Basin-Based Wastewater Management System in Japan, the Netherlands and Indonesia: A Comparative Study for Surface Water Quality Improvement in Upper Citarum Basin

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A B S T R A C T

The water quality in upper Citarum River Basin, has been deteriorating especially for the last a decade. Apart from the water pollution due to non-point sources, inadequate wastewater treatment for households and industries in the basin has been strongly considered to be the major factor contributing to this poor state. The efforts undertaken to improve the quality of Citarum River have not yet achieved an expected result as it is indicated by some key parameters such as Chemical Oxygen Demand (COD). A comprehensive approach could probably be required to deal with the water quality management in upper Citarum Basin. Basin-Based Wastewater Management (BBWM) approach is introduced in the paper which views the perspective from a basin-wide context through the assessment of structural measures (public sewerage system) and non-structural measures (e.g. private-initiated individual and communal on-site treatment) dealing with wastewater management. BBWM system of 3 different regions: Upper Citarum Basin, West Java Province (Indonesia), Suwa Basin, Nagano Prefecture (Japan), and Delfland, South Holland Province (the Netherlands) is incorporated in this comparative study. High coverage of public sewerage system (structural measures) and combination of structural and non-structural measures have resulted in a low pollutant discharge and further increasing the quality of surface water as it is shown in the basins investigated (Suwa and Delfland Basins). However, insufficient structural measures such as in upper Citarum Basin, BBWM is entirely required. Case in Japan's system has shown that adequate non-structural measures could overcome a short of structural measures as it is shown in the earlier phase of Suwa Basin related to sewage system. Therefore, efforts to encourage non-structural measures in upper Citarum Basin due to a slow development of public sewerage development should be highly endorsed. In addition, appropriate non-structural measures generated should be supported by increasing community awareness to obtain highest output.

Keywords: Basin-based wastewater management, structural and non-structural measures, rapid urbanization, land use change, pollutant load, water quality

1. Introduction

This paper investigates the basin-wide wastewater management of 3 different regions: upper Citarum Basin, West Java Province (Indonesia), Suwa Basin, Nagano Prefecture (Japan), and Delfland, South Holland Province (the Netherlands). The study is conducted in the frame of generating options for improving surface water quality in upper Citarum Basin particularly Cikapundung Sub-Basin, which will be formulated from comparative analysis conducted through perspective of Basin-Based Wastewater Management (hereinafter called BBWM). BBWM approach is introduced in the paper which views from a basin-wide context through the assessment of structural and non-structural measures dealing with wastewater management.

Upper Citarum Basin has been developed rapidly stimulated by the fast development of Bandung city as the biggest city in the basin area. Such a rapid population growth has resulted in a high pressure leading to a deterioration of water quality of water bodies. The problems regarding water quality of surface water in upper Citarum Basin have been confirmed by many studies (Bukit, N. T., 1995; Wangsaatmaja,, 2004; Soewondo, P., 2007). Apart from the water pollution due to non-point sources, inadequate wastewater treatment for households and industries in the basin has been strongly considered to be the major factor contributing to this poor state. The efforts undertaken to improve the quality of upper Citarum River have not yet achieved an expected result as it is indicated by a continuous decrease in the key parameter such as COD. As a result, the problem of surface water quality degradation has not been solved sufficiently. A comprehensive approach could probably be the best way to deal with the water quality problem in upper

Citarum Basin. A comparative study investigating BBWM implemented by other systems is described in this paper as one of important stages to obtain some possible options which would be appropriate for improving the surface water quality in upper Citarum Basin. The two other basins are incorporated in this study: Suwa Basin in Nagano Prefecture, Japan and Delfland Region, in South Holland Province, The Netherlands.

2. Hypothesis

An integrated approach through BBWM should be introduced to cope with decreasing surface water quality. BBWM approach on water pollution control would be needed especially under: (1) rapid urbanization, (2) weak governance, (3) low financial support, (4) limited and slow development of public sewerage system (structural measure). Under such a situation, BBWM plays an important role in the total view of wastewater management in the basin by overcoming any shortage of mitigating measure. In addition, together with increasing community awareness (social aspect), non-structural measures through on-site treatment system needs to be increasingly encouraged to compensate a slow development of structural measures (Matsushita, 2007).

3. Method of analysis on verification

To verify the above hypothesis, 3 different basins were incorporated in the comparative study. Each basin is analyzed particularly from the viewpoint of public sewerage system (structural measure) and on-site wastewater treatment system (non-structural measure) described in step-by-step approach (phases). Based on the existing population growth and the land use trend of each basin, the pollutant load generation is analyzed. Additionally, comparing structural and non-structural measures could recognize and assess the degree of BBWM implementation in each basin. Furthermore, this leads to assess the impact of each system's performance on pollutant discharge and water quality.

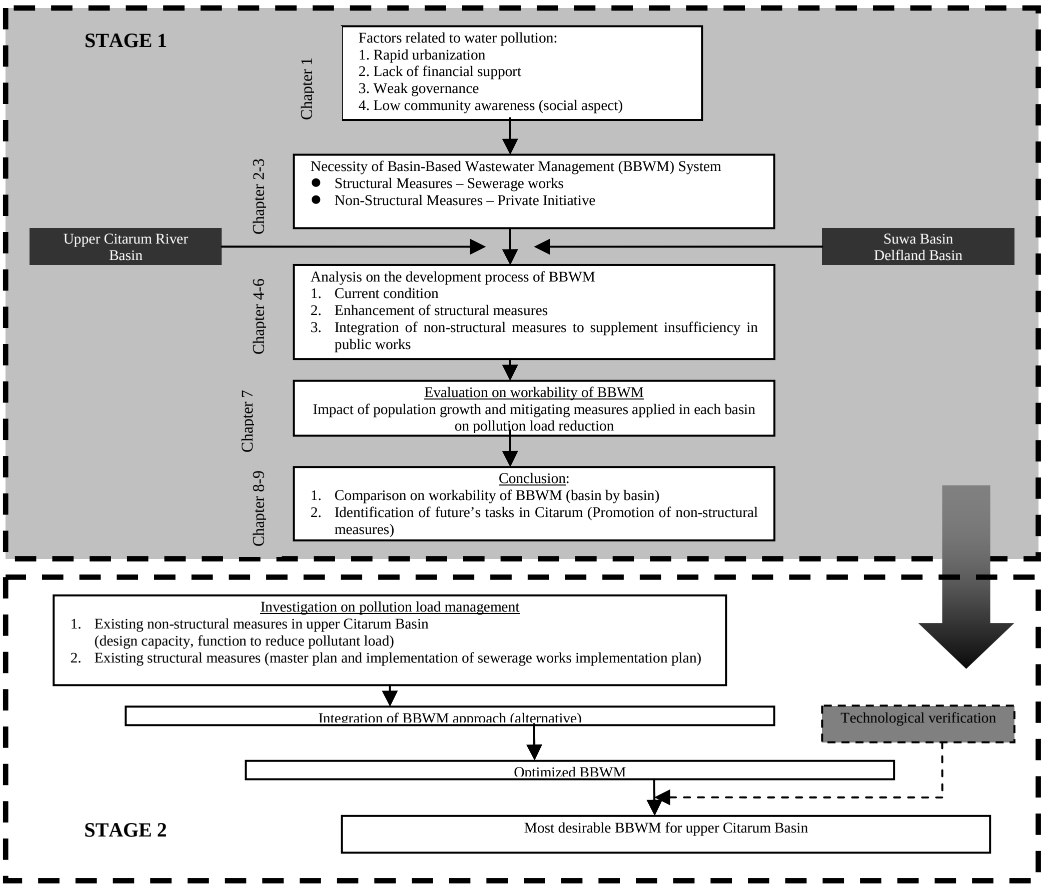


Figure 3.1 : System Approach

Table 3.1 - Comparison among the systems

	Cikapundung Sub-Basin, Upper Citarum Basin– (Basin 1)	Suwa Basin (Basin 2)	Delfland Region, West Rhine Basin (Basin 3)
Population (million)	2.6 (2001)	1.4 (2000)	1.25 (2003)
Area (km^2)	434	515	410
Structural Measures	Relatively low coverage of sewerage connection (around 20% of total population of Bandung city in 2000). (Risyana et al, 2001).	High coverage of sewerage connection (97.1% in 2005) (Suwako Regional Sewerage System, 2006)	High coverage of sewerage connection (99% in 2004) (RIONED, 2006).
Non-Structural measures	On-site treatment system (individual and communal septic tank) has been introduced with still relatively low coverage (around half of population served by the system).	Johkasou system was already introduced. In 1969, when the structural standard for Johkasou was enacted, the population relying on Johkasou system was almost equal to that severd by sewerage system (JECES, 2005).	A very high percentage of public sewerage connection with almost all of the population connected to the sewerage system has resulted in a small percentage of on-site domestic wastewater treatment system.

4. Explanation on 3 basins

4.1 Upper Citarum Basin, West Java Province (Indonesia)

4.1.1 Description of Upper Citarum Basin

Citarum Basin is a highland and surrounded by mountains located in West Java Province, Indonesia. Upper Citarum Basin covers 4 municipalities including Bandung City (650-700 m above sea level) as the Province's capital city. The area of upper Citarum Basin is 2,340 km2. with the population of 5.7 million (2001) and the average density of about 25 People/ha. Citarum River is one of strategic rivers in Indonesia from which main supply for 3 multipurpose dams (drinking, agriculture, fisheries, irrigation, and hydropower generator for Java and Bali Islands) originates In upper Citarum Basin, Cikapundung Sub-basin is the most highly populated area (about with approximately 2 million inhabitants and the density of about 90 People/ha in 2001 (Wangsaatmaja, 2004) in which Bandung—the capital city of West Java Province and one of national strategic centres—is located.

In the period of about 20 years, upper Citarum Basin has experienced a drastic land-use change. Decreasing forest area occurs about 54% (from 1983 to 2002) and increasing urban area is approximately doubled (223%). While the comparison for the last 10 years shows an increase in urban area (1993-2002) of about 49% and industrial area of approximately 35% (Wangsaatmaja, 2004). As a result, this land-use change not being followed by appropriate measures has resulted in water quality degradation (upstream through downstream).

Table 4.1– Land use change of Upper Citarum Basin (1983-2002) (Wangsaatmaja, 2004)

Landuse	1983 (Ha)	1993 (Ha)	2002 (Ha)
Forest	85,138	69,454	39,150
Agricul-ture	52,702	44,575	23,510
Urban	5,117	10,499	17,038
Sub Urban	2,473	5,156	6,304
Industry	355	2,553	3,444

4.1.2 Sewerage connection (Structural measure)

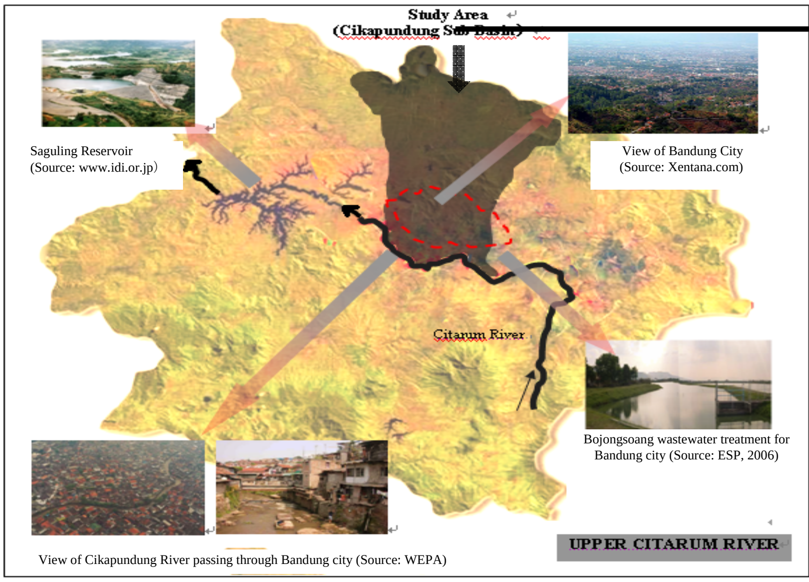
Sewerage system in Bandung city which is the largest city in Citarum River Basin was originally built by Dutch in 1916. The new sewerage system was built under Bandung Urban Development Projects (BUDP) started in 1979 covering the west-center which includes the old Dutch system and the east system. The sewerage system of the city has about 90,000 connections serving about 450,000 people or 20% of the city population (Risyana et.al, 2001) in around 2000.

The output of the sewerage system finally reaches the wastewater treatment plant in Bojongsoang (Bandung Regency) area, about 10 km south-east Bandung city. This treatment plant using stabilization pond has been operated since 1994 with an area of 85 ha and the treatment capacity of 80,835 m3/day (14 ponds) to serve the city of Bandung. However, only about 50% of total capacity is currently used (ESP, 2006). This is due to a partial sewer coverage of the city which mostly eastern part of the city.

4.1.3 On-site wastewater treatment system (Non-Structural measure)

Sewerage system only serves part of inhabitants in Bandung city area. The remaining part has to be served by on-site systems. Among individual wastewater treatment system, septic tank is the most popular method used in the region. However, groundwater contamination problem has reportedly occurred due to improper design of this facility. In addition, for areas with very high population density (about 90 person/ha in Cikapundung Sub-Basin), there is no sufficient space available for septic tank to be constructed. Therefore, currently communal septic tank becomes an alternative to anticipate such a condition.

Figure 4.1 - Upper Citarum Basin, West Java



4.2 Suwa Basin, Nagano Prefecture (Japan)

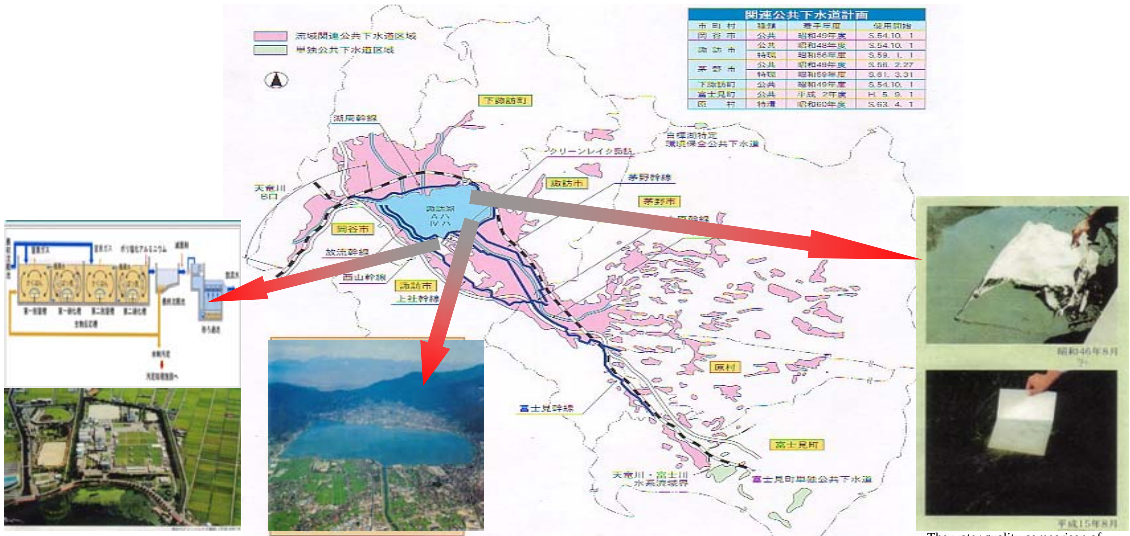
4.2.1 Description of Suwa Basin

As an attractive place located in the centre of Nagano Prefecture and almost in the middle of Japanese archipelago, Lake Suwa offers an opportunity for people especially tourists to enjoy nature. With an altitude of 759 m above the sea level and surface area of 13.3 km2, Lake Suwa becomes one of most favorite places in Japan. Lake Suwa region is inhabited by around 210 thousand people and 2.6 million tourists per year (2005), while a whole basin is about 515 km^2 with an estimated population of about 1,400,000 people in 2000.

This ecological change of Lake Suwa was likely stimulated one of which by a high number of tourists visiting the places around the lake. As a result, the outbreak of algae, a bad smell, death of fish were unpleasant phenomenon. The damage occurred had brought about a situation which was far from the image of it had been as "Suwa lake to be able to swim" (Nagano Prefecture, 2006).

4.2.2 Sewerage connection (Structural measure)

To reduce the impact of pollution on Lake Suwa, sewerage network has been introduced mainly since 1979 in the same period as the commencement of Clean Lake Suwa construction. The network system increased rapidly and currently more than 97% of population in Suwa region has been served by sewerage system (Nagano Prefecture, 2006). Responding to environmental damage of Lake Suwa, the wastewater treatment facilities of Clean Lake Suwa initiated in 1971 and started to operate in 1979. By this wastewater treatment plant, the water pollution control has been undertaken eversince. Expansion of the plant with the construction of more advanced treatment was introduced in 1994 at Toyoda Sewage Treatment Plant to further improve the wastewater treatment performance. The domestic and industrial wastewater including tourism (hotels and restaurants) are treated in the Toyoda wastewater treatment plant. However, industries must treat their wastewater and achieve appropriate standard set up by the government before it can be discharged into the treatment plant.



View of Lake Suwa (right) and Clean Lake Suwa wastewater treatment plant (left)

The water quality comparison of Lake Suwa during eutrophication problem (top) and current situation (bottom)

Figure 4.2 – Suwa Basin, Nagano Prefecture, Japan
(Source: *Clean Lake Suwa Treatment Plant, Nagano Prefecture*)

The operation of Clean Lake Suwa Wastewater treatment plant has been very significantly improve the Suwa Lake water quality. This is shown by a very significant improvement of key water quality parameters including COD which is one of the key parameters set up by the Environmental Standard Law instituted by Ministry of the Environment to monitor the quality of lakes (Nagano Prefecture, 2006)

4.2.3 On-site wastewater treatment system (Non-Structural measure)

According to JECES (2005) Japan's first johkasou was installed in 1911, but the term "johkasou" did not appear in laws or regulations until 1944 when it was first used in the Standards for Building Site Sanitation Facilities. It was only after World War II that johkasous actually began to spread in Japan. Johkasou systems spread rapidly in the 1960s when the demand for flush toilets heightened strongly with the modernization of people's life. The structural standard of johkasou systems attached to the Building Standards Law was established in 1969.

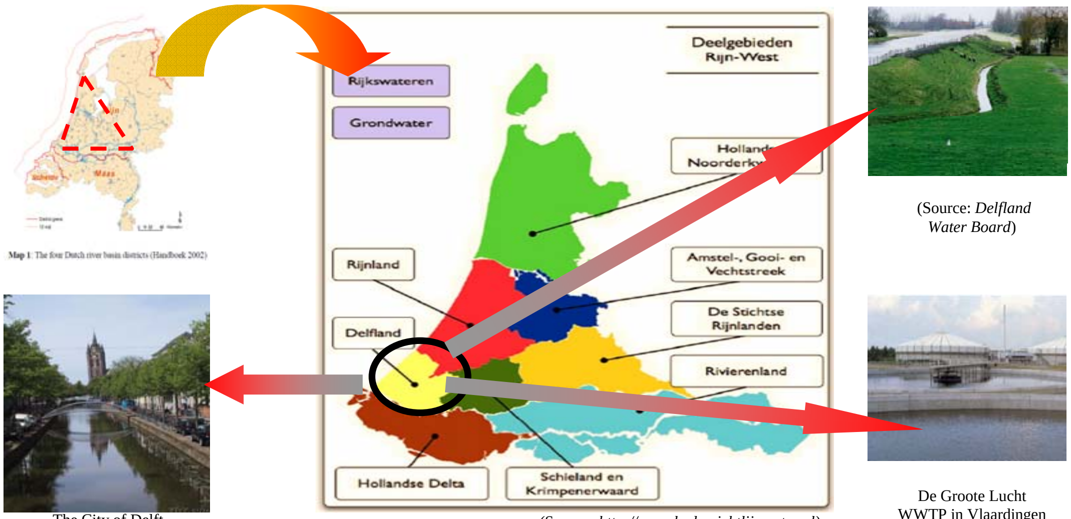
4.3 Delfland Basin, South Holland Province (The Netherlands)

4.3.1 Description of Delfland Region

Delfland region is located in the western part of The Netherlands (West Netherlands Basin), in the Province of South Holland, which is part of bigger Rijn river basin district. This region covers the city of The Hague, Delft, and Rotterdam with an area of about 410 km2 and approximately 1.25 million inhabitants in 2003 (Enserink et.al., 2003).

4.3.2 Sewerage connection (Structural measure)

The fast development of sewerage network construction in the Netherlands started around in 1930 (*Nederland left met water*, 2004) which is also the period of wastewater treatment plant construction began. The plant was initiated formerly by municipalities and provinces before the plants were transferred to water boards after the 1969 Surface Water Act which gave the responsibility to the water boards.



The City of Delft (Source: *7is7.com*)

(Source: *http://www.kaderrichtlijnwater.nl*)

(Source: *Delfland Water Board*)

De Groote Lucht WWTP in Vlaardingen (Source: *Delfland Water Board*)

Figure 4.3 – Delfland Region, Zuid Holland Province

5. Evaluation on Basin-Based Wastewater Management System's workability

As can be seen from the figure 5.1, the pollutant load in Cikapundung Sub-Basin (upper Citarum Basin) in terms of Chemical Oxygen Demand (COD) has very significantly expanded especially from domestic and industries.The figure also indicates that unsewered domestic and industrial wastewater among the highest portion of wastewater discharged with 37.4% and 19.2% respectively (2002). As can also be seen from the figure with an inadequate public sewerage (the lowest population coverage), the pollutant discharge remains high in terms of COD loading in ton/year.

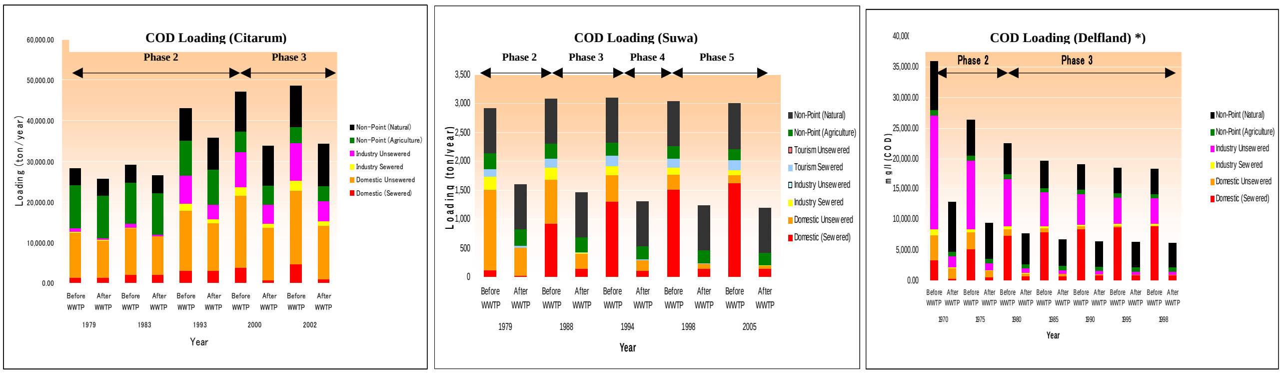
In the case of Suwa Region, COD load from point sources are generated from domestic, tourism, and industry, while agriculture and natural source are considered as non-point sources to be incorporated in the pollutant load. Increasing population served by sewerage system has significantly reduced the pollutant load in terms of COD.

Table 5.1 – Comparison of BBWMS among 3 Basins

Mitigating Measures	Basin 1 (Cikapundung Sub-Basin, Upper Citarum Basin)	Basin 2 (Suwa Basin)	Basin 3 (Delfland Region, West Rhine Basin)
Structural Measures	Relatively low coverage of sewerage connection (around 20% of total population of Bandung city in 2000). (Risyana et al, 2001).	High coverage of sewerage connection (97.1% in 2005) (Suwako Regional Sewerage System, 2006)	High coverage of sewerage connection (99% in 2004) (RIONED, 2006).
Non-Structural measures	On-site treatment system (septic tank) has been introduced in upper Citarum Basin. However, its coverage has not been sufficiently established, which is still around 60% of population. (NAP, 2003). Communal treatment system has been introduced and recently promoted.	On-site system has contributed in reducing the pollution load serving areas without sewerage connection. Johkasou system was already introduced driven by Sanitation Law established in 1900, in which discharging human excreta into public water bodies was banned. In 1969, when the structural standard for Johkasou was enacted, the population relying on Johkasou system was almost equal to that served by sewerage system (JECES, 2005).	A very high percentage of public sewerage connection with almost all of the population connected to the sewerage system has resulted in a small percentage of on-site domestic wastewater treatment system

Table 5.1 - Comparison of BBWMS among 3 Basins (continued)

Effect of Combined Measures	Relatively much lower percentage of population served by public sewerage system and on-site treatment system has resulted in a high pollutant discharge. Enhancement of public sewerage supported by on-site treatment systems are entirely required.	A significant role of non-structure measures is clearly noticed in the primary stage for lowering pollutant discharge and structural measures play bigger role in the secondary stage.	The impact of high percentage of population served by structural measures is clearly noticed. A very high percentage of population connected to public sewerage system in Delfland Region has resulted in low pollutant discharge.



Basin 1 **Basin 2** **Basin 3**

*) Refer to nation-wide discharge of oxygen-consuming substances per million population equivalent (Schut, 1995)

Figure 5.1 – Chronological change of pollutant load (COD) in 3 basins from various sources

In the West Netherland Basin (Delfland Region), the figure indicates that domestic wastewater has continuously increased, while industrial wastewater had decreased by 30% in the period of 1970 to 1990 before it continues to increase afterwards. The total pollutant load has consequently decreased during that period as the figure shows. This considerable reduction in industrial wastewater was associated with the situation in which industry, whether under compulsion or not has largely accomplished its task with respect to society (Schut, 1995).

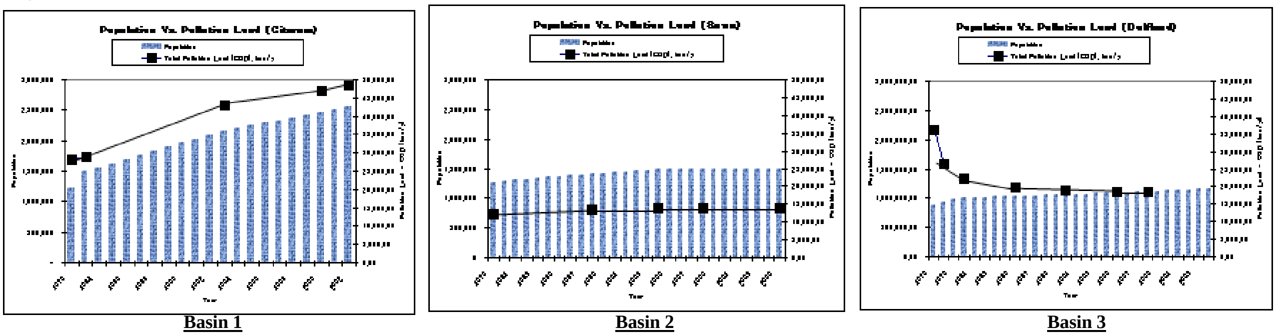
6. Comparison on Workability of Basin-Based Wastewater Management System

6.1 Comparison on population against pollutant Load

The pressure incorporated with pollutant load due to high population pressure in upper Citarum Basin is relatively much higher than that in Suwa and Delfland Regions as can be seen from the figure. As the basin with highest population density (90 people/ha) and growth rate 3.2%, upper Citarum Basin has received much heavier pollutant load compared to Suwa and Delfland Basins. This situation in upper Citarum Basin is jeopardized with unsufficient coverage and treatment of wastewater generated resulting in poor quality.

6.2 Comparison on land use change against pollutant load

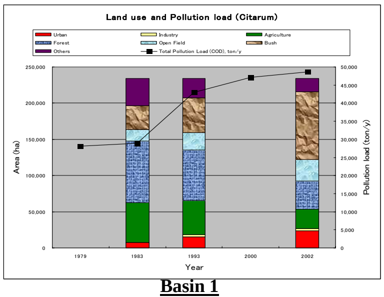
Land use change especially conversion into urban and industrial areas does not occured significantly in Suwa and Delfland region with only a slight increase in urban and industrial use (less than 5% per year for both purposes). On the other hand, land



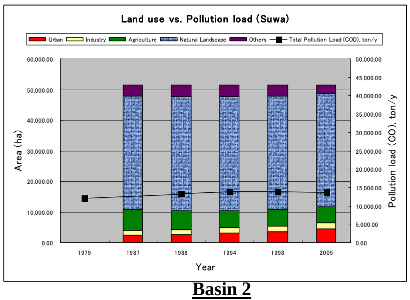
Basin 1 **Basin 2** **Basin 3**

Figure 6.1– Population of basins associated with pollutant load

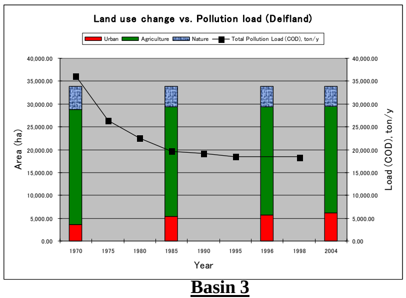
use change has very significantly occurred in upper Citarum Basin with 49 and 35% conversion into urban and industrial area respectively especially from 1993 to 2002 as it is reported. Increase in pollutant load trends to be clearly observed in the basin with high land use change (upper Citarum Basin).



Basin 1



Basin 2

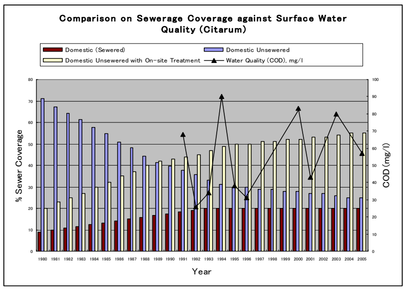


Basin 3

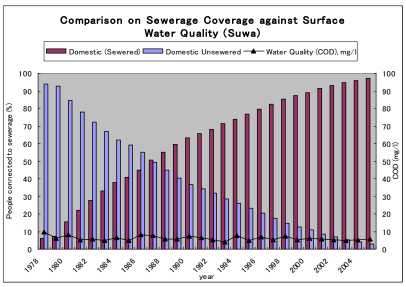
Figure 6.2 - Comparison of land use change impact on pollutant load

6.3 Comparison on structural measures (sewerage connection) against surface water quality

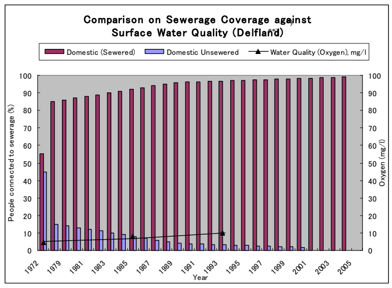
Concerning mitigating measures, the impact of higher sewerage coverage (structural measures) on water quality is also clearly indicated. In terms of Chemical Oxygen Demand (COD), a higher percentage of population connected to sewerage system as in Suwa and Delfland Basin has resulted in much better quality of surface water quality. However, the case in Suwa Basin where the level of COD still fluctuates and above the standard (3 mg/l) even with higher sewerage coverage has been likely due to the inner production mechanism within the lake system and the high load of non-point sources in this region. While in upper Citarum River, both point and non-point pollutant sources have contributed to the deterioration trend of Citarum River.



Basin 1



Basin 2



Basin 3

*) The trend of sewerage coverage was referred to the nation-wide

**)Water quality in Rijn Basin (expressed in oxygen-demanding substance) with the sewerage coverage referring to nation-wide trend

Figure 6.3 - Comparison of sewerage connection on water quality

6.4 Comparison on non-structural measures

On-site treatment system (non-structural measures) has been introduced in upper Citarum Basin. However, a sufficient coverage has not been established, which is only around half of population. In Suwa region, on-site "Johkasou" system has significantly contributed in reducing the pollutant load for areas without sewerage connection which was already applied before sewerage system was introduced (Phase 1). However, a large number of tourists visiting Suwa region had probably contributed to the pressure on the water quality of Lake Suwa. In the Netherland case, focus on structural measures is largely higher than that on non-structural measures. Therefore, a very high percentage of sewerage connection with currently more than 95% of the population connected to the sewerage system.

7. Conclusion

The comparison of 3 basins have shown the different development and existing circumstance of structural and non-structural measures with their associated impact on pollutant discharge and further to the quality of surface water, though there are some similar points of the basins are recognized (i.e.

currently a very high coverage of public sewerage system in Suwa and West Netherlands Basins). This comparative study has given a general idea and important information regarding the necessity of BBWM approach for the improvement of upper Citarum Basin in the future. However, more detail figures and further investigation should be conducted to obtain the most appropriate options for water quality improvement in upper Citarum Basin.

High coverage of public sewerage system (structural measures) and combination of structural and non-structural measures has resulted in a low pollutant discharge and further increasing the quality of surface water as it is shown in the basins investigated.

BBWM System would probably not be needed in a basin with sufficient structural measures as in the region of Delfland Basin. However, insufficient structural measures such as in upper Citarum Basin, BBWM System is totally required. Case in Japan system has shown that adequate non-structural measures could overcome a shortage of structural measures as it is shown in the earlier phase of Suwa Basin related to sewage system.

Population pressure has stimulated a land use change as it is indicated in upper Citarum Basin. Consequently, pollutant load generation has become increasing. On the other hand, insignificant land use change which could probably be owing to lower population pressure tends to relatively lower pollutant load generation. Moreover, in the latter case region, either a very sufficient structural measures like in the region of Delfland or combination of structural and non-structural measures like in Suwa has effectively overcome increasing pollutant load generation and consequently improved the water quality. Both approaches are not yet the case in upper Citarum Basin in which pollutant load discharge still remains high which threatens the quality of surface water.

Through comparing the 3 basin-based wastewater management systems, the following tasks could probably become appropriate options for improving surface water quality in upper Citarum Basin. Owing to a low financial support and weak governance together with very rapid urbanization in the region, providing sufficient structural measures as noted in Dutch wastewater management system would probably take a very long period and presently facing enormous shortcomings. Instead, a combination between structural and non-structural measures under BBWM System as implemented in Japanese wastewater management system could probably become an appropriate approach to deal with increasing pollutant generation and improving surface water quality. Therefore, efforts to encourage non-structural measures in upper Citarum Basin due to a slow development of public sewerage development should be promoted. In addition, appropriate non-structural measures generated should be supported by increasing community awareness to obtain the most appropriate approach.

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Appendix

Table 5.1– Development phases of sewerage and on-site treatment system (upper Citarum Region)

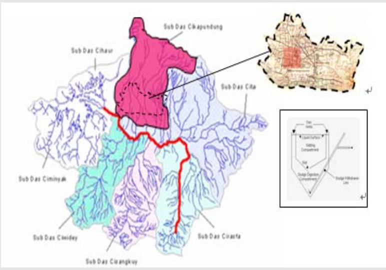
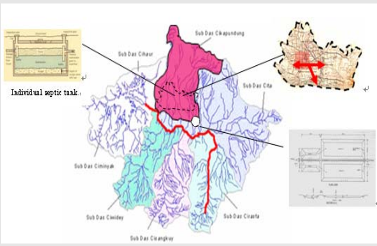
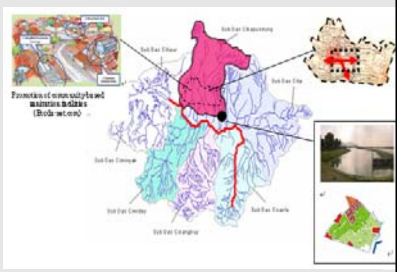
Phase	Year	Description	
1	Phase 1 (Before 1979)	The first sewerage system in Cikapundung Sub-Basin (Bandung city) was built by the Dutch. Basically no treatment applied for the city in this phase. Imhoff Tank used to be the treatment system applied. However, it had no longer functioned due to excessive load and continuous operation in the past without proper maintenance. Sewerage coverage less than 10%. Concern over wastewater management was relatively low in this phase. Concentration was mainly on provision of basic sanitation facilities such as MCK (toilet). On-site wastewater treatment is served by individual Septic Tank has been introduced but in a very limited number.	
2	Phase 2 (1979-1993)	Through Bandung Urban Development Project (BUDP) the sewerage system in the city was expanded during this period. In addition WWTP is started to be constructed. Sewerage connection still less than 20% coverage. An increasing on-site wastewater treatment introduction during this phase. Individual Septic Tank is relatively more than and communal Septic Tank. Coverage around 35% (estimated).	

Table 5.1– Development phases of sewerage and on-site system in upper Citarum Region (Cikapundung Sub-Basin) - continued

Phase	Year	Description
3	Phase 3 (1994-2007)	Centralized domestic wastewater treatment plant in Bojongsoang covering Bandung city started operating in 1994. Sewerage connection reach about 20% population. On-site wastewater treatment in the form of Communal Septic Tank is highly encourage, especially for high population density in urban area. These on-site system serve the population coverage estimated of about 55% 

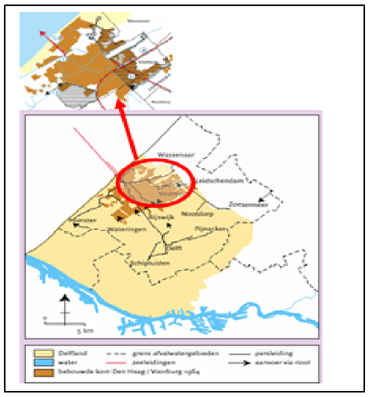
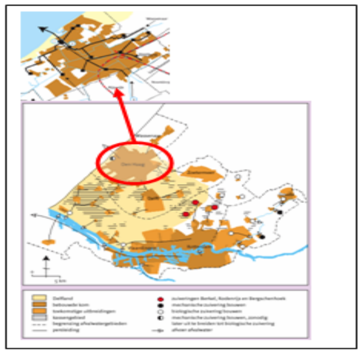
Note: Conclusion: In Cikapundung Sub Basin (upper Citarum Basin), Basin Management System has been applied to some extends in a limited area. This include old public sewerage developed by the Dutch in the origin of Bandung City area and further extended outward especially to the eastern part of the city. Non-structural measure has been conducted in some areas with individual septic tank. However, the coverage is still relatively low. Recently, communal treatment system has been introduced and promoted.

Table 5.2– Development phases of sewerage system (Suwa Region)

Phase	Year	Description	
1	Before 1979 (No *to limited* sewerage connection; less than 7.2%)	Wastewater treatment system was relied on on-site system. Johkasou systems spread rapidly in the 1960s when the demand for flush toilets heightened strongly with an increase in people's lifestyle.	
2	1979-1987 (Introduction of sewerage system; connection of 7.2-50.5%)	Start of operation of sewage works Lake Suwa basin sewerage service start（Okaya-shi, Suwa-shi, the Shimosuwa-cho public sewer) and change its name of Lake Suwa construction office to Lake Suwa basin sewerage office	
3	1988-1993 (First Expansion of sewerage system; connection of 55-71.4%)	Expansion of sewerage service started to serve the area of Hara Village	
4	1994-1997 (Introduction of Advanced System; connection of 73.7-82.4%)	Advanced wastewater treatment has been introduced at Toyoda Sewage Treatment. The removal rate of BOD can be raised and highly efficient removal nitrogen-phosphorous can be achieved through the addition of new processes (Modified Ludzack-Ettinger Process+Rapid Filtration in addition to Recycled Nitrification/Denitrification Process)	
5	1998-2005 (Second Expansion of Sewerage System; connection of 85.5-97.1%)	Expansion of sewerage service started to serve the area of Fujimi City	

Note: Basin Management System has been effectively applied in Suwa Basin, Nagano Prefecture (Japan) including Johkasou as on-site wastewater treatment at the beginning phase where the public sewerage coverage was still relatively low. Gradually, structural measures was increasingly introduced and promoted to include higher coverage of population. Additionally further development of structural measures was introduced in through constructing more advanced sewage works system.

Table 5.3 – Development phases of sewerage system (Delfland Region) *)

Phase	Year	Description	
Phase 1 (Initiation phase of sewerage work construction development)	Before 1970	Sewerage system in Delfland (Rotterdam) was already developed in 1800s. The widespread development of urban sewer systems only began on a large scale starting from around 1930. During the same period, the municipalities in particular built the first works where wastewater was purified before being discharged into the surface water. In this phase, about up to 44% population covered by sewerage system is estimated.	 (Source: Jan van den Noort, Rotterdam 2003)
Phase 2 (Extensive sewerage work construction development)	1970-1980	The coming into effect of the Pollution of Surface Waters Act in 1970 gave a new impetus to the construction of sewage treatment plants. In this phase, the population served by sewerage system rapidly increased reaching 86%*) of the population in 1980.	 (Source: Jan van den Noort, Rotterdam 2003)
Phase 3 (Maintaining high population coverage with more than 95% of population)	1981-2004	In 2004, Delfland region has 12 municipalities and 1,200,000 inhabitants with 5 WWTP**) (RIONED, 2006). In this phase, 96%*) of population is connected to sewerage (1998); 98%*) of population is connected to sewerage (2001); 99%*) of population is connected to sewerage (2004).	 (Modified from www.hhdelfland.nl in Enserink et al, 2003)

Note: The structural measure in the West Rhine Basin (Delfland Region), South Holland Province, the Netherlands, has been extensively developed. This has indicated that the structural measure is more dominantly applied compared to the non-structural measure. This indicates the total Basin Management System applied is highly through structural measure.

*) Using the pattern of total sewerage coverage in The Netherlands **) Wastewater Treatment Plant