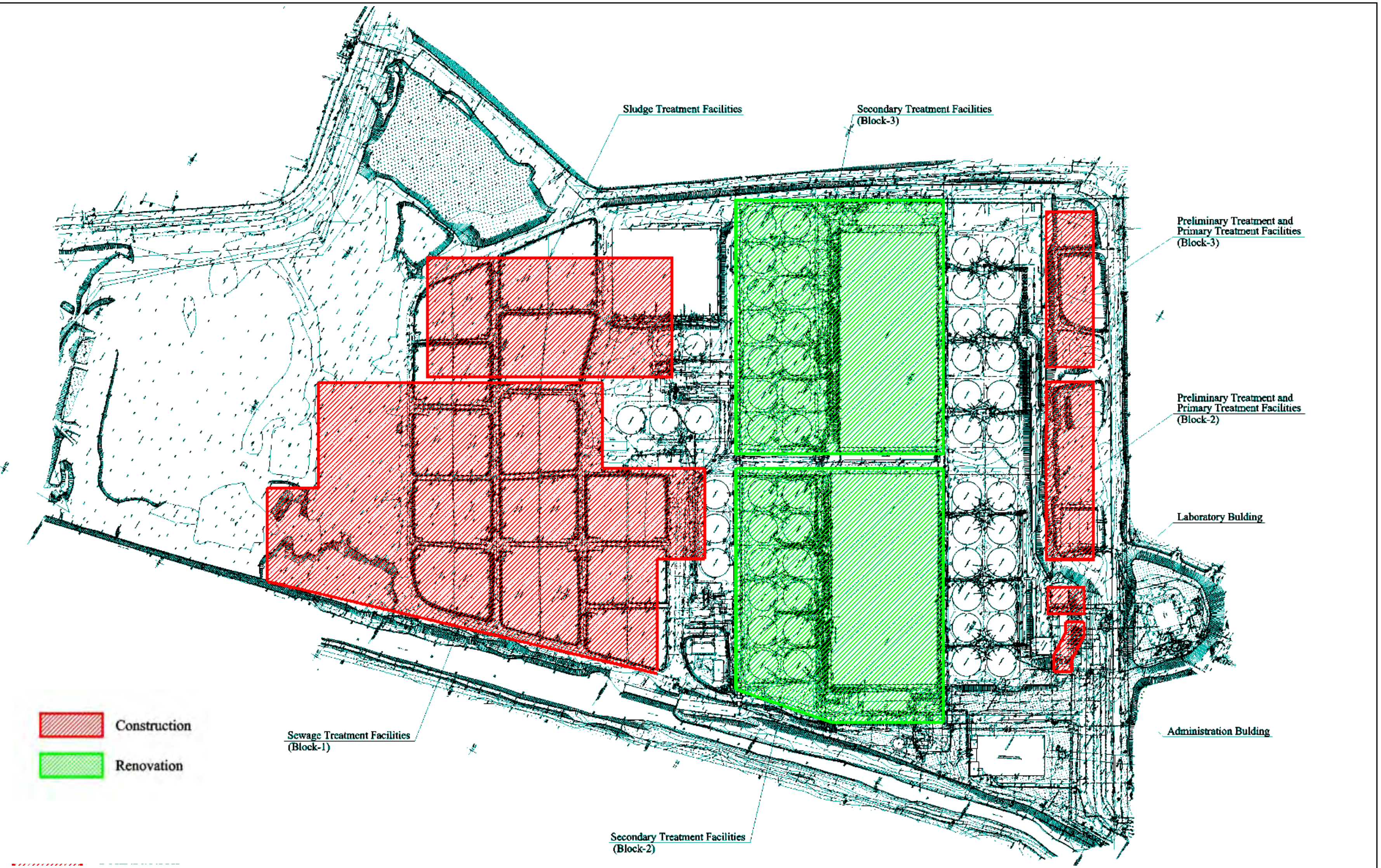
The dimensions of main facilities and specifications of equipment are calculated according to the design criteria shown in Table 4.79. The outlines of the facilities are summarized in Table 4.84. The general layout of the facilities, process flows for sewage treatment, sludge treatment and sludge incineration are shown in Figure 4.41, Figure 4.42, Figure 4.43 and Figure 4.44, respectively. The singe line diagram and SCADA system configuration are shown in Figure 4.45 and Figure 4.46, respectively. The drawings of the facilities, which are newly constructed and renovated under the Project, are presented in Appendix-Drawings.

Table 4.84 Outlines of Facilities Planning

No	Facilities / Dimension / Specification	Number
1.	Preliminary and primary treatment facilities for Block 1	
1-1	1st stage fine screen (channel: 2.5m)	5 nos. (1 standby)
1-2	2nd stage fine screen (channel: 2.5m)	5 nos. (1 standby)
1.3	Grit and grease removal (8mW * 31mL)	5 channels
1.4	Primary settling tank (lamella type: 16mW * 16mL * 8mD)	14 tanks
2	Secondary treatment facilities for Block 1	
2.1	Aeration tank (oxidation ditch type)	4 nos.
2.2	Secondary settling tank (diameter 59m × 5mD)	12 tanks.
2.3	Return activated sludge pump ($33m^3$/min × 12m × 110kW)	16 nos. (4 standbys)
2.4	Sludge collector (circular type)	12 nos.
2.5	Blower building	2 nos.
2.6	Blower ($340m^3$/min × 95kPa × 710kW)	12 nos. (4 standbys)
3.	Tertiary treatment facilities for Block 1	
3-1	Actiflo settler	4 tanks

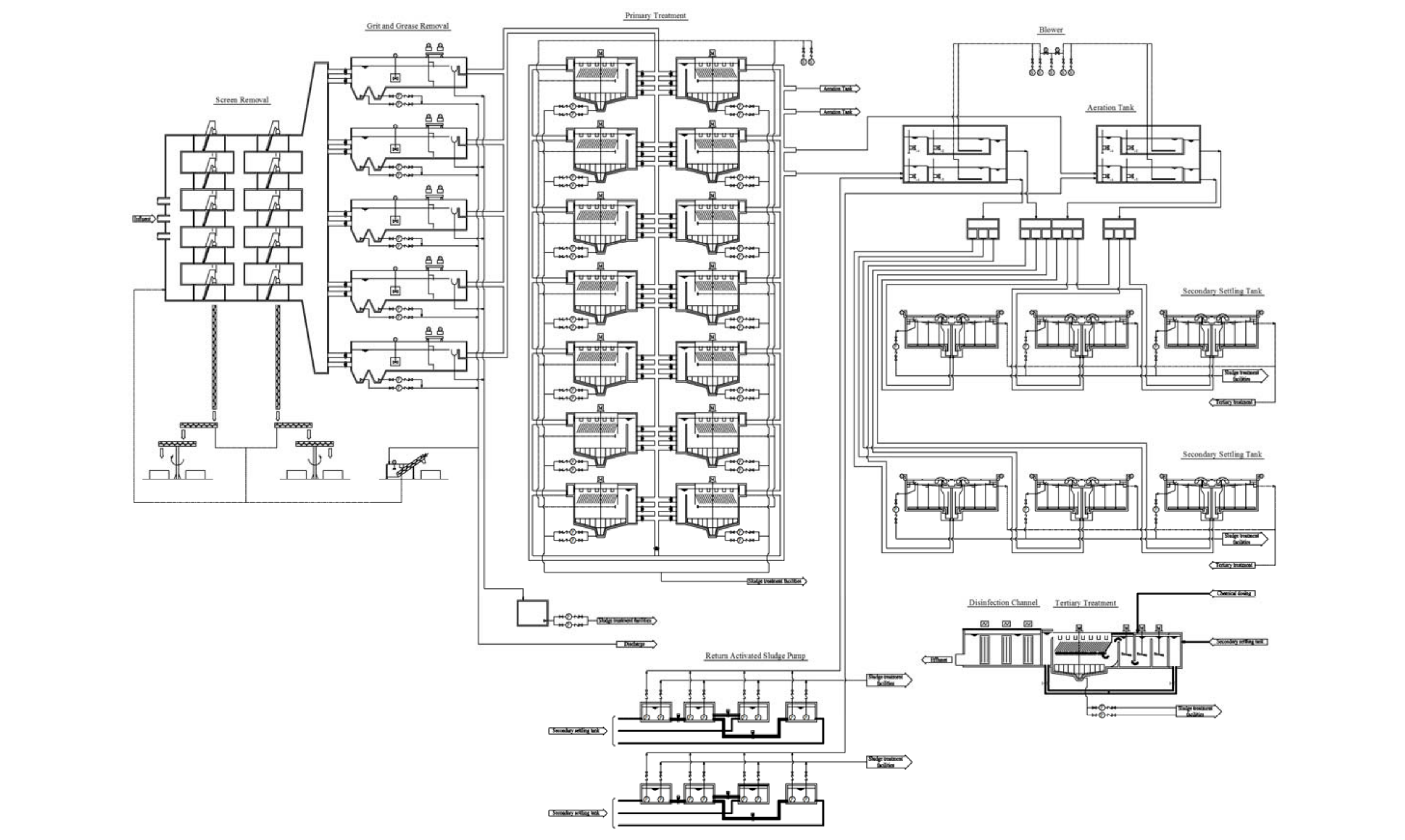
No	Facilities / Dimension / Specification	Number
4.	Disinfection facilities for Block 1	
4-1	Disinfection channel (UV lamp)	4 channels
5.	Preliminary and primary treatment facilities for Block 2	
5-1	1st stage fine screen (channel: 2.5m)	5 nos. (1 standby)
5-2	2nd stage fine screen (channel: 2.5m)	5 nos. (1 standby)
5.3	Grit and grease removal (8mW * 31mL)	5 channels
5.4	Primary settling tank (lamella type: 16mW * 16mL * 8mD)	14 tanks
6.	Preliminary and primary treatment facilities for Block 3	
6-1	1st stage fine screen (channel: 2.5m)	4 nos. (1 standby)
6-2	2nd stage fine screen (channel: 2.5m)	4 nos. (1 standby)
6.3	Grit and grease removal (8mW * 31mL)	4 channels
6.4	Primary settling tank (lamella type: 16mW * 16mL * 8mD)	10 tanks
7.	Reconstruction of secondary treatment facilities for Block 2	Refer to Table 4.77/Table 4.78
8.	Reconstruction of secondary treatment facilities for Block 3	Refer to Table 4.77/Table 4.78
9.	Gravity thickener facilities	
9-1	Gravity thickener (diameter 33m × 4mD)	4 tanks
9-2	Sludge collector (circular type)	4 nos.
10.	Mechanical thickening facilities	
10-1	Belt type thickener (capacity: 150m^3/hour)	9 nos. (1 standby)
10-2	Polymer preparation tank (continuing type)	2 nos.
11.	Mechanical dewatering facilities	
11-1	Screw press dewatering machine (diameter 1200mm*2 screw)	10 nos. (1 standby)
11-2	Polymer preparation tank (continuing type)	6 nos.
11-3	Sludge cake silo (capacity: 140m^3)	1 no.
11-4	Sludge cake hopper	1 no.
11-5	Sludge cake receiving hopper	1 no.
11-6	Sludge cake pump (from sludge cake silo to incinerator)	4 nos.
11-7	Sludge cake pump (from receiving hopper to sludge cake silo)	1 no.
12.	Sludge incineration facilities	
12-1	Pressurized fluidized bed incinerator (capacity: 425ton/day)	4 nos.
12-2	Steam turbine generation system	1 no.
13.	Common facilities	
13-1	Administration building (5-storied building)	1 no.
13-2	SCADA system	1 set
13-3	CCTV system	1 set
13-4	Laboratory building (4-storied building)	1 no.

Source: JICA Study Team



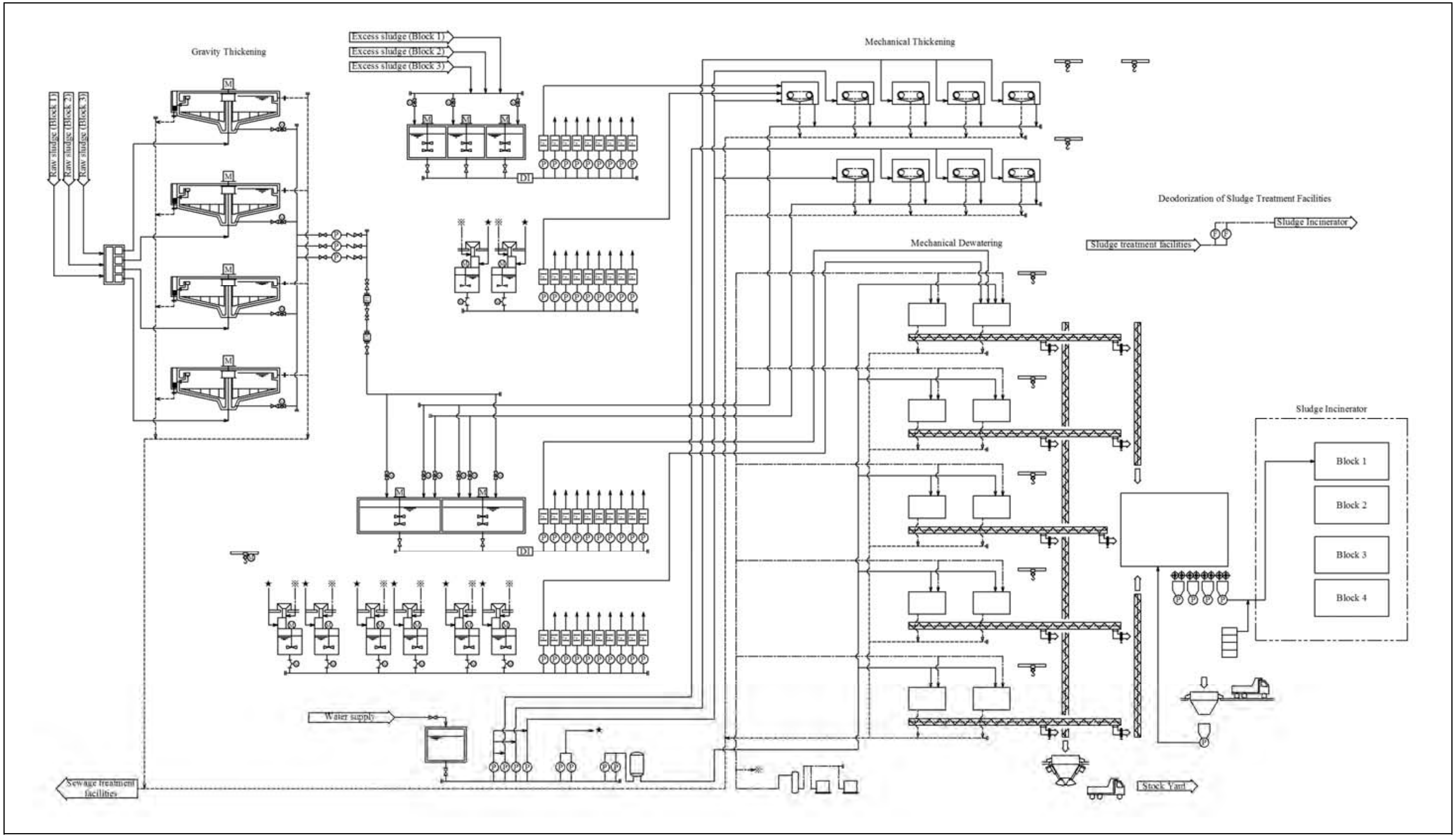
Source: JICA Study Team

Figure 4.41 General Layout



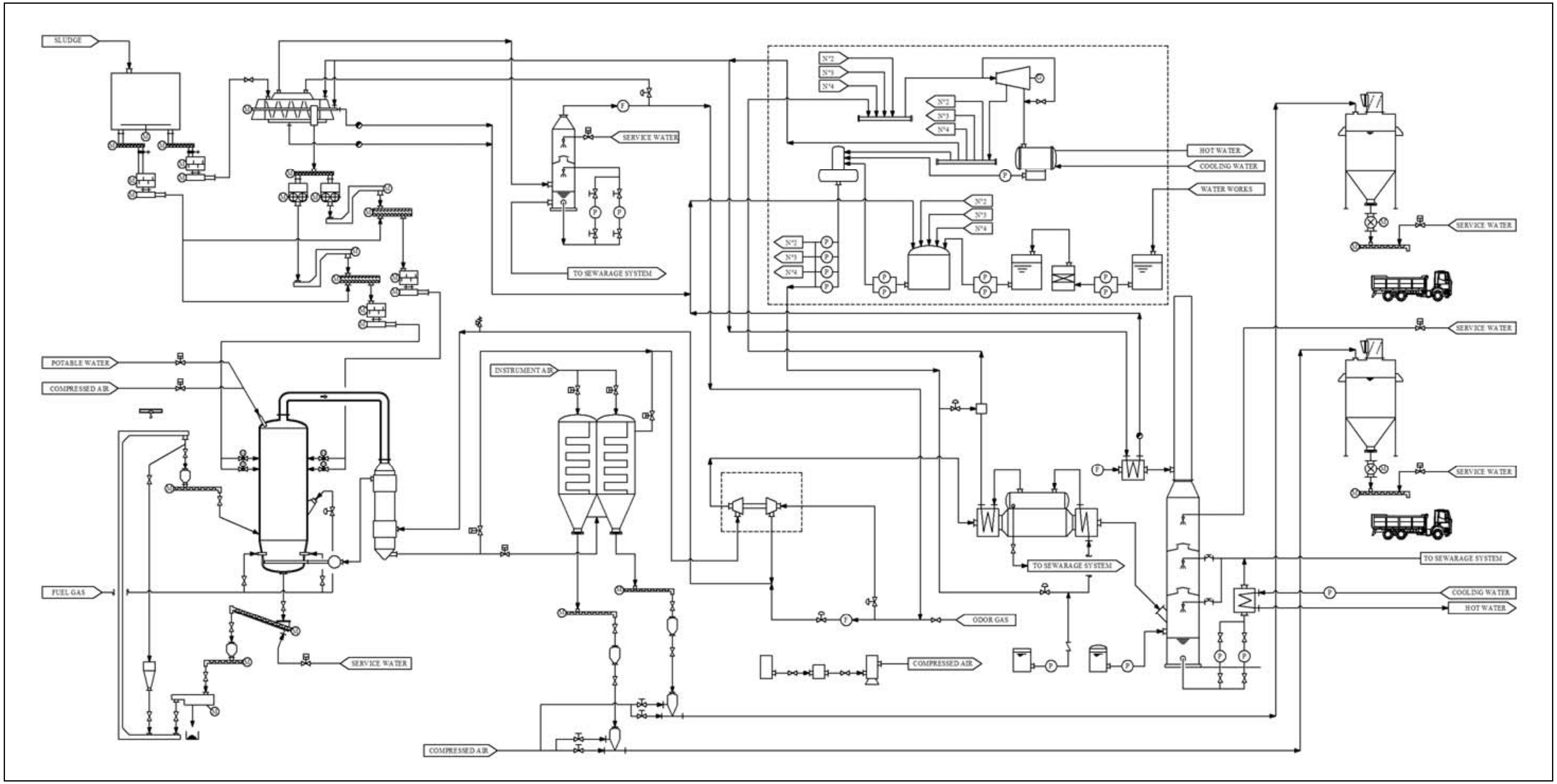
Source: JICA Study Team

Figure 4.42 Process Flow of Sewage Treatment



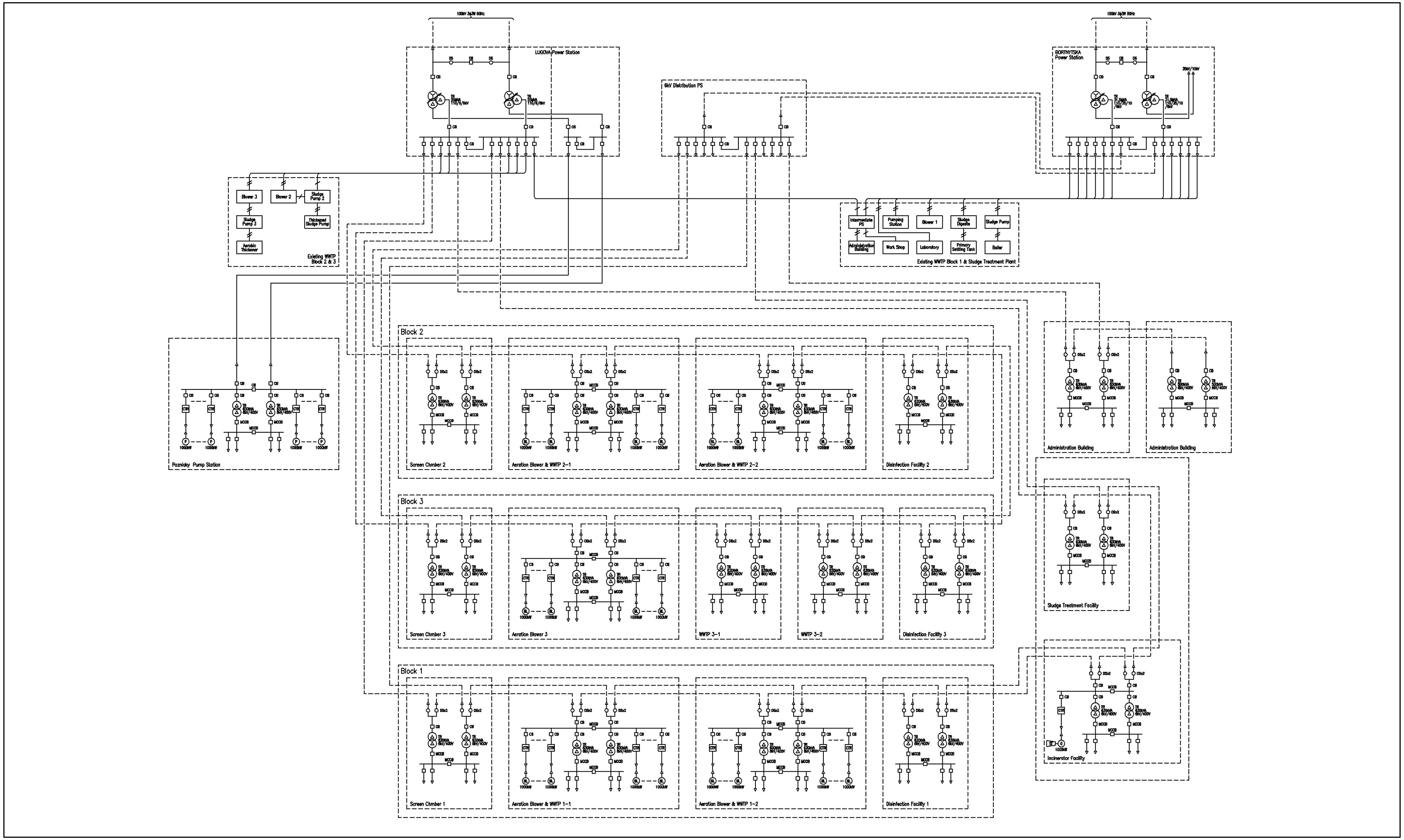
Source: JICA Study Team

Figure 4.43 Process Flow of Sludge Treatment



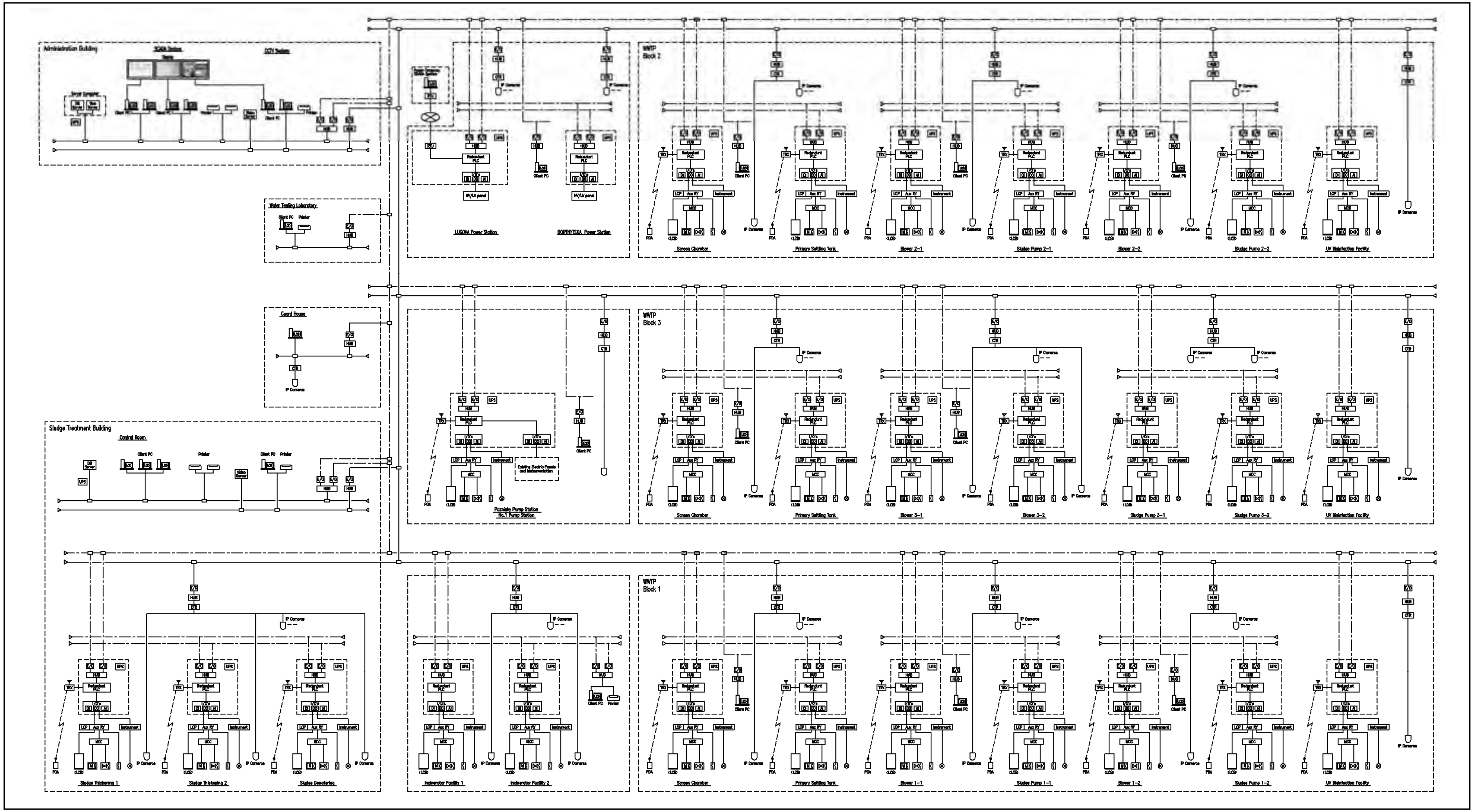
Source: JICA Study Team

Figure 4.44 Process Flow of Sludge Incineration



Source: JICA Study Team

Figure 4.45 Single Line Diagram



Source: JICA Study Team

Figure 4.46 SCADA System Configuration