MONITORING AND STUDIES ON WATER QUALITY IN SOME RIVERS AND RELATED WATER BODIES IN INDONESIA

By : H. Achmadi Partowijoto
Ir. CAE, PU-SDA, MAsr.

I. INTRODUCTION

In total there are over 5000 rivers flowing throughout Indonesia with a potential available water resource of around 2 billion m^3, 111,790 m^3 is used for irrigation, industry, domestic, fishery and life stock. In Sumatra flows 735 main rivers, in Java and Madura 615, in Bali and Nusa Tenggara 1.505, Kalimantan 514, Sulawesi 1.251, in Maluku 306 and in Papua 274 rivers.

Most of the rivers and its basin had been degraded and many are critically deteriorated caused by miss management of land and water resources, such deforestation, inapproper land use and poor agricultural practices. The condition of river basins are also influenced by the percentage of forested area, run-off coefficient and population density. According to RePPProt (2001) forested area in Java is continuously decreasing and at present is estimated only 10 % of the total area, while according to Central Bureau of Statistics around 20 % of the total land area.

River basins are grouped in to 90 (ninety) units, 15 managed by the central government, 73 by regional governments and 2 by state owned companies There are 30 units in Sumatra, 15 in Java, 7 in Bali, and Nusa Tenggara , 14 in Kalimantan , 17 in Sulawesi, 3 in Maluku and 4 units in Papua. Two river basin units managed by state owned companies are Jasa Tirta I dan Jasa Tirta II, and there will be 6 (six) other river basin units namely Jratun Seluna, Serayu, Bengawan Sala and Ciliwung-Cisadane in Java, W.Sekampung- W Seputih in Sumatra and Jeneberang in Sulawesi.

In 1984 there were 22 critically degraded river basins, increased to 39 in 1994, 42 in 1998, and 58 in 2000. Potential and condition of rivers can be classified based on its dependable discharge, and its maximum and minimum discharge, which in turn depends on the condition of its catchment area which include the acreage, length of the river, land slope, geological condition, yearly rainfall and drainage pattern.

Potential of rivers as source of water depends on its physical, chemical and biological water quality. Water quality in rivers and its related water bodies such play important role in management of water resources for irrigation, industry, municipal and domestic supply. Deterioration of water quality in rivers and lakes had been reported in many parts of the country, especially in densely populated and industrial area.

Pollution of water in rivers, lakes, reservoirs and canal may caused by disposal of both solid and liquid waste, either point source and non-point source, from improper practice of domestic, industrial and agricultural activities. Monitoring and case studies on water quality had been conducted for decades by many institutions such as universities, research centers and industries, as well as non-government organizations.

Based on Government Regulation No. 22, 1982, rivers throughout Indonesia was grouped into 90 (ninety) river basin units which are managed by central government (15 units), provincial government (63 units) and private companies (2 units). At present the total number of river basins is (tentatively) 136, which might increase in number depending on the proposal of local governments.

This paper contains compilation of brief information of monitoring and case studies on water quality in rivers, lakes, reservoirs and canals in some area conducted by different institutions. The information is expected to contribute the general knowledge of water quality in some rivers, lakes, reservoirs and canal in the regions. This paper is written only as informative media and therefore, readers who need detail data and further information may refer to references listed in the Annex at the end of this paper.

II. MONITORING ON THE QUAILITY OF RIVER WATER

2.1. Monitoring on river water quality in thirty provinces

2.1.1. Implementation of monitoring

Monitoring and observation of water quality in rivers throughout 30 (thirty) provinces had been conducted in the year 2004 with sampling frequency twice a year. The thirty provinces are Aceh, North Sumatra, Riau, West Sumatra, South Sumatra, Bengkulu, Jambi, Bangka, Belitung, Lampung, Banten, DKI Jakarta, West Java, DI Yogyakarta, Central Java, East Java, Bali, West Kalimantan, South Kalimantan, Central Kalimantan, East Kalimantan, West Nusa tenggara, East Nusa Tenggara, North Sulawesi, Gorontalo, Central Sulawesi, Southeast Sulawesi, Maluku, North Maluku, and Papua,

The monitoring and observation which include parameters of Dissolved Oxygen (DO), Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD), Fecal Coli (FC) and Total Coli (TC), showed that over 50 % or majority of river water fail to meet water quality standard of Class I according to Government Regulation No.82, 2001. Other parameters monitored are TSS, NO_2. NO_3, NH_3, PO_4,

The standard requirement of Class I defined in the Government Regulation No. 82, 2001 is water which can be utilized as raw water for drinking water, and other kind of uses which requires standard water quality equal to the fore mentioned water utilization. The standard requirement of Class II defined in the Government Regulation No. 82, 2001 is water which can be utilized for recreation, fishery, animal husbandry and irrigation, and other types of water uses which requires quality standard equal to the fore mentioned water utilization.

The result of the monitoring for parameter BOD, showed that only 26 % from the total samples meet water quality standard of Class I and 33 % meet water quality standard of Class II. For parameter of COD, only 29 % meet water quality standard of Class I.

2.1.2. Result of the monitoring

(a) Acidity (pH)

According to Government Regulation No. 82, 2001, the criteria of Class I and II for water acidity is pH value of 6 to 9. The result of the monitoring showed that around 90% of the monitored river meet the water quality standard of Class I and II, with a range of pH value from 6 to 9. However, low pH value were detected at the river Batanghari in Jambi, river Musi in South Sumatra, river Kapuas in West Kalimantan, river Martapura in South Kalimantan, river Ciliwung and nriver Citarum in West Java, with an extreme low pH value of 4,9 for water in the river Kampar in Riau Province.

(b) Biological Oxygen Demand (BOD)

According to the Government Regulation No. 82, 2001, the standard criteria of Class I for BOD is 2 mg/l and for Class II is 3 mg/l It was found that majority of rivers monitored in 30 (thirty) provinces showed BOD exceeding water quality standard of Class I and II. The highest BOD concentration had been detected at river Citarum in West Java (162 mg/l) and river Tallo in South Sulawesi (160 mg/l). The river water meet standard quality of Class I at all locations is river Dendeng in East Nusa Tenggara.

(c) Chemical Oxygen Demand (COD)

According to Government Regulation No. 82, 2001, the standard criteria of Class I for COD is 10 mg/l and for Class II is 25 mg/l. For the parameter of COD, majority of rivers shows concentration higher than 100 mg/l, far exceeding the standard criteria. Those rivers are rivers Deli in North Sumatra, Citarum in West Java, Kahayan in Central Kalimantan, Talo in South Sulawesi, Palu in Central Sulawesi, Batu Gajah and Batu Merah in Maluku, and Anafre in Papua.

(c) Dissolved Oxygen (DO)

According to Government Regulation No. 82, 2001, the standard criteria of Class I for COD is 6 mg/l and for Class II is 4 mg/l. For the parameter of Dissolved Oxygen, around 40 % of rivers meet water quality standard of Class I and 72 % of Class II. Some rivers show value of Dissolved Oxygen approaching to zero at several locations. Those rivers are among others river Deli in North Sumatra, Ciliwung in Jakarta, Citarum in West Java, Surabaya in East Java, and river Dendeng in East Nusa Tenggara.

(d) Total Suspended Solid (TSS)

According to the Government Regulation No. 82, 2001, the standard criteria of Class I and Class I is 500 mg/lt. For the parameter of TSS, around 71 % of the rivers which had been monitored meet the standard criteria. Several rivers have wide range of variable in the value of TSS such as rivers Progo in Yogjakarta, Kahayan in Central Kalimantan, Jeneberang in South Sulawesi, Martapura in South Kalimantan and Anafre in Papua. The highest value of TSS is found in river of Jeneberang in South Sulawesi.

(e) Nitrogen and Phosphor (NO_2, NO_3, NH_3 and PO_4)

The result of the monitoring showed around 78 % of the rivers meet water quality standard of Class I and II for parameter NO_2 (0.05 mg/l). For NO_3, both rivers Progo in Yogyakarta and Tukad Badung in Bali exceed water quality standard of Class I and II (0,05 mg/l), where the first mentioned showed highest concentration (84,9 mg/l).

For the parameter of NH_3, several rivers such as river Deli in North Sumatra, Tallo in South Sulawesi, Rangkui in Bangka Belitung and Anafre in Papua, showed water quality exceeding standard criteria for NH_3 (0.5 mg/lt) in most sampling stations. The highest concentration of NH_3 was detected at river Anafre in Papua (55.2 mg/l) followed by river Brantas in East Java (32,8 mg/l).

For the parameter of PO_4, result of the monitoring showed that almost all of the monitored river showed water quality exceeding the standard criteria of Class I and II (0.2 mg/l). The highest concentration of PO_4 is detected in the river Batang Agam in West Sumatra at almost all locations with maximum concentration of 13.5 mg/l.

(f) FC and TC.

For the parameters of FC and TC, result of the monitoring showed that the majority of rivers flowing in densely populated area, especially in Java, tend to be highly polluted by bacteria. The particular rivers are river Progo in Yogyakarta, Ciliwung in Jakarta and Citarum in West Java. The highest concentration of bacteria was detected in river Ciliwung with concentration approaching 1 million cells for the parameter of FC and exceeding for parameter of TC.

2.1.3. Status of river water quality in thirty provinces

The status of rivers in 30 (thirty) provinces in Indonesia had been classified based on the criteria stated in the Government Regulation No. 82, 2001 and the Decree of the Minister of Environment No. 115, 2003, using sampling data and limited parameters which vary in different provinces. The status of rivers based on water quality in the up stream and down stream of 30 (thirty) rivers in Indonesia is shown in Table 1.

For the upstream part of the rivers monitored in 30 (thirty) provinces, 12.5 % meet the standard criteria, 56 % slightly polluted, 23 % moderately polluted and 8 % heavily polluted. Upstream part of rivers which meet the standard criteria are the rivers Krueng Tamiang (Aceh); Progo (Yogyakarta); Dendeng (East Nusa Tenggara), Jangkok (West Nusa Tenggara); Palu (Central Sulawesi; Batu Merah (Maluku) and Tabobo (North Maluku). Upstream part of rivers which are heavily polluted are rivers Ciliwung (West Java-Jakarta); Cisadane (Banten) and Kahayan (Central Kalimantan)

Table 1. The Status of Water Quality in 30 rivers (based on Criteria of Class II).

Province	River	Status of Water Quality	
		Up-stream	Down-stream
Aceh	K. Tamiang	Slightly polluted - normal	Normal
North Sumatra	Deli	Slightly polluted	Slightly polluted
Riau	Kampar	Slightly-mod. polluted-	Moderately polluted
West Sumatra	Batang Agam	Slightly polluted	Moderately polluted
Jambi	Batang Hari	Moderately polluted	Moderately polluted
Bengkulu	Batang Agam	Slightly polluted	Slightly-moderately polluted
South Sumatra	Musi	Slightly polluted	Slightly polluted
Lampung	W.Sekampung	Slightly polluted	Slightly polluted
Bangka Belitung	Rangkui	Moderately polluted	Slightly polluted-normal
Banten	Cisadane	Heavily polluted	Slightly polluted
Jakarta	Ciliwung	Heavily polluted	Heavily polluted
West Java	Citarum	Moderately polluted	Moderately polluted
Yogjakarta	Progo	Slightly polluted-normal	Moderately polluted
East Java	Brantas	Moderately polluted	-
Bali	T. Badung	Slightly polluted	Slightly polluted
W.N. Tenggara	K. Jangkok	Slightly polluted	Moderately polluted
E.N.Tenggara	K. Dendeng	Normal	Slightly polluted
W.Kalimantan	Kapuas	Slightly polluted	Slightly polluted - normal
C.Kalimantan	Kahayan	Slightly-heavily polluted	Slightly - moderately polluted
S.Kalimantan	Martapura	Slightly polluted	Moderately polluted
E. Kalimantan	Mahakam	Slightly polluted	Slightly polluted
North Sulawesi	Tondano	Slightly polluted	Slightly polluted
Gorontalo	Bone	Slightly polluted	Slightly polluted
Central Sulawesi	Palu	Mododerately polluted	Slightly polluted
South Sulawesi	Tallo/J.Berang	Slightly polluted	Slightly polluted - normal
SE Sulawesi	Konaweha	Slightly polluted	Moderately polluted
Maluku	Batu Gajah	Slightly polluted	Moderately polluted
Maluku Utara	Tabobo	Slightly polluted-normal	Normal
Papua	Anafre	Slightly polluted	Moderately polluted

Source : Office of the Minister for Environment,, 20024

For the upstream part of the rivers monitored in 30 (thirty) provinces, 12.5 % meet the standard criteria, 56 % slightly polluted, 23 % moderately polluted and 8 % heavily polluted. Upstream part of rivers which meet the standard criteria are the rivers Krueng Tamiang (Aceh); Progo (Yogyakarta); Dendeng (East Nusa Tenggara), Jangkok (West Nusa Tenggara); Palu (Central Sulawesi; Batu Merah (Maluku) and Tabobo (North Maluku). Upstream part of rivers which are heavily polluted are rivers Ciliwung (West Java-Jakarta); Cisadane (Banten) and Kahayan (Central Kalimantan).

For the downstream part of the rivers monitored in 30 (thirty) provinces, 10 % meet the standard criteria, 40 % slightly polluted, 42 % moderately polluted and 3 % heavily polluted. Down stream part of rivers which meet the standard criteria are : rivers Krueng Tamiang (Aceh); Rangkui (Bangka Belitung); Kapuas (West Kalimantan); Jeneberang (South Sulawesi); and Tabobo (North Maluku).

2.2. Monitoring of river water quality in Sumatra, Java and Kalimantan

2.2.1. Implementation of monitoring.

Monitoring and observation of water quality in 16 (sixteen) rivers in Sumatra, Java and Kalimantan had been conducted in 2001-2202 which include parameters of Biological Oxygen Demand, Chemical Oxygen Demand, Dissolved Oxygen, Total Dissolved Solid and Total Suspended Solid. Water in the river is considered as polluted if the concentration of parameters exceeding the water quality standard. The observation and sampling of water quality was implemented separately at upstream part and down stream part of each river.

2.2.2. Result of the monitoring

Based on the parameters mentioned above, the result of water quality for the sixteen rivers are shown in the following tables.

Table 2. Water quality in six rivers in Sumatra.

Province	River	Location	BOD	COD	DO	TSS	TDS
North Sumatra	Deli	Upstream	-	-	7.50	0.50	10.00
		Downstream	-	-	5.90	2.50	40.00
Jambi	Batanghari	Upstream	4.31	7.50	6.52	-	87.00
		Downstream	7.43	45.50	7.59	-	370.70
Riau	Siak	Upstream	-	-	4.18	55.0	-
		Downstream	-	-	2.45	79.00	-
South Sumatra	Musi	Upstream	3.70	8.00	4.20	45.00	-
		Downstream	5.30	12.50	3.90	35/.00	-
Lampung	Terusan	Upstream	4.36	12.17	5.36	-	20.00
		Downstream	8.33	18.50	3.56	-	356.00
	Pangubuan	Upstream	2.55	15.09	5.24	-	22.00
		Downstream	20.45	46.64	4.99	-	321.00

Table 3. Water quality in six rivers in Java

Province	River	Location	BOD	COD	DO	TSS	TDS
West Java	Citarum	Upstream	-	30.98	5.69	-	202.50
		Downstream	-	58.24	2.83	-	137.55
	Ciliwung	Upstream	-	-	6.60	-	
		Downstream	-	-	6.20	-	
Banten	Ciujung	Upstream	1.80	8.20	-	55.20	-
		Downstream	4.80	22.40	-	13.30	-
Jakarta	Ciliwung	Upstream	17.83	34.82	-	105.00	-
		Downstream	15.45	29.85	-	88.00	-
	Cipinang	Upstream	11.25	22.91	-	30.00	-
		Downstream	23.58	60.28	-	40.00	-
	Mokevaart	Upstream	35.59	88.22		86.00	
		Downstream	56.30	197.22		259.00	
Yogyakarta	Opak	Upstream	2.74	14.60	5.18	-	-
		Downstream	4.50	16.60	5.40	-	-

Table 4. Water quality in three rivers in Kalimantan

Province	River	Location	BOD	COD	DO	TSS	TDS
E.Kalimantan	Mahakam	Upstream	2.20	37.35	5.10	115.00	23./00
		Downstream	11.05	46.95	4.65	113.00	10.30
W.Kalimantan	Kapuas	Upstream	12.80	23.00	--	21.00	16.45
		Downstream	14.40	32.50		16.00	14.45
S.Kalimantan	Martapura	Upstream	-	-	4.60	76.00	13.00
		Downstream	-	-	2.02	230.00	45.00

2.3. Minister's Regulation in water quality management

In the context of water quality control, several Government Regulation had been issued by the Office of the Minister of Environment, among others are :

(1) Minister of Environment Decree No. 37, 2003, on the Method of Water Quality Analysis and Sampling for Surface Water.

(2) Minister of Environment Decree No. 110, 2003, on the Guidance for Determination of the Carrying Capacity for Water Pollution at Water Sources.

(3) Minister of Environment Decree No. 111, 2003, on the Guidance for Requirement and Mechanism and Guidance for the Disposal of Liquid Waste into Water Bodies and Water Sources
(4) Minister of Environment Decree No. 112, 2003, on the Standard Quality for Domestic Liquid Waste.
(5) Minister of Environment Decree No. 113, 2003, on the Quality Standard for
(6) Liquid Waste for Mining Companies
(7) Minister of Environment Decree No. 114, 2003, on the Guidance for the Identification and Determination of Water Quality
(8) Minister of Environment Decree No. 115, 2003, on the Guidance for Water Quality Classification
(9) Minister of Environment Decree No. 142, 2003, on the Correction of the Decree No. 111, 2003.

III. STUDIES ON WATER QUALITY IN RIVERS

3.1. Rivers in Sumatra.

Study on water quality in 22 (twenty two) rivers which are located in the Provinces of Aceh, North Sumatra, Riau, West Sumatra, Jambi, South Sumatra and Lampung were conducted in 1989-1990. Based on the criteria for water quality classification, rivers were classified into Class A, Class B and Class C as shown in the Table 2. The criteria for classification include turbidity (mg/l SiO2) and Coli (total/100). For turbidity ; Class A = < 50; Class B 50-100 and Class C >1.00, while for Coli ; Class A < 5.000; Class B < 20.000 and Class C > 20.000.

Table 5. Classification of rivers in Sumatra**.**

Class A	
Province	River
North Sumatra West Sumatra South Sumatra	Asahan at Porsea; Asahan Siruar; Asahan at Tangga Bt. Tambuo -Ikua Labuah Komering -Sungai Dua
Class B	
Riau Jambi South Sumatra Lampung	Siak Batang Hari; Batang Tembesi Musi - Pulokerto W. Seputih Dalam
Class C	
Aceh North Sumatra Riau West Sumatra Jambi Lampung	Peusangan – Matang Deli- Simpang;Semayang;Asahan-Tj.Balai; Merbau - Merbau; Tapung Kanan -Kotagaro; Tapung KJiri-Tandun Batang Agam -Kampung Durian Batang Tabir-Rantau panjang W.Seputih-Padang Ratu ; W.Pangubuan-Terbangi Besar

Based on water quality in rivers and its classification, an alternative design for water treatment plant was set up. For Class A river, the necessity of treatment plant is Conventional Type A, for Class B is conventional Type B, and for class C conventional system type C.

3.2. Rivers in Sumatra, Java and Kalimantan.

Study on water quality in several rivers in Sumatra, Java and Kalimantan Java, showed a range of BOD and COD from 6.1 to 9.9 mg/l and from 14.6 to 64 mg/l respectively, as shown in the following table.

Table 6. Water quality in terms of BOD and COD concentration (mg/l)

River	BOD	COD	River	BOD	COD
North Java*)	1.8-33	77-14.5	Madiun	7.5	28
Cisangkuy	9.9	24	Brantas	4.9	64
Ciliwung	4.4	14.6	Musi	9.1	30
Cisadane	6.2	25	Kapuas	6.1	12

**) Include rivers : Citarum, Cipunegara, Cimanuk, Cisanggarung, Pemali, Comal, Sambong and Pekalongan.*

3.3. River Cidanau, Banten

Case study on water quality was conducted with 14 (fourteen) sampling points along the river Cidanau, Banten Province. The result of the observation showed the neutral to slightly basic water, where the lowest pH of 6.6 is detected at sampling point 13 at the down stream part and the highest pH of 8.8 at the point 2. at the upstream part of the river. Electrical conductivity ranges from 42 at point 3 to 3.17 at point 9.

Turbidity ranges from 16 at sampling point No. 11 to 90 at sampling point 5. The DO vary from 1.9 at sampling point 4 to 5.1 at sampling point 3, both in upstream part of the river. Water temperature range from 25.6 ^{0}C at sampling point 3 to 28.8 ^{0}C at sampling point 12. The concentration of NO_3 vary from 2 mg/lt to at sampling points 7, 8 and 12 to 4 mg/lt at sampling points 1,2,5,6,9 and 10.

3.4. River Ciliwung, West Java - Jakarta

A case study on water quality in river Ciliwung had been implemented in 2004 with sampling at 15 (fifteen) sampling locations covering physical, chemical and biological components of water quality. The water quality in river Ciliwung is becoming worse toward the down stream part of the river.

The parameter of BOD plays an important role in water quality. Fecal Coli (FC) and Total Coli (TC) contribute significantly to the decrease in water quality. The bacteria pollute river water from upstream to down stream with very high concentration, far exceeding the standard criteria for FC and TC parameters. The status of water quality will also decreasing from upstream of river Ciliwung in Bogor to down stream of in Jakarta. The status of river vary from scale 50 at Atta Awun, Cilember, Gadog, and Sempur in the upstream, to 80 – 85 at Manggarai, Kwitang and PIK in the down stream.

Deterioration of water quality in rivers flowing in Jakarta area had been detected for many years, as well as water quality in rivers flowing in the surrounding area of Tangerang and Bekasi. Based on the result of studies, water quality in river Ciliwung is no longer suitable for drinking water (Group B), particularly in regard to parameters of Phenol, Fecal Coli, and Dissolved Oxygen, While for fishery, the and life stock, the limiting factor in water quality are Zing, Phenol and Dissolved Oxygen. The upstream part of Ciliwung which is located in Bogor area is considered safe from water pollution point of view because water quality is still in relatively good condition.

The Clean River Program which had been implemented during the period of ten years and involving 355 companies, 60 hospitals, 66 hotels, 39 offices, 31 workshops and 14 other business enterprises, had successfully decrease the waste load in five rivers in Jakarta area, as shown in the following table.

Table 7. Decrease in waste load (kg/day) in five rivers in Jakarta area.

River	BOD		COD		TSS	
Ciliwung	10.585	556	19.791	1.444*	4.129	635*
Cipinang	5.271	484	18.796	1.034*	1.944	210*
Mokevaart	24.220	523	56.713	2.405	1.672	167
Grogol	336	63*	918	130*	423	218
Cakung	1.054	1.720*	100.238	650	8.820	78*

Note : Exceeding target

Achmadi Partowijoto, Ir. CAE, PU-SDA, MAsr. Indonesia Water Partnership.

3.5. River Citarum

Observation on parameter BOD at 10 (ten) sampling locations along the river of Citarum in the period of 7 (seven) years (1993 to 1999) resulting a variation of BOD concentration along the river as shown in the following table.

Table 8. Variation of BOD (mg/l) in Citarum and its tributaries.

River	Sampling locations	Average of BOD (mg/l)		
		1993	1997	1999
Citarum	Sapan	31.43	33.30	34.50
	Batujajar	60.01	70.20	76.80
	Tanjungpura Kiri	12.67	14.30	19.60
	Rengasdengklok	10.53	16.00	9.20
Cikapundung	Dayeuh Kolot	56.88	28.33	30.27
Cisangkuy	Dayeuh Kolot	37.91	19.68	23.87
Cimahi	Nanjung	186.03	197.99	236.43
Cikao	Cikao Bandung	15.55	29.05	31.17
Cikarang	Kampung Muara	35.43	45.19	18.67
Kali Bekasi	Warung Pojok	14.55	19.88	14.10

The average BOD concentration increase at 7 (seven) locations and decrease in 3 (three) other locations (Citarum-Rengas, Cikapundung and Cisangkuy). The highest BOD concentration was detected in river Cimahi at Nanjung and is increasing, while the lowest is in Citarum at Rengasdengklok and decreasing during the period.

Another study on water quality in river Citarum and its tributaries hade been conducted in 2001 at 13 (thirteen) sampling locations. The sampling were carried out by following the Method for the Examination of Water and Wastewater (1992), where the material (benthos) were filtered by using filter of 30 US Standard, and preserved with formalin. Physical, chemical and biological analysis of water quality were conducted using the National Standard for Public Works on Water Quality (1990) and Method for Examination of Water and Wastewater (1992).

Sources of water pollution were detected as disposal of industrial and domestic wastes, and also waste from animal husbandry and fishery. Industrial wastes were disposed from around 530 small scale and large scale industries located in Bandung, Purwakarta, and Krawang regencies, consisting mainly (70%) of textile industries. Source of domestic waste are people activities along the riversides, where the total population is approaching 10 million. From the total domestic waste, only 5 % are processed in the treatment plant and 4 % in the septic tank, while the remaining are disposed directly into the rivers.

The result of the study on river water quality with 6 (six) sampling stations (Wangisagara; Sapan; Margahayu; Nanjung; Curug; Tanjungpura) and using 8 (eight) parameters were stated in term of Physical-Chemical Index (PCI). The parameters used are Oxygen Saturation; BOD; pH; EC; Temperature; Total Ammonia; Nitrate; and Ortho phosphate. The formula is : $PCI = \prod^{n}.Q^{iWi} = Q^{1\ W1} \times Q^{2\ W2} \times \ldots Q^{s\ Ws}$, where n = number of parameters; Qi = sub-index for parameter i (0-100); Wi = factor value for parameter i.

The result of the analysis showed a range PCI from 0.0 to 80.0, with variation at Wangisagara 80.0; Sapan 25.0; Margahayu 20.0; Nanjung 0.0; Curug 65,0; and at Tanjungpura 45.0. For the tributaries of river Citarum, the PCI is shown in the following table.

Table 9. Physical-Chemical Index for tributaries of river Citarum

No.	Tributary	Sampling location	PCI
1	Cidurian	Jl. Suci, Bandung	30
2	Cikapundung	Jl. Siliwangi Bandung	91
32	Cibeuruem	Ledeng	69
4	Cimahi	Cisarua	85
5	Ciwdey	Soreang	91
6	Cisangkuy	Banjaran	86
7	Cirasea	Ciparay	84

The biological component is stated in term Diversity Index and the formula is :

$$DI = -\sum_{I=1}^{S} \frac{ni}{N} \ln \frac{ni}{N}, \quad \text{where : } S = \text{total species per sample;}$$

ni = total of individual per species number I;
N = grand total of individual in the sample

The result of water quality analysis for river Citarum showed high DI at Wangisagara (1.46) which is located at the most upstream part of the river. At Curug, where water is improving due to purification process at Saguling Reservoir, the DI is also high at 1.69. At Tanjungpura, water quality is very low with only one species with total individual of 3, resulting in DI value of 0.0. For the tributary, there are still many species found in water, except in the river Cidurian, where the PCI is lowest and the DI is only 0.02.

3.6. River Brantas, East Java

A Case study on water quality in river Brantas and its tributaries was conducted since 1987 with specific purpose to set-up target for water quality management enacted by the Governors Decree. To anticipate the increasing pollution hazard, a reliable Master Plan to control water quality was prepared in 1989 and evaluated in 1997. The Short Term Plan (1990-1995) included control dominant industrial and domestic wastes.

The Intermediate Term Plan (1995-2000) included control of industry and domestic waste (continuation); preparation of low flow management; and The Long Term Plan (1200-2010) include control of wastes (continuation); implementation of low flow management; and stabilization of pollution control.

A scenario was set up to decrease liquid waste load to achieve the long term target (2010) that is 80 % reduced of industrial waste and 50 % of domestic waste. The following table show an example of pollution control target for river Surabaya illustrating the difference between the condition of without control measures and with control measures.

Table 10. The long term target in Surabaya river

Target	Short Term (→ 1995)	Intermediate Term (→ 2000)	Long Term (→ 2010)
Without control measures (waste in ton/day, Q river 25 m3/sec)			
Domestic	109	140	212
Industry	54	63	73
Total	163	203	285
With control measures (waste in ton/day, Q river 25 m3/sec)			
Domestic	28	107	49
Industry	12	7	7
Total	40	114	56

The monitoring activities in the study was implemented at 51 (fifty one) stations, monthly for river Brantas, weekly for river Surabaya and daily at Karang Pilang and Ngagel. Priority was given for 41 (forty one) industry location disposing specific type of waste and contributing heavy pollution. Parameters for monitoring include : physical parameters (turbidity; temperature; dissolved oxygen; color) and chemical parameters (BOD, COD, NO_3, NO_2, Mg, SS).

IV. STUDIES ON WATER QUALITY IN LAKES AND RESERVOIRS

4. Water Quality in Lakes

4.1.1. Lake Toba in Sumatra and Lake Batur in Bali.

Monitoring on water quality was implemented on two sample lakes, namely Lake Toba in North Sumatra and Lake Batur in Bali. Both lakes showed BOD exceeding the standard criteria for Class I, while for parameter of Sulfide (S), the quality of water exceeding the standard criteria at all sampling location. Cadmium was detected at 6 (six) sampling locations in Lake Toba. The existence of heavy metal and organic pollutant, which is measurable from the BOD parameter, is caused by disposal of domestic, industry and agricultural pollutants from the surrounding area of the lakes.

4.1.2. Lake Cidanau, Banten.

Case study on water quality had been conducted with 7 (seven) sampling points (A – G) in lake Cidanau in Banten Province. Result of the observation showed acidity of the water ranging from pH 6.4 at point C to 7.6 at point E.. Electrical conductivity ranges from 103 at point B to 272 MSCm at point G, turbidity from 4 at point A to 85 at point G. The DO vary from 0.20 at point C to 4.66 at point E, temperature from 25.6 ^{0}C at point A and B to 27.0 ^{0}C at point E, while concentration of NO_3 are the same at all points. The change of water quality from point E to point F may result from drainage of paddy field in up stream the area.

4.1.3. Lake Gede and Cipondoh, West Java.

Study on water quality in lake Gede in Bogor and Cipondoh in Tangerang were conducted in October – December 1999, the result are shown in the following tables.

Table 15. Water quality in lake Gede.

Parameter	Unit	Sta-1	Sta-2	Sta-3
Temperature	^{0}C	28	27	25
Conductivity	Umhos/cm	60	67	67
TDS	mg/l	40	45	45
TSS	mg/l	30	43	58
Turbidity	NTU	0.48	0.50	0.52
pH	-	6,8	6,5	6,0
Free-CO_2	mg/l	4,7	5,9	6,3
DO	mg/l	5,7	5,7	5,5
BOD	mg/l	4.7	5,9	6,3
N-NH_3	mg/l	0,34	0,43	0,49
N-$N0_3$	mg/l	1,46	3,40	4,03
N-$N0_2$	mg/l	trace	0,02	0,02
Total P	mg/l	0,21	0,27	0,31

Water in lake Gede is used for irrigation and fishery, and from the result of the study it was found that the water quality belongs to good condition.

Table 16. Water quality in lake Cipondoh.

Parameter	Unit	Sta-1	Sta-2	Sta-3	Sta-4	Sta-5
Temperature	^{0}C	29	29,5	28	29,5	30
TSS	mg/l	32	25	60	48	48
Turbidity	NTU	7,1	4,5	135	110	105
pH	-	7,4	7,3	6,9	7,1	6,9
DO	mg/l	5,7	5,7	4,1	4,1	6,6
BOD	mg/l	3,5	3,7	5,9	3,5	2,9
N-NH_3	mg/l	0,34	0,28	0,20	0,19	0,14
N-$N0_3$	mg/l	0,15	0,07	0,12	0,18	0,01
N-$N0_2$	mg/l	0,04	0,02	0,02	0,01	0,01
Total P	mg/l	0,52	0,27	0,38	0,28	0,59

Water in lake Cipondoh is used for fishery (catching, casting net and lift net) and from the result of the study it was found that water quality is in good condition. For fishery development, the suggestions include training on awareness, preservation and skill development. The site selection should consider: depth > 4 m for floating net, 1-3 m for embedded net, open for oxygen penetration process from the air and free from pest and pollutant disturbance.

4.2. Case studies on water quality in reservoirs.

4.2.1. Reservoirs Saguling, Cirata and Jatiluhur.

A study on water quality were conducted at reservoirs Saguling, Cirata and Jatiluhur in the mid year of 2001. There were 4 (four) sampling stations for each reservoir, namely at the inlet, fishery activity, intake of hydropower and outlet of the reservoir. Monitoring were implemented twice, that was in July and in September 2001.

The method used in the sampling in reservoirs Saguling, Cirata and Jatiluhur was the Indonesia National Standard 06-2412-1991 (Method of Sampling for Water Quality Analysis). Observation on water quality in reservoirs of Saguling, Cirata and Jatiluhur

during the period of seven years (1993 to 1999) revealed deterioration of water quality and increase in BOD as shown in the following table.

Table 11. Increase of BOD in Saguling, Cirata and Jatiluhur (1993-1999)

Reservoir	Capacity (million m3)	Average of BOD (mg/l)		
		1993	1997	1999
Saguling	982	18.04	19.54	23.75
Cirata	2.165	7.15	7.70	18.76
Jatiluhur	3.000	3.19	2.58	4.74

Result of another study showed a high content of organic matter, Nitrogen and Phospor from waste material disposed into the reservoirs.

Table 12. Content of Organic Matter, Nitrogen and Phospor in the reservoirs.

Reservoir	Content (ton/year)		
	Organic Matter	Nitrogen	Phospor
Saguling	49,974	2,186	311
Cirata	199,224	8,715	1.242
Jatiluhur	16,791	735	105

4.2.2. Fishery area in reservoir of Jatiluhur

Study on water quality in the fish cage surrounding area of Ciganea, around 3 ha (< 0.05 % of reservoir area), was conducted in 1996 to respond the sudden dead of huge amount of various fish species in the reservoir. Before the incident, the content of oxygen content was decreasing around 50 % from 8 mg/l down to 4 mg/l, while at the time of the incident the oxygen content was very low at 1 – 2 mg/l and the content of ammonia increased significantly from 0.369 to 1,476 mg/l at the surface.

Ten days after the incident the oxygen content increased to 5.86 mg/l and ammonia decreased to untraceable. The decrease of oxygen content is believed as result of cloudy weather for many days where photo synthesis process of algae is very low, while high ammonia content is caused by back-current of the water. Water temperature in the fish cage surrounding area is shown in the following table.

Table 13. Water temperature (^{0}C) at three different depth of the reservoir

Time of the day	Depth of water			Time
	0 meter	10 meter	25 meter	
Day time	28.3	26.9	26.2	14.00
Night time	27.5	26.6	25.5	05.00

Back current is not likely to occur, however during cloudy weather water temperature at the surface and in the deep almost similar which may caused back current. In November – December before the incident the transparency reach 1.6-3.5 m, however at time of the incident, it was only 0.5-0.6 m. and after one week increased to normal at 1.6 m The water acidity before the incident was measured at pH = 8, decreasing to pH = 7.0 and after a few days the pH increased to pH = 8. The decrease of pH value is due to low photo synthesis activity of algae. Oxygen content for the time before and after the incident is shown in the following table.

Table14. Oxygen content (mg/l) at the time before, during and after the incident.

Time period	Date in 1996	At the surface	At a depth of 2 m
Prior to the incident	November 3	7.7	7.7
During the incident	January 5-7	2.1	3.7
After the incident	December 15	4..5	4.0

Measurement by the Fishery Center resulting in oxygen content of 1.0 mg/l at the surface; 1.7 mg/l at 2 m depth; 2.4 mg/l at 8 m depth and 2.8 mg/l at 20 meter (bottom of the reservoir at the site). During the second week of January, the oxygen content increased slightly from 3.7 to 4.1 mg/l. In the third week under good weather the oxygen content was measured at 5.5 mg/l at the surface and 4.3 mg/l at a depth of 2 m.

4.2.3. Lake Gede and Cipondoh, West Java.

Study on water quality in lake Gede in Bogor and Cipondoh in Tangerang were conducted in October – December 1999, the result are shown in the following tables.

Table 15. Water quality in lake Gede.

Parameter	Unit	Sta-1	Sta-2	Sta-3
Temperature	^{0}C	28	27	25
Conductivity	Umhos/cm	60	67	67
TDS	mg/l	40	45	45
TSS	mg/l	30	43	58
Turbidity	NTU	0.48	0.50	0.52
pH	-	6,8	6,5	6,0
Free-CO_2	mg/l	4,7	5,9	6,3
DO	mg/l	5,7	5,7	5,5
BOD	mg/l	4.7	5,9	6,3
N-NH_3	mg/l	0,34	0,43	0,49
N-$N0_3$	mg/l	1,46	3,40	4,03
N-$N0_2$	mg/l	trace	0,02	0,02
Total P	mg/l	0,21	0,27	0,31

Water in lake Gede is used for irrigation and fishery, and from the result of the study it was found that the water quality belongs to good condition.

Table 16. Water quality in lake Cipondoh.

Parameter	Unit	Sta-1	Sta-2	Sta-3	Sta-4	Sta-5
Temperature	^{0}C	29	29,5	28	29,5	30
TSS	mg/l	32	25	60	48	48
Turbidity	NTU	7,1	4,5	135	110	105
pH	-	7,4	7,3	6,9	7,1	6,9
DO	mg/l	5,7	5,7	4,1	4,1	6,6
BOD	mg/l	3,5	3,7	5,9	3,5	2,9
N-NH_3	mg/l	0,34	0,28	0,20	0,19	0,14
N-$N0_3$	mg/l	0,15	0,07	0,12	0,18	0,01
N-$N0_2$	mg/l	0,04	0,02	0,02	0,01	0,01
Total P	mg/l	0,52	0,27	0,38	0,28	0,59

Water in lake Cipondoh is used for fishery (catching, casting net and lift net) and from the result of the study it was found that water quality is in good condition. For fishery development, the suggestions include training on awareness, preservation and skill development. The site selection should consider the following : depth > 4 m for floating net, 1-3 m for embedded net, open for oxygen penetration process from the air and free from pest and pollutant disturbance.

REFERENCES

Deputy Binsartek Pengelolaan Lingkungan Hidup, KLH. (2005).Status Lingkungan Hidup Indonesia Tahun 2004. Kementrian Lingkungan Hidup. Jakarta.

Hernowo, M. (2000) Pengelolaan Air dan Sumber Air di WS Citarum. Diskusi Penatagunaan SDA di WS Citarum. Dep. Kimbangwil Jasa Tirta I, Jakarta.

Hidayat, R. (1998) Water Potential of Rivers in Sumatra in supporting Water Treat Plant. Proc. The Tenth Afro-Asian regional Conference. Denpasar, Bali

Indreswari G. and Tri M. Sunaryo. (2003) Indentifikasi Masalah Sumber Air. Fakultas Teknik, UI. Jakarta

Indreswari, G. (2001) Penyebaran dan Penerapan Teknologi Air dalam Pembangunan Daerah. Prosiding Lustrum IV HATHI., Jakarta.

Partowijoto, A. (2001) Pencemaran Air oleh Senyawa Kimia dan Masalah Kesehatan di Wilayah DKI Jakarta. Masyarakat Peduli Air, Jakarta

Partowijoto, A. (2004) Brief Information on Water Resources in Indonesia. ADB Water Week, Manila.

Perum Jasa Tirta II (2005) Pengembangan Sistem Air Baku Jatiluhur untuk Jabodetabek. Kumpulan Makalah Seminar HATHI. Krisis Air Baku Jabodetabek – Banten 2010 dan RJP 2025.

Rasudin, Y. (2004) Penmgelolaan Kualitas Air pada Kawasan Aliran Sungai. Kantor Menteri Lingkunan Hidup, Jakarta.

Ratna Hidayat dan Yusilyanna. (2003) Pengkajian Berbagai Aspek Air Minum Dalam Kemasan. PIT-HATHI XX, Samarinda.

Simon S.B.et al. (1998) Kualitas Air dikolam jala terapung saat kejadian kematian ikan di Waduk Jatiluhur, Jawa Barat. Puslitbang SDA, Bandung

Sudharma, D et al. Case Study on Aquatic Ecology in Small Lake Gede Bogor and Cipondoh Tangerang. Proceeding of International Seminar, BAU, Bogor.

Tantowi (2002) Penelitian Pemantauan Kualitas Air Menggunakan Organisme Air sebagai Indicator. Prosiding Kolokium, Puslitbang SDA, Bandung.

Yamaji, E. (1999) Water Quality of Lake Cidanau in Cidanau Watershed. Proceeding of International Seminar on Sustainable Resource Management of Cidanau Watershed. RUBRD-UT/BAU, Bogor.

Achmadi Partowijoto, Ir. CAE, PU-SDA, MAsr. Indonesia Water Partnership.