4.3.3. Real Time Monitoring System

(1) Design

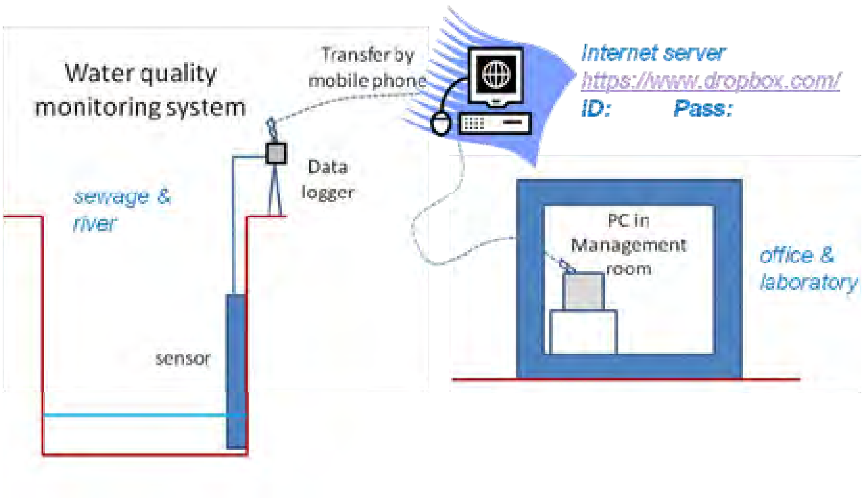
Some automatic BOD monitoring systems have already been developed and are commercially available on the market. However, the sensors of these highly accurate but expensive instruments have low durability under polluted conditions. The BOD is generally analyzed with incubating water samples for 5 days, so it is not so easy to analyze, using the in situ sensors or analysis (Bourgeois et al., 2001). In case of in situ analysis, a small chemical laboratory with automatic analyzer and an auto water sampler are needed. On the other hand, a sensor to automatically measure some indicators for estimation of BOD, in situ sensors, such as biosensors, optical sensors, etc is needed. The shortcomings of these alternative sensors to monitor more directly the BOD are durability and cost in Indonesia.

On the other hand, the electrical conductivity (EC) sensor is generally simpler and has low cost and high durability. In this report, the Survey team proposes a real time monitoring system and transfer system with low price and high performance, using EC sensor. The system comprises monitoring sensors for EC, pH, temperature and DO and data transfer system as shown Fig. 4.3.4a.

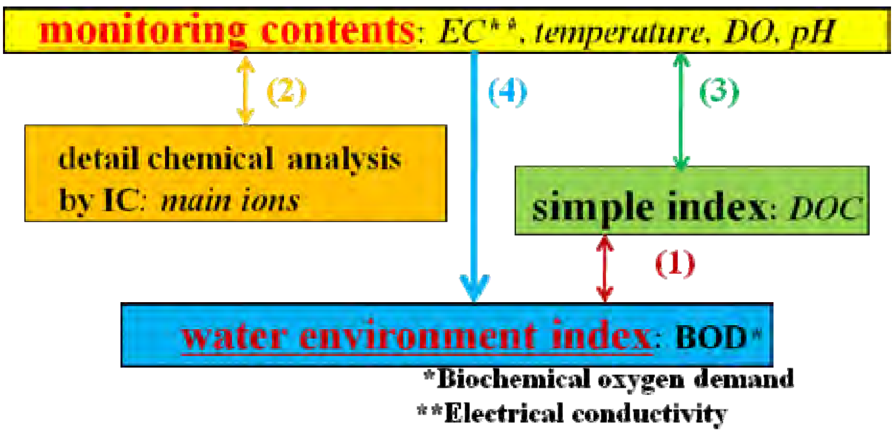
To utilize such simple system, it is necessary to confirm the relationship between BOD and DOC, EC and detail chemical components, EC and DOC, and EC and BOD (Fig. 4.3.4b) on the basis of the data to be collected in Jakarta. In this Survey, the Survey team aimed to examine (1) collections of previous data and construction of data base, (2) detail analysis of water quality in river and canal sewage water samples, (3) confirmation of some relationships, and (4) quality check of low cost real-time monitoring system for water quality.

The cost comparison on BOD automatic monitoring system in Japan and the proposed system is listed in Fig. 4.3.1c. The price of this EC system is one fifth of the BOD system. If the relationships in Fig. 4.3.4c are available in Jakarta, the cost performance of this system would be better.

(a)



(b)



(1) confirmation of relationship between DOC and BOD
(2) confirmation of relationship between detail ion contents and monitoring contents
(3) confirmation of relationship between DOC and monitoring contents
(4) estimation of BOD, using the above relationships and monitoring contents

(c)

	cost	system example
BOD monitoring	**¥5,000,000**	**monitoring system in Japan**
EC monitoring	**¥1,000,000**	**proposing system**

Fig. 4.3.4 Schematic diagram showing (a) automatic monitoring and data transfer system, (b) estimation scheme of pollution index in the monitoring system, and (c) cost comparison on two types of automatic monitoring system

(2) Test Monitoring and Data Collection in a Sewage of Jakarta

In this survey, the Survey team conducted the test monitoring at a sewage pumping station of PD PAL JAYA in Jakarta. The image showing installation and the flow chart of data transfer process are shown in Fig. 4.3.5 and Fig. 4.3.6, respectively. The manual of data transfer process is described in Appendix B.

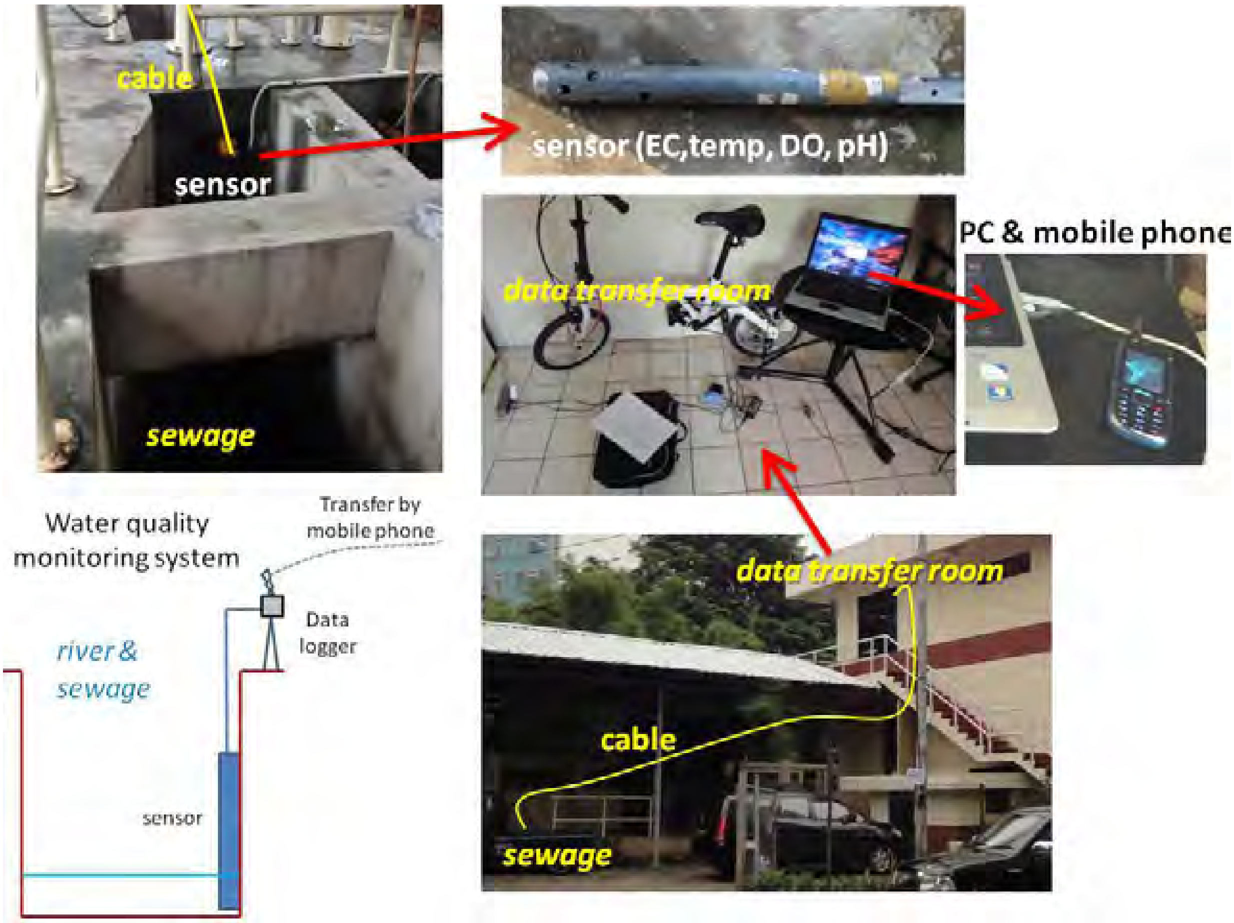


Fig. 4.3.5 Image showing installation of real time monitoring system at the pumping station of PD PAL JAYA, Jakarta

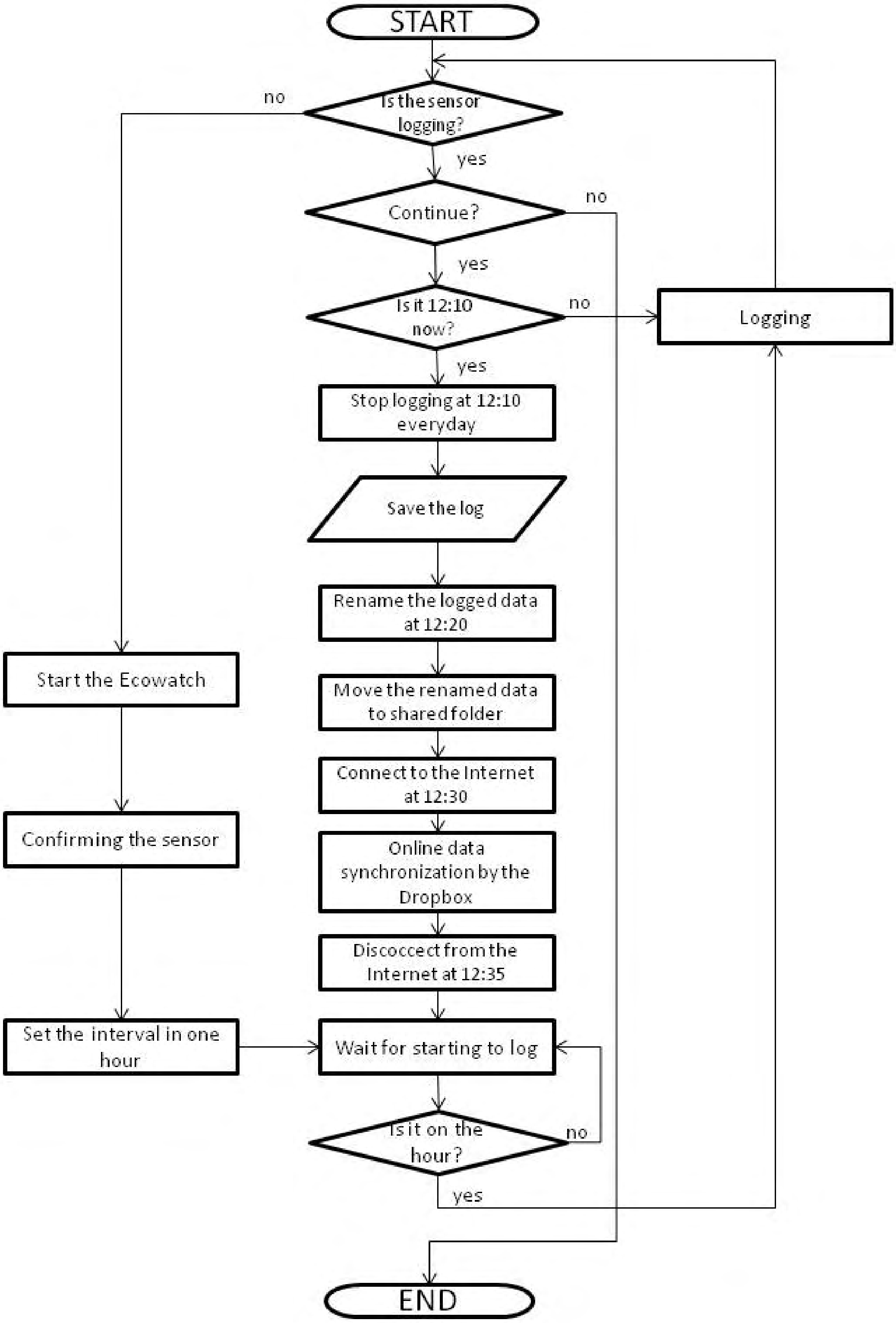


Fig. 4.3.6 Flow chart of data transfer process for real time monitoring system

* The manual of data transfer process and PC control is described in Appendix B

The sensor durability was verified for a period of two months, and no technical difficulties were found. In addition, data transfer process was successfully checked for one week, but without pricing of the data transfer charge. An example of the collected data is plotted in Fig. 4.3.7, in which the water level data is the raw value before converting to the absolute value, (i.e., water level around 34 feet was equivalent to zero absolute level). The EC values were extremely high with the water flowing, but nearly zero during the dry up. This implies that water in the sewage flowed only during the pumping up.

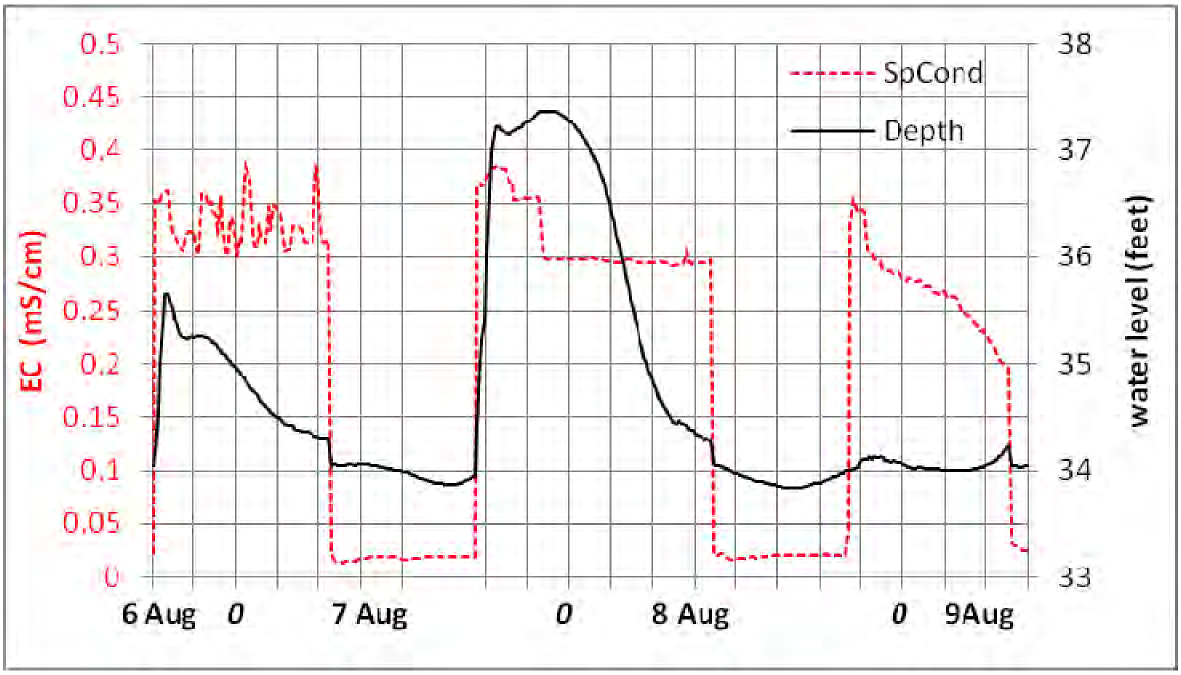


Fig. 4.3.7 Example of collected data, EC (specific conductivity)
and water depth during August 6- 9, 2010

4.3.4. BOD Estimation

(1) BOD and EC Relationship in Japan

For estimating BOD value using an EC monitoring system, it is needed to find a good correlation between EC and BOD as shown in Fig. 4.3.8. Firstly, The Survey team examined the data sets from Yamato River in Osaka metropolitan area, central Japan and Saba River in Yamaguchi Prefecture, in western Japan and Osaka metropolitan area, central Japan, respectively. The former is a polluted river in rural area, and latter a non-polluted urban river. These monthly water quality data are compiled from the original data base in 1984 to 2009.

Fig. 4.3.8 demonstrates the relationship between the EC and BOD in the Yamato River and Saba River from 2007 to 2009. The regressed results indicate good correlation between EC and BOD in Yamato River, but not in Saba River. This suggests that it is practicable to estimate BOD using EC in polluted condition.

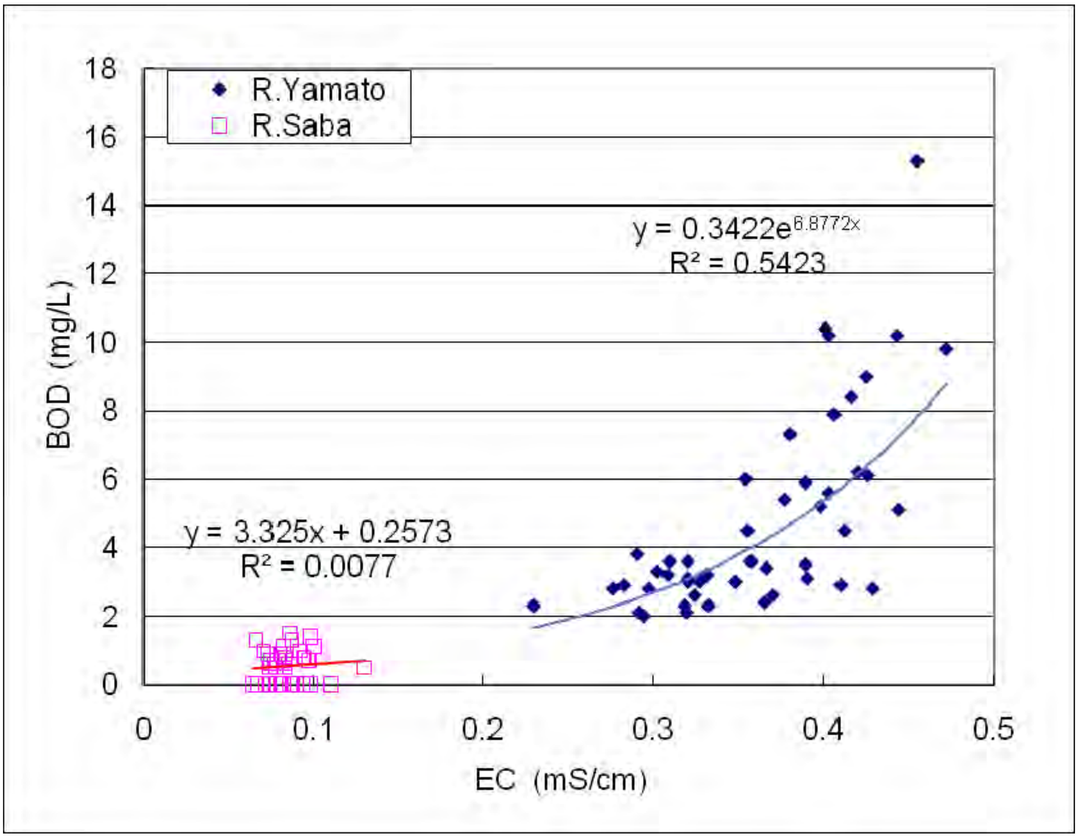


Fig. 4.3.8 Relationship between the EC and BOD in Yamato and Saba Rivers from 2007 to 2009

However, the relationship became unclear if data set longer than 4 years is used, since the seasonal variation in EC and BOD is similar but long-term variation is different. Figs. 4.3.9 and 4.3.10 show similar decreasing trend and the long-term variation in BOD and suspended solid in Yamato River over 25years from 1984 to 2009, signaling a likely recovery process of water pollution in this river; but the long-term variation in EC was not obvious in BOD. This suggests that the BOD is related to the dissolved solid and EC in seasonally varying suspended solid over a longer term. In addition, it seems also that BOD is controlled by suspended organic materials in the polluted river but by dissolved organic materials in the recovering process.

Therefore, it would be necessary to include a suspended solid sensor, presently costing ¥500,000, in the proposed system for estimation of BOD in Jakarta. This would improve the correlation shown in Fig. 4.3.8 and render the instrument more effective in case of low suspended concentration.

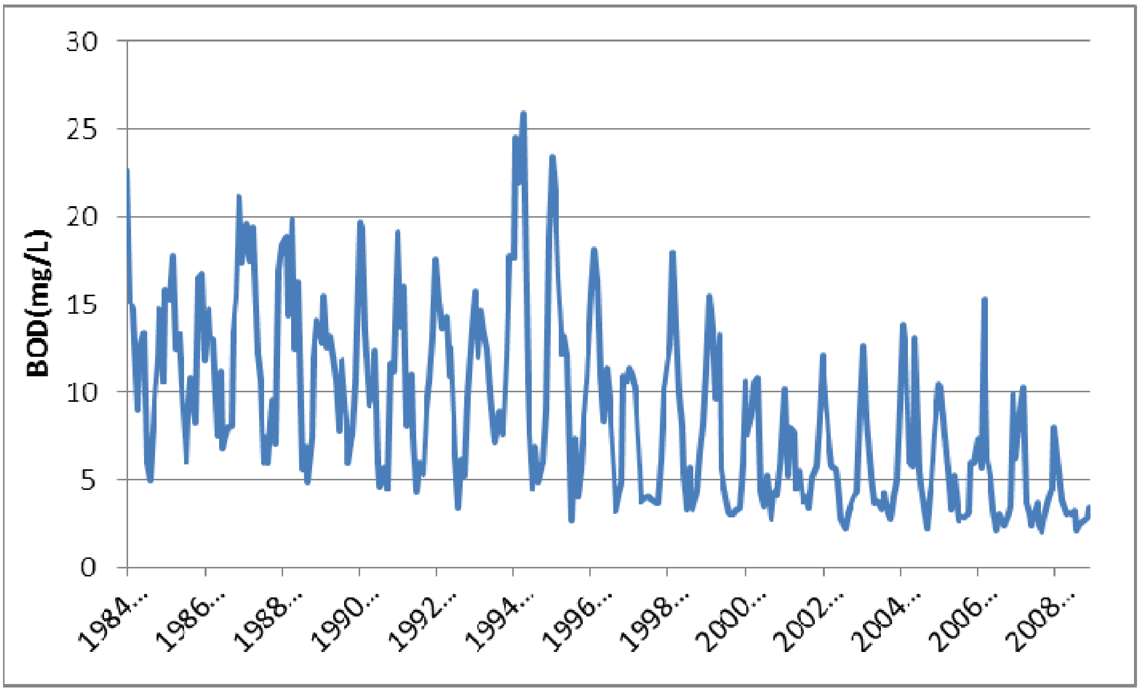


Fig. 4.3.9 Long-term variation in BOD in Yamato River from 1984 to 2009

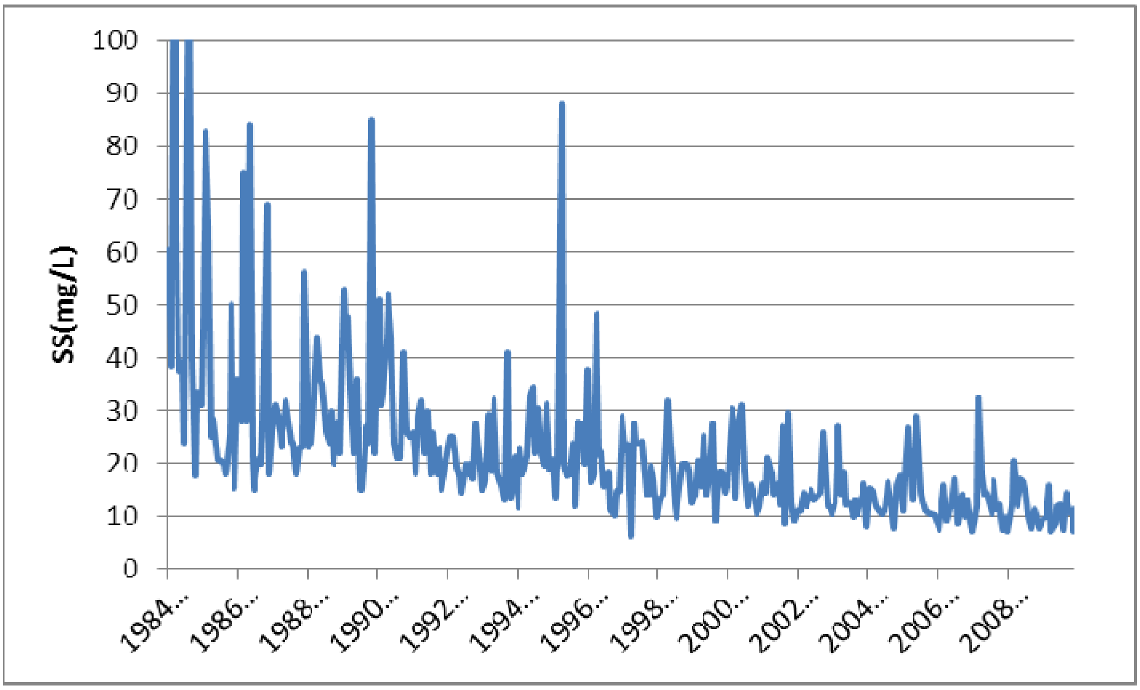


Fig. 4.3.10 Long-term variation in SS using EC in Yamato River from 1984 to 2009

(2) BOD and EC Relationship in Jakarta

Water samples were collected in the Ciliwung River, sewage and ponds on 25 - 26 April in 2010 under a low flow condition and 12 - 13 June in 2010 under a high flow condition after a storm flood. Fig. 4.3.11 shows the spatial distribution of EC, DO, BOD and DOC in the Ciliwung River from mid-stream to downstream on 12 - 13 June, 2010. The locations of the sampling points along river and at sewage are shown in Fig. 4.3.12 and Fig. 4.3.2b. The EC and DO were measured by portable meters, BOD analyzed by PD PAL JAYA, and DOC analyzed in Hiroshima University.

In Fig. 4.3.11, the EC and DOC values increased, accompanying decrease in DO, from mid-stream to down-stream. These suggest that water pollution was more serious in down-stream than in up-stream. On the other hand, the BOD value was high in up-stream as well as in down-stream. Based on the results in Yamato River, it could be estimated that the suspended organic materials dominated in biochemical oxygen demand in up-stream, whereas dissolved organic content in down-stream.

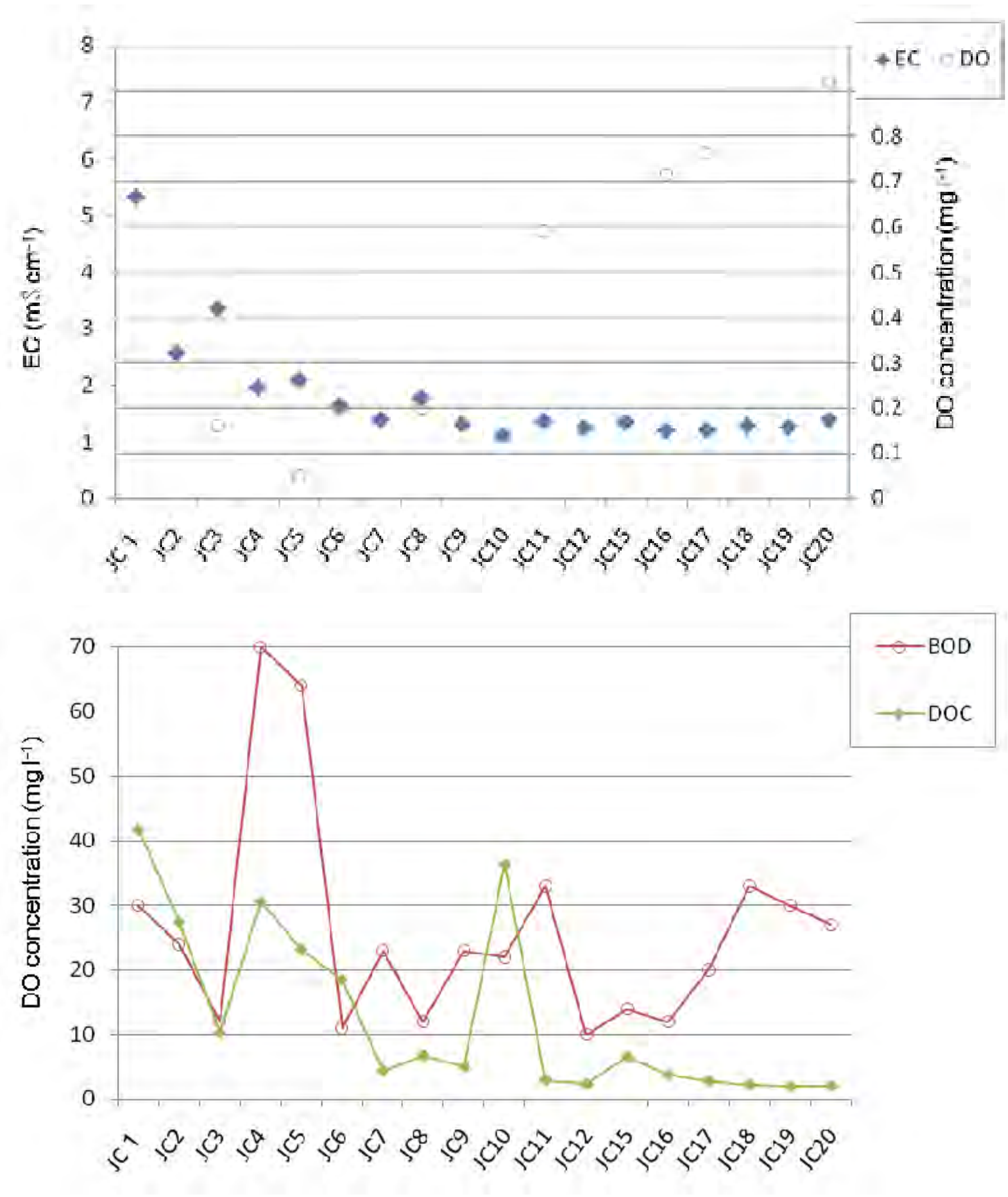


Fig. 4.3.11 Spatial distribution of EC, DO, BOD and DOC in the Ciliwung River from mid-stream to downstream on 12 - 13 June, 2010

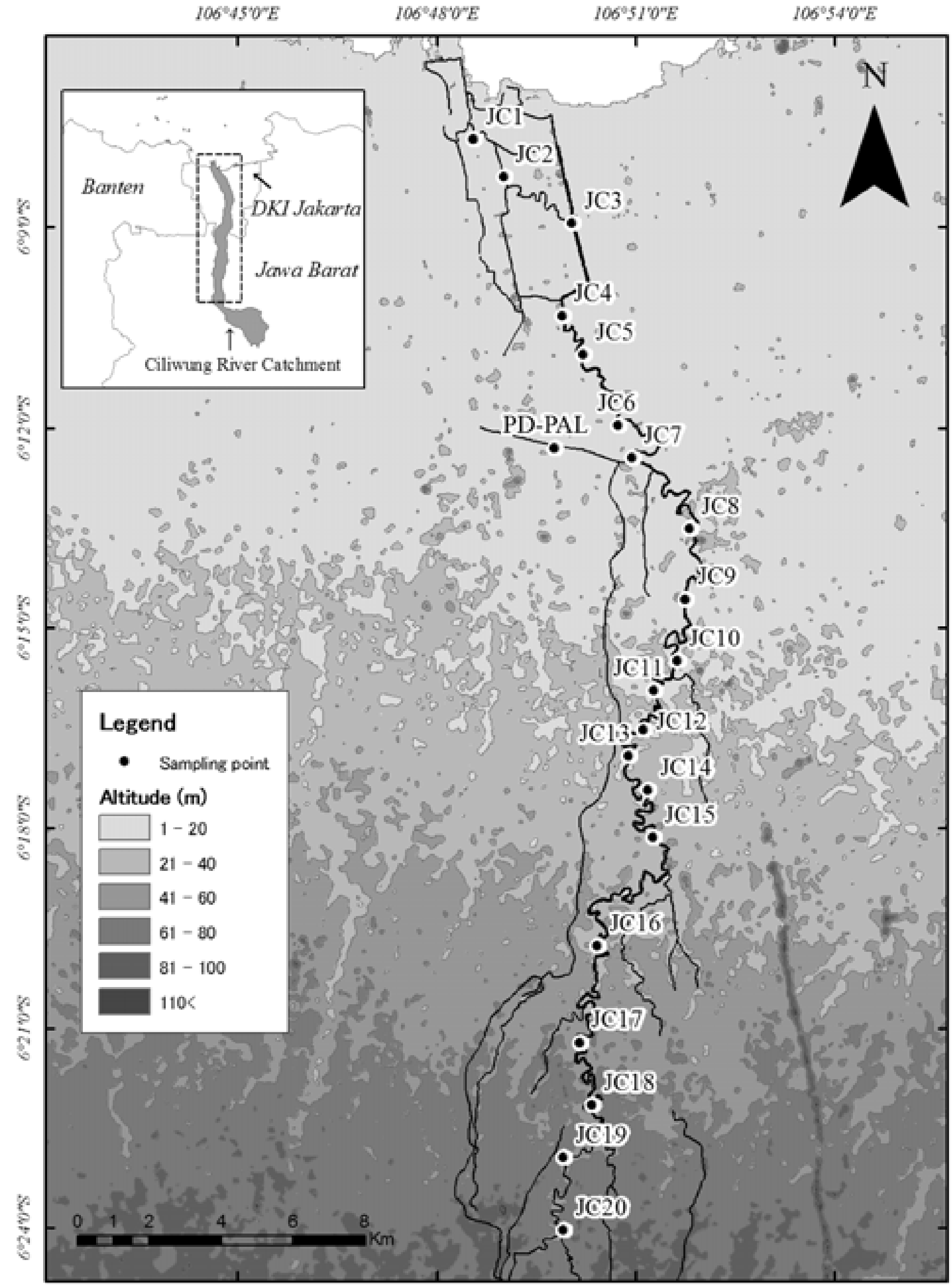


Fig. 4.3.12 Locations of sampling sites in river and sewage in Jakarta

Fig. 4.3.13 shows the relationship between EC and BOD in river and sewage in Jakarta with the best-fit curve of Yamato River from 2007 to 2009. In the case of water with less suspended materials, such as the sewage or river water in downstream, the EC and BOD relationship was similar to the best-fit curve shown. On the other hand, BOD values were high and EC were low in water with suspended solid.

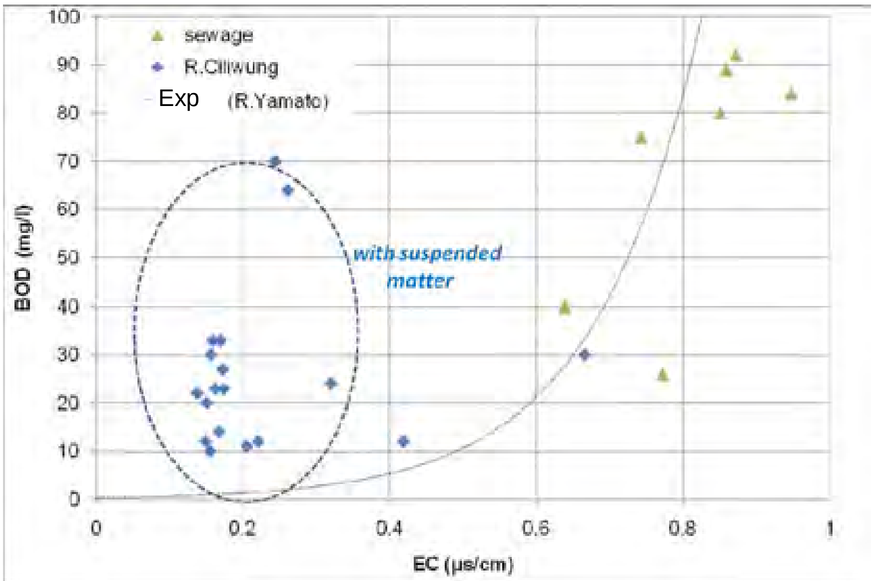


Fig. 4.3.13 Relationship between EC and BOD in river and sewage in Jakarta with the best-fit curve for Yamato River in 2007 to 2009

Furthermore, Figs. 4.3.14 and 4.3.15 exhibit the relationships between BOD and DOC in river in Jakarta in June 2010 and between EC and DOC in April and June in 2010, respectively. The BOD values were higher in the most of the water samples than DOC in June. As described above, it was estimated that these water samples included the suspended solids of organic substances. In addition, the EC and DOC relationship in April was better than that in June. The water samples with suspended solids tended to have high DOC concentration.

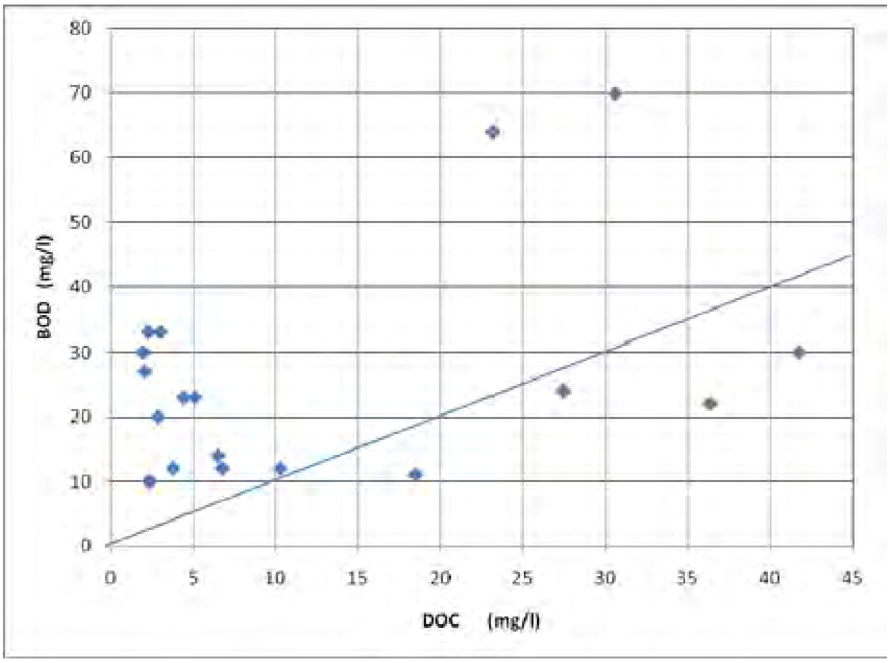


Fig. 4.3.14 Relationship between BOD and DOC in river in Jakarta in June 2010

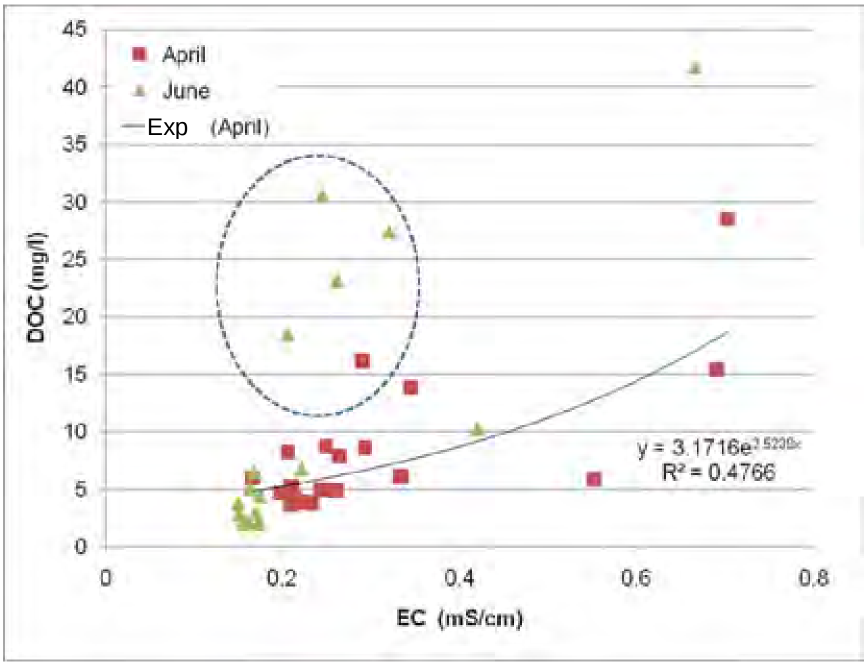


Fig. 4.3.15 Relationship between EC and DOC in river in Jakarta in April and June in 2010

EC is normally related to total ion, and DOC is one of the main ions in case of organic polluted area. The good correlation between EC and DOC supports these properties. But in case of high suspended concentration, part of DOC includes unionized compounds.

(3) Additional Comments to Real Time Monitoring System

Based on the preliminary results of this survey, the Survey team finally proposed a real time monitoring system which included a suspended solid sensor to the system in Fig. 4.3.4 and Fig. 4.3.5. Good correlation between EC and DOC, and EC and BOD were confirmed in many cases including that from Japan. Based on these relationships, The Survey team could estimate BOD in sewage without suspended material. However, it is required to use the relationship between SS and BOD in case of high suspended concentration.

In our proposed system, the cost is one fifth of that of BOD and the sensor has high durability. The Survey team is confident that the proposed monitoring system for Indonesia would be effective.

4.3.5. Ion Chromatography Analysis

In the biological treatment system under the aerobic conditions, there are at least two major treatment processes. One is BOD-oxidation process for BOD/COD removal and the other is biological nitrification process for nitrogen (NH_4^+) removal. In the BOD-oxidation process, pH and DO as well as BOD/COD concentrations are used to optimize the treatment system as the process control parameter. On the other hand, in the biological nitrification process for NH_4^+ removal, pH and DO as well as NH_4^+, NO_3^-, and HCO_3^- concentrations is also used to optimize the treatment as the process control parameter.

In addition to the BOD/COD measurements, the measurement of nutrients (such as nitrogen and phosphorus as well as silicate) is also performed to optimize the biological wastewater treatment process and to evaluate the effect of human activity to domestic wastewaters (such as sewage). Since the increase in discharged amounts of these nutrients in urban stream including domestic waster causes the eutrophication of aquatic environment, the water quality monitoring of the nutrients and the relating ionic components is very important for the aquatic environmental management/control operated by any public-sector institutions.

According to JBIC's SAPS Research Project performed jointly by Hiroshima University/ Mitsubishi Research Institute in 2007, the capacity/ performance of water quality monitoring operation in a developing country like Indonesia was judged as extremely poor. This was due to the decreased management capacity of provincial water quality monitoring laboratories operated by local government. Accordingly, to enhance the capacity of water quality monitoring operation, it was concluded that an advanced water quality monitoring system with high performance and low cost should be introduced to water quality monitoring operation by the provincial environmental monitoring laboratories.

The major ionic components of environmental waters like river, pond, and sewage waters consist of the common cations H^+, Na^+, NH_4^+, K^+, Mg^{2+}, and Ca^{2+}, and the common anions Cl^-, NO_3^-, and SO_4^{2-}, as well as phosphate and silicate ions as the nutrients and HCO_3^-(alkalinity) as the inorganic-carbon source to synthesize a bacteria in the biological nitrification process under the aerobic conditions. Recently, both of phosphate and silicate are also recognized to be significant nutrients causing the eutrophication in lake, pond, river, inland sea, etc. It has been shown that the ionic balance between these anionic and cationic components is almost unity, suggesting that other ionic components have an insignificant contribution. Therefore, the ionic balance is extremely important concept in terms of water chemistry in aquatic environment, as shown in the equation below based on the principle of electro-neutrality,

$$\text{Ionic balance} = [\sum \text{anions}] / [\sum \text{cations}] \fallingdotseq 1.0$$

(1) Significant of Application of Advanced Ion Chromatography Technology to Water Quality Monitoring

The introduction of a simple, convenient, highly sensitive, and low-cost analytical method for monitoring simultaneously the ionic components above-described is very important to enforce absolutely the environmental water quality monitoring operation, especially in developing countries. In particular, for the water quality evaluation of the various environmental waters, ion chromatography has been recognized to be a very useful and powerful method for monitoring the anions or the cations commonly found in various environmental waters.

Recently, ion chromatography (IC) technology authorized internationally as the official analytical methods such as US-EPA, JIS, and ISO methods has been world-widely applied to the water quality monitoring of various environmental waters not only in developed countries but also in developing countries like Indonesia.

The IC method commonly used for water quality monitoring is a technique for sequential (simultaneous) determination of anions or cations using a separation column packed with ion-exchange resin and conductivity detector to detect the ionic substances separated. The conventional ion chromatography system is simple and consists of an eluent-delivery pump, a sample injector, a separation column packed with ion-exchange resin, a conductivity detector, and a chromatographic date processor to measure chromatographic peaks and to optimize control the chromatographic system. When the eluent background conductivity is high, a suppressor column (packed-bed suppressor) or membrane suppressor was often used in the determination of the common anions or cations. However, there are several problems for the determination of the anions or cations by the conventional ion chromatography technology. When using the ion chromatography technologies based on the ion-exchange separation mechanism, it is impossible to determine simultaneously the anions and cations. Therefore, two ion chromatography systems consisting of one for anions determination and other for cations determination are commonly used for the water quality monitoring.

In a modern ion chromatography technology, the simultaneous ion-exclusion/cation-exchange chromatography developed recently by Tanaka et al. (J. Chromatogr., 671, 239 (1994)) has been recognized to be useful and powerful water quality monitoring technology. The results are briefly described below.

1) Simultaneous, selective, and low-cost water quality monitoring of common anions and cations by using very diluted and non-toxic organic carboxylic acid as the eluent
2) Selective, highly sensitive, and low-cost water quality monitoring of phosphate and silicate ions by using water as the eluent

3) Selective, highly sensitive, and low-cost water quality monitoring of alkalinity (HCO_3^-) as an inorganic-carbon source by using water as the eluent

As described in the previous section, the water quality monitoring operation performed by the local government sector based on the environmental policy is an important task for evaluating the impact to aquatic environment of domestic waste waters including sewage and urban river waters. However, in present time, the un-treated sewage collected from various business and housing complex in Jakarta metropolitan area is introduced into two-small ponds near PD PAL JAYA office located in central Jakarta and then discharged into urban river without special physical/chemical and biological treatments under the environmental management/control by PD PAL JAYA.

As part of environmental management operation by PD PAL JAYA, a monthly water quality monitoring including BOD, COD, SS, pH, NH_4^+, detergent, oil contents, etc., as described elsewhere, is performed periodically using time-consuming and inconvenient official analytical methods. However, the water quality monitoring operation is absolutely insufficient for evaluating the treatment capacity of the ponds because of the lack of monitoring of nutrients such as NH_4^+, NO_3^-, and phosphate and silicate ions as well as alkalinity (HCO_3^-) as an inorganic carbon source.

On the other hand, since the proposed ion chromatography technology for the simultaneous determination and highly sensitive detection of common anions, cations, nitrients, and alkalinity is to achieve a simple, convenient, low running cost, and non- or less chemical reagent water quality monitoring operation, its application in a developing country like Indonesia is meaningful, especially for the introduction to a public-sector institution like PD PAL JAYA.

In this survey study, based on the above-described concept for advanced water quality monitoring, the following advanced ion chromatography technologies consisting of simultaneous ion-exclusion/cation-exchange chromatography of common anions and cations using conductimetric detection (J. Chromatogr.A, 671, 239 (1994)), ion-exclusion chromatography of phosphate and silicates ions (Anal. Chim. Acta, 619, 110 (2008)), and ion-exclusion chromatography of alkalinity (HCO_3^-) using UV-detection (Talanta, 70, 174

(2006); J. Chromatogr A, 1092, 250 (2005)) are introduced for the advanced water quality monitoring, respectively.

In the first stage of this survey study during March 21-29, 2010, the usefulness of high performance and low-cost advanced ion chromatography was demonstrated for the practical applications to evaluate the water quality of several environmental waters including sewage and urban river waters in central Jakarta.

Additionally, in the second stage of this survey study during June 13-19, 2010, the water quality monitoring of the Ciliwung River waters, the most important watershed in Jakarta metropolitan area, was performed using the advanced ion chromatography technology and the water quality was evaluated.

(2) Sampling Locations in Jakarta

Several environmental water samples were taken from the east and west ponds in PD PAL JAYA (4 water samples), urban rivers in the central Jakarta (4 water samples), and along the Ciliwung River from Bogor to Jakarta (18 water samples; length of main stream of the watershed: about 55 km from coastline). Figs. 4.3.16 to 4.3.18 show locations and pictures of the sampling site in the two ponds, urban rivers, and the Ciliwung River, respectively. All the water samples taken from surface water were injected to the advanced ion chromatograph for analyzing the major water quality parameters.

Fig. 4.3.16 Sampling locations at the east- and west ponds of PD PAL JAYA

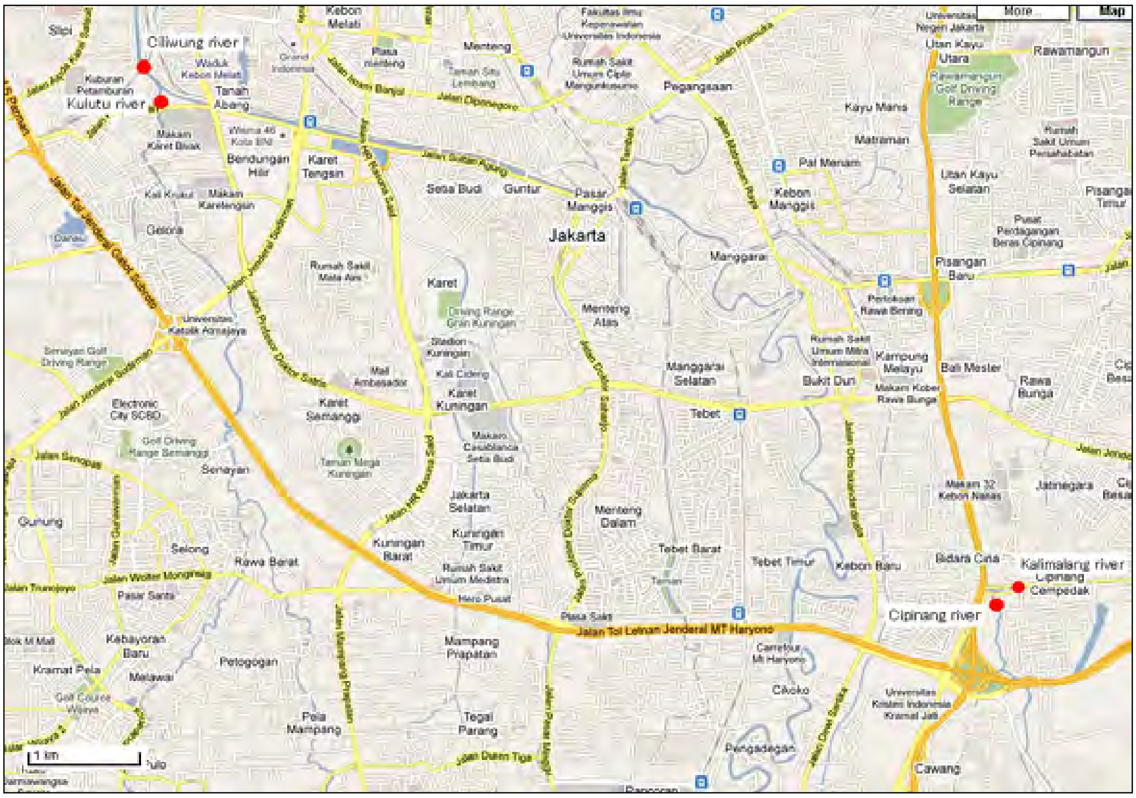


Fig. 4.3.17 Sampling locations at urban rivers of the central Jakarta

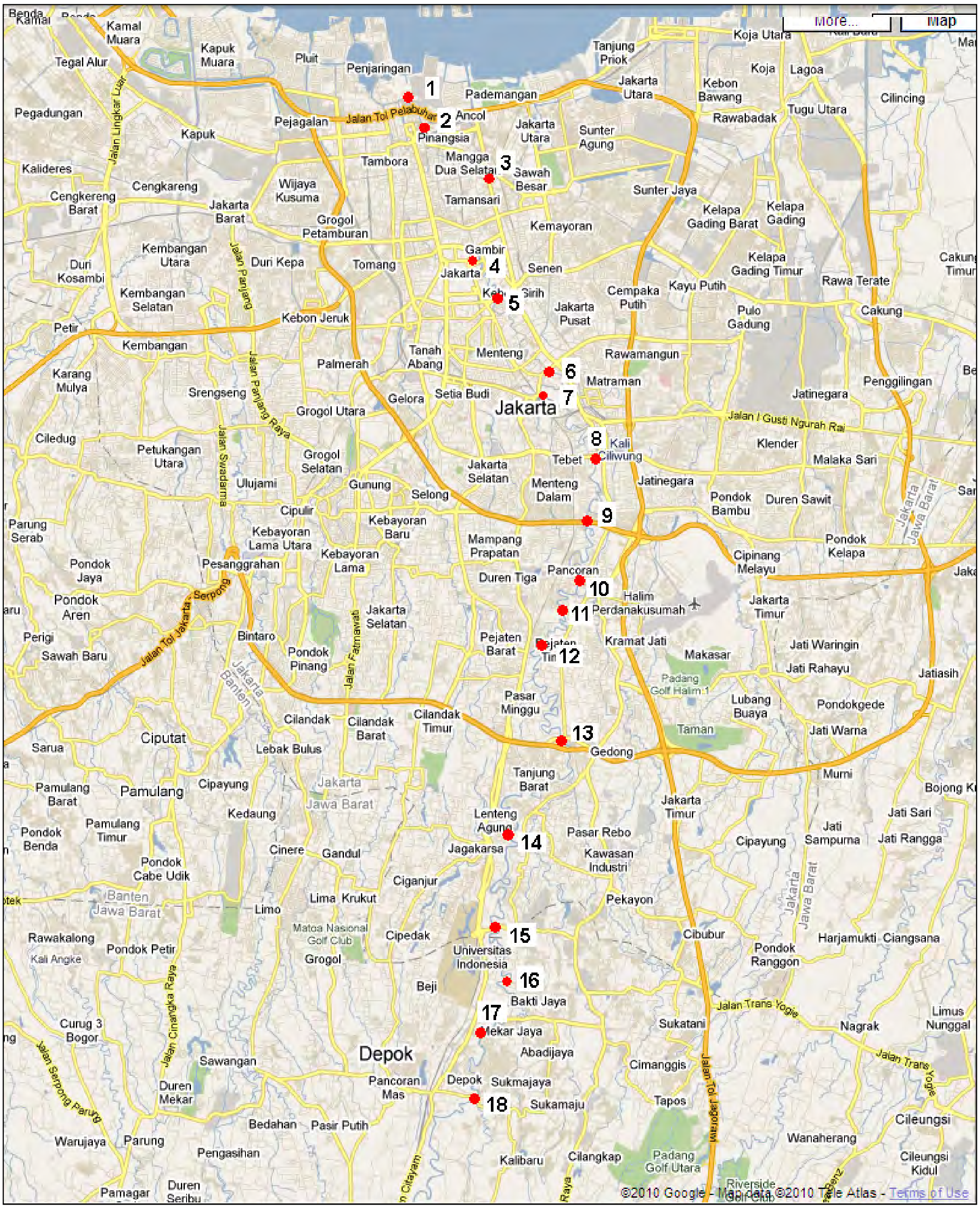


Fig. 4.3.18 Sampling locations at the Ciliwung River watershed

(3) Ion Chromatography Methodology and Sample Pretreatment

As has been mentioned in the section of “Introduction”, in order to evaluate the water quality of various environmental waters taken in the two small ponds in PD PAL JAYA (Fig. 4.3.16), urban rivers in Jakarta metropolitan area (Fig. 4.3.17), and the Ciliwung River watershed from Jakarta to Bogor (Fig. 4.3.18), the monitoring of common anions, cations, nutrients, and alkalinity was performed using ion chromatograph equipped with conductivity and visible detectors (Fig. 4.3.19).

For taking practical water samples, each of sampled water was filtered with a 0.45 mm membrane filter and then injected onto the separation column without further pretreatment for evaluating the water quality.

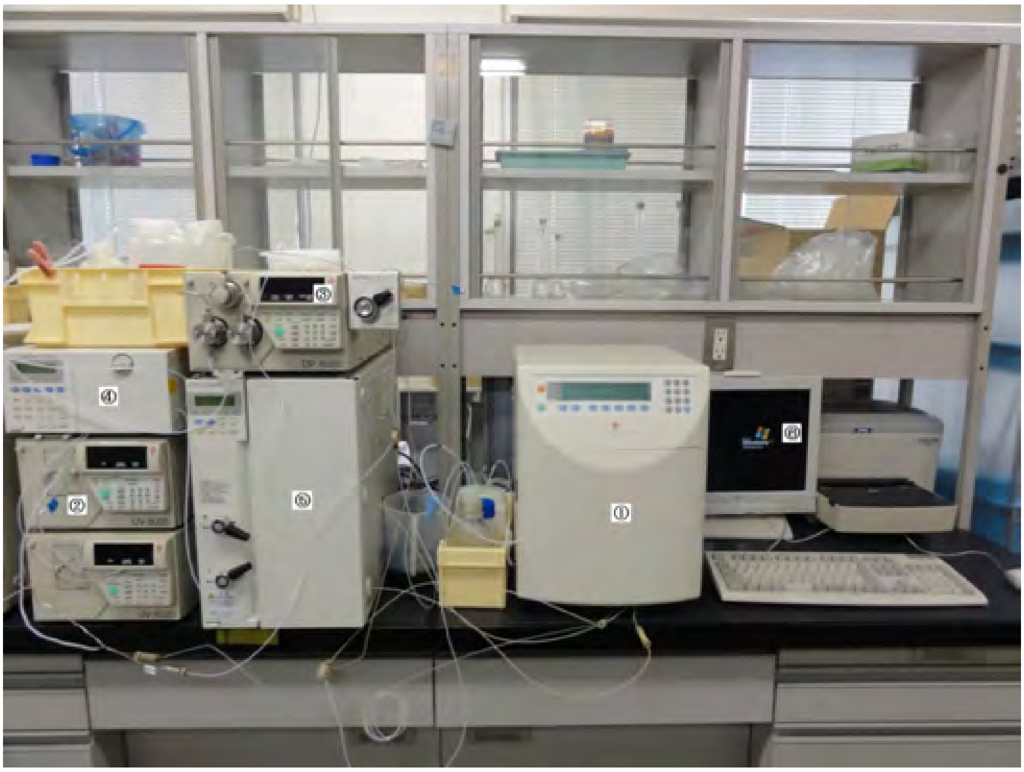


Fig. 4.3.19 Versatile ion chromatograph equipped with conductivity and visible detectors used for monitoring common anions, cations, nutrients, and alkalinity

IC components:

① IC-2001 ion chromatograph for determining simultaneously common anions and cations

② Visible detector (UV-8020) for determining simultaneously phosphate and silicate ions

③ Pump-1 (DP-8020) for delivering reducing agent of nutrient determination

④ Pump-2 (DC-10AD) for delivering color-forming reactant of nutrient determination

⑤ Column oven for separating simultaneously nutrients and alkalinity

⑥ Work station for data processing

(4) Results and Discussion

1) Water Quality Monitoring of Common Anions and Cations in Sewage and Urban River Waters

In the first stage of this Survey study, several practical domestic wastewater samples including that from two small ponds (west- and east-pond) accepting un-treated waste waters from housing/ business districts in downtown Jakarta and urban rivers at central Jakarta were taken to determine the common anions and cations, nutrients, and alkalinity using advanced ion chromatography.

Fig. 4.3.20-A shows the simultaneous ion-exclusion/cation-exchange chromatogram of common anions and cations obtained using the advanced ion chromatography by elution with 15 mM tartaric acid/ 2.5 mM 18-crown-6 at 1.0 ml/min. A good separation and conductimetric detection was obtained in ca. 15 min for both the anions and cations.

As shown in Fig. 4.3.20-B, a good water quality monitoring of common anions and cations in the pond water was achieved using the advanced ion chromatography for the simultaneous monitoring of the common anions and cations. The analytical results for evaluating water quality of several kinds of practical water samples obtained using the advanced ion chromatography described above are listed on Table 4.3.3, together with electrical conductivity (EC), pH, and DO.

As shown in Fig. 4.3.20-B and Table 4.3.3, a large concentration of NH_4^+ and a small concentration of NO_3^- were detected at the influent site of the pond under the un-aerobic conditions at decreased DO concentration (0.5 mg/l). Whereas, as can be seen clearly from Fig. 4.3.20-C and Table 4.3.3, part of NO_3^- formed biologically was de-nitrified to form N_2 gas by the presence of BOD/COD components under the un-aerobic conditions at decreased DO (0.7 mg/l) at the effluent site of the pond.

Local water quality was in extremely poor situation and the formation of N_2 gas from bottom of the pond was always observed (Fig. 4.3.21) due to the biological denitrification process for NO_3^- under the presence of increased BOD/COD concentration and the absence of DO. From the above result, by applying the advanced ion chromatography methodologies for the simultaneous determination of anions and cations, it is concluded that the ponds in the PD PAL JAYA did not function satisfactory as a biological oxidation reactor in terms of the removal of BOD/COD and NH_4^+.

However, successful water quality monitoring of common anions and cations in the unban river water was also achieved in ca. 15 min using the advanced ion chromatography for the simultaneous determination of common anions and cations (Fig. 4.3.20-D and Table 4.3.4). The concentration of NO_3^- in this river water sample was higher than that of NH_4^+. This means that the biological nitrification process from NH_4^+ to NO_3^- under the aerobic conditions (DO ~4.8 mg/l) and the presence of alkalinity was well proceeded. From the above result, it may be concluded that the water quality monitoring operation using advanced ion chromatography for the simultaneous determination of common anions and cations was very effective and useful for the practical applications to sewage and urban river waters in Jakarta metropolitan area.

Since the nutrients, such as NH_4^+ and NO_3^- were playing an important role in the biological oxidation reaction in river water environments, advanced ion chromatography technologies was employed in the second stage of this survey study on the water quality monitoring and performed systematically for practical water samples taken from the Ciliwung River watershed.

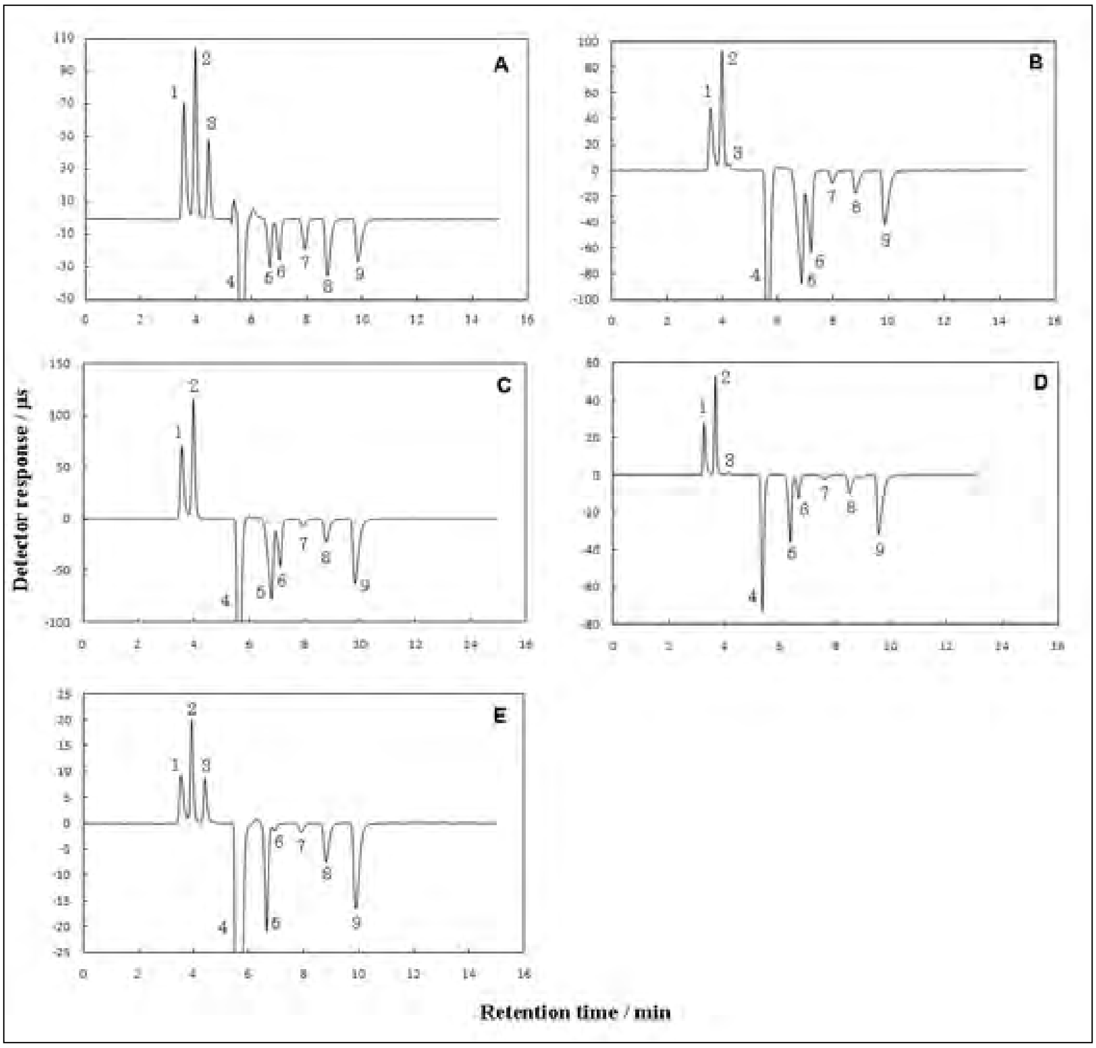


Fig. 4.3.20 Typical ion-exclusion/cation-exchange chromatograms of common anions and cations commonly found in environmental waters

Chromatograms:

A: Standard solution of common anions and cations

B: Influent water of pond

C: Effluent water of pond

D: Urban river water

E: Ciliwung-river water at central Jakarta

Peaks:

1 = SO_4^{2-}, 2 = Cl^-, 3 = NO_3^-, 4 = Eluent-dip, 5 = Na^+, 6= NH_4^+, 7 = K^+, 8 = Mg^{2+}, 9 = Ca^{2+}

Pond-1 (Influent)

Pond-2

Pond-3

Pond-4 (effluent)

Fig. 4.3.21 Pictures depicting water sampling locations from east/ west ponds at PD PAL JAYA

Table 4.3.3 Analytical results of water quality of several pond waters by advanced ion chromatography

Sampling point	SO_4^{2-}/mM	Cl^-/mM	NO_3^-/mM	HCO_3^-/mM	PO_4^{3-}-P/mM	SiO_4^{4-}-Si/mM
Pond-1(influent)	0.381	0.877	0.072	3.966	0.120	0.610
Pond-2	0.423	1.097	0.000	3.807	0.010	0.660
Pond-3	0.386	1.170	0.018	3.549	0.010	0.550
Pond-4(effluent)	0.386	1.192	0.000	3.564	0.010	0.560

Sampling point	Na^+/mM	NH_4^+/mM	K^+/mM	Mg^{2+}/mM	Ca^{2+}/mM	EC/ms cm^{-1}	DO/ppm
Pond-1(influent)	2.223	1.509	0.268	0.252	0.820	742.000	0.500
Pond-2	1.773	0.882	0.194	0.302	1.120	593.000	5.600
Pond-3	1.756	1.071	0.191	0.226	1.001	593.000	1.300
Pond-4(effluent)	1.789	1.086	0.201	0.241	1.000	706.000	0.700

Source: This survey experiment

Table 4.3.4 Analytical results of water quality of several urban river waters at Central Jakarta by advanced ion chromatography

Sampling point	SO_4^{2-}/mM	Cl^-/mM	NO_3^-/mM	HCO_3^-/mM	PO_4^{3-}-P/mM	SiO_4^{4-}-Si/mM
Kulutu river	0.122	0.477	0.007	1.795	0.157	0.615
Ciliwung river	0.081	0.197	0.103	0.729	0.107	0.313
Kalimalang river	0.194	0.098	0.054	1.246	0.121	0.632
Cipinang river	0.160	0.551	0.742	1.983	0.010	0.642

Sampling point	Na^+/mM	NH_4^+/mM	K^+/mM	Mg^{2+}/mM	Ca^{2+}/mM	EC/ms cm^{-1}	DO/ppm
Kulutu river	0.019	0.454	0.708	0.164	0.120	0.303	1.500
Ciliwung river	0.011	0.307	0.321	0.030	0.059	0.143	4.800
Kalimalang river	0.008	0.119	0.258	0.001	0.049	0.179	4.600
Cipinang river	0.007	0.532	0.134	0.107	0.329	0.280	0.300

Source: This survey experiment

2) Water Quality Monitoring of Phosphate and Silicate Ions in Sewage and Urban River Waters

In order to monitor the nutrients such as phosphate and silicate ions in domestic waste waters, the advanced ion chromatographic system equipped with a visible detector, developed by Tanaka et al (Anal. Chim. Acta, 619, 110 (2008)) was performed using water as the eluent and post column derivatization with molybdate/ascorbic acid (molybdenum-blue method).

As shown in Fig. 4.3.22-A, the selective and highly sensitive advanced ion chromatography by visible-detection at 700 nm s was achieved for both phosphate and silicate ions in ca. 7 min.
On the other hand, when injecting several practical water samples onto the separation column, a good simultaneous monitoring was also achieved for evaluating water quality of the two small ponds and urban river waters (Fig. 4.3.22-B-D).

However, in the application to the two-small ponds in PD PAL JAYA, there was negligible water quality improvement based on the biological nitrification reaction of NH_4^+ to NO_3^- because of extremely low level of DO (Fig. 4.3.22-B, C and Tables 4.3.3 and 4.3.4). According to annual report on 2009 of water quality by PD PAL JAYA, the concentrations of DOC meaning organic-carbon content in the two-ponds waters were extremely high (54~25 mg/l). Therefore, there might be complete biological denitrification reaction of NO_3^- to N_2 under the presence of extremely high concentration of organic carbon substances as the organic-carbon source.

For the removal of PO_4^{3-} from the two-small ponds under the un-aerobic conditions, there was significant difference of the concentrations of PO_4^{3-} between influent and effluent waters. The decrease might be due to the biological consumption of PO_4^{3-} taking place by various biological reactions such as BOD-oxidation and nitrification reactions occurred slightly at aerobic conditions like surface water of the ponds, as well as denitrification and methane-formation reactions occurred at un-aerobic conditions like bottom water of the ponds. In conclusion, the advanced ion chromatography was judged as effective and useful water quality monitoring system applicable to the practical sewage.

Besides, application using urban river waters showed that the concentration of PO_4^{3-} were extremely low (Fig. 4.3.22-D and Tables 4.3.3 and 4.3.4). This was perhaps due to the formation and precipitations of ferric phosphate based on the chemical-physical reaction of PO_4^{3-} under the presence of ferric oxides in unban river waters. As can be seen from Fig. 4.3.23-A-D, the urban river water samples might contain ferric oxides with brown color. Thus, the usefulness of the advanced ion chromatography methodologies was also demonstrated on the applications to the practical urban river waters.

From the preliminary results described above for the application to water quality monitoring of urban river waters, since the nutrient such as phosphate and silicate ions was playing an important role in the biological reaction and physical-chemical reactions in river water environments, it was decided to apply the advanced ion chromatography technologies systematically for water samples taken in the Ciliwung River watershed, in the second stage survey study the water quality monitoring.

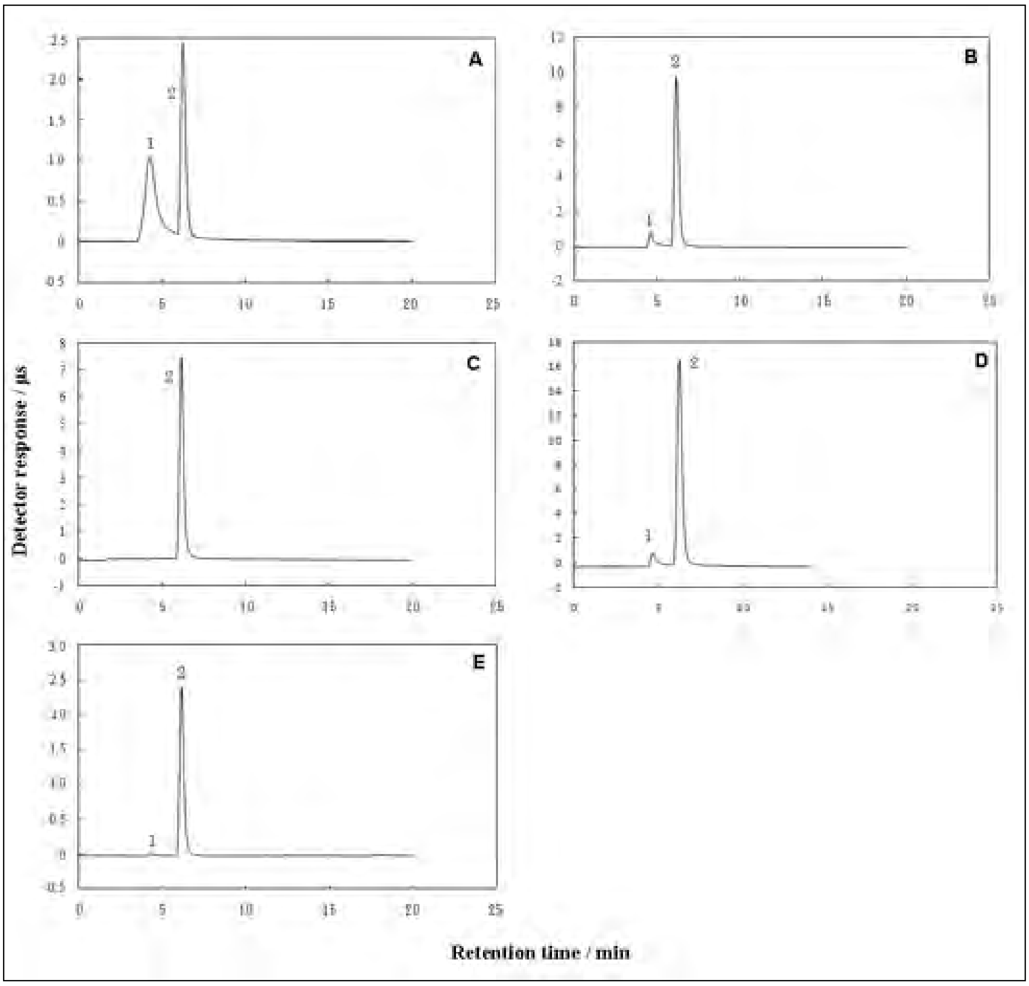


Fig. 4.3.22 Ion-exclusion chromatograms of phosphate and silicate ions commonly found in environmental waters

Chromatograms:

A: Standard solution of phosphate and silicate ions

B: Influent water of pond

C: Effluent water of pond

D: Urban river water

E: Ciliwung-river water at central Jakarta

Peaks: 1 = Phosphate ion, 2 = Silicate ion

3) Water Quality Monitoring of Alkalinity in Sewage and Urban River Waters

It is well-known that increased concentrations of nutrients such as NH_4^+ and NO_3^- may cause the eutrophication of aquatic environment. In conventional biological treatment process, NH_4^+ in wastewater is oxidized biologically to NO_3^- under the aerobic conditions in the presence of alkalinity (HCO_3^-) as an inorganic carbon source and then reduced biologically to N_2 gas under the un-aerobic conditions in the presence of BOD/COD components as an organic-carbon source. Therefore, in the process of biological nitrification-denitrification the monitoring of NH_4^+ and NO_3^- as well as HCO_3^- is extremely important for the process control and the water quality management.

Fig. 4.3.23-A indicates an ion-exclusion chromatogram of HCO_3^- (standard solution) obtained using the advanced ion chromatography by elution with water. A good separation and highly sensitive enhanced conductivity detection was achieved in ca. 12 min. for alkalinity.

As shown in Fig. 4.3.23-B-D and Table 4.3.3 and Table 4.3.4, when injecting several practical water samples onto the separation column, a good simultaneous monitoring was also achieved in 12 minutes for alkalinity for waters taken from the two small ponds and urban river waters.

In conclusion, this advanced ion chromatography for monitoring alkalinity (HCO_3^-) was again judged to be effective and useful water quality monitoring system applicable to the practical sewage wastewater and urban river water samples.

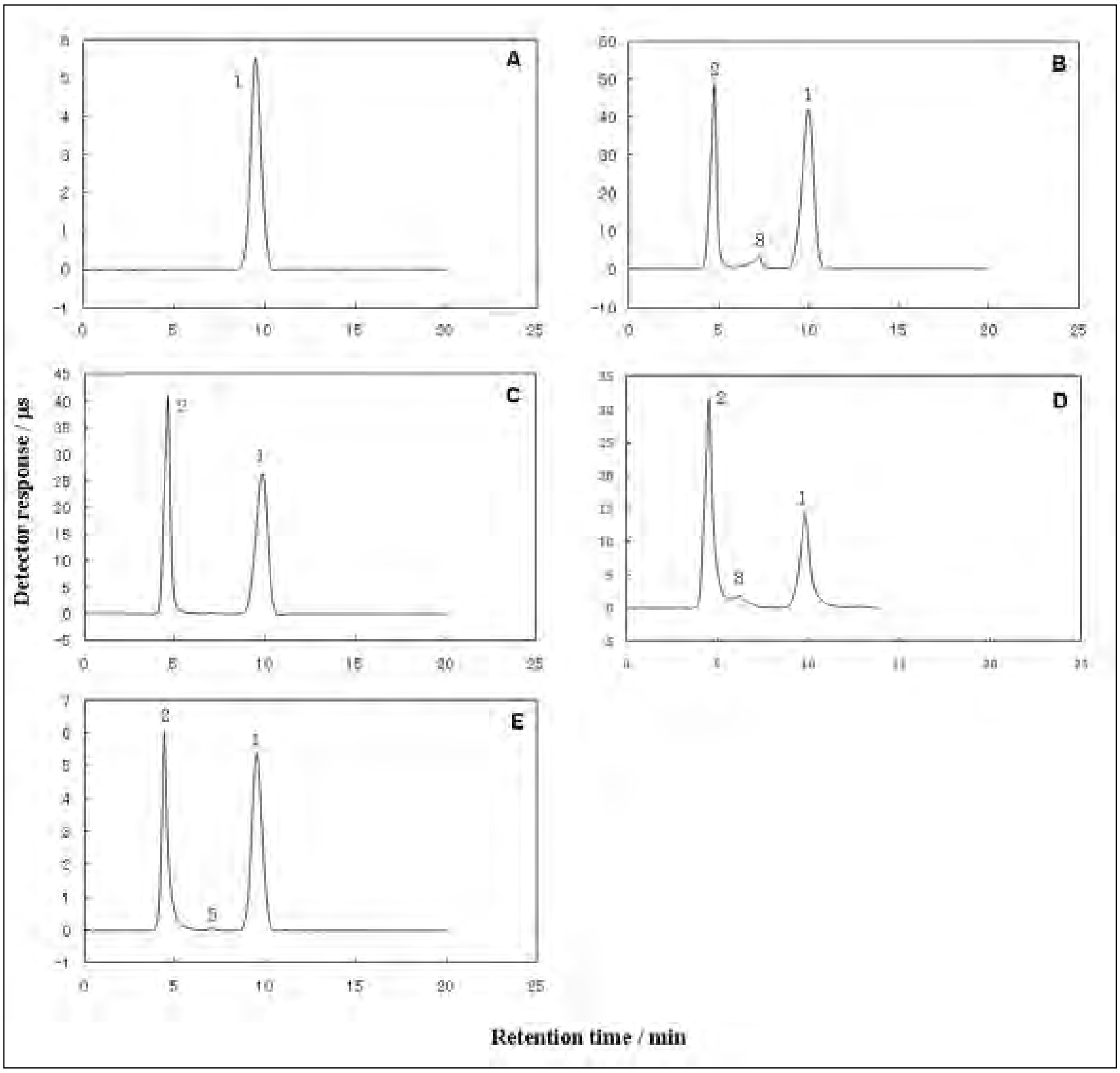


Fig. 4.3.23 Ion-exclusion chromatograms of alkalinity (HCO_3^-) commonly found in environmental waters

Chromatograms:

A: Standard solution of HCO_3^-

B: Influent water of pond

C: Effluent water of pond

D: Urban river water

E: Ciliwung-river water at central Jakarta

Peaks:

1 = HCO_3^-, 2 = Strong acid anions such as Cl^-, SO_4^{2-}, and NO_3^-, 3 = Unknown

Ciliwung River Kulutu River

Cipinang River Kalimalang River

Fig. 4.3.24 Pictures of water sampling locations of urban river waters in Jakarta

4) Water Quality Monitoring of the Ciliwung River Watershed by Advanced Ion Chromatography

Water quality monitoring of common anions and cations in the Ciliwung River watershed samples was satisfactorily achieved in about 15 minutes using the advanced ion chromatography for the simultaneous determination of common anions and cations (Fig. 4.3.20-E and Tables 4.3.3 and 4.3.4). The concentrations of NO_3^- in the river water sample from the Ciliwung River watershed were higher than that of NH_4^+. This means that the water quality of the Ciliwung River watershed samples was in aerobic conditions (DO = 7.36 mg/l for upper stream and 1.39 mg/l for downstream) and the biological nitrification process from NH_4^+ to NO_3^- was almost completed. Therefore, it can be concluded that this water quality monitoring method using the advanced ion chromatography for the simultaneous determination of common anions and cations was very effective and useful for the practical applications to the Ciliwung River watershed in Jakarta metropolitan area.

Fig. 4.3.25 and Table 4.3.5 show the relationship among sampling locations and conductivity, and anions and cations for evaluating the water quality of the Ciliwung River watershed. The decrease in the concentrations of common anions (except HCO_3^- and NO_3^-) and common cations (except NH_4^+) as well as the DO was founded decreased by the increase of the electrical conductivity due mainly to the increased human activity in the Ciliwung River watershed. The increase in NH_4^+ was also due to the increased human activity in the Ciliwung River watershed.

As shown in Fig. 4.3.26 and Table 4.3.5, the decrease in DO and HCO_3^- was perhaps due to the increase in human activity and biological activity of NH_4^+ to NO_3^- under the presence of HCO_3^- in the Ciliwung River watershed, especially in downtown area of the Ciliwung River watershed, respectively.

On the other hand, as seen in Figs. 4.3.25, 4.3.26 and 4.3.27 and Table 4.3.5, the concentrations of phosphate and silicate ions as the nutrient increased gradually due to the increase in the electrical conductivity in the Ciliwung River waters. Whereas, the concentration of NO_3^- decreased by increasing the electrical conductivity due to the formation of denitrification reaction based on the increased concentration of BOD/COD and the decreased concentration of DO in Jakarta downtown area. The above-described results suggest that the water quality monitoring operation is extremely useful for evaluating the potentiality of natural purification capacity for the Ciliwung River watershed.

Table 4.3.5 Analytical results of water quality for samples from the Ciliwung River using advanced ion chromatography

Sampling point	SO_4^{2-}/mM	Cl^-/mM	NO_3^-/mM	HCO_3^-/mM	PO_4^{3-}-P/mM	SiO_4^{4-}-Si/mM
1	0.241	1.961	0.037	2.685	0.022	0.432
2	0.195	0.662	0.037	2.053	0.004	0.377
3	0.203	1.017	0.037	2.177	0.009	0.349
4	0.136	0.430	0.069	1.529	0.004	0.374
5	0.139	0.420	0.102	1.674	0.005	0.404
6	0.107	0.317	0.114	1.295	0.003	0.355
7	0.099	0.287	0.131	1.086	0.003	0.378
8	0.095	0.270	0.135	1.028	0.003	0.344
9	0.088	0.265	0.145	0.970	0.003	0.353
10	0.078	0.234	0.134	0.838	0.003	0.397
11	0.084	0.241	0.145	0.937	0.003	0.332
12	0.083	0.246	0.142	0.878	0.003	0.369
13	0.079	0.330	0.132	0.885	0.002	0.305
14	0.058	0.158	0.103	0.670	0.002	0.230
15	0.074	0.222	0.128	1.157	0.002	0.122
16	0.080	0.230	0.135	0.921	0.002	0.290
17	0.081	0.182	0.127	0.920	0.003	0.349
18	0.075	0.185	0.145	0.758	0.002	0.261

Sampling point	Na^+/mM	NH_4^+/mM	K^+/mM	Mg^{2+}/mM	Ca^{2+}/mM	EC/ms cm^{-1}	DO/ppm
1	2.590	0.614	0.177	0.408	1.313	666.000	—
2	1.068	0.304	0.118	0.286	1.059	320.000	—
3	1.716	0.400	0.134	0.287	1.013	419.000	1.290
4	0.708	0.170	0.092	0.250	2.508	244.000	—
5	0.730	0.172	0.099	0.257	0.870	261.000	0.390
6	0.542	0.084	0.086	0.232	0.781	205.000	1.590
7	0.493	0.061	0.081	0.219	0.740	174.000	—
8	0.463	0.049	0.080	0.219	0.721	221.000	1.600
9	0.439	0.050	0.074	0.213	0.705	162.300	—
10	0.388	0.028	0.069	0.197	0.623	137.500	—
11	0.408	0.023	0.072	0.208	0.671	169.600	4.730
12	0.411	0.020	0.067	0.208	0.674	155.200	—
13	0.501	0.022	0.089	0.209	0.663	167.400	
14	0.280	0.016	0.058	0.157	0.564	149.200	5.730
15	0.401	0.012	0.070	0.193	0.599	150.100	6.100
16	0.430	0.042	0.070	0.207	0.646	159.400	—
17	0.341	0.015	0.070	0.231	0.683	156.500	—
18	0.337	0.018	0.069	0.190	0.598	172.800	7.360

Source: This survey experiment

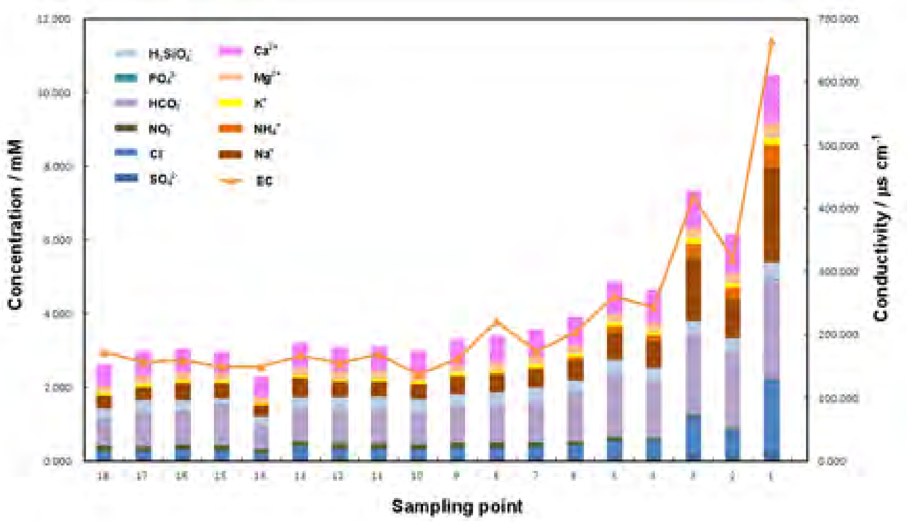


Fig. 4.3.25 Relationship among sampling locations and conductivity, and anions and cations on water quality of the Ciliwung River watershed

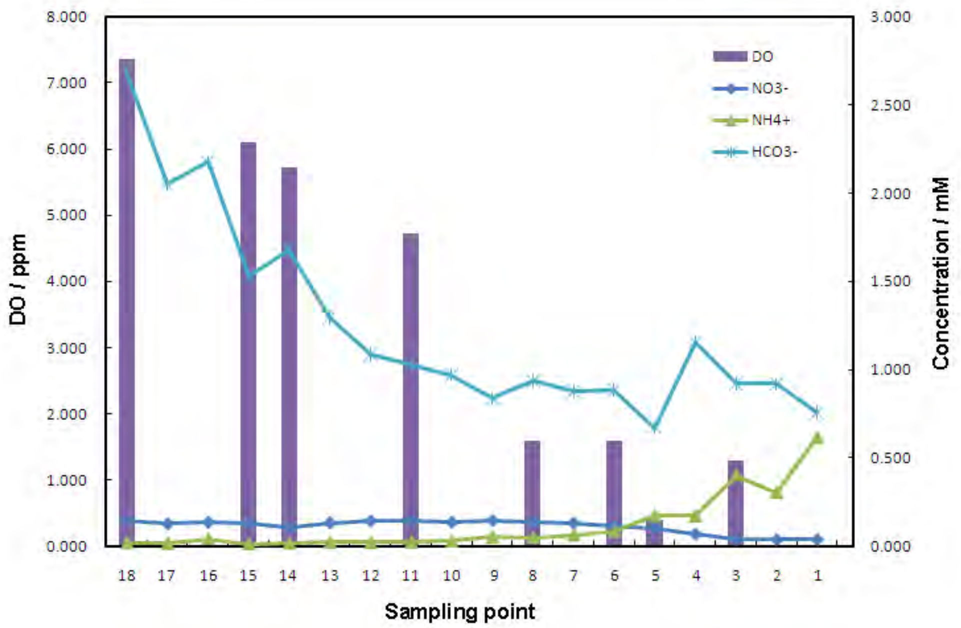


Fig. 4.3.26 Relationship among sampling locations, DO, nutrients, and alkalinity (HCO_3^-) on water quality of the Ciliwung River watershed

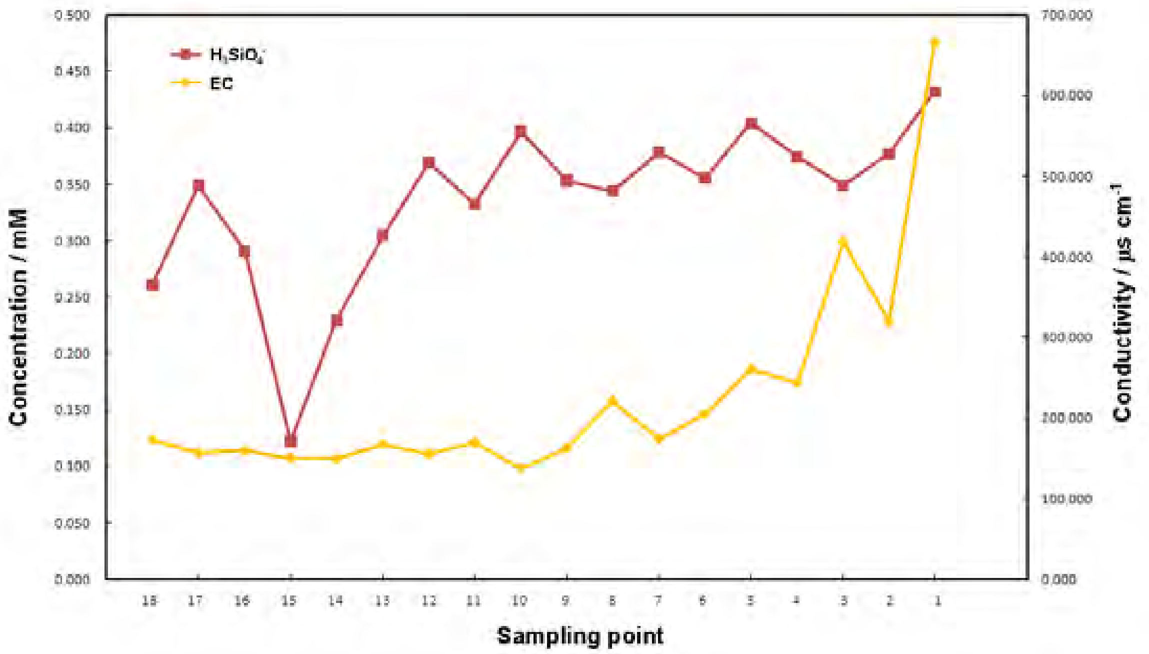


Fig. 4.3.27 Relationship between sampling location and silicate ion on water quality of the Ciliwung River watershed

(4) Conclusion and Recommendation for Enhancing Aquatic Environmental Capacity of Jakarta Metropolitan Area

When considering synthetically the above-described water quality monitoring data and the analytical data provided by PD PAL JAYA on BOD/COD, the formation of following biological reaction are estimated for the two small ponds near PD PAL JAYA office.

1) In both ponds, there was negligible formation of biological oxidation reaction for BOD/COD removal due to un-aerobic conditions. However, there was slight biological nitrification reaction due to the slightly increased concentration of NO_3^-.
2) In both ponds, there was considerable formation of biological de-nitrification reaction for NO_3^--N removal due to un-aerobic conditions under the presence of BOD/COD.

3) The two small ponds near PD PAL JAYA office were later judged not to function for biological treatment.
4) Based on the viewpoints of water quality monitoring technology and water treatment technology, the introduction of a highly efficient biological treatment system such as Down-flow Hanging Sponge (DHS) is strongly recommended.
5) In the urban river water, in addition to NO_3^-, there was the presence of NH_4^+, indicating human activity in urban area. In conclusion, the direct discharge of sewage wastewater to the urban river should be strictly prohibited by the relevant water quality regulations in the future.

In this survey study of sewage treatment system at central Jakarta, urban river waters in central Jakarta and the Ciliwung River watershed from Bogor to Jakarta, the usefulness of advanced ion chromatography technologies for water quality monitoring were demonstrated based on the applications to several practical waters discharged from housing and business complex, any industrial and agricultural sectors and urban rivers, as well as the Ciliwung River watershed in Jakarta metropolitan area.

Since the proposed ion chromatography technology, which enables the water quality evaluation based on the simultaneous determination and highly sensitive detection of common anions, cations, nutrients, and alkalinity, will be very useful for applications in a developing country like Indonesia, in the future, the introduction and technical assistance in Indonesia and Japan for water quality monitoring method using IC technology are strongly recommended, as well as the educational support on environmental analytical chemistry, environmental sciences/chemistry, wastewater treatment technology including biological and physical-chemical treatment technologies for wastewaters.

Finally, as mentioned before, the ion chromatograph is as extremely useful and powerful tool for the water quality monitoring currently operated by the public sector institutions in Jakarta. However, the capital costs (ca. US$ 40,000 each) for the operation are relatively high compared to a conventional colorimeter for determining respectively the common anions and cations. Although the running costs is also somewhat expensive due to high price of a separation column packed with ion-exchange resin (~ca. US$ 2,000), reduced cost can be expected by careful handling and maintenance of the ion chromatographic hardware.

However, the following issues should be taken into account for successful operation of the ion chromatograph regarding water quality monitoring.

1) Quick response to repairing of the ion chromatograph and the related parts
2) Stocks of consumable and reserved items for ion chromatograph and other related parts
3) Quick response to dealers of ion chromatographic equipment when ion chromatograph and is out of order. By accessing internet to http://www.tosoh.co.jp/ for Tosoh Corporation, http://www.shimadzu.com/ for Shimadzu Corporation, and http://www.dionex.com/en-us/index.html for Dionex Corporation, useful technical and business information are available.

Additionally, the following actions should be taken into account for successful operation of the ion chromatograph.

1) Action of SOP of data control
2) Action of calibration for analytical instrument equipment operation
3) Increased budget for laboratory infrastructure and man-power
4) Increased budget for laboratory maintenance for hardware
5) Action of periodical training and education for analytical chemistry and environmental sciences
6) Accessibility to academic information data-base through internet or e-library
7) Action of “Round Robin Test” to evaluate analytical monitoring operation

4.4. Sewage Treatment System

4.4.1. Appropriate Technology System for Sewage Treatment

It is suspected that even though the sophisticated sewage treatment system, which have been widely spread in Japan, can be transferred to a developing country such as Indonesia and elsewhere; the system might not work well. To popularize sewage treatment system in a developing country, the transfer of appropriate technology specified for the instruments, inexpensive in Japan, is strongly required, besides the factor of low cost and easy maintenance. The locality of a developing country in terms of its economy, society and so on must be also considered to make the sewage treatment system functional.

UASB (Up-flow Anaerobic Sludge Blanket) reactor for sewage treatment has been adopted as the standard sewage treatment system in India. UASB would be the best promising method even in Jakarta because methane gas can be produced as energy from sewage. Not only in India but also several counties such as Brazil (Florencio, 2001), Mexico (Monroy et al., 1998), Colombia (Schellinkhout et al., 1992, Kooijmans et al., 1985), Egypt (Schellinkhout et al., 1992; Vieira et al., 1994), Jordan (Halalsheh et al., 2005), Thailand (Gnanadipathy et al., 1993) and Indonesia (Bogte et al., 1993), UASB has been installed for sewage treatment.

However, UASB reactor usually needs post-treatment to meet regulated water quality of effluent. As UASB post-treatment systems, there are several systems such as wetland, pond, trickling filter, aerated bio-filters and rotating biological contactor. Wetland and pond systems, which require large area, are not suitable for big cities and cannot produce good water quality. Trickling filter also has minor problem in effluent quality. With regard to rotating biological contactor, the operation is complicated. On the other hand, DHS (Down-flow Hanging Sponge) reactor with no external aeration input possesses good features of cost-effective and easy maintenance with good effluent. Okubo (2010) has summarized treatment performance, land area and electricity required, with regard to several post-treatment systems. Fig. 4.4.1 shows the relationship between COD (=COD_{Cr}) removal and hydraulic retention time (HRT). The natural processes such as stabilization pond and so on, which rely on natural purification, are taking a long HRT. Nevertheless, good treatment performance cannot be expected. In terms of mechanized processes such as aerated biofilter, external energy is required, but high COD removal can be obtained with short HRT. DHS reactor has the lowest cost and the smallest area required in the mechanized processes which do not need no external aeration input (Table 4.4.1). Based on the survey and experimental data, Okubo (2010) concludes that DHS reactor would be best as UASB post-treatment.

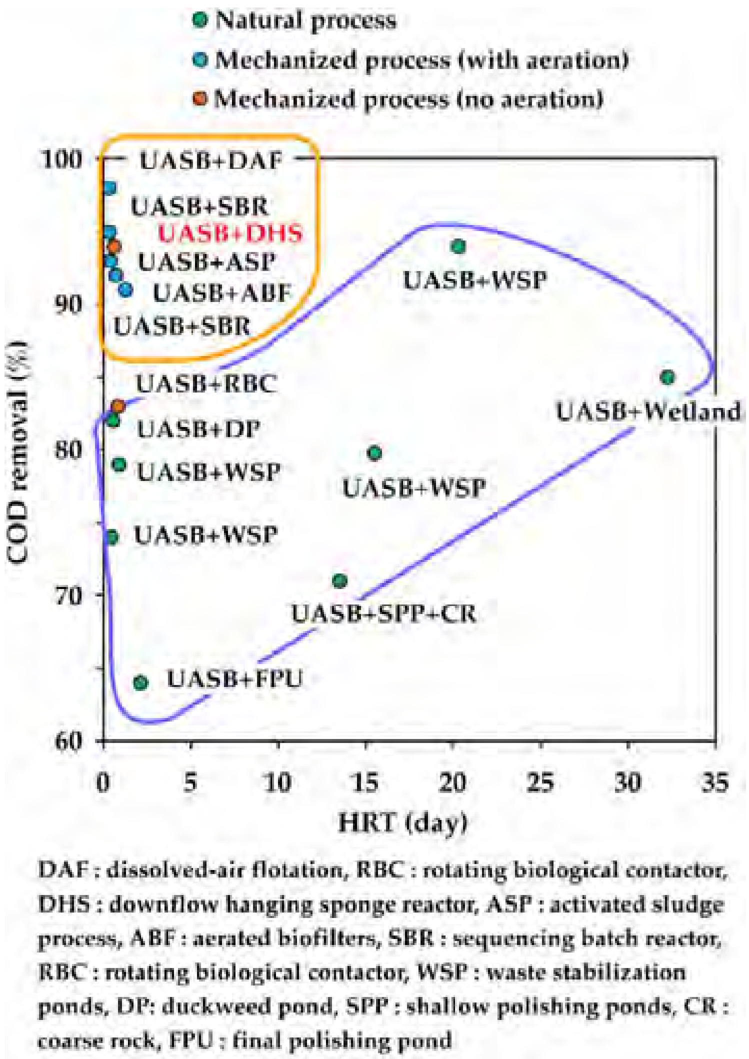


Fig. 4.4.1 Comparison on treatment performance and hydraulic retention time (HRT) (Okubo, 2010)

Table 4.4.1 Land area and process power required

Process	Land required in warm climate (m^2/person)[a]	Process power required (kWh/person-year)[a]	COD_{Cr} removal (%)
UASB	0.030	-	-
UASB[b]	0.014	3.4	60
UASB + ASP	0.04-0.10	14-20	93
UASB + SBR	0.03-0.08	14-20	91-95
UASB + DAF	0.03-0.08	8-12	98
UASB + DHS[b]	0.018	7.8	94
UASB + FPU[b]	0.164	3.4	64

[a] Sewage flow of 180 L/day

[b] Based on Karnal 40 MLD STP

Source: Okubo, 2010

In mechanized processes with aeration, approximately half of the energy required in the operation is generally used for aeration. This implies that treatment processes without external aeration input, such as DHS reactor, almost half of the running cost compared with aerating processes.

In a JICA training (the third domestic wastewater treatment course for Latin America region, 2009), the characteristics of the UASB and DHS system was explained. After the training, many foreign trainees (Bolivia, Dominican Republic, Mexico, and Nicaragua) were eager to install UASB and DHS system in their countries, as described in the report. It is no wonder that they were able to easily understand the advantages of UASB and DHS system.

Therefore, the Survey team had decided to investigate whether the combination system of UASB and DHS reactors is applicable to sewage treatments in Jakarta.

3.4.2. Preliminary Measurement of Water Quality of Sewage in Ponds

In order to carry out a rough treatment performance experiment using an artificial sewage in Hiroshima University prior to using actual sewage in Jakarta, sewages in the ponds were taken during the first investigation (March 25-30, 2010), and the samples were analyzed.

(1) Sampling Sites

Sampling sites are shown in Fig. 4.4.2. Influents coming into the ponds were taken at three sites, two from East pond and one from West pond. One effluent was sampled from East pond.

Fig. 4.4.2 Sampling sites in the ponds of PD PAL JAYA

(2) Water Quality Measured

Results of water quality in the samples are shown in Table 4.4.2. COD (soluble and total), NH_4^+-N, and NO_3^--N concentrations were measured using HACH method. pH was measured on the sites. Both of soluble and total COD (s-COD and t-COD) concentrations in Site-1 were higher than other sites of influent, reaching 61 (s-COD) and 255 (t-COD) mg/l, respectively. NH_4^+-N concentration was also higher at Site-1 comparing with other sites. NO_3^--N was not detected in all the samples. NH_4^+-N decreased and s-COD still remained at the effluent site (Site-3), indicating that weak denitrification would have occurred in the East pond.

Table 4.4.2 Water quality of the samples from ponds

Sample	pH	Soluble COD (mg/l)	Total-COD (mg/l)	NH_4^+-N (mg/l)
Site-1 (inf.) 26/3/2010	7.2	61	255	20.1
Site-2 (inf.) 26/3/2010	7.6	54	111	13.7
Site-4 (inf.) 26/3/2010	7.5	26	137	2.9
Site-4 (inf.) 27/3/2010	7.4	39	142	10.3
Site-3 (eff.) 26/3/2010	7.2	30	358	3.9

Source: This survey experiment

(3) Comparison with the Data Measured by PD PAL JAYA

The pond waters have been regularly measured by PD PAL JAYA. The resulting water quality was the same as the measured by the Survey team.

3.4.3. Bench-scale Treatment Using Artificial Sewage

Before setting up a bench-scale UASB-DHS system on site in Jakarta and carrying out a long-term experiment for continuous treatment using actual sewage, the Survey team had to assess the rough performance and operation method of the system. Consequently, an artificial sewage treatment using the same UASB-DHS system were set up and conducted at Hiroshima University to obtain the fundamental information about their performance.

(1) Composition of Artificial Sewage

Based on the measurement of the pond influent, the Survey team determined composition of artificial sewage (Table 4.4.3). The Survey team had a plan to set up UASB and DHS reactors near Site-1 in Jakarta. Therefore, COD and NH_4^+-N concentrations in the artificial sewage modeled on Site-1 were set at 200 and 20 mg/l, respectively.

Table 4.4.3 Composition of artificial sewage

Composition	Unit : mg/L
Organic carbon sources (200 mg-COD_{Cr}/L)	
Sucrose	80.16
Sodium acetate	57.66
Sodium propionate	38.57
Yeast extract	20.00
Nitrogen sources (20 mg NH_4^+-N/L)	
NH_4Cl	40.00
$(NH_4)_2SO_4$	48.00
Nutrient elements	
$KHCO_3$	200
$NaHCO_3$	200
$Na_2HPO_4 \cdot 12H_2O$	300
$MgSO_4 \cdot 7H_2O$	20.0
$CaCl_2 \cdot 2H_2O$	5.00
$FeSO_4 \cdot 7H_2O$	0.45
Trace metal elements	
$CuSO_4 \cdot 5H_2O$	0.0250
Na_2SeO_4	0.0050
$NiCl_2 \cdot 6H_2O$	0.0190
$CoCl_2 \cdot 6H_2O$	0.0240
$Na_2MoO_4 \cdot 2H_2O$	0.0220
$MnCl_2 \cdot 4H_2O$	0.0990
H_2BO_4	0.0014
$ZnSO_4 \cdot 7H_2O$	0.0430

Source: This survey experiment

(2) Sewage Treatment System

The Survey team was proposing the combination system of UASB and DHS reactors, which could be applicable to sewage treatments in Jakarta. However, by single DHS reactor alone might be adequate to treat the sewage flowing into the pond in Jakarta, because the influent COD concentration was relatively low compared with general sewages due to dilution with river water. The Survey team then decided to operate two treatment systems, combined UASB-DHS and single DHS, in order to assess their performance. The schematic diagrams of both systems and their operating parameters are shown in Fig. 4.4.3. In the combined UASB-DHS system, HRT was 10.3 hrs (8 and 2.3 for UASB and DHS, respectively), that for the single DHS system was 8 hrs.

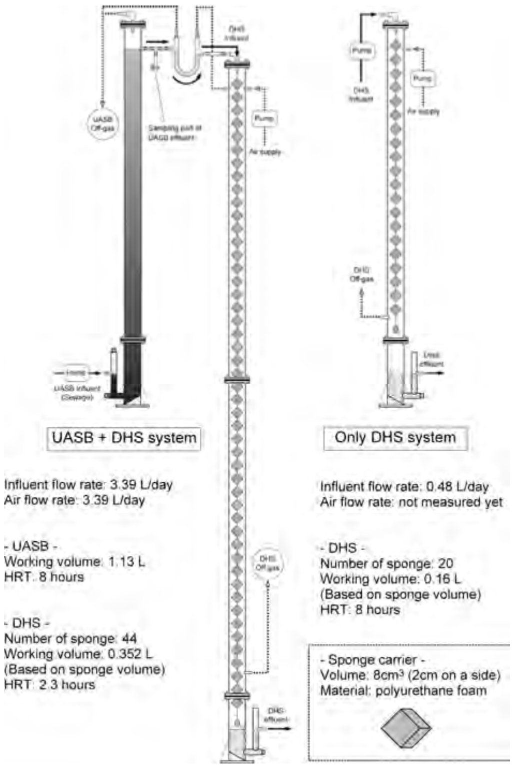


Fig. 4.4.3 Schematic diagrams and operating parameters of the two systems

(3) Result of System Performance

The Survey team operated both systems for about 2 weeks in Hiroshima University. The results of performances are tabulated in Tables 4.4.4-4.4.7 and Figs. 4.4.4-4.4.5. A smooth startup was carried out with good effluents in both systems. The treatments were stably performed during the experiment except for one day of an operation miss. The effluent t-COD was almost below 20 mg/l, which was low enough to be discharged to water bodies. Methane concentration of biogas produced from the UASB reactor was around 40 %, which was also lower than that of general methane fermentation (60-65%), because of low COD influent. In the case of single DHS system, nitrification occurred efficiently even though no methane energy was recovered.

Table 4.4.4 Performance data of the two systems in treating artificial wastewater (Total COD)

DATE (2010)	Elapsed days	Total-COD_{Cr} (mg/L)				COD_{Cr} removal (%)			
		Substrate	Combined system		Single DHS system	Combined system			Single DHS system
			UASB	DHS		UASB	DHS	Whole	
4/15	2	117	97	0	22	17	100	100	81
4/16	3	172	168	6	0	2	97	97	100
4/20	7	91	79	22	28	13	72	76	69
4/21	8	245	222	91	91	9	59	63	63
4/22	9	155	73	0	0	53	100	100	100
4/23	10	184	78	10	6	58	87	95	97
4/25	12	184	83	4	8	55	95	98	96
4/26	13	180	72	3	0	60	96	98	100
4/27	14	117	107	4	6	8	96	97	95

Source: This survey experiment

Table 4.4.5 Performance data of the two systems in treating artificial wastewater (Soluble COD)

DATE (2010)	Elapsed days	Soluble-COD_{Cr} (mg/L)			
		Substrate	Combined system		Single DHS system
			UASB	DHS	
4/15	2	121	75	0	10
4/16	3	133	91	6	0
4/20	7	64	34	46	34
4/21	8	224	164	85	97
4/22	9	145	60	0	0
4/23	10	145	27	2	0
4/25	12	162	58	2	5
4/26	13	160	50	2	0
4/27	14	111	58	3	6

Source: This survey experiment

Table 4.4.6 Performance data of the two systems in treating artificial wastewater (Biogas production)

DATE (2010)	Elapsed days	Biogas production (L/m^3-reactor/day)	CH_4 concentration (%)	CH_4 production rate (kg-COD/m^3-reactor/day)
4/15	2	-	-	-
4/16	3	-	-	-
4/20	7	127	38	0.20
4/21	8	123	14	0.07
4/22	9	113	20	0.10
4/23	10	146	18	0.10
4/25	12	136	16	0.09
4/26	13	137	49	0.30
4/27	14	97	46	0.19

Source: This survey experiment

Table 4.4.7 Performance data of the two systems in treating artificial wastewater (Nitrogen)

DATE (2010)	Elapsed days	Ammonia (mg-N/L)				Nitrite + Nitrate (mg-N/L)			
		Substrate	Combined system		Single DHS system	Substrate	Combined system		Single DHS system
			UASB	DHS			UASB	DHS	
4/15	2	19	46	24	1	0	0	3	11
4/16	3	20	30	10	1	0	0	3	3
4/20	7	16	22	1	1	0	0	3	3
4/21	8	17	21	1	1	0	0	0	0
4/22	9	16	21	0	0	0	0	17	10
4/23	10	19	23	1	1	0	0	17	10
4/25	12	20	22	2	0	0	0	15	7
4/26	13	20	24	1	0	0	0	14	8
4/27	14	20	26	1	0	0	0	14	4

Source: This survey experiment

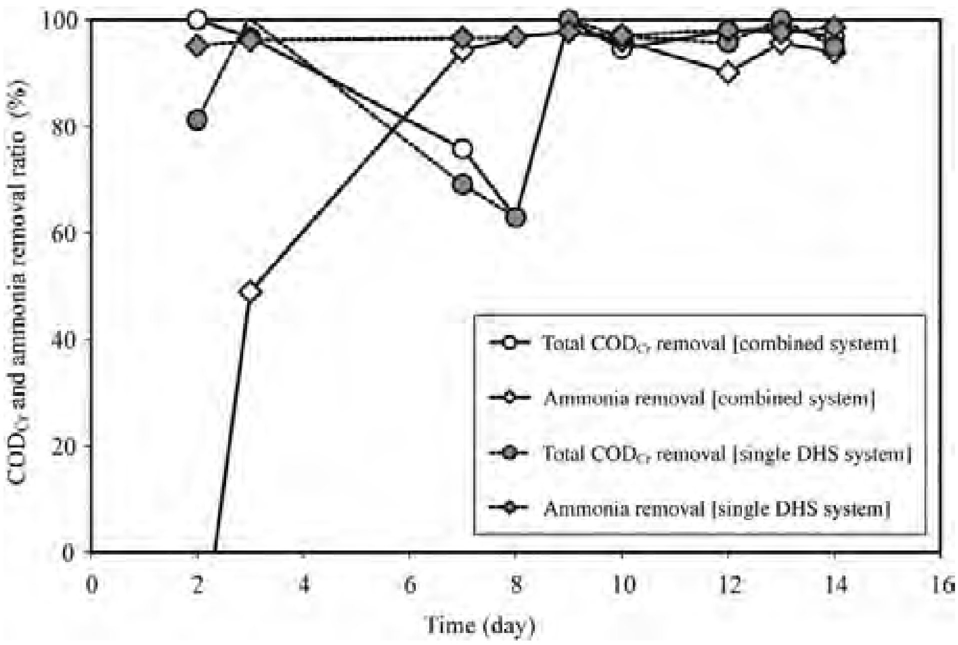


Fig. 4.4.4 Performance of the two systems in treating artificial wastewater (Total COD)

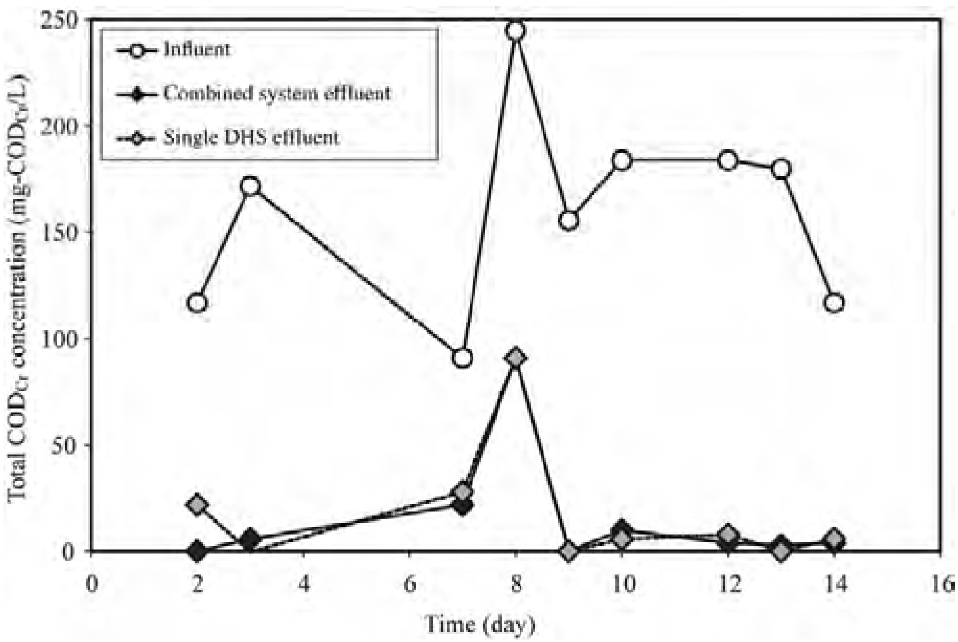


Fig. 4.4.5 Performance of the two systems in treating artificial wastewater (Removal efficiency)

(4) Operation Parameters Desired

The most important operation parameter was HRT. As described above, when the two systems were operated at HRTs of 10.3 and 8 hrs for the combined UASB-DHS and the single DHS, respectively, which were under almost the same condition as activated sludge process, good quality effluents were obtained. The quality level was identical to that of activated sludge process. This means that the HRTs operated were appropriate for the artificial wastewater modeled on the actual sewage in Jakarta. Therefore, the Survey team had determined to set up and operate the two systems on site at the same HRTs. Air supply to the DHS reactors was also conducted under the same flow rate condition.

3.4.4. Actual Sewage Treatment by the Systems Set up in Jakarta

To investigate whether the combination system of UASB and DHS reactors was appropriate for sewage treatments in Jakarta, both treatment systems combined UASB-DHS and DHS alone, which were the same units once operated at Hiroshima University, were transported to Jakarta.

(1) Experimental Method

The combined UASB-DHS and single DHS systems were set up in a control room of PD PAL JAYA on May 4, 2010 for ready operations (Fig. 4.4.6). Actual sewages treated in this experiment were collected at Site 1 of the east pond (Figs. 4.4.2 and 4.4.7) every three days and reserved in a feeding tank connecting to the treatment systems. HRTs were set at 10.3 hrs (8 and 2.3 hrs for UASB and DHS, respectively) for the combined UASB-DHS system and 10 hrs for the single DHS system. HRT of the single DHS system was changed to 6 hrs from June 18, 2010.

The influent and effluent from each reactor were analyzed three times a week (on Monday, Wednesday, Friday) until the end of July for three months. The measurement items were COD, ammonium, nitrate and nitrite, which were measured by HACH methods. Temperature, pH, and flow rate were also measured. The biogas from UASB reactor and the off gas from DHS reactor were collected into gasbags once a week and the methane concentrations were analyzed by gas-chromatography. The effluent quality of east pond (Site 3 in Fig. 4.4.2) was investigated to compare the treatment performance between the UASB-DHS and the single DHS systems.

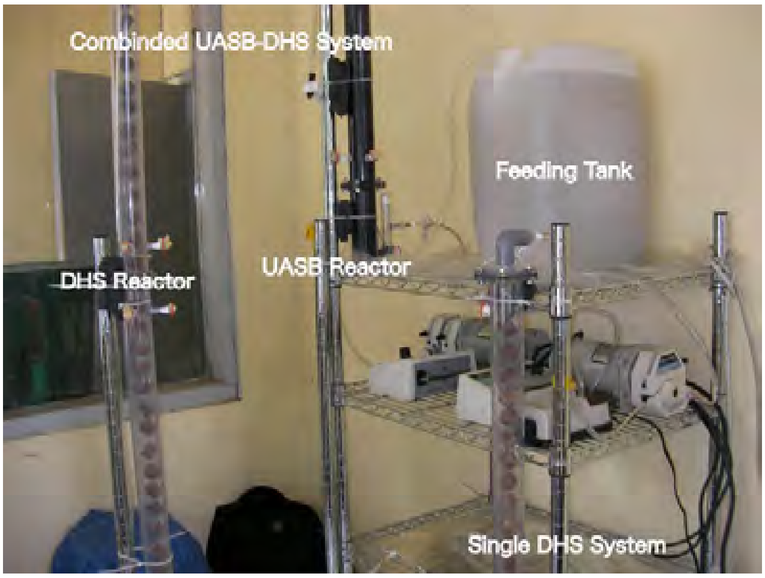


Fig. 4.4.6 Combined UASB-DHS and single DHS systems set up at PD PAL JAYA from May to July in 2010

Fig. 4.4.7 Sewage collection Site 1 of the east pond

(2) Influent Quality

Total COD concentration of the influent on Site 1 coming into the east pond significantly fluctuated, ranging from 76 to 426 mg COD/L, as shown in Tables 4.4.8-4.4.9 and Figs. 4.4.8-4.4.9. The average t-COD was 224 mg COD/L, being quite low compared with general sewages of developed countries like Japan (about 400 mg COD/L in average). The ammonium concentration of the influent, 26.4 mg N/L (on average), was also low (Table 4.4.10). The fluctuation and low concentrations could be dependent on dilution with stream water. The pH was neutral, suggesting no technical problem in biological treatment.

(3) Treatment Performances on the Site in Jakarta

The treatment performance data and the operational conditions are shown in Tables 4.4.8-4.4.14 and the time course of water quality was depicted in Figs. 4.4.8-4.4.13.

In the combined UASB-DHS system, COD removal by UASB was insufficient, but a very good quality was obtained on the polishing DHS reactor without influence of fluctuating influent COD. The whole COD removal achieved 90% on average throughout the operation. The COD effluent of 18 mg COD/L on average is also in compliance with environmental standards. Methane production from the UASB reactor was negligible (methane concentration 5%, gas production rate 0.7 ml-CH_4•m^{-3}-sewage•d^{-1}) because the amount of removed COD was small due to low COD influent. A major part of the methane produced should be dissolved in the UASB effluent. The dissolved methane was then re-directed to the following DHS reactor and almost completely bio-oxidized because methane was not detected in the off gas of DHS reactor. This dissolved methane removal means that DHS reactor had a capability for protecting methane emission to the atmosphere in anaerobic wastewater treatments. Nitrification occurred in the DHS reactor, and 26.4 mg N/L of ammonium was reduced to 6.2 mg N/L.

The single DHS system also worked well in not only COD but also ammonium removal. The effluent quality was comparable to the combined UASB-DHS system. Remarkable treatment performance was found in the DHS reactor, so eventually the Survey team decided to the operation mode of HRT from 10 to 6 hrs on June 18, 2010. Even though HRT was reduced, excellent performance was maintained until the end of operation.

On the other hand, the east pond had little treatment capability, where the COD effluent was almost half of the influent (t-COD removal 52%) because mechanical intermittent aeration would be insufficient. Nitrification would not be expected in the east pond.

Table 4.4.8 Treatment performance data in Jakarta (Total COD)

DATE (2010)	Elapsed days	Total-COD_{Cr} (mg/L)					COD_{Cr} removal (%)				
		Sewage	Combined system		Single DHS syste	Pond eff.	Combined system			Single DHS syste	Pond eff.
			UASB	DHS			UASB	DHS	Whole		
5/12	8	137	364	30	31		(165)	243	78	77	
5/14	10	113	106	22	31		6	74	81	72	
5/17	13	119	181	21	9		(52)	135	82	93	
5/26	22	101	56	13	20		45	43	87	80	
5/31	27	140	74	20	12	37	47	39	86	92	73
6/02	29	84	95	16	10		(12)	93	81	89	
6/04	31	162	66	21	19		59	28	87	88	
6/07	34	129	70	10	16	74	46	47	93	88	43
6/09	36	170	90	9	7		47	48	95	96	
6/11	38	76	66	16	11		13	66	79	86	
6/14	41	187	52	8	6	142	72	24	96	97	24
6/16	43	213	62	17	14		71	21	92	94	
6/18	45	252	60	16	13		76	17	94	95	
6/21	48	262	66	14	25	99	75	20	95	90	62
6/23	50	272	56	18	32		80	14	93	88	
6/25	52	170	45	8	14		73	22	96	92	
6/28	55	191	47	16	12	156	75	17	92	94	18
6/30	57	140	50	40	16		64	7	71	89	
7/02	59	416	60	37	15		86	5	91	96	
7/05	62	211	45	35	19	144	78	5	83	91	32
7/07	64	211	23	17	17		89	3	92	92	
7/09	66	426	30	9	11		93	5	98	97	
7/12	69	385	51	13	18	79	87	10	97	95	79
7/14	71	272	32	20	21		88	5	93	92	
7/16	73	324	47	26	12		85	7	92	96	
7/19	76	293	44	13	6	79	85	11	96	98	73
7/21	78	242	31	12	12		87	8	95	95	
7/23	80	272	37	12	15		86	9	96	95	
7/26	83	303	35	12	18	107	88	8	96	94	65
7/28	85	313	52	19	16		84	10	94	95	
7/30	87	354	37	13	5		89	7	96	99	
Average		224	69	18	15	102	56	34	90	91	52

Source: This survey experiment

Table 4.4.9 Treatment performance data in Jakarta (Soluble COD)

DATE (2010)	Elapsed days	Soluble-COD_{Cr} (mg/L)				
		Sewage	Combined system		Single DHS system	Pond eff.
			UASB	DHS		
5/12	8	70	254	24	18	
5/14	10	89	101	13	27	
5/17	13	82	145	30	31	
5/26	22	60	43	15	14	
5/31	27	99	47	19	11	7
6/02	29	62	54	7	4	
6/04	31	103	54	12	12	
6/07	34	80	66	7	12	66
6/09	36	142	54	4	7	
6/11	38	45	43	12	10	
6/14	41	113	38	5	6	29
6/16	43	54	54	16	11	
6/18	45	62	56	13	9	
6/21	48	82	37	9	17	50
6/23	50	56	31	13	9	
6/25	52	31	27	6	3	
6/28	55	111	39	14	11	41
6/30	57	52	37	28	16	
7/02	59	60	37	15	11	
7/05	62	54	40	18	18	34
7/07	64	34	21	13	10	
7/09	66	37	27	8	4	
7/12	69	38	27	11	13	38
7/14	71	39	33	12	17	
7/16	73	60	26	14	10	
7/19	76	52	34	11	6	21
7/21	78	54	26	7	11	
7/23	80	42	27	12	5	
7/26	83	43	40	11	11	39
7/28	85	54	35	16	16	
7/30	87	49	28	10	4	
Average		65	51	13	11	36

Source: This survey experiment

Table 4.4.10 Treatment performance data in Jakarta (Nitrogen)

DATE (2010)	Elapsed days	Ammonium (mg-N/L)					Nitrate (mg-N/L)				
		Sewage	Combined system		Single DHS system	Pond eff.	Sewage	Combined system		Single DHS system	Pond eff.
			UASB	DHS				UASB	DHS		
5/12	8	0.2	1.8	0.1	0.0		0.05	0.10	0.44	0.3	
5/14	10	1.8	2.9	0.0	0.0		0.07	0.23	0.61	0.9	
5/17	13	30.6	32.2	6.3	0.3		0.01	0.29	6.40	8.6	
5/26	22	30.6	32.2	6.3	0.5		0.12	0.09	3.07	10.0	
5/31	27	27.4	32.0	13.2	0.6	17.8	0.09	0.07	2.51	7.2	0.12
6/02	29	30.0	32.6	5.2	0.5		0.07	0.15	8.62	7.0	
6/04	31	29.4	33.6	7.9	0.7		0.12	0.07	3.90	4.2	
6/07	34	31.6	29.2	9.9	0.8	18.4	0.15	0.23	7.79	11.1	1.40
6/09	36	31.2	28.4	10.3	0.6		0.18	0.12	10.84	4.2	
6/11	38	29.2	27.4	5.4	2.6		0.07	0.07	3.62	4.2	
6/14	41	18.8	21.5	1.0	1.9	21.7	0.07	0.12	4.18	4.2	0.26
6/16	43	23.5	22.5	19.8	0.5		0.09	0.04	33.34	11.1	
6/18	45	24.1	23.3	4.9	0.6		0.07	0.29	3.34	7.0	
6/21	48	25.1	21.1	5.0	0.9	17.4	0.07	0.40	4.32	9.7	0.09
6/23	50	30.0	28.4	10.9	1.6		0.12	0.26	5.29	8.3	
6/25	52	28.6	25.3	8.4	0.6		0.09	0.07	7.09	11.1	
6/28	55	28.4	29.8	10.4	0.6	17.2	0.07	0.12	5.01	11.1	0.07
6/30	57	31.6	32.8	9.0	0.7		0.15	0.15	0.29	11.1	
7/02	59	32.8	33.0	10.7	0.7		0.04	0.09	7.23	4.2	
7/05	62	21.1	25.7	9.9	1.1	14.0	0.07	0.04	11.68	22.2	0.07
7/07	64	20.5	21.5	1.2	0.5		0.07	0.15	3.90	2.8	
7/09	66	23.3	24.3	0.6	0.4		0.09	0.18	3.34	2.8	
7/12	69	25.1	26.7	1.4	0.4	12.3	0.09	0.07	4.46	30.6	0.04
7/14	71	22.9	22.7	0.8	0.4		0.01	0.12	3.34	9.7	
7/16	73	29.2	27.2	10.0	0.4		0.07	0.12	3.62	19.5	
7/19	76	28.6	31.2	9.4	0.6	13.2	0.12	0.18	6.68	9.7	0.15
7/21	78	28.8	29.0	0.7	0.4		0.12	0.09	11.12	16.7	
7/23	80	29.4	30.2	0.6	0.2		0.09	0.18	13.07	9.7	
7/26	83	34.7	35.7	6.5	0.5	19.6	0.09	0.15	0.79	20.8	0.09
7/28	85	34.0	38.3	4.4	0.7		0.09	0.09	14.73	8.3	
7/30	87	34.7	31.8	3.2	0.7		0.07	0.04	15.01	22.2	
Average		26.4	26.9	6.2	0.7	16.8	0.09	0.14	6.76	10.0	0.25

Source: This survey experiment

Table 4.4.11 Treatment performance data in Jakarta (Biogas)

DATE (2010)	Elapsed days	Biogas production (L/m^3-reactor/day)	CH_4 concentration (%)	CH_4 production (mL-CH_4/L-sewage)
5/12	8	28.2	3.1	0.30
5/17	13	51.0	3.4	0.60
5/18	14	99.4	4.0	1.37
5/19	15	44.4	6.4	0.97
5/21	17	37.1	14.3	1.86
5/24	20	26.2	9.5	0.85
5/26	22	22.4	17.4	1.33
5/27	23	24.1	4.6	0.38
5/28	24	17.3	0.0	0.00
5/31	27	53.5	8.7	1.61
6/01	28	74.4	9.4	2.39
6/02	29	8.8	0.0	0.00
6/03	30	65.1	0.0	0.00
6/04	31	18.6	2.8	0.18
6/07	34	3.8	3.9	0.05
6/14	41	6.3	2.0	0.04
6/21	48	6.4	0.0	0.00
6/28	55	4.0	0.0	0.00
7/05	62	5.9	2.7	0.03
7/12	69	5.9	1.5	0.02
7/19	76	8.9	3.4	0.04
7/26	83	8.9	0.0	0.00
7/30	87	8.9	3.2	0.04
Average		29.1	4.6	0.57

Source: This survey experiment

Table 4.4.12 On-site treatment performance data in Jakarta (Summary of the performance)

Analysis item	Unit	Raw sewage	Combined system		Single DHS system (10H)	Single DHS system (6H)	pond
			UASB	DHS			
Total-COD_{Cr}	mg/L	224	69	18	15	16	102
Soluble-COD_{Cr}	mg/L	65	51	13	13	11	36
Total-COD_{Cr} removal	%	-	90		88	94	54
Ammonia	mg-N/L	26.4	26.9	6.2	0.7	0.6	16.8
Nitrate	mg-N/L	0.1	0.1	6.8	6.1	12.0	0.3
temperature	˚C	28.2	27.9	27.7	28.3	27.6	28.6
pH	-	7.4	7.3	6.6	7.8	7.9	7.6
Methane production	mL-CH_4/L-	-	0.7	-	-	-	-

Source: This survey experiment

Table 4.4.13 Treatment performance data in Jakarta (Temperature and pH)

DATE (2010)	Elapsed days	Temperature (℃)					pH (-)				
		Sewage	Combined system		Single DHS system	Pond eff.	Sewage	Combined system		Single DHS system	Pond eff.
			UASB	DHS				UASB	DHS		
5/12	8	28.1	28.9	28.7	29.0		7.5	8.4	7.9	8.1	
5/14	10	27.8	28.1	28.0	28.9		7.2	7.9	6.5	8.0	
5/17	13	28.1	28.7	28.2	28.5		7.9	7.4	6.9	7.4	
5/19	15	30.3	30.0	28.5	30.5		7.1	7.1	6.5	7.7	
5/21	17	30.0	29.4	29.8	29.6		7.0	7.1	6.3	7.9	
5/24	20	28.1	28.9	28.9	28.0		7.5	7.0	6.3	8.1	
5/26	22	27.8	27.8	27.8	27.6		7.7	7.5	6.4	7.6	
5/28	24	30.1	28.7	30.1	30.1		7.5	7.0	6.4	7.9	
5/31	27	28.7	27.9	28.0	27.9	29.3	7.9	7.7	6.3	7.8	7.5
6/01	28	29.6	28.9	29.0	29.3		7.2	7.7	6.5	7.7	
6/02	29	28.4	28.9	28.7	28.4		7.6	7.3	6.4	8.1	
6/03	30	29.8	29.6	29.6	29.2		7.5	7.2	6.6	7.8	
6/04	31	29.0	28.6	28.5	27.9		7.6	6.8	6.3	8.0	
6/07	34	27.8	27.5	27.2	27.4	28.3	7.3	7.4	6.5	7.8	7.5
6/08	35	27.7	27.5	27.3	27.1		7.3	7.3	6.1	7.4	
6/09	36	26.7	26.6	26.6	26.5		7.0	7.3	6.4	7.8	
6/10	37	28.6			27.8		7.2	6.6	6.4	7.9	
6/11	38	28.1	26.7	27.8	27.9		7.4	7.0	6.5	7.5	
6/14	41	28.8	28.0	28.0	27.9	28.5	7.6	7.1	6.4	7.9	7.4
6/16	43	26.8	26.1	26.1	25.8		7.4	7.1	6.1	7.9	
6/18	45	27.0	27.2	26.6	26.4		7.6	7.4	6.4	7.7	
6/21	48	27.7	27.8	28.3	28.1	28.9	7.6	7.5	6.3	7.6	7.7
6/23	50	28.1	28.4	27.9	28.4		7.4	6.9	6.5	7.7	
6/25	52	27.1	26.5	25.8	26.0		7.3	7.4	6.4	7.3	
6/28	55	28.4	27.8	27.3	28.4	28.0	7.5	7.0	6.5	7.7	7.6
6/30	57	27.0	28.3	27.4	28.5		7.8	7.3	7.1	7.5	
7/02	59	28.2	28.4	27.6	28.3		7.8	7.3	6.8	7.4	
7/05	62	28.7	28.5	28.2	28.4	28.3	7.7	7.3	7.1	8.0	8.0
7/07	64	28.4	28.1	27.8	28.4		7.5	7.1	6.6	8.1	
7/09	66	26.7	27.2	26.6	28.0		7.2	7.3	7.2	7.8	
7/12	69	28.1	27.9	27.2	28.1		7.3	7.6	6.8	8.4	
7/14	71	27.6	26.8	26.7	27.4		7.6	7.3	7.0	8.1	
7/16	73	28.6	26.3	26.5	25.6		7.3	7.1	6.6	8.0	
7/19	76	27.3	27.8	27.0	27.8		7.4	7.2	7.1	7.9	
7/21	78	28.2	28.2	27.1	27.5		7.5	7.8	7.1	8.1	
7/23	80	28.1	27.9	27.1	28.2		7.4	7.4	6.8	8.0	
7/26	83	28.2	27.8	27.7	27.8		7.6	7.8	6.5	8.0	
7/28	85	27.6	26.9	26.9	26.2		7.1	7.6	6.2	8.3	
7/30	87	28.0	26.7	27.2	27.1		7.4	7.9	7.8	8.1	
Average		28.2	27.9	27.7	27.9	28.6	7.4	7.3	6.6	7.8	7.6

Source: This survey experiment

Table 4.4.14 Operation conditions of the treatment in Jakarta (HRT and flow rate)

DATE (2010)	Elapsed days	Combined system HRT UASB (hour)	Combined system HRT DHS (hour)	Combined system Liquid flow rate (L/day)	Combined system DHS gas flow rate (L/day)	Single DHS HRT (hour)	Single DHS Liquid flow rate (L/day)
5/12	8	8.3	2.6	3.3	2.62	10.7	0.43
5/14	10	8.5	2.6	3.2	2.62	11.6	0.40
5/17	13	8.4	2.6	3.2	1.53	10.7	0.43
5/19	15	8.4	2.6	3.2	1.44	10.7	0.43
5/21	17	8.1	2.5	3.3	1.49	9.5	0.49
5/24	20	8.4	2.6	3.2	1.15	10.9	0.42
5/26	22	8.2	2.5	3.3	1.34	11.0	0.42
5/28	24	8.2	2.5	3.3	1.97	9.6	0.48
5/31	27	8.2	2.5	3.3	2.24	9.6	0.48
6/01	28	8.4	2.6	3.2	1.41	10.2	0.45
6/02	29	8.2	2.6	3.3	1.92	10.8	0.43
6/03	30	8.2	2.6	3.3	2.24	10.8	0.43
6/04	31	8.1	2.5	3.3	1.96	10.6	0.43
6/07	34	8.1	2.5	3.3	1.44	10.6	0.43
6/08	35	8.3	2.6	3.3	1.50	11.3	0.41
6/09	36	8.3	2.6	3.3	0.72	10.9	0.42
6/10	37	8.2	2.6	3.3	0.72	11.8	0.39
6/11	38	8.6	2.7	3.2	0.72	10.9	0.42
6/14	41	8.2	2.5	3.3	0.39	11.2	0.41
6/16	43	8.8	2.7	3.1	0.39	10.7	0.43
6/18	45	7.8	2.4	3.5	0.39	6.8	0.68
6/21	48	7.6	2.4	3.6	0.22	6.8	0.67
6/23	50	7.8	2.4	3.5	0.22	6.3	0.74
6/25	52	7.8	2.4	3.5	0.22	6.8	0.67
6/28	55	7.8	2.4	3.5	0.45	6.1	0.75
6/30	57	7.7	2.4	3.5		6.3	0.73
7/02	59	7.6	2.4	3.6		6.1	0.75
7/05	62	7.9	2.5	3.4	0.95	6.5	0.71
7/07	64	7.6	2.4	3.6		6.4	0.72
7/09	66	7.6	2.4	3.6		6.7	0.69
7/12	69	6.5	2.0	4.2	0.98	6.5	0.71
7/14	71	7.5	2.4	3.6		6.3	0.73
7/16	73	7.4	2.3	3.7		6.3	0.73
7/19	76	7.3	2.3	3.7	1.08	6.2	0.75
7/21	78	7.2	2.3	3.7		6.2	0.75
7/23	80					6.1	0.75
7/26	83	7.4	2.3	3.7	1.08	6.0	0.76
7/28	85	7.7	2.4	3.5		6.1	0.75
7/30	87	7.7	2.4	3.5	1.08	6.1	0.76
Average		7.9	2.5	3.4	1.22		

Source: This survey experiment

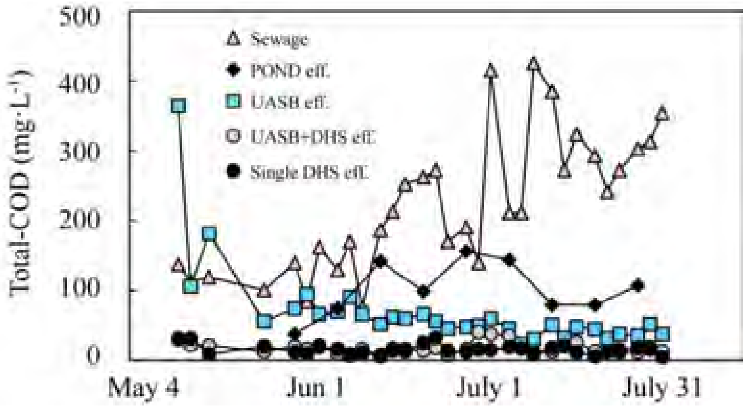


Fig. 4.4.8 Time series of t-COD in the treatments by UASB-DHS and single DHS systems

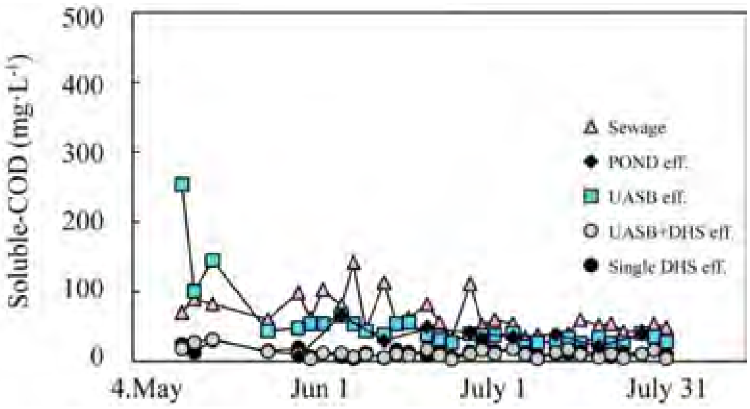


Fig. 4.4.9 Time series of t-COD in the treatments by UASB-DHS and single DHS systems

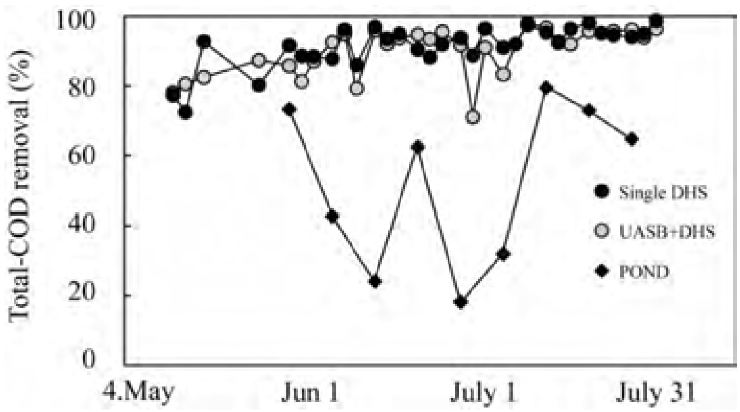


Fig. 4.4.10 Time series of COD removal in the treatments by UASB-DHS and single DHS systems

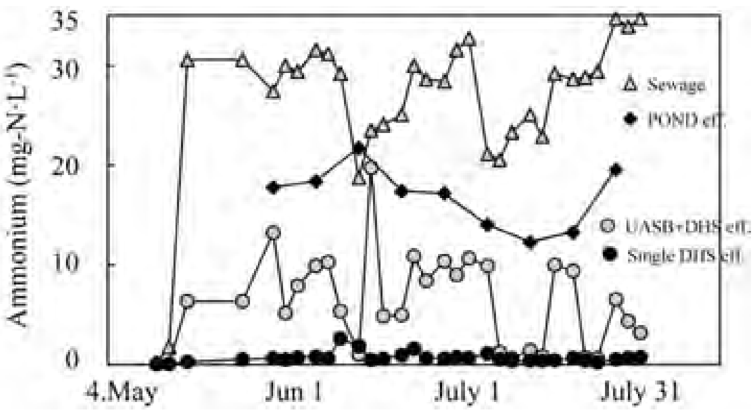


Fig. 4.4.11 Time series of ammonium in the treatments by UASB-DHS and single DHS systems

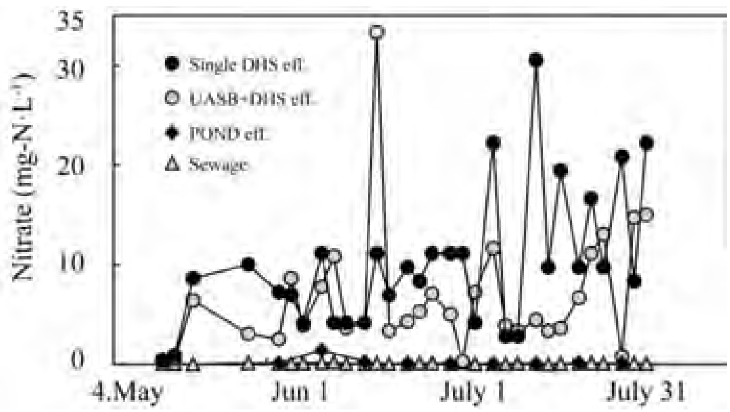


Fig. 4.4.12 Time series of nitrate in the treatments by UASB-DHS and single DHS systems

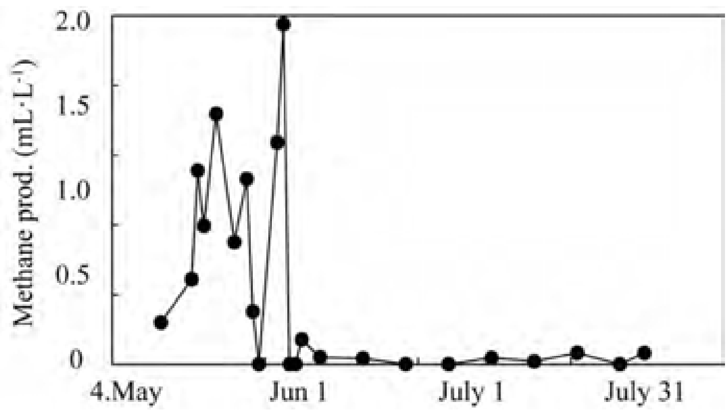


Fig. 4.4.13 Time series of methane production by UASB reactor in the treatments

(4) Discussion

The treatment experiments using the actual sewage in Jakarta demonstrated that not only the combined system of UASB and DHS reactors but also the single DHS system would be applicable to sewage treatments at a general HRT of activated sludge process. UASB reactor had great advantage to recovery methane gas as useful energy from sewages. However, in low strength wastewaters like the sewage flowing into the east pond, methane recovery could not be expected because methane concentration of biogas produced from UASB was too low for biogas to be burnable. The very small bench-scale UASB was used in the experiment and the collection of small amount of biogas was so difficult. If a pilot scale UASB were used, methane concentration could be higher. Even though recovered biogas was useful as energy, the amount might be trivial.

In Medan a full scale UASB reactor (9,120 m^3 = 3 units x 19.2 m x 39.02 m x 4.06 m) has been operated for municipal sewage treatment. Biogas is not produced at all from this treatment plant because the COD concentration of UASB influent is always low. The CODs of influent (raw sewage), UASB effluent, aerated pond effluent were 187, 113, and 69 mg COD/L on average, respectively (data in Feb. 2010). A primary setting tank was installed prior to the UASB reactor, and some organic matter was removed. If the raw sewage were directly introduced to the UASB without the primary setting tank, biogas might be produced and recovered into the gasholder set in the plant.

4.4.5. Designing

The onsite sewage treatment experiment demonstrates that the combined UASB-DHS system and the single DHS system are both applicable for sewage treatment in Jakarta. Each of these systems was able to obtain excellent effluent, which was possible to be discharged into water bodies.

With regard to designing, pilot-plant size was determined as a function of amount of sewage and HRT. The most important parameter for design and operation of pilot-plant was HRT. Based on the bench-scale experiment data in Jakarta, the Survey team has determined HRT for appropriate treatment as follows.

1) Combined UASB-DHS system: 10.3 hrs (8 and 2.3 hrs for UASB and DHS reactors, respectively)
2) Single DHS system: 6 hrs (depends on sponge volume)

In combined UASB-DHS system, methane gas was generally produced and recovered from sewage. For low strength wastewaters like the sewage flowing into the pond in Jakarta, however, little methane production was to be expected. On the other hand, almost complete nitrification and some denitrification were expected in the single DHS system at shorter HRT.

In conclusion, the Survey team recommended the single DHS system would be the most preferred unit to the low cost sewage treatment system in Jakarta. If higher COD sewage would be collected into the pond, the combined UASB-DHS system shall be recommended because methane gas recovery is expected.

4.4.6. Low Cost Sewage Treatment Facilities

As mentioned above, methane recovery is considered to be difficult in sewage treatments in Jakarta. Therefore, a low cost sewage treatment facility cooperated with UASB-DHS system and gasification power-generating unit, which utilizes incineration of recovery methane, is not feasible. The only wastes flowing into the pond is possible to be collected and utilized as energy source for gasification power-generation.

4.5. Solid Waste Management at the Surface Water Area

4.5.1. Legislation on Solid Waste

Table 4.5.1 details the environmental acts and regulations in Indonesia. The Environment Management Act, No. 23/1997 sets the foundations of the various environmentally related legislations.

Table 4.5.1 Environmental acts and government regulations in Indonesia

The Constitution of 1945 (Undang-undang Dasar Negara 1945)	
Environmental Conservation and Management Act	Act No.5/1990 on Conservation of Biological Resources and Ecosystems Act N0.5/1991 on UN Convention on Biological Diversity Act No.6/1994 on Ratification of the UN Framework Convention on Climate Change Act No. 23/1997 on Environmental Management Act No.26/2007 on Spatial Plan and Management Act No.18/2008 on Solid Waste Management Act No.19/2009 on Ratification of Stockholm Convention on Persistent Organic Pollutants Act No.32/2009 on Environmental Protection and Management
EIA	Government Regulation No.27/1999 of Environment Impact Assessment
Hazardous and toxic waste management	Government Regulation No. 18/1999of Hazardous and Toxic Waste Management Government Regulation No. 85/1999 of Amendment of Government Regulation No. 18/1999 Government Regulation No. 74/2001of B3 Management
Water quality management and water pollution control	Government Regulation No. 82/2001 of Water Quality Management and Water pollution Control
Sea pollution and damage control	Government Regulation No. 19/1999 of Sea Pollution and Damage Control
Air pollution control	Government Regulation No.41/1999 of Air Pollution Control
Biological resources damage control	Government Regulation No.150/2000 of Land Degradation Control for Biomass Production Government Regulation No.4/2001 of Environment Pollution and/or Damage Control relating to Forest Fire and/or Land Government Regulation No.21/2005 of Safety of Biological Products in Genetic Engineering

Source: MOE, 2010

Solid waste is defined under the Solid Waste Management Act, No.18/2008. Prior to the enactment of this Act in 2008, despite the hazardous waste regulations, there was no regulation on domestic waste from residents. The comprehensive approach to municipal waste in Indonesia is likely to be just begun. The key points of Solid Waste Management Act No.18/2008 are (1) public service principles, (2) scoping of domestic solid waste and specific waste with waste minimization and handling (Article 19), (3) building incentives and disincentives mechanism (Article 3 and 4), (4) share of role and responsibility among government level, (5) funding system and compensation, (6) cooperation among local government and local government with private sector, (7) roles of community, (8) prohibition and (9) administrative and criminal sanction. Selection of waste processing and dumping technologies must be safe and healthy, and conform to Indonesian situation. Open dumping and open burning are forbidden.

Prior to the enactment of this Act in 2008, despite the hazardous waste regulations, there was no regulation on domestic waste from residents. The comprehensive approach to municipal waste in Indonesia is likely to be just begun.

4.5.2. Government agencies related Municipal Solid Waste in DKI Jakarta

With the enactment of the Government Regulation No.25/2000 on decentralization, the Government of Indonesia introduced a new policy to provide a larger responsibility and role for local governments to provide urban services that include provision of water supply and sanitation services. The Ministry of Environment (MOE) is now responsible for policy developments, regulation formulations and coordinating efforts in pollution control caused by waste, whereas the Ministry of Public Works (PU) is responsible in providing technical guidance, promoting pilot projects, and supervising large-scale off-site sanitation systems including waste management system.

As municipal solid waste service provider, DKI Jakarta Province has 5 institutions which are responsible for municipal waste management, that is, the Regional Environment Management Board (BPLHD); the Cleansing Department (Dinas Kebershhan); PD PASAR JAYA; the Landscape Gardening and Beauty City Department（Dinas Pertamanan & Akeindahan Kota）; and the Provincial Public Works Department (DINAS PU). BPLHD is to formulate environmental policy and monitor the environmental condition and other four agencies are to implement cleansing activities designated to each agency (Fig. 4.5.1).

The Cleansing Department is a core implementing agency of waste management to transport waste from the 978 temporary disposal sites (TPS) in Jakarta to the Bantar Gebang final disposal site (TPA) in Bekasi Municipality. PD PASAR JAYA is Jakarta’s public company in cleansing and collecting waste in market areas. The Landscape Gardening and Beauty City Department has responsibility to keep clean the public parks and gardens. And DINAS PU maintains river basin area (rivers, channels, reservoirs and lakes) by means of dredging and removal of waste which can cause flood and damage to the infrastructures and facilities. Each Department has Sub-Unit in each of 5 Municipalities.

Fig. 4.5.1 Responsible organizations for cleansing works in DKI Jakarta

4.5.3. Solid Waste Generation in DKI Jakarta

In 2009 the volume of garbage generated in DKI Jakarta was 28,286 m^3 per day and the volume transported by the Cleansing Department was 24,323 m^3 per day, boosting the collection ratio to 86.0% (Table 4.5.2).

Table 4.5.2 Volume of garbage generated in DKI Jakarta (m^3/day)

	2001	2002	2003	2004	2005	2006	2007	2008	2009
Generation	25,600	25,176	25,687	26,966	26,264	26,444	27,966	29,217	28,286
Transported	22,196	24,162	24,675	25,925	25,446	25,904	26,962	27,756	24,323
Remainder	3,404	1,014	1,012	1,041	818	540	1,004	1,461	3,963
Ratio (%)	86.7	96.0	96.1	96.1	96.9	98.0	96.4	95.0	86.0
Compost (product)	771	770	770	757	757	748	748	841	789

Source: Cleaning Department, DKI Jakarta

Table 4.5.3 shows daily garbage product and transported by 5 Municipalities in 2009. The untreated waste ratio in North Jakarta was relatively high compared with others, while that of Central Jakarta was the lowest.

Table 4.5.3 Daily garbage product and transported by municipality, 2009

Municipality	Area	Population	Generation	TPS→TPA	Unhandled	%
	(km^2)		(m^3/day)	(m^3/day)		
South Jakarta	141.27	2, 141,773	5,107	4,517	590	11.6
East Jakarta	188.03	2 ,428,213	6,331	5,427	904	14.3
Central Jakarta	48.13	894,740	5,338	5,194	144	2.7
West Jakarta	129.54	2,202, 672	6,490	5,698	792	12.2
North Jakarta	146.66	1, 459,360	5,020	3,487	1,533	30.5
Total	662.33	9,146,181	28,286	24,323	3,963	100.0

Source: Cleaning Department, DKI Jakarta

The estimation of waste origin is shown in Table 4.5.4. The high percentage (58%) of waste was caused by the waste source composition dominated by household waste. The local government could not collect total amount of household waste for treatment purposes such as composting, recycling or incineration, so that several auxiliary waste handling systems are done by community (MOE, 2008). On the other hand, for waste produced in public and commercial areas, the municipal government is directly responsible. In Jakarta the most of the unhandled waste by the Cleansing Department is household waste and this renders the high waste collection ratio in Central Jakarta Municipality within which only a small number of households exists.

Table 4.5.4 Rough estimation of waste origin in 2009

Origin of Waste	Volume (m^3/day)	%
Household	16,406	58
Market	2,829	10
Commercial	4,243	15
Industry*	3,677	13
Roads, parks, rivers etc.*	1,131	4
Total	28,286	100

* adjusted for consistency by the Survey team

Source: Cleansing Department, DKI Jakarta

Based on the West Java Management Project (WJMP), the largest composition of waste in DKI Jakarta is compostable organic waste as bio-waste 55.37%; paper products 20.57%; and plastic 13.25%, as shown in Table 4.5.5.

Table 4.5.5 Composition of garbage in DKI Jakarta (%)

1.Organic		55.4
2. Non-organic		44.6
2.1	Paper	20.6
2.2	Plastic	13.3
2.3	Wood	0.1
2.4	Cloth/Textile	0.6
2.5	Leather	0.2
2.6	Metal	1.1
2.7	Glass	1.9
2.8	Construction	0.8
2.9	Toxic	1.5
2.10	Others (stone, sand etc)	4.7

Source: WJEMP DKI, January 2005

According to MOE (2008), the wastes that cannot be collected by the local government are individually treated by the community. This leads to high percentage of improper waste treatment such as open burning, buried waste and disposal to the river. In 2006, the waste was transported to landfill (69.0%), buried (9.6%), composted (7.2%), burnt (4.8%) and disposed in river (2.9%) as shown in Table 4.5.6. In case of Jakarta, waste thrown into the rivers is estimated between 2.7% to 10% and it exacerbates seasonal flood damage in the poorer areas.

Table 4.5.6 Household waste treatment in Indonesia, 2006

Method	Amount (Million ton/year)	Percentage (%) of total method
Transported to landfill	11.6	69.0
Buried	1.6	9.6
Composted	1.2	7.2
Burnt	0.8	4.8
Disposed in river	0.5	2.9
Others	1.1	6.5
Total	16.8	100.0

Source: MOE, 2008

Total waste trucks owned by the Cleansing Department amounted to 789 units in 2009 (Table 4.5.7). In addition to the above number of trucks, the Cleansing Department rents 100 trucks from private lease companies. Furthermore, 22 private cleansing companies provide their own services by using total 161 trucks and some of them do several related business such as compost production, office cleaning service. Jakarta Municipalities pay Rp.120, 000 to Rp.130, 000/ton to the private company.

Table 4.5.7 Number of waste trucks in 2009

Cleansing Department	11
Central Jakarta Sub Unit	155
North Jakarta Sub Unit	147
West Jakarta Sub Unit	184
South Jakarta Sub Unit	139
East Jakarta Sub Unit	151
Total	789

Source: Cleansing Department DKI Jakarta

The Cleansing Department collects waste from a total of 978 TPS located in DKI Jakarta. Although this number is expected to be sufficient to cover one or two neighborhoods (RWs), actually there appear to be in shortage. Operation of the Cleansing Department is divided into five Municipalities. The garbage goes to the Bantar Gebang TPA in Bekasi, which is operated by the private company-PT.GODANG TUAJAYA & PT. NASIGAT (Australian company) since 1993, via either the Sunter Transfer Station at North Jakarta or Cakung-Cilicing Composting and Recycling Site (PDUK) at East Jakarta. In the case of the South Jakarta Municipality which is further away from the Transfer Stations, all the collected garages are directly transported to TPA.

At the Sunter Transfer Station which is maintained by the Technical Implementation Unit, the city's garbage is received from approximately 140 collection vehicles in one day and is reloaded into containers with a capacity of 80-100 m^3 each. A total of 18-25 truckloads of garbage are sent to the Bantar Gebang Final Disposal Site every day. The number of trips for garbage collection vehicles is 3 times per day. The Sunter Transfer Station is designed as a facility that can dispose of a maximum of 6,000 m^3 of garbage per day on a maximum of three 8-hour shifts. The number of shifts to be undertaken is determined according to seasonal fluctuations in the volume of garbage and other factors, but the real maximum disposal capacity of the transfer station is considered to be 4,000 m^3 per day because of limited personnel expenses due to difficulties in securing operation and maintenance budgets, and inadequate facility maintenance.

Fig. 4.5.2 depicts the existing waste management in DKI Jakarta handed by PU, whose current duty includes developing new sanitary landfill plan in DKI Jakarta as part of national policy.

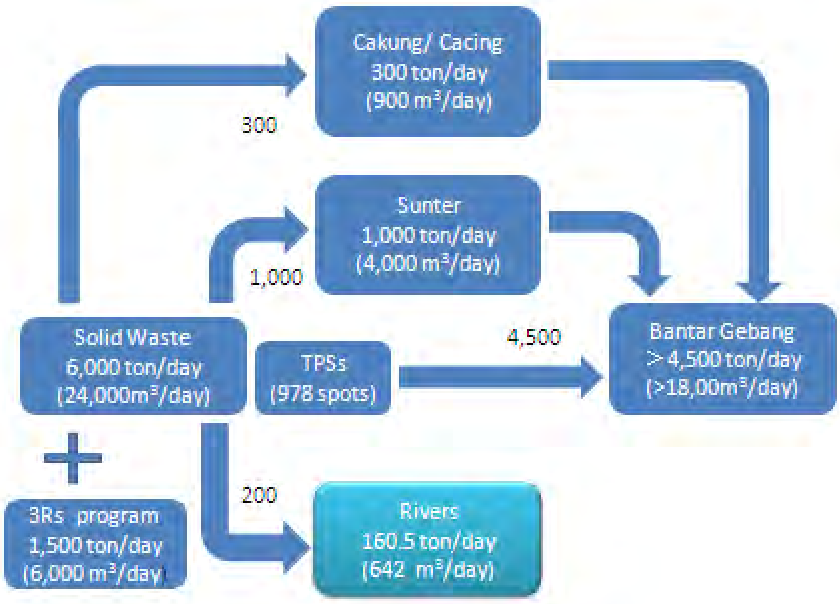


Fig. 4.5.2 Waste flows in DKI Jakarta

For practical application, it is assumed one ton waste is equivalent to $4m^3$ in volume. At present, the waste dumped into rivers is estimated as 200 ton/day (2.7% of total 7,500 ton/day) in DKI Jakarta and from which 160.5 ton/day ($642m^3$/day) is collected at the estuaries of S. Blencong Marunda, Cakung drain, Kali Angke, Kali Muara Karang, Kali Japot, Marina (Anak Ciliwung) and Kali Kamal.

4.5.4. Surface Water System in Jakarta and MSW as Obstacles

Water quality in DKI Jakarta is classified by BPDLH according to the Guideline on Decree No, 115/200 (see Table 2.2.1).Water quality in rivers and canals in DKI Jakarta is general in poor condition. A total of 12 out of the 19 rivers/canals in Jakarta are heavily polluted. Only water of three rivers (Krukut, Kali Baru Barat and Mookervart) can be utilized as drinking purpose (Table 4.5.8).

Table 4.5.8 Water quality clarification of the 19 major rivers/canals in Jakarta in 2008

	River/Canal	Length (m)	Area (m^2)	Average Width (m)	Lowest Elevation (m)	Highest Elevation (m)	Water Quality
1	Ciliwung	46,200	1,155,000	25	8	291	Heavy polluted
2	Krukut	28,750	172,500	6	7	117	Small Polluted
3	Mookervart	7,300	233,600	32			Small Polluted
4	Kali Angke	12,810	538,200	42	3	220	Heavy polluted
5	Kali Pesanggrahan	27,300	354,900	13	3	205	Intermediate Polluted
6	Sungai Grogol	23,600	165,200	7	29	100	Intermediate Polluted
7	Kali Cideng	17,800	234,810	13			Heavy polluted
8	Kalibaru Timur	30,200	392,600	13			Heavy polluted
9	Cipinang	27,350	464,950	17	12	107	Heavy polluted
10	Sunter	37,250	1,080,000	29	12	122	Heavy polluted
11	Cakung	20,700	414,000	20	6	90	Heavy polluted
12	Buaran	7,900	158,000	20	9	45	Heavy polluted
13	Kalibaru Barat	17,700	177,000	10			Small Polluted)
14	Cengkareng Drain	11,200	672,000	60			Heavy polluted
15	Jati Kramat	3,800	19,000	5			Heavy polluted
16	Cakung Drain	12,850	771,000	60			Heavy polluted
17	Ancol	8,300	240,700	29			Heavy polluted
18	Banjir Kanal Barat	7,600	380,000	50			Intermediate Polluted
19	Banjir Kanal Timur	23,000	1,380,000	60			Intermediate Polluted
	Total /average	371,610	9,003,460	24			

Source: BPLHD DKI Jakarta (Jakarta Dalam Angka 2009, p12), the elevations from NEDECO, 1973

In addition to the water degradation, many floodings have occurred in recent time during the rainy season. About 10,000 ha (100 km^2) were flooded on February 4, 2002, which was 1/6 of DKI Jakarta area, totaling 661.52 km^2. One of the main causes of flood as well as river and coastal pollution in Jakarta is due to the illegal-dumping of garbage into the 13 rivers in Jakarta. Due to the poor management of DINAS PU of DKI Jakarta, solid wastes and sediments have been accumulated in the rivers and drains over the years and as a result floodways have being narrowed due to the reduction of the river flow area by the accumulated garbage. Consequently, the streets and the houses have been flooded when the rain storm comes in January and February, as the main drains could not convey the excessive amount of rain storm water and the water level becomes high results (Table 4.5.9). When solid waste covers the water gates and drainage canals, serious damage by flood could be expected.

Table 4.5.9 Rainfall at the Soekarno-Hatta observation station in Jakarta by month, 2008

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Total Rainfall (mm)	226.5	677.6	212.4	218.4	25.9	51.4	9.5	36.4	97.3	85.8	113.8	154.2
Number of rainfall	14	29	22	16	6	5	1	5	3	9	17	22

Source: DKI Jakarta

The increase of solid waste in the rivers also becomes an obstacle for the river to provide raw drinking water. Some inlets of the Water Supply Enterprises (PDAMs) are covered by solid waste accumulation in the rivers, which has often caused damages to pumping facilities. As a result, the quality of the raw water becomes low and hence increases the producing cost of drinking water. It is anticipated that similar problems would cause when a sewage treatment system is introduced in future, because even now the garbage into the Banjil Kanal Reservoir controlled by PD PAL JAYA is scavenged by full-time staff every day. Furthermore, the waste disposal produces adverse effect on ecosystem, agriculture and fisheries.

4.5.5. River Cleaning Service by Provincial Public Works Department in DKI Jakarta

DINAS PU is implementing cleaning services for rivers and channels in DKI Jakarta through dredging and solid waste collection. There are two type of solid waste: floating waste and subsurface waste. The floating waste is removed by waste-picking and subsurface waste is removed by dredging the sediments. The DINAS PU's operational areas are divided into three flow system (West, Central, and East) for flood control operation. The micro channels are not included as a responsibility of each Municipality. However, even excluding micro channels, the total coverage length of rivers and channels by DINAS PU is still not high because of budget shortage (Table 4.5.10).

Table 4.5.10 River/channel cleaning service by DINAS PU (km)

Description	Overall Length	Cleaning Services		Unhandled	
Rivers	442.7	288.9	65.3%	203.8	34.7%
Drainage channels	1,054.2	342.2	32.5%	712.0	67.5%
Micro channels	13,595.1	0.0	0.0%	13,595.1	100.0%
Total	15,092.0	631.1	4.2%	1,4510.9	95.8%

Source: DINAS PU, DKI Jakarta

A comparison between budgetary request and allocated amount for cleaning service of rivers and channels in recent years (Table 4.5.11), reveals that there was a declining trend in the amount approved since 2003, revealed that there was a declining trend in treatment approved since 2003,and only 40.7% of the budgetary requested was approved in 2008.

Table 4.5.11 Trends in river cleaning service budget

Year	Budgetary Request (Rp.)	Approved Amount (Rp.)	%
2003	12,000,000,000	10,944,706,635	91.2
2004	19,500,000,000	18,534,132,000	95.0
2005	33,000,000,000	22,831,339,116	69.2
2006	27,750,000,000	22,504,374,400	81.1
2007	30,375,000,000	26,304,231,807	86.6
2008	30,180,400,000	12,282,273,125	40.7

Source: DINAS PU, DKI Jakarta

Therefore, the Ministry of Public Works has to apply the World Bank's soft loan (Rp. 200 billion) for the purpose of reducing flood damage, large scale drainage work of 13 rivers are planned in 2010. However, for sustainable development of municipal solid waste management at the surface water areas, it is unavoidable to make effort to allocate enough budgets to DINAS PU by DKI Jakarta.

In general, the responsibility of DINAS PU is to bring the waste to TPS and the Cleansing Department has responsibility from TPS to TPA (Fig. 4.5.3). The removal work of floating waste is outsourced to a private firm. At present, garbage collecting service is implemented at 244 points including the Manggarai Watergate every day by hiring single private company.

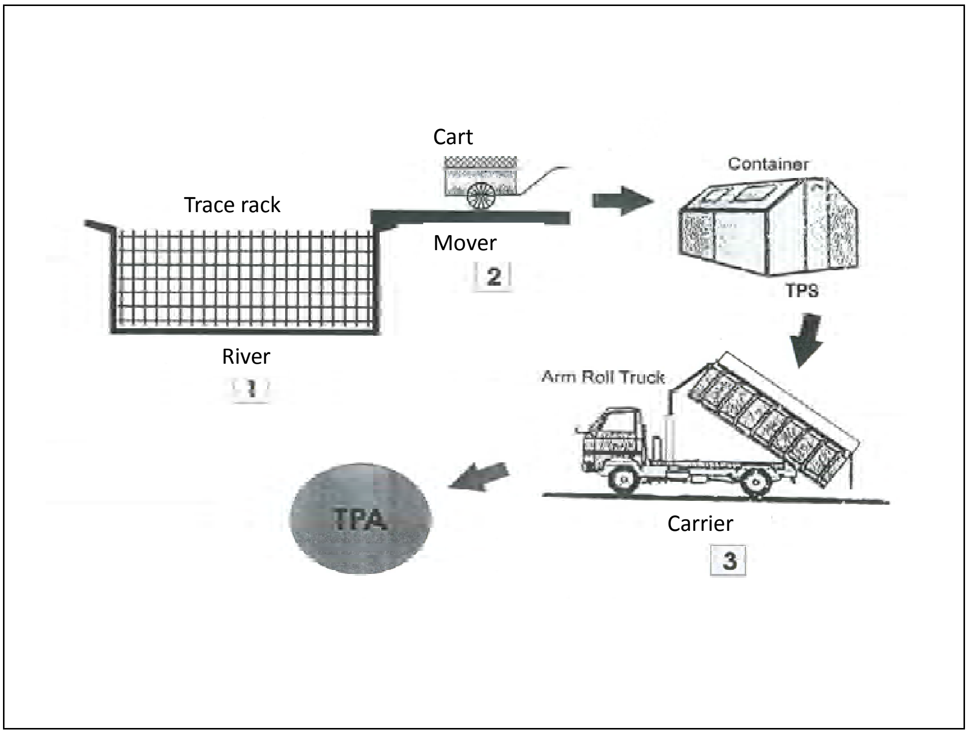


Fig. 4.5.3 River waste management mechanism

Since 2004, automatic screens for catching the flowing garbage have been installed at the rivers. As of May 2010, the automatic screens are installed at 21 places (Table 4.5.12).

Table 4.5.12 List of automatic garbage removal screens in DKI Jakarta, May 2010

	Location	Region	Year	Length (m)	Screen (Units)	Ownership	Remarks
1	Spilway Waduk Pluit	North Jakarta	2005	36	4	DPU	Trouble
2	Kali Sentiong	North Jakarta	2008	30	5	PU	Trouble
3	Kali Grogol T.Gong	North Jakarta	2004	24	3	DPU	Trouble
4	Kali Sunter Kresek	North Jakarta	2007	40	5	DPU	
5	Kali Lagoa Tirem	North Jakarta	2007	20	3	DPU	Electricity*
6	Waduk Sunter Selatan	North Jakarta	2007	30	3	DPU	
7	Kali Moukervart	West Jakarta	2007	31	5	DPU	Building**
8	Cengkareng Drain	West Jakarta	2007	55	6	DPU	
9	Kali Sekretaris	West Jakarta	2005	19	2	DPU	Trouble
10	PHB. Kyai Tapa Citraland	West Jakarta	2007	N/A	2	SDPU	
11	Kali Grogol Golkar	West Jakarta	2007	26	3	DPU	Trouble
12	Kali Grogol Palmerah	South Jakarta	2005	16	2	SDPU	
13	Kali Cideng	South Jakarta	2005	12	2	PU	Electricity*
14	Kali Cideng Inlet Waduk Setiabudi Timur	South Jakarta	2008	16	3	PU	
15	Kali Baru Barat TB. Simatupang	South Jakarta	2004	11	2	SDPU	
16	Kali Baru Timur (Cawang)	East Jakarta	2009	9	2	DPU	
17	Waduk Pulo Mas	East Jakarta	2007	12	2	DPU	
18	Kali Sunter Perintis Kemerdekaan	East Jakarta	2005	26	5	DPU	Trouble
19	Kali Baru Timur (PGS)	East Jakarta	2009	14	2	DPU	
20	Kali Cipinang Tol Jagorawi	East Jakarta	2009	30	5	DPU	
21	Kali Baru timur HEK PS. Induk	East Jakarta	2008	14	4	.PU	

(Note) DPU is DINAS PU. SDPU is Sub-unit of DINAS PU in Municipality. PU is Ministry of Public Works

*Trouble of electricity supply

**Necessity of operation building repair

Source: Field Maintenance SDA, DINAS PU, DKI Jakarta

There are 6 screening points in North Jakarta, 5 points in West Jakarta, 4 points in South Jakarta, 6 points in East Jakarta. Flowing garages on the Ciliwung River are collected at the Manggarai Watergate in Central Jakarta. The screens at 15 points are installed by DINAS PU and the remaining are by each Jakarta Municipality (3 points) and PU (3 points). However, some of screens are not operating due to trouble in devise and electricity supply. Repair and installation of new filters are seemed necessary.

The largest volume of the waste has been collected at the Manggarrai Watergate located in the Central Jakarta Municipality (Fig. 4.5.4). All the floating wastes from the upstream of the Ciliwung River is stopped and collected here. In the survey once conducted, a total of 152 different items of waste, such as plastic, cups, tables, mattresses, pillows, cabinets and more, were counted (Buletin Pengawasan N0.77, 2010.PU). The hired private company has been implementing waste collection works at 3 times in April 2010 during the Survey. During flood season from January to February, huge amount of waste had been collected at the Water Gate. According to the company, just after the flood in February 18, 2010, they sent 20 trucks operating 5 times per day for collecting the waste. As a truck can carry 24 to 30 m^3 garbage, this implies the total collected waste volume at the Water Gate reached 24,000 to 30,000 m^3/day. This was approximately 10% of the total daily waste generated in Jakarta.

Fig. 4.5.4 Mangarrai Watergate (30 April 2010)

4.5.6. Waste Handling at Jakarta Bay

The waste on the rivers is moving with the flowing water 24 hours around the clock. When there is no screen in the river, the waste flows into the Jakarta Bay. The estuaries are hence targeted as areas for the prevention of waste into the sea.

The solid waste contribution from 11 river estuaries was 452.73m^3/day in 2006 (Table 4.5.13). Volume of waste at three estuaries (i.e., Pluit, Cengkareng Drain (west side of North Jakarta) and Murunda (east side of North Jakarta)) was exceeding, and together they occupied 65.4% of the total waste. Amongst these, Cengkaereng Drain and Marunda was the largest producer of waste collected. In need, there are many areas that are needed to provide infrastructure and facilities for residential garbage service improvement.

Table 4.5.13 Solid waste contribution from 11 river estuaries

Estuary	kg/hour/m^2	ton/day	m^3/day	%	m^3/day*
Marunda	54	23.97	79.9	18.0	95.86
Cilincing	25	11.10	37	8.2	-
Kresek	29	12.87	42.9	9.5	44.40
Japat	11.5	5.10	17.0	3.8	20.42
Marina	5	2.22	7.4	1.6	-
Sunda Kelapa	10	4.44	14.8	3.3	-
Pluit	80	35.52	118.4	26.1	-
Muara Karang	10	4.44	14.8	3.3	17.76
Muara Angke	10.5	4.66	15.53	3.4	-
Cengkareng Drain	66	29.30	97.6	21.6	117.21
Kamal Muara	5	2.22	7.4	1.6	8.88
Total	306	135.84	452.73	100.0	-

(Note) Calculated as waste area of each estuary is 18.5m^2 (4.3m by 4.3m) and 1ton is 3.3 m^3.

*Figures from the other survey

Source: result of consultant analysis, 2006

According to DINAS PU, total volume of waste handling by DINAS PU was 1,395 m^3 /day. DINAS PU estimates that more than 400 m^3 /day of garbage in river is not collected on the basis of the following calculation in Table 4.5.14.

Table 4.5.14 Estimation of non- handled waste in river

Waste production per person: 2.5 litter /day= 0.0025 m^3 /day
Population in Jakarta: 12 million
Volume of waste: 12 million×0.0025 m^3 /day = 30,000 m^3 /day
Assumed ratio of waste dropped into the water body: 6%
Waste dropped in the water body: 30,000 m^3 /day×6%= 1,800 m^3 /day
Waste handled by DINAS PU & 5 Sub unit of DINAS PU: 1,395 m^3 /day
No handled waste in the water body: 1,800 m^3 / day－1,395 m^3 /day = 405m^3 /day

(Note) The generation rate of MSW is generally calculated as 2.5 to 3.0 litters/ capita/day based on national standard of MSW generation (SNI S 04-1993-03) established in 1993. The average of solid waste generation per capita in major cities in Indonesia is around 2.68 liter or equal to 0.8 kg per day (BPS2001).

Source: DINAS PU, DKI Jakarta

The amount of garbage collected at the Thousand Islands, located 45 km north from Jakarta Bay, ranged between 20,428 and 28,435 m^3/month in 2008 (according to a staff of Cleansing Department). There is no doubt that part of the waste comes from Jakarta Bay.

Fig. 4.5.5 shows the sea waste handling pattern at Jakarta Bay; among them prevention activities of settlement is one of the most important activities.

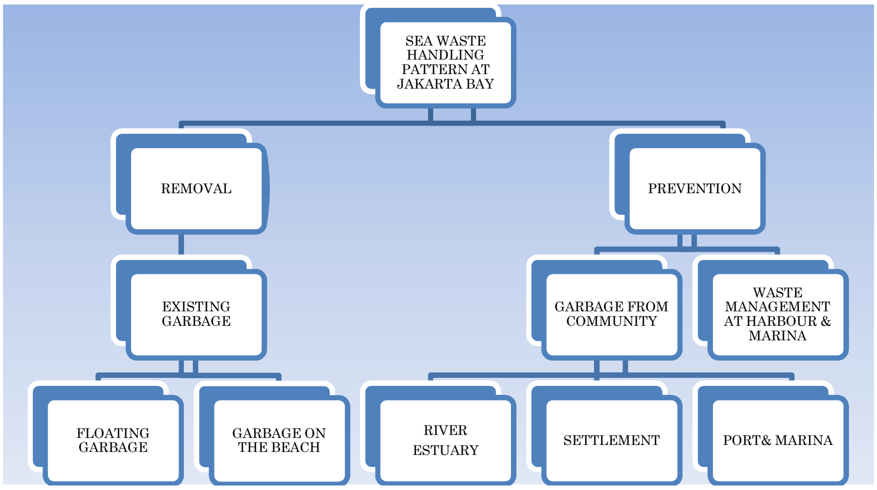


Fig. 4.5.5 Sea waste handling pattern at Jakarta Bay

4.5.7. Result of the JICA Interview Survey

JICA/MOE jointly published the guidance "Practices to Stop Solid Waste Dumping into River" in 2008 to offer useful tips to stop solid waste dumping into rivers.

According to the result of the interview with the residents who live at Bogor, Bandung, Palembang and Gorontalo Cities, it shows 30% of the residents who live along the river dump solid waste into the river and nobody who lives beyond 50 m from rivers do the same. The dumping action mostly conducted from their houses or windows which are directly by or above a river. It shows that the priority to stop the solid waste dumping should be put on the community who lives closer to a river.

The Guidance states that it is effective to provide garbage container properly and collect the garbage routinely at the river side area because the interview results shows 15% of population who live within 100 m from a garbage container dump solid waste into river, and on the other hand, 70% of the population who live between 100 m and 200 m from a garbage container dump solid waste into river. Especially it is important to consider the proper collecting system in the densely populated area which has tight alleyways and/or steep slopes. Local government may cooperate with the manufactures and firms to provide the garbage containers and carts to the community who live around them.

In Bandung and Bogor Cities, where settlement area have narrow spaces and steep slopes, some additional small garbage containers are provided to avoid people from dumping solid waste into the river. The community then collects those garbage containers and delivers the solid waste to TPS. Since several TPSs are located on river side, the guidance recommends making wall to prevent people's scattering and solid waste falling into the river. Composting is also recommended as other alternative solutions to reduce the solid waste in the steep slope and densely populated area which have the problem with the usual collecting system. Composting as 3R activity has also a merit to generate new income for the community.

Basically local governments have issued regulations with relevance to illegal waste dumping into the river basin area. However, only a small percentage of the residents are aware of the regulation; the interview results indicated that only 12% of the total respondents aware of the rule and sanction of dumping solid waste into rivers. Law enforcement must be conducted properly based on the stipulated regulations. The Guidance recommends fixing the warning board along the river side that may be effective to prevent the illegal dumping. In addition, local governments shall have a long term targets to apply the regulation of the minimum broader line between the right of way of a river and building/houses. It is necessary to relocate the illegal houses along the river.

4.5.8. Solid Waste from the Households Living along River Banks

The average amount of garbage collected from 13 rivers in Jakarta was 768 m^3/ day in 2008, about 3% of garbage collected by the Cleansing Department, DKI Jakarta (personal communication with Mr. Saiful Bahri, Technical Development Division). PU estimated that the garbage thrown into rivers was 200 ton/day (900 m^3/ day) as mentioned. On the other hand, DINAS PU estimated it as 1,800 m^3/ day based on national standard of MSW generation. Furthermore, the highest estimation from a researcher in MMAF was that 10% of garbage generated (2,800 m^3/ day) had been thrown into the rivers.

The river side area has become the solid waste dumping area for the people who live along it. Data from Environmental Statistics 2006/2007 (BPS, 2007) shows that many households are still living crammed along the river banks. In Indonesia, the household number living along river banks was 118,891 in 2005 of which around 23,000 are DKI Jakarta, the largest number in Indonesia. On the other hand, the ratio of the households disposing their garbage to the rivers in DKI Jakarta was only 1.2%, which was the lowest in several major provinces in Indonesia (the average in Indonesia is 7.7%). However, the ratio of 1.2% means more than 26,000 households, which is an extremely large number of the households in real term. It is considered that the 23,000 households living along the river banks are target group for implementing efficiently and effectively countermeasure against illegal waste dumping into rivers.

The people who live near or along river consider it as a solid dumping area that they can instantly move away the waste because they do not see the accumulation of the waste directly from their own houses. The dumped solid waste is carried by the river water and accumulated at the downstream area. When water overtops, most solid waste at the riverbank is washed into the river and only heavy debris such as metals, broken glass pieces remain on the river bed. Waste disposal drifted to the mouth of the rivers degrades the beach environment and affects the water recreational activities.

The Ciliwung River runs through two provinces, namely, West Java and DKI Jakarta, with a total length about 90 km. Its upstream is located in the Bogor-Punchak-Cianjur area, while the downstream ends in the Jakarta Bay (see Table 4.5.15). Regarding the land use of the Ciliwung River basin, the settlement area reaches to 26,594 ha (50.6%).

Table 4.5.15 Distribution of pollution load in the Ciliwung River in 2006

		BOD (kg/hr)	COD (kg/hr)	Height above the sea level (m)
Bogor Regency	Telga Wama-Katulampa	2,592	6,678	350-290
Bogor Municipality	Katulampa-Kedunghalang	2,970	7,920	290-190
Bogor Regency	Kedunghalang-Jembatan Panus	180	360	190-140
Depok Municipality	Jembatan Panus-Kelapa Dua	4,680	7,560	140-50
DKI Jakarta	Kelapa Dua-Manggarai	23,400	51,300	50-4
DKI Jakarta	Manggarai-Ancol	33,822	73,818	4-0

Source: MOE (State of the Environment Report in Indonesia 2008, p.22)

* Sea level was estimated from several sources

Fig. 4.5.6 shows a community along the Ciliwung River at Bogor Municipality. It seemed that the community here has good activity for solid waste management. The signboard on tree says “Trash is prohibited here” (top-right photo). The concrete container is set (bottom-right photo). A worker was collecting cardboard boxes from households by using a pushcart (bottom-left photo). Also a notice regarding cleaning activity from Bogor District Center was posted on a bulletin board.

Fig. 4.5.6 Examples of solid waste management in Bogor Municipality (25 April 2010)

Fig. 4.5.7 contains the scenes taken on two bridges at Depok Municipality. Many garbage thrown into the river were caught by the parallel members of the bridge (top-left and bottom-left photos). A flag near the bridge stated “Trash is prohibited here. It violates local regulation No.14/2001” (top-right photo). Still, a lot of garbage had been trashed on the river bed (bottom-right photo). These suggest that throwing garbage into the river may be common practice for some people.

Fig. 4.5.7 Garbage on bridge decks and river bank in Depok Municipality (25 April 2010)

Fig. 4.5.8 shows the polluted condition at Condet in East Jakarta Municipality. There was a signboard of the Ciliwung Condet Community (top-left photo), stating “Save our Ciliwung” (literally in English). There was also a flag with “the Ciliwung River Eco-Tourism”. The Survey team member joined a river trip by a kayak. The Ciliwung River was terribly polluted here by a lot of solid waste and liquated waste. A just-thrown plastic garbage bag was floating from upstream (bottom-right photo), which would eventually drift down to the Manggarai Watergate (seen in Fig. 4.5.4).

Fig. 4.5.8 River polluted by waste in Condet Sub-District, East Jakarta (6 May 2010)

4.5.9. Survey Result of Solid Waste Management for Surface Water Areas

The results of the Survey concerning solid waste management at the surface water areas in Jakarta revealed the following facts:

1) First, the available and reliable data concerning the solid waste at the surface water area in Jakarta is rather poor. As waste collecting service is implemented at 244 places including the Manggarai Watergate every day by a single private company, it may be possible to implement a detailed survey of the river-waste by getting a support from this private company. It is necessary to hire interpreter when Japanese researchers conduct the survey.
2) Secondly, the effect of river cleaning service by DINAS PU is not enough due to the budget shortfall. For the purpose of reducing flood damage, large scale drainage works of 13 rivers are to be started in August 2010 by PU using the World Bank’s soft loan (Rp. 200 billion). However, for sustainable development of municipal solid waste management at the surface

water areas, it is imperative to make effort to allocate enough budgets to DINAS PU by DKI Jakarta.

3) Thirdly, higher priority should be given to conduct community based environmental education. Especially, the most important fundamental solution is to provide environmental infrastructure as well as environmental education for economically-deprived squatter communities residing along rivers.

5. Water Environment Improvement Plan

5.1. Proposal of Low Cost Sewage Treatment System

5.1.1. Solid Waste Incinerator for Garbage Dumped into the River

The Survey team clarified the basin-wide waste disposal problems in the previous chapter. Since the illegally-disposed garbage into the rivers, especially the Ciliwung River that consists of miscellaneous debris from plastic to wood, the possibility of introducing incinerator was examined, together with power supply to the UASB-DHS sewage treatment system.

As part of Survey results, the Survey team found it is difficult to use methane gas recovered from UASB reactor as power generator due to the low methane gas density in the Setiabudi Pond (Fig. 5.1.1).

Fig. 5.1.1 Setiabudi waste treatment pond (May 2010)

The Survey team then only examined the possibility of introducing of incinerator to local community separating from the UASB-DHS system. However, the Survey team could not find the strengths to promote actively the introduction of small incinerators to local communities along the river even if the incinerator is inexpensive and safe.

At present, incinerators are only used in the hospitals in Jakarta as part of hazardous waste management. Once, three small incinerators (2-3 m^3/ hr) were introduced in Central Jakarta and in Southern Jakarta. However, they didn't work well. According to BPLHD, one of the main reasons for the failure was high operation cost. The price of kerosene as fuel of incinerator was doubles that of the gasoline in Indonesia. Therefore, it was not sustainable.

Since the price of the incinerator mainly depend on the capacity, it is difficult to find out the feasibility of the incinerator without a detailed cost-benefit analysis. Thus, this survey report only describes the mechanism of gasification incinerator in order to understand its advantage. Fig. 5.1.2 shows structure of a dry distillation (combustion retorting) type waste incinerator which have been used in Japan.

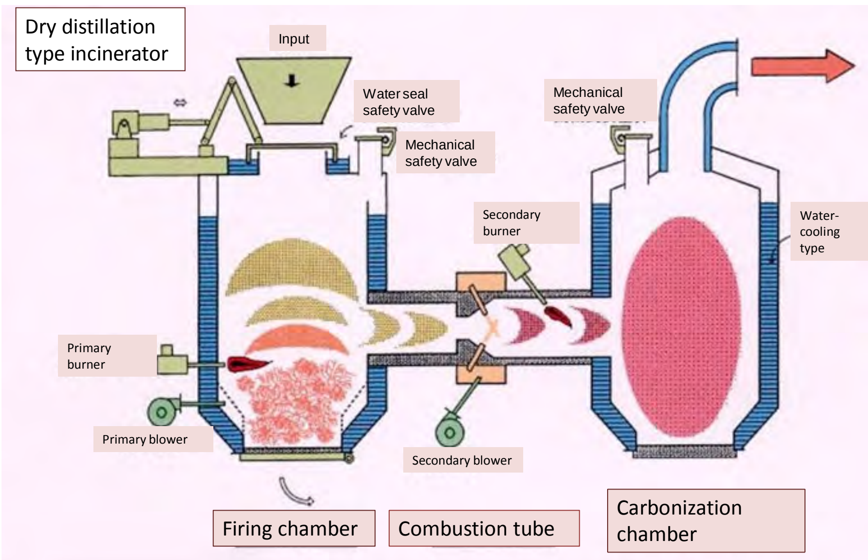


Fig. 5.1.2 Dry distillation type incinerator

The incinerator has a simple structure and can be readily manufactured in developing countries. The waste sent into the carbonization room is ignited with a burner, burned and dried by air injected through a blower and generates dry distillation gas composed by oxygen, hydrocarbons, hydrogen, carbon monoxide, and nitrogen. This dry distillation gas is fed into the combustion chamber through the combustion cylinder and burned at high temperature (1000) to reduce dioxin emissions. The heat generated in the combustion chamber can be used for electric power generation. Since the structure of the incinerator is very simple, it seems that local firm can manufacture it except the burner at the combustion tube and the blowers.

The advantages of gasification incinerator are clean, energy-saving and easy maintenance. Furthermore, the exhaust gas or oil can be recovered. Table 5.1.1 shows energy conversion efficiency of the waste.

Table 5.1.1 Energy conversion efficiency

	Digestion gas yield	Electricity conversion	Kerosene conversion
Raw garbage (1 ton)	100~150m^3	200~250kw	50~70 liters
Livestock excreta (1 ton)	25~40m^3	40~60kw	10~20 liters
Organic sludge (1 ton, 95% moisture)	20~30m^3	30~40kw	7~10 liters
Glycerin effluent (1 ton, 45% concentration)	300~350m^3	450~500kw	100~130 liters

Source: Mitsubishi Kakouki Kaisha Ltd.

Taking as reference, instead of burning waste, there is a method that can directly crushes and sorts the waste (Fig. 5.1.3).

Crushing machine: First, a wood crusher crushes driftwood to chips. Second, the rings and blades attached to rotors which rotate at high speed crush waste introduced during its fall, and then a windmill at the bottom pushes the waste into the sorter.

Sorting machine: Out of the crushed garbage which are sent into the sorter with the wind, finer-grained organic materials fall to the chute of the bottom through mesh, heavy material such as metals are recovered by scraper inside the trommel screen, and lightweight materials such as plastic film are carried away forward by wind power and collected selectively.

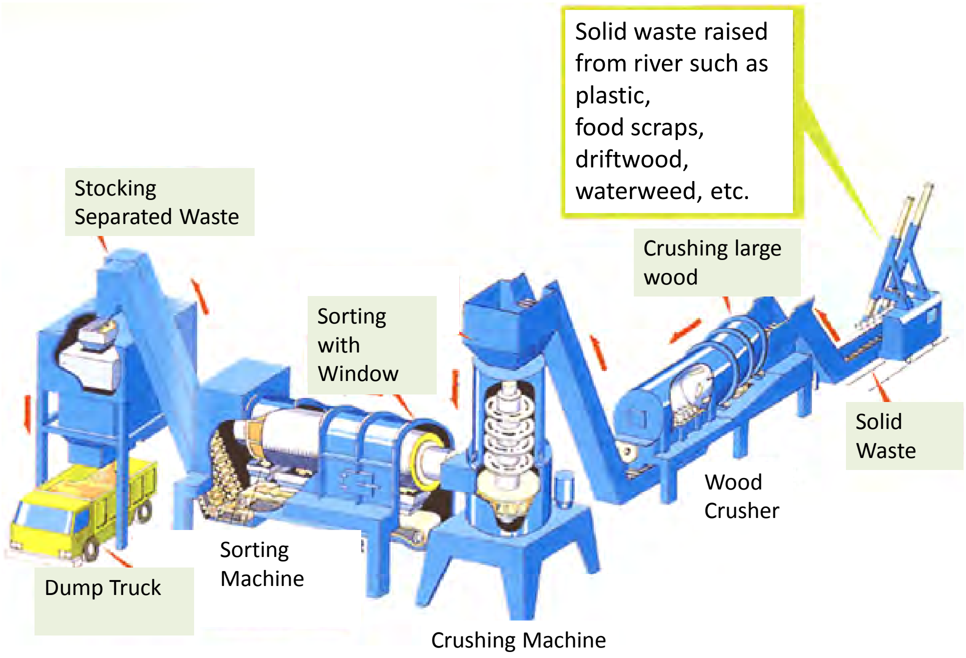


Fig. 5.1.3 Example of a crushing and sorting machine

5.1.2. Installing Adequate Designed Screens in Rivers

The automatic screens for catching the flowing garbage are installed at the rivers at 21 places in DKI Jakarta. However, some of screens are not operating because of trouble associated with the devise and electricity. There are various types of waste removal screen. The key is to design the adequate screen fitting the river features individually.

In addition, Table 5.1.2 and Fig. 5.1.4 shows characteristics of waste removal screen on four basic types.

Table 5.1.2 Type and characteristics of waste removal screen

	Form	Characteristics
A	Rack Type	Easy maintenance. The full screen can be utilized efficiently because the rakes reach near the water bottom.
B	Front Scratch Type	Large waste removal capacity. The stable operation is possible because of continuous scratching by the endless chain.
C	Back Scratch & Rake Inversion Type	Large waste removal capacity. The stable operation is possible because of continuous scratching by the endless chain.
D	Rotary Net Type	Waste removal capability can be selected freely depending on the shape of the basket and running speed. The open mesh can be selected depending on the type of the waste. It can handle larger waste by attaching a bar instead of a net.

Source: Sanwa Engineering Co.

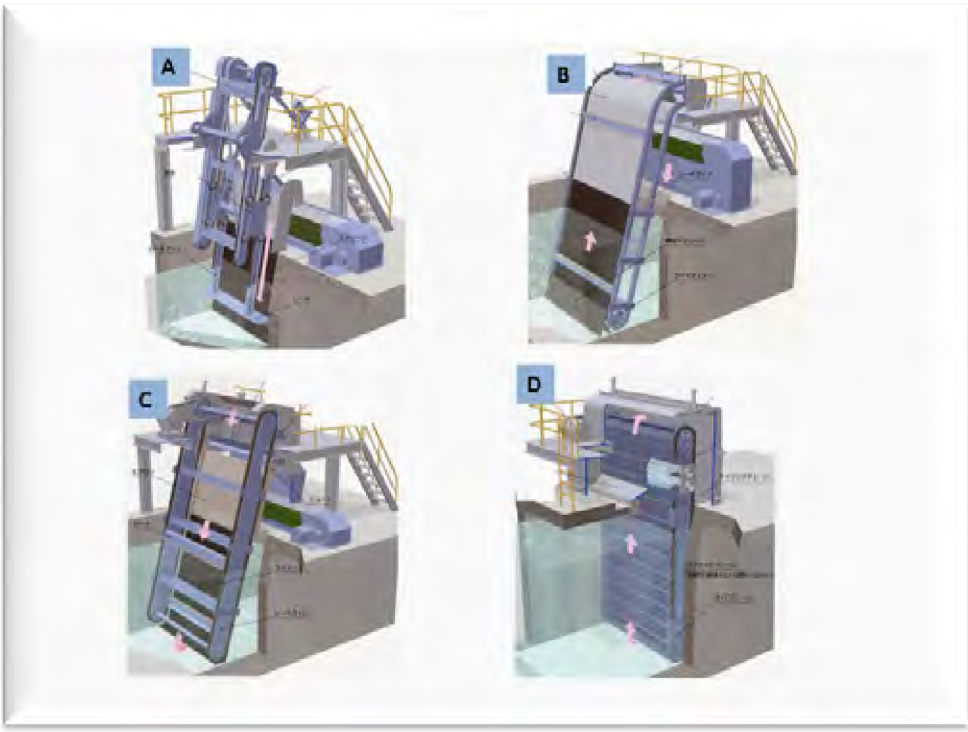


Fig. 5.1.4 Types of waste removal screen

Floats with screen between units and rope can be utilized for floating waste removal (Fig. 5.1.5). The orange floats and rope on the water in this figure is automatically released for flood control when rain water level reaches 1.6 m. However, the waste removal work is done manual.

Fig. 5.1.5 Floats used as floating waste removal for Hikiji River, Fujisawa in Japan

Since float and rope are low cost, it is recommended to use it in a positive manner. For example, float and rope can be used for preliminary separation before picking up garbage from river. By setting up a float and rope on the water and leading to the desired location, workers can capture only plastic. The preliminary separation is important to reduce cost for waste management.

5.2. Comprehensive Water Environmental Assessment System

The Survey team proposed the "Comprehensive Water Environment Assessment System" which consists of the low-cost and high precision water quality analysis method and the low-cost and high performance environment simulator using PC cluster.

Fig. 5.2.1 demonstrates the integrated system proposed, including inputs and outputs.

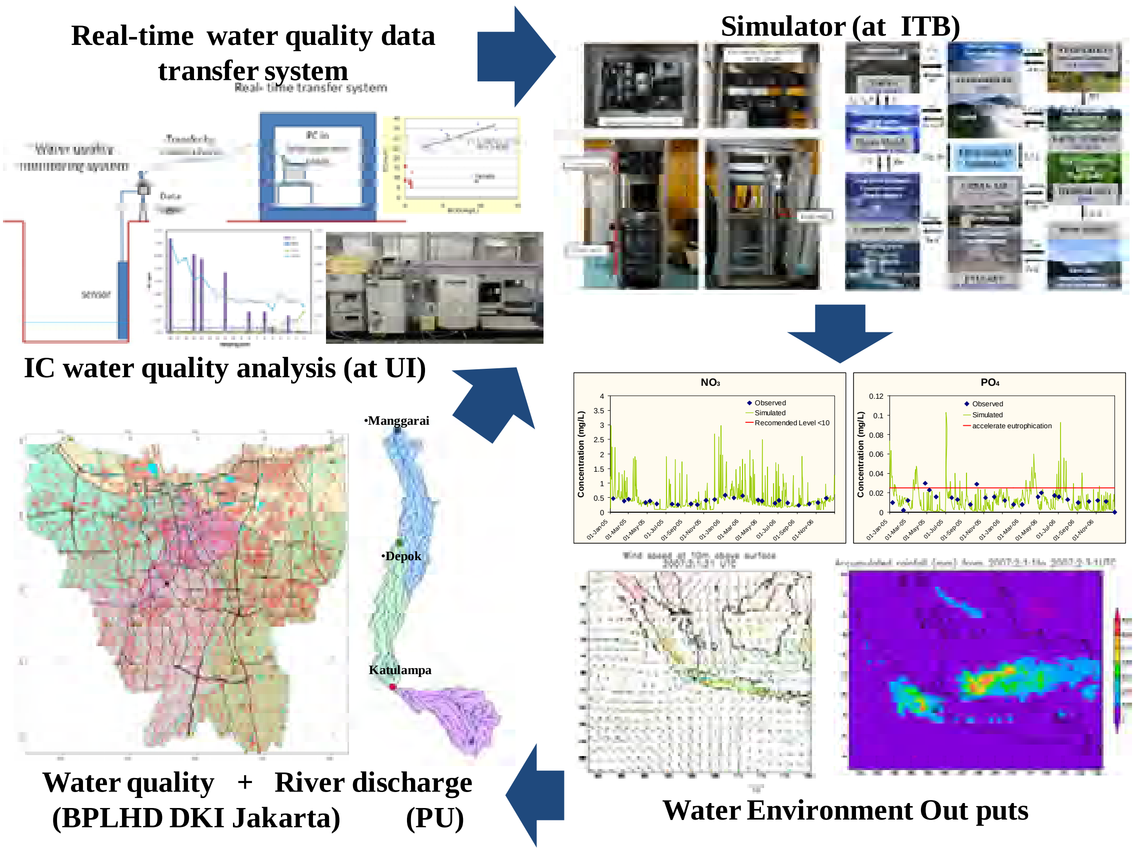


Fig. 5.2.1 Comprehensive Water Environment Assessment System

In the "Comprehensive Water Environment Assessment System", the existing water quality monitoring system conducted by BPLHD DKI Jakarta, the river discharge monitoring system is administrated by PU, the meteorological observation data in the Ciliwung watershed should be transferred to the proposed environment simulator operated at ITB.

The proposed “Real-time water quality data transfer system” shown in Chapter 4 will be linked to the environment simulator at ITB. Using these data and global weather forecasting data, reanalysis of global weather data or global climate prediction data, the environment simulator can simulate (i) the weather (temperature, winds, precipitation) in Jakarta area, (ii) waves, currents and water quality in the Jakarta Bay, (iii) hydrological conditions (river discharge and sediment transport, river water quality), in the four dimensional (time and space) fields. These simulation results will be opened to the public on the web for community in Jakarta. The government (DKI Jakarta, PU, MOE, MOF, MMAF etc.) should make the most of them for proper management of the water environment in JABODETABEK.

IC water quality analysis system operated at UI/PD PAL JAYA will be used to water quality analysis in the sewerage system as well as verification of “Real-time water quality data transfer system”.

From the survey of Comprehensive Water Environment Assessment System, the Survey team confirmed the followings:

1) Available operation of regional environment simulator by ITB researchers
2) Necessity of effective use of simulation results by community and government
3) Availability of IC water quality analysis by UI/PD PAL JAYA
4) Necessity of continuous monitoring under the existing water quality monitoring system. IC water quality analysis should verify the results of existing water quality monitoring system.
5) Working possibility of real-time water quality data transfer system
6) Necessity of continuous measurement of water quality monitoring through real-time water quality data transfer system to link to the environment simulator
7) Possibility of assessing river water quality as a flux (concentration multiply current). River discharge measurement and constituent concentration analysis data should be combined to obtain the fluxes of pollutant and nutrient.

The Survey team recommends the client to consider the introduction of Comprehensive Water Environment Assessment System for environmental preservation with community and government under the support of universities (UI and ITB).

The Survey team also recommends the client to consider the operation measures of the Comprehensive Water Environment Assessment System. For example, some fund to operate the system should be allocated for UI and ITB in the form of an official task from the central/local government.

5.3. Costal Revitalization and Its Environmental Impact Assessment

Estuaries and coastal area are some of the most productive ecosystems in the world. Many animal species rely on estuaries for food and as places to nest and breed. Human communities also rely on estuaries for food, recreation, and jobs. Because they are transitional areas between the land and the sea, and between freshwater and saltwater environments, estuaries can be seriously impacted by any number of human, or anthropogenic, activities. Garbage and pollutant from the rivers are piled up in the estuary and coastal area due to wave forces from the sea and river flow from the land. On a tropical coast, once mangrove forest area has a weak soil condition due to tropical wood peat backside of mangrove, the area becomes vulnerable to land subsidence when groundwater dropped. Coastal area is the most difficult place to maintain. The coastal area of DKI Jakarta is a typical case of difficult management with fragile nature. DKI Jakarta has been striving in vain to revitalize and reproduce its coastal area and estuary. However, many environmental and social problems to be solved have been remained in this area. One of the possible solutions is reclamation. Several perspectives have been proposed for revitalization of coastal region of Jakarta. Fig. 5.3.1 shows the revitalization activities in the coastal region of DKI Jakarta.

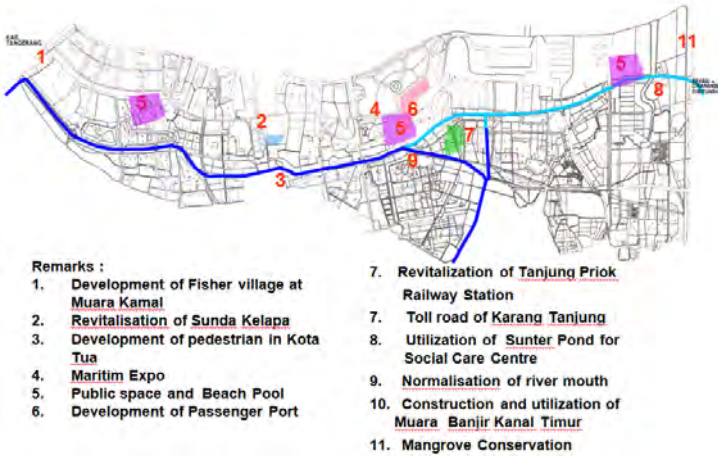


Fig. 5.3.1 Revitalization activities in coastal area of DKI Jakarta (from Appendix A)

This revitalization plan by reclamation is indispensable for a good management of coastal region where so many difficult problems have existed. It is also important to consider reclamation, water quality and flood control together. Regional environmental simulator can contribute to the environmental impact assessment of this plan.

The possible causes of water environment degradation including flood in Jakarta lowland area are described as follows:

1) Increase of the runoff coefficient due to over-logging in upstream forest and urbanization in the major river watershed. The outflow of agricultural chemicals from the cultivated land and orchard. The outflow of the contaminant from urbanized city region.
2) Reduction of the river channel area caused by abandonment of the household garbage to a river and the reclamation of river channel for getting more space to live in.
3) Corrosion oxidization of underground wood peat due to groundwater table subsidence by pumping water for industrial and drinking uses which may have caused a large-scale and rapid land subsidence in the west part of lowland area in Jakarta.
4) The reduction of river conveyance due to land reclamation (needs as a city waste disposal place) in the Jakarta Bay. On the other hand, this reclamation reduces the possibility of tide-induced flooding in the estuary. In addition to the sea level rise by global warming, the

sea level rise caused by fluctuation of moon path with 18.6 years period might enhance the flooding in Jakarta Bay in 2007.

Considering these causes, natural and anthropogenic, and the status quo of water environmental degradation in DKI Jakarta, the revitalization plan with reclamation has to be investigated thoroughly again and an environmental impact assessment should be conducted by regional environment simulator that will be executed by ITB.

5.4. Land Subsidence and Groundwater Control

5.4.1. Introduction

In order to propose the water environment improvement plan, it is also essential to consider the groundwater environment in a megacity such as Jakarta. In this section, the status and situation of groundwater environment and land subsidence were confirmed, based on the previous reports (Abidin et al., 2001; 2007; Delinom, 2008; Taniguchi, 2010; Fukuda, 2010; Onodera, 2010, etc.). In addition, some management methods were proposed.

5.4.2. Groundwater Environment Problems and Background

The population of Asia has increased rapidly over the last three decades. In 1995, there were more than five megacities with populations > 10 million in Asia (Jiang et al., 2001), and this number exceeded 25 in 2010. Tokyo and Osaka became megacities in the 1960s, Seoul, Shanghai, and Mumbai in the 1980s, Beijing and Karachi in the 1990s, and Jakarta and Manila in the early 2000s. The populations of several other Asian cities are also approaching 10 million, e.g., Dacca, Kolkata, Deli, Tianjin, and Bangkok. The highly intensive population pressures result in high consumption of resources such as water, energy, and food.

In Tokyo and Osaka, groundwater, rather than surface water, was used as a water resource during the period of rapid population increase before 1970 (Environment Agency Japan, 1969) as shown in Fig. 5.4.1. Surface water was not suitable for drinking because of contamination and insufficient volumes (Foster, 2001). After this period, however, groundwater use was restricted because of pollution and the decline in the groundwater level. Consequently, groundwater resources in Tokyo and Osaka have been degraded (Environment Agency Japan, 1996). To use groundwater in a sustainable manner in developing megacities such as Jakarta, Manila, and Bangkok, it is important to conserve groundwater quality and quantity based on the experience gained earlier in Tokyo and Osaka. However, the process of groundwater degradation, including depletion and contamination, has not been confirmed in these developing megacities. In addition, it is necessary to gain an understanding of the variation in groundwater flow and solute transport, as well as in contaminant inputs and their sources.

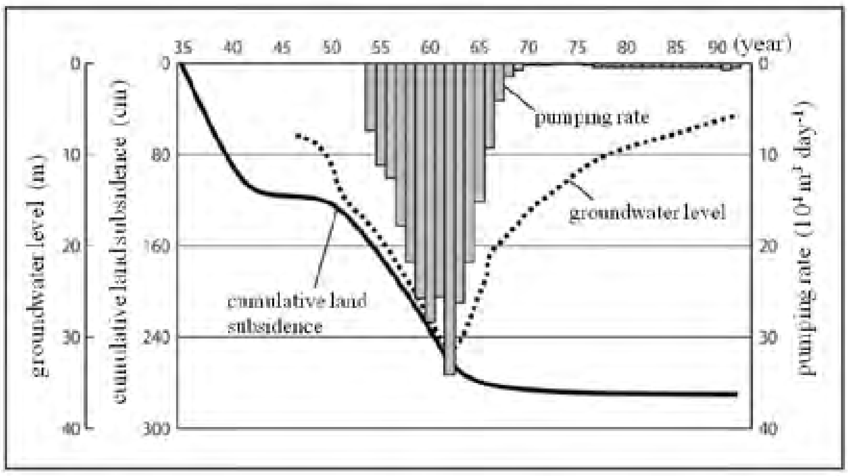


Fig. 5.4.1 Changes in groundwater level, pumping rate, and cumulative land subsidence in Osaka

Groundwater flow has been verified by both simulations and hydrogeological observations (Tóth, 1963). Fig. 5.4.2 shows the conceptual model of groundwater flow. Groundwater is naturally recharged from highlands and is discharged from lowlands (Freeze and Cherry, 1978; Domenico and Schwartz, 1990). Based on this concept of groundwater flow, mountains and uplands correspond to areas of groundwater recharge in a watershed, whereas coastal zones and lowlands are areas of discharge. However, intensive groundwater pumping in some areas has caused a serious decline in water levels and variations in flow. For example, the water level decreased by > 30 m from the 1950s to the 1970s in the High Plains aquifer in the USA (Schwartz, 2006), by > 30 m from the 1950s to the 1960s in the Tokyo and Osaka aquifers in Japan (Environmental Agency Japan, 1996), and by > 10 m during the 1980s in the Highland aquifer of Tanzania (Onodera et al., 1996). In general, the horizontal hydraulic gradient of groundwater is similar to or less than the topographic gradient. If the groundwater head declines by > 10 m in flat continental upland or coastal alluvial plains, both horizontal and vertical hydraulic gradients change markedly. In the case of Tokyo and Osaka, the direction of groundwater flow has been downward for more than 30 years, even though they are in coastal areas. In addition, the decline in groundwater potential has caused seawater intrusion through the saltwater–freshwater boundary in the subsurface, as well as land subsidence in most coastal Asian megacities (Environmental Agency Japan, 1996; Phien-wej et al., 2006; Abidin et al., 2007). Severe land subsidence produces a depressed area below sea level, where surface water converges during storm events.

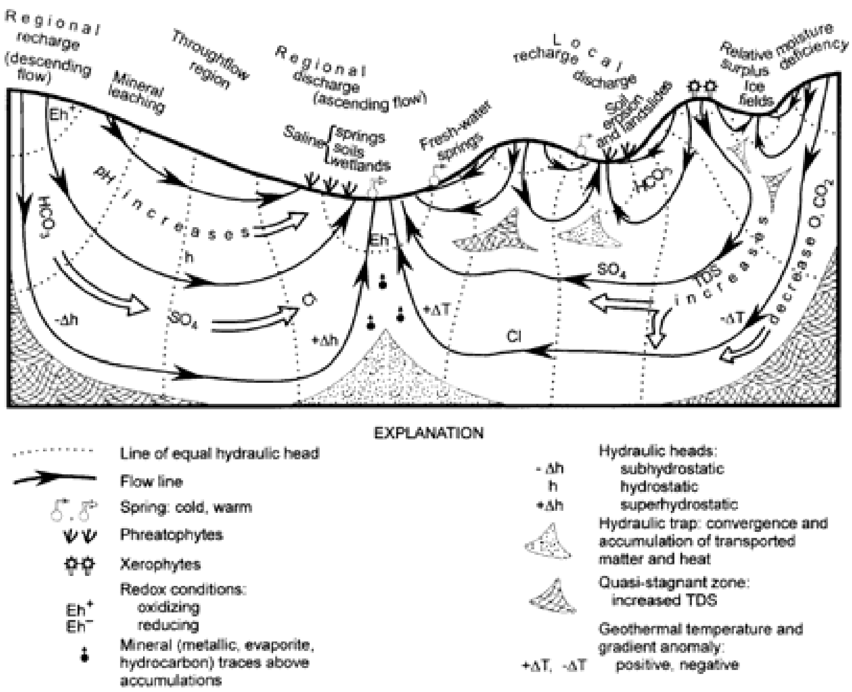


Fig. 5.4.2 Conceptual model of groundwater flow and quality of groundwater (Toth, 1999)

Kamra et al. (2002) have reported vertical contaminant transport in groundwater after a decline in water level caused by pumping extraction. It is necessary to confirm vertical contaminant transport in groundwater as the groundwater level declines in rapidly developing megacities such as Jakarta and Bangkok. The Survey team reports here the effects of urbanization on contaminant transport in the groundwater of these two Asian megacities.

5.4.3. Situation in Jakarta

In the geological setting of Jakarta, the base of the aquifer system is formed by impermeable Miocene sediments, which also outcrop at the southern boundary of the basin (Djaja et al., 2004). The basin fill consists of marine Pliocene and Quaternary sand and delta sediments up to 300 m thick. Quaternary deposits may be conveniently divided into three aquifer systems on the basis of hydraulic characteristics and depth: the Phreatic Aquifer System (0 to –40 m), the Upper Confined Aquifer System (–40 to –140 m), and the Lower Confined Aquifer System (deeper than –140 m). Around the Jakarta metropolitan area, the average horizontal hydraulic conductivity is approximately 1.0×10^{-3} cm/sec and the vertical value about 1.0×10^{-5} cm/sec, respectively.

Jakarta has a population of approximately 12 million. The groundwater abstraction has been so large for the last 20 years (Fig. 5.4.3). Consequently, groundwater potential declined extremely. Fig. 5.4.4 displays the vertical distribution in groundwater potential and groundwater flow in the upstream to downstream profile in 2006. The groundwater potential is lowest at the depth of 150 m in the coastal area. The groundwater flow direction is generally from the upstream to downstream and it shifts the upwards from a deeper layer to the shoreline in the discharging area into the sea and coastal area. But the downward flow was found from the surface to the deep layer in the coastal area.

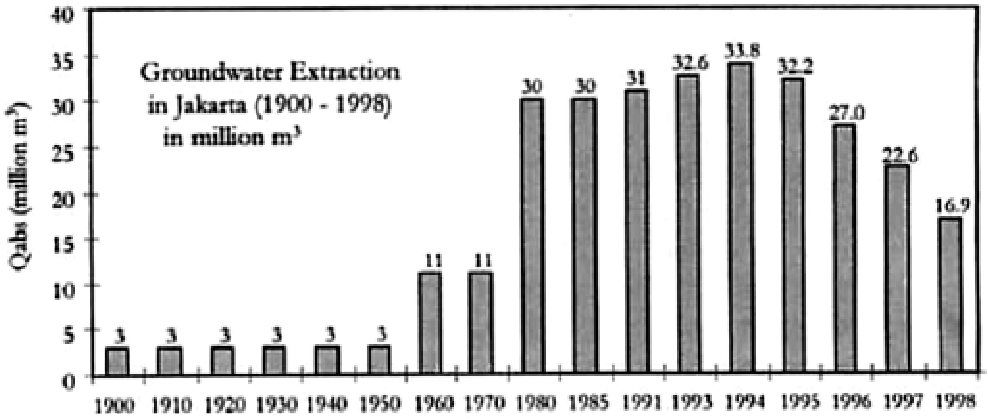


Fig. 5.4.3 Variation in groundwater extraction in Jakarta from 1900 to 1998

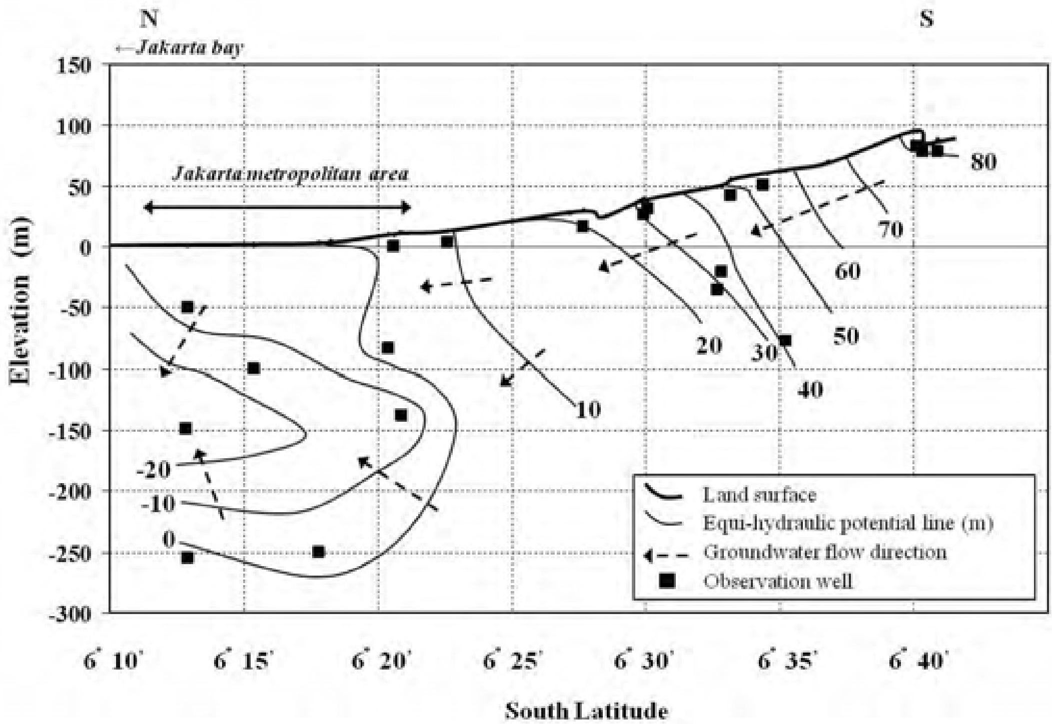


Fig. 5.4.4 Groundwater flow in Jakarta plain (Onodera et al., 2009)

* The groundwater potential is lowest at the depth of 150 m in the coastal area

In addition, the land subsidence has occurred since 1980s. Fig. 5.4.5 shows the land subsidence distribution at various sites with different altitudes in Jakarta in 1980s and 1990s. The lowland had serious problem and the range increased in 1990s. Fig. 5.4.6 indicates the land subsidence rates in 1980s and 1990s. The rates were 1-10 cm/year in 1982- 1991, but worsened in 1991-1997, with the maximum subsidence about 25 cm (Abidin et al., 2007). The land subsidence has been monitored using the stand pipe method (Fig. 5.4.7), topographic survey method, gravity method, satellite method, etc. (Abidin et al., 2007; Fukuda, 2009 etc.).

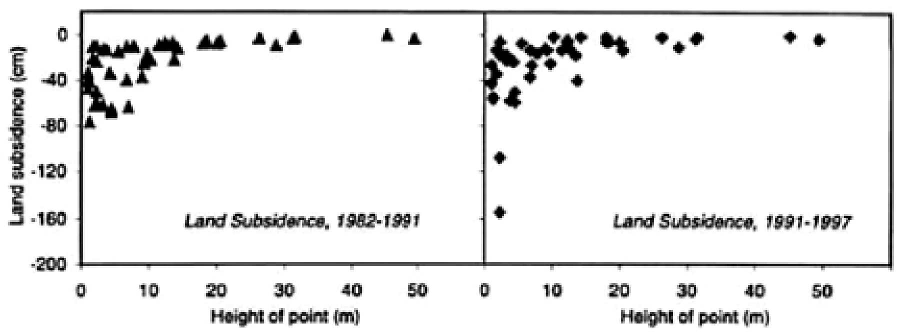


Fig. 5.4.5 Spatial variation in land subsidence in 1980s and 1990s (Abidin et al., 2007)

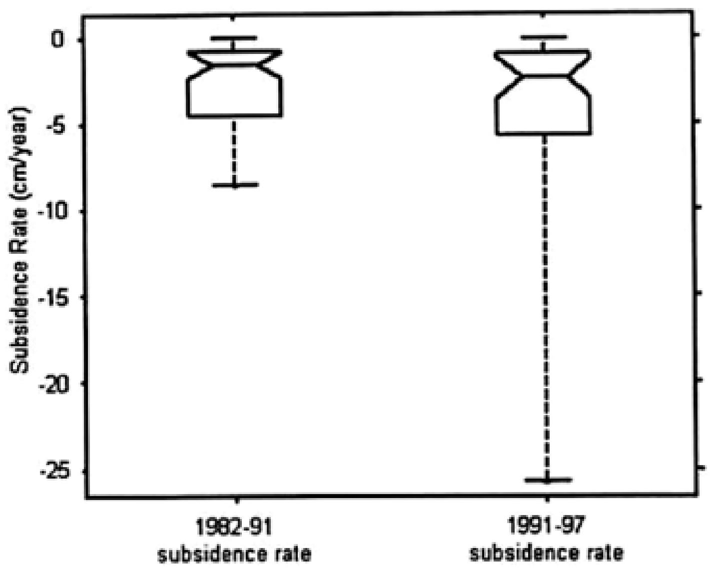


Fig. 5.4.6 Box plot showing land subsidence rate in 1980s and 1990s (Abidin et al., 2007)

Fig. 5.4.7 Land subsidence monitoring using stand pipe and dug well in Jakarta

Fig. 5.4.8 shows the spatial distribution of a 3-year average in land subsidence rate (cm/ year) in 2000s from 2002 to 2005, in which western Jakarta had the larger value. These coincide with distributions of groundwater abstraction rate and decline rate of groundwater potential.

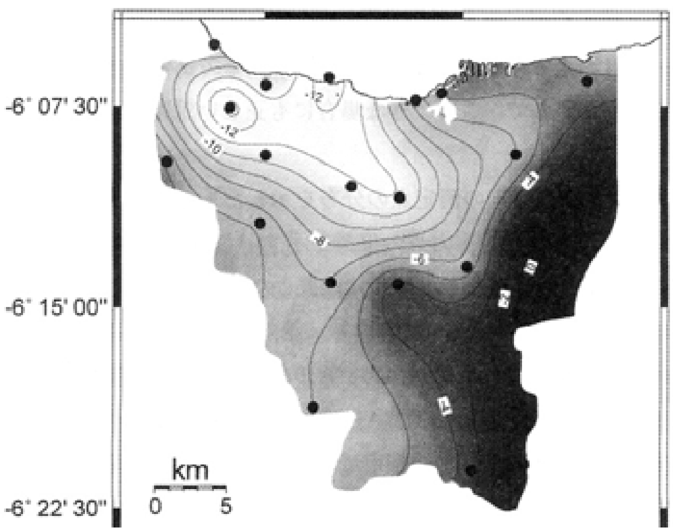


Fig. 5.4.8 Spatial distribution in land subsidence rate in 2000s

*3 year average (cm/year) of 2002-2005

5.4.4. Additional Problem

As mentioned above, the groundwater potential controls land subsidence. If a rapid decline occurs, land subsidence is expected to follow, and it would cause groundwater flow downward from surface layer (Fig. 5.4.4). This change would allow the intrusion of surface pollution to deep layer. Fig. 5.4.9 indicates Mn pollution in groundwater around Jakarta in 2006. The concentration at the deep layer in coastal area exceeded hundred times of the environmental standards.

Fig. 5.4.10 shows the salinity distribution in groundwater in 2006. The salinity line bent landward can be seen at the deep layer in coastal area. This phenomenon is called seawater intrusion. Likewise, the increase of salinity in the groundwater is also an indicator of the degradation of water environments. The degradation is serious in a coastal area of Jakarta, for example, the seawater intrusion may have reached 9 ~ 10 kilometers landwards from the Bay, to downtown Jakarta approximately (at the 6.20 mark on the abscissa).

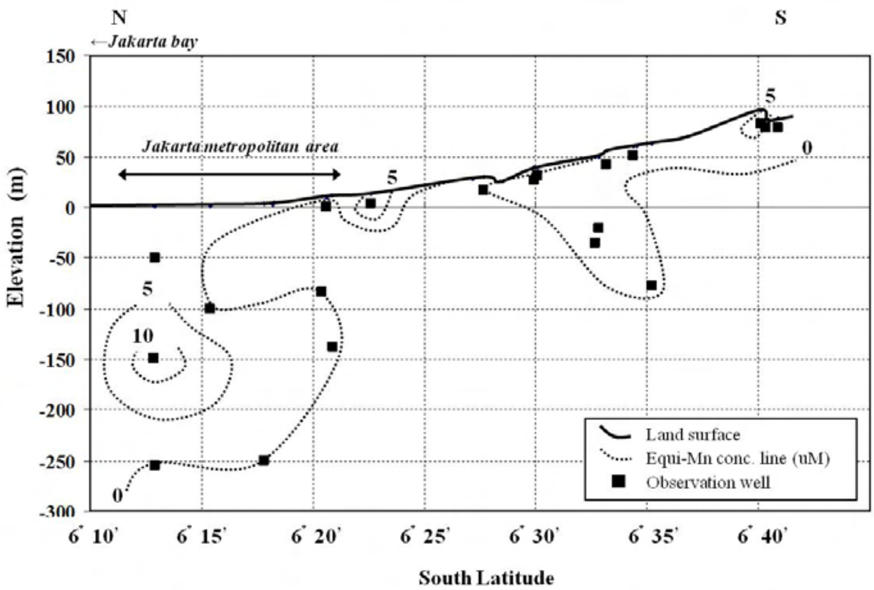


Fig. 5.4.9 Mn pollution in groundwater around Jakarta in 2006

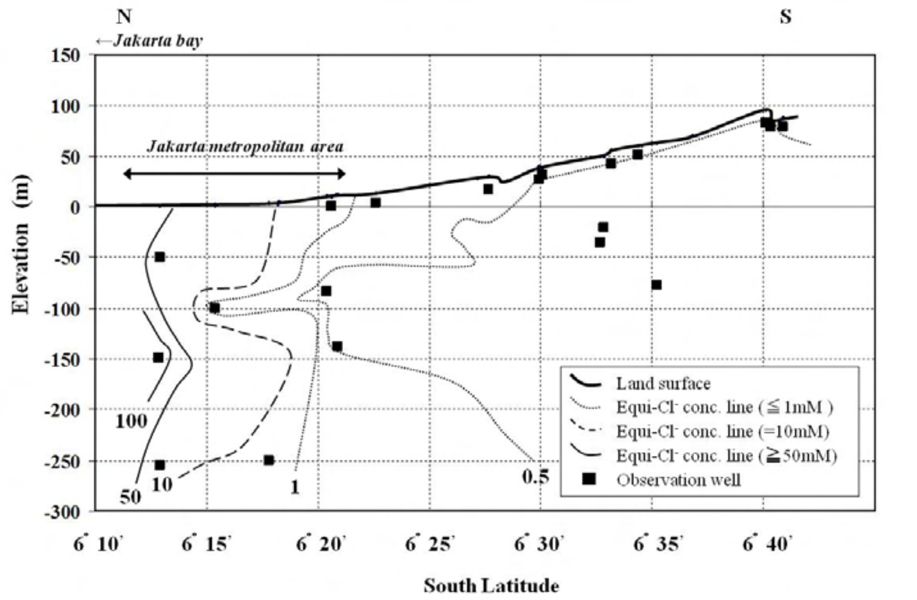


Fig. 5.4.10 Spatial distribution of salinity in groundwater in 2006

5.4.5. Management Options for Groundwater Environment in Future

The degradation of groundwater environment is very serious in Jakarta region. To improve these situations, the Survey team would like to propose some management options as follows:

1) Groundwater recharge conservation such as land use control; particularly the conservation of rainfall infiltration area for maintaining groundwater recharge amount, and the control of pollutant load for water quality control
2) Regulation of groundwater extraction. It is necessary to secure alternative water source, produce legislation and taxing water users etc.
3) Application of artificial groundwater recharge. It is effective to use flood control reservoirs in mid streams and groundwater recharge area.

5.5. Water Environment Improvement System by Administrative Authorities, Industries and Citizens

5.5.1. Wastewater Management Activity by DKI Jakarta

The wastewater management areas in DKI Jakarta are classified as off-site treatment (sewerage) area, high level on-site treatment areas and simple on-site treatment areas by Sub-District (KEC). According to a JICA report (2010) on National Policy of Indonesia, centralized treatment plant is adopted in area where population density is more than 300 capita/ha, modular plant, like anaerobic buffer reactor is adopted in area of 100-300 capita/ha of population density and individual treatment process like septic tank is adopted in area of less than 100 capita/ha.

However, this is not realistic because the population density of DKI Jakarta was the densest in Indonesia reaching 138 capita/ha in 2009 and that at Central Jakarta Municipality was highest in Jakarta region to 186 capita/ha. There may be even some KEC where this value could be more than 300 capita/ha in DKI Jakarta. The Survey team, however, couldn't obtain the data and information. The "ALGOLITHM OF SANITATION TECHNOLOGY CHOICES" by PU shows that sewerage system can be introduced anywhere regardless population density criteria, if the following three conditions are matched. These are not-high permeability, more than 2% land slope and financial viability. According to a staff in charge of sanitation in PU, the policy made on the basis of population density criteria is not strictly applied due to financial restriction.

Concerning waste management activity, the Cleansing Department and the Sub-Unit of 5 Municipalities in DKI Jakarta have conducted on-site treatment service traditionally. There are 3 models for urban community based sanitation for on-site treatment. These are communal septic tanks (CST), communal shallow sewers for 100 families and communal bath-wash-toilet (small bored sewer). Table 5.5.1 shows the treatment service revenue of the Cleansing Department and the 5 Sub-Units in 2009.

Table 5.5.1 On-site treatment service revenue in DKI Jakarta in 2009

	Target (Rp.)	Achievement (Rp.)	%
Cleansing Department	4,490,708,000	4,370,718,550	105.3
Sub-Unit of Central Jakarta	889,230,000	560,405,000	63.0
Sub-Unit of North Jakarta	834,190,000	464,830,000	55.7
Sub-Unit of West Jakarta	824,400,000	444,067,500	53.9
Sub-Unit of South Jakarta	920,978,500	478,950,000	52.0
Sub-Unit of East Jakarta	977,798,500	772,743,000	58.0
Total	8,937,305,000	7,246,091,050	81.1

Source: Cleansing Department, DKI Jakarta

On the other hand, the Wastewater Management Enterprise (PD PAL JAYA) was formed in order to develop sewerage system in DKI Jakarta in accordance with the Local Government Regulation No.10/1991 dated on September 26, 1991. PD PAL JAYA, an autonomous enterprise under DKI Jakarta, has 104 staff as of this survey in March 2010. In 2008 its total income was Rp. 27,656 million against the cost of Rp. 17,700 million. The net profit excluding tax was Rp. 7,089 million in 2008, doubling from Rp. 3,524 million in 2005. In addition to the tax, PD PAL JAYA distributes 14% of the profit to DKI.

Wastewater management services conducted by PD PAL JAYA are mainly sewage system (off-site treatment) but there is some local system (on-site treatment) service too. At present PD Pal Jaya is providing 7 STP Mobiles in commercial and/or multistory buildings. The capacity of the STP Mobile is 200m^3/day.

Table 5.5.2 shows the coverage area of the sewage pipeline. PD PAL JAYA has provided wastewater pipeline service, using off-site system called Casablanca system. The total length of the pipeline reaches 76 km at the South-Central Zone in DKI Jakarta at the time of the survey in March 2010.

Table5.5.2 Coverage area of sewage pipeline in DKI Jakarta

Coverage Area goes to East Setiabudi Pond	Coverage Area goes to West Setiabudi Pond
Kelurahan Guntur	Kelurahan Setiabudi
Kelurahan Manggarai	Kelurahan Karet
Kelurahan Manggarai Selatan	Kelurahan Karet Kuningan
Kelurahan Bukit Duri	Kelurahan Tanah Abang
Kelurahan Menteng Atas	Kelurahan Senayan (SCBD)
Kelurahan Pasar Manggis	

Source: PD PAL JAYA

PD PAL JAYA plans to extend additional 2 km length between Jl. HR. Rasuna and Said-Kuningan with Rp.19 million investments in 2010. The recent increase of the income depends on the increase of the customers by the extension of the pipeline. The total number of the customers of PD PAL JAYA was 1,366 in 2009 shown in Table 5.5.3, in which "Non Household" stands for large commercial complex.

Table 5.5.3 Customer categories receiving seweage management service in 2009

Customer categories	Amount (unit)	Total floor Area (m^2)
Household	1,179	130,216
Non Household	187	4.495,996
TOTAL	1,.366	4.626,212

Source: PD PAL JAYA

The Setiabudi Pond including sewerage system was developed as aerated lagoon by the Sewerage and Sanitation Project (1992-1996) funded by IBRD Loan. The design capacity is 38.9 m^3/ day and the current capacity utilized is 19.0 m^3/ day. However, it seems that the present Pond doesn't function well as sewerage treatment system. Although the seven units of the aerator which have capacity to supply 48 kg/ hr oxygen are installed in the Pond, some of them are out of order.

PD PAL JAYA has a vision that they have ability to treat wastewater as reuse water with 28% service coverage of the population in DKI Jakarta by the end of 2015. They implemented "the

Study on Urban Drainage and Wastewater Disposal Project in the City of Jakarta" to introduce wastewater treatment plants and sludge treatment plants in the 10 Service Areas devised.

5.5.2. Water Pollution Management Programs by Ministry of Environment

The Ministry of Environment (MOE) has been implementing several water pollution management programs as stated in its Strategic Planning for the year 2005-2009. Some of the programs are the Clean River Program (PROKASIH) and the Pollution Control Evaluation and Rating Program (PROPER) which urges the industry to obey so they do not discard their waste into the river, and the Clean and Green Cities Program (ADIPURA) for processing solid domestic waste. The main purpose of the programs aims to decrease or, if possible, outright stop the pollution in the rivers of Indonesia.

The PROKASIH Program was inaugurated to reduce water pollution loads in critical watersheds in 1989 and it has been carried out in cooperation with provincial and city governments. The program has targeted the worst industrial polluters in the 24 highly polluted rivers. It is that the specific firms in highly polluting industries sign voluntary letters to reduce pollution loads by 50% within an agreed timeframe. Between 2003 and 2008, 341 companies engaged and signed in the contract to participate in PROKASIH. The results of a monitored program in FY 2006 showed that 65% of the signed companies had a good performance.

The PROPER Program started from FY 2002 with the main goal to maximize the PROKASIH. Its basic principle is to encourage companies to adopt the ecosystem through a reputation based on incentive; implying good performance on ecosystem management would lead good reputation. The performance level is categorized into 5 levels of color, from the lowest: black to red, blue, green and finally gold. A specific color designates the performance of a company on ecosystem management.

In FY 2006, the total number of companies participating in PROPER was 520,which comprised 254 manufacturing industries, 15 service industries, 101 agro-industries, and 149 mining, gas, oil and energy industries. The participation from mining, gas, oil and energy industry has increased remarkably during 2002 to 2005 (Fig. 5.5.1), especially the oil and energy industry. As of the end of the fiscal year 2006, 199 companies have been categorized as having fulfilled the requirements; 86% from the manufacturing industry, 6.5% from the service industry, and lastly 7.5 % from the agro industry. No gas, oil and energy industry achieved the requirement.

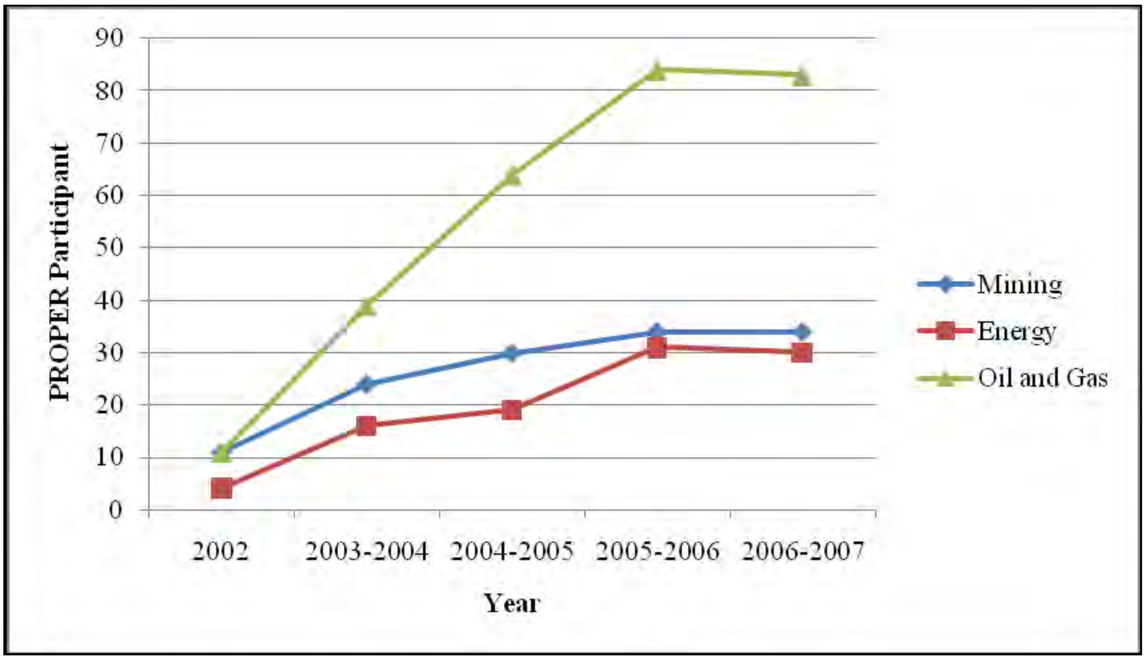


Fig. 5.5.1 PROPER's participants in 2002-2007 from mining, energy and oil-gas

The implementation of PROKASIH and PROPER has been carried out by provincial authorities with the support of MOE. In addition, the media were encouraged to report on environmental damage caused by pollution and on significant clean-up efforts, and NGOs helped to facilitate the participation of community groups in related environmental activities.

Since participation in PROKASIH and PROPER is voluntary in nature, the total number of companies which follows the program remained low compared to the total number of companies. Actually the numbers of companies who adhere to the laws are rather low; perhaps the reputation based incentive has limitations. Additional schemes may be required to strengthen the economic incentive such as strict punishment and tax reduction.

The purpose of the ADIPURA program is to encourage local governments to manage their solid waste. The cities in Indonesia that have successfully managed their own solid wastes are given an award called ADIPURA. This has had a positive impact all over the country as it brought about a positive sense of competitiveness among cities. Since the fiscal year 2005, all cities in Indonesia are obligated to participate in the ADIPURA Program. As a result, the ADIPURA Program participant numbered 360 cities. According to the evaluation results and ranking in the category of metropolitan cities in 2007, DKI Jakarta was the top scorers with Central Jakarta 72.44; West Jakarta 71.98; South Jakarta 71.95; North Jakarta 71.93 and East Jakarta 71.37, averaging 71.91.

5.5.3. Community-Based Waste Management Activities

The primary waste collection system is facilitated by community. The community initiative and retribution are widely implemented by the local governments in improving the public participation in waste management. There are a range of community initiatives, such as women-owned collection cooperatives, Community (RW) based youth groups for collection, contract to micro-enterprises, and hiring garbage men with pushcarts to collect garbage for door to door service. The community has to pay small amount of cost for community savings to pay operational activities such as the salary of garbage collectors and street sweepers, purchasing garbage bins and containers and carts. The amount of community fee charged depends on the living conditions of the residential area and is decided based on consensus of the community members.

The waste management activities are controlled and monitored through the local government to enhance the awareness of community. The active participation and monitoring by local government and the participation of the communities is a key to the success of the waste management. For sustainable waste management, the participation of the community is essential. The activities of waste management have already been undertaking by many communities. Some residential areas succeeded to process waste in DKI Jakarta are shown in Table 5.5.4.

Table 5.5.4 Statistics showing residential areas succeeded to process waste in Jakarta

Region	Areas
Central Jakarta	Rawasari - Cempaka Putih RW.01/08 Pengelolaan kompos cair di Cempaka Baru RT.014/RW08 Kec. Kemayoran oleh H.A. Oisca Benhil - Tanah Abang RT.011/RW.06 Gondangdia Cikini Gunung Sahari Selatan Kel. Serdang RT.013/RW.04 – Kemayoran
North Jakarta	RW.011 Kel. Warakas RW.05 Kel. Kelapa Gading Barat RW.08 Kel. Ancol
West Jakarta	RW.05 Kel. Cengkareng Barat Komplek Kodam Kalideres Komplek Merpati Kel. Kalideres Komplek kantor Walikotamadya
South Jakarta	Pengelolaan sampah terpadu di Kampung Rawa Jati RW.03 Kel. Rawa Jati – Kec. Kalibata (Ibu Sri Bebasari & tim BPPT) Banjar Sari Kel.Cilandak Barat – Kec. Cilandak RW.04 Kel. Menteng Dalam RW.03 Kel. Mampang SMA Negeri 34 Lebak Bulus
East Jakarta	Kp. Bulak RW.15 Kel. Klender – Duren Sawit RW.08 Kel. Ciracas – Kec. Ciracas RW.04 Kel. Cijantung RW.010 Kel. Kramat Jati Pengelolaan kompos ”mutu elok di daerah Cipinang Elok

Source: DKI Jakarta