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Sustainability Evaluation of Wastewater System in
Bandung City

バンドン市の下排水システムのサステナビリティ評価

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ABSTRACT

As one of the biggest city in Indonesia, Bandung has been experiencing considerable economic development and followed by rapid population growth at the same time. Since then, the need for sufficient water supply and sewerage service had strongly emerged for a better life standard in the future; this need had been fulfilled by constructing a centralized wastewater treatment in Bandung city. Demand for the development of the present system towards more sustainable future has been increasing. Many attempts have been done by either the local government or the water company to fulfill the wish. Yet oftentimes one effort that supposed to be a solution for one problem is producing another problem as a by product. As time goes by, the problem within the wastewater as well as urban water system has shown it shape in more complex way. A constructive way of working with wastewater system is to formulate a set of operational sustainability criteria and indicator. This case study applied SDI to evaluate the current wastewater system in Bandung city, Indonesia. The result of the evaluation confirms that the wastewater system of this city is not moving toward sustainable development. Service reliability is the key point that determines whether the whole system could really work well or not. Improving the service reliability is one important thing to do to help the system moving toward sustainability.

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Chapter I

INTRODUCTION

1.1 Research Background

As one of the biggest city in Indonesia, Bandung has been experiencing considerable economic development and followed by rapid population growth at the same time. Since then, the need for sufficient water supply and sewerage service had strongly emerged for a better life standard in the future. In 1992, using the ADB financial aid, Bandung Urban Development Plan (BUDP) was conducted. As a part of the program, a wastewater treatment plant was established and readily operated and sewerage channel was also installed across the city. However, the water company as the institution in charge for operating, maintaining and developing the urban water system, seems to be failed to make the citizen of Bandung city comprehend the necessities of using the wastewater system facilities. That is why; this project seems to be not so satisfied, if we refer to the improvement of water shed quality and sanitation conditions of the city. Demand for the development of the present system towards more sustainable future has been increasing. Many attempts have been done by either the local government or the water company to fulfill the wish. Yet oftentimes one effort that supposed to be a solution for one problem is producing another problem as a by product. As time goes by, the problem within the wastewater as well as urban water system has shown its shape in more complex way. As a reaction to these phenomena, voices are arguing for what kind of change or improvement or alternative should be taken for a better wastewater system.

Sustainability concept is appears as one likely approach for resolve the wastewater system in Bandung city. Although some scientist consider sustainability concept as an ambiguous concept yet it has the ability to explain and unravel the complex situation in a holistic perspective. In a decision making process, it is always essential to use a holistic way of thinking when comparing different alternatives. However, before coming to the stage of determining the alternative, it would be better if we could see or map the current situation and find out where the current development is leading us.

One good approach in evaluating the sustainability of a system is the sustainability development indicator (SDI). The common way of doing research using SDI is starting from a general perspective about wastewater system. From this part, the category, criteria and indicator for sustainable development is acquired. This set of indicator is afterward being tested by picking one

place as a case study and conduct the evaluation on the real wastewater system of the case study. Instead, in my study I derived the set of sustainable development indicator directly from the case study, Bandung city. Through a field survey over the case study, I have collected some facts and data which are very useful for developing the set of indicator. Then, the set of indicator is applied right away on the case study itself. The result of the evaluation is expected to be constructive enough for helping the current wastewater system to moving on toward a sustainable level and as well, hopefully any other similar systems could get some benefits by learn some things from this evaluation. The difference between the sustainability evaluation path that had been done by other researchers before and the sustainability evaluation path that I did can be seen in figure 1.1 bellow.

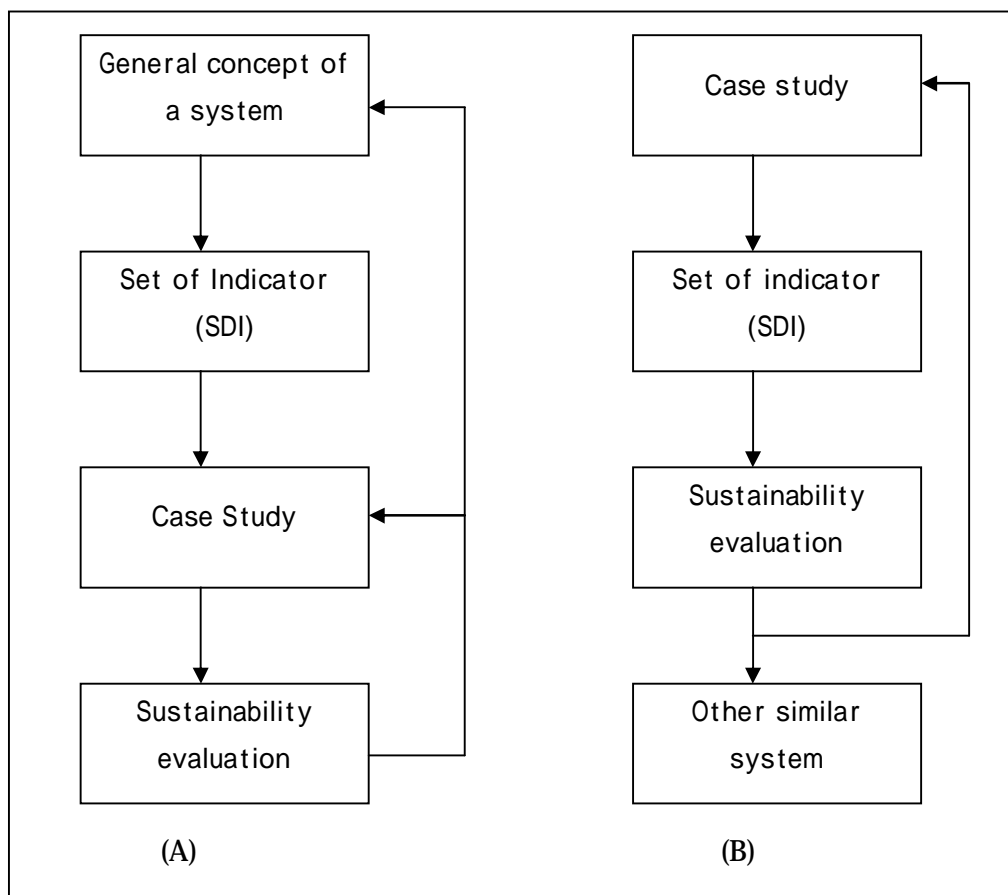


Figure 1.1 The common path of sustainability research (A) and the path of sustainability research in this study (B)

1.2 Research Objectives

The objectives of this master thesis are:

1. Evaluate the sustainability of the wastewater system in Bandung city, Indonesia using sustainability development indicator approach.
2. Suggesting some improvement which necessary to help the wastewater system in Bandung city moving toward sustainability.
3. Finding a critical point which determines whether the wastewater system in Bandung city could move toward or away sustainability.

Chapter II

CASE STUDY OF THE RESEARCH

2.1 General information of Bandung city

2.1.1 Geographic

- altitude and longitude

Bandung city is located at 107° 32' 38.91" east longitudes and 6° 55' 19.94" south latitudes, around 180 km away in southern Jakarta, the capital of this country. The position of Bandung is considered to be strategic because it is located in highway axis between:

- a. North and south, able to facilitate the traffic service for plantation in northern part of the city
- b. East and west, facilitate the connection to Jakarta, the country's capital.

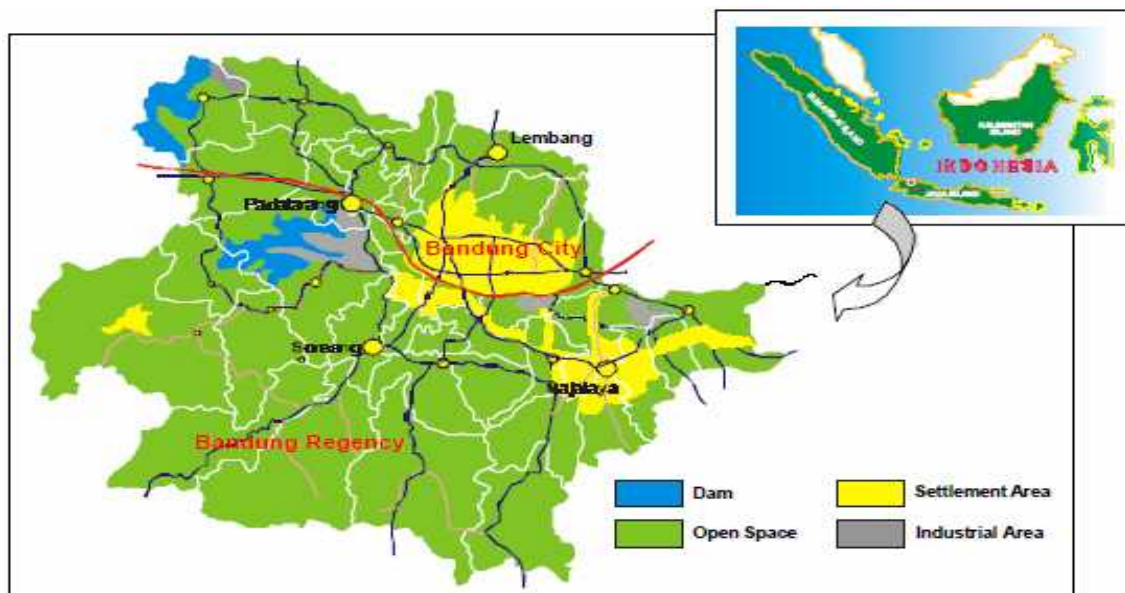


Figure 2.1 Bandung city map and Indonesia (inset)

- Geological condition

Topographically, Bandung city is situated 791 meters above the sea level. The highest point of the area is located around 1050 meters above the sea level while the lowest point of the area is located around 675 meters above the sea level. Both figure 2.2 and figure 2.3 will describe the geological condition of Bandung city in an geological illustration.



Figure 2.2 The Landscape image of Bandung city.

Both Bandung city and Bandung regency are located in a basin, which known as Bandung Basin. This basin is originally constructed by eruption of volcanoes in the north, east and south. The geological condition and soil in Bandung City area was built at quarter's period and have alluvial soil layer from Tangkuban Perahu Mount explosion.

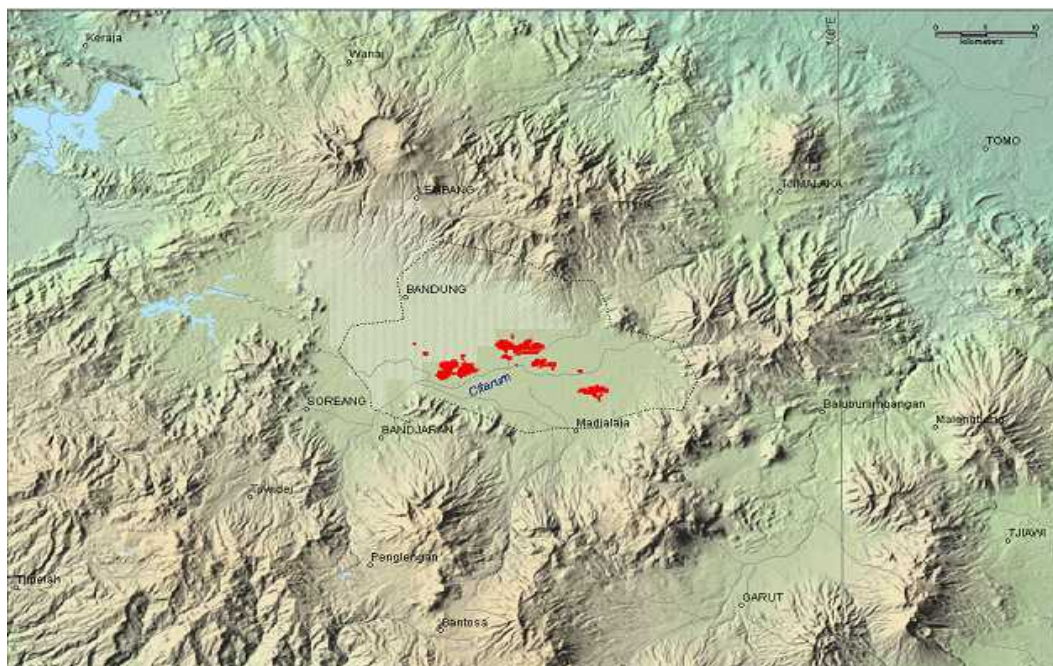


Figure 2.3 the geological condition of Bandung city

- climate

The climate in Bandung city is affected by mountain climate which is humid (over 60% humidity) and cool. The average temperature is 23.6°C. The average rainfall in Bandung city is 154 mm and there are 15 days of rainy day every month (Bandung Annual Statistic, 2003).

2.1.2 Demographic

Bandung city is the capital of west java province, Indonesia (figure 2.4). This city includes 26 districts within northern, western, eastern, southern and center of Bandung city. As the fourth biggest city in Indonesia, Bandung city also face a rapid population growth. By March 2004, the population has reached 2.5 million within 167 km² area of Bandung city. There are more than 1.2 million households exist in the city where only around 40% which connected to the sewerage system. With a high population density (150 person/ha) and rapid population growth, the urgency for clean and stable water distribution all over the city is very strong.

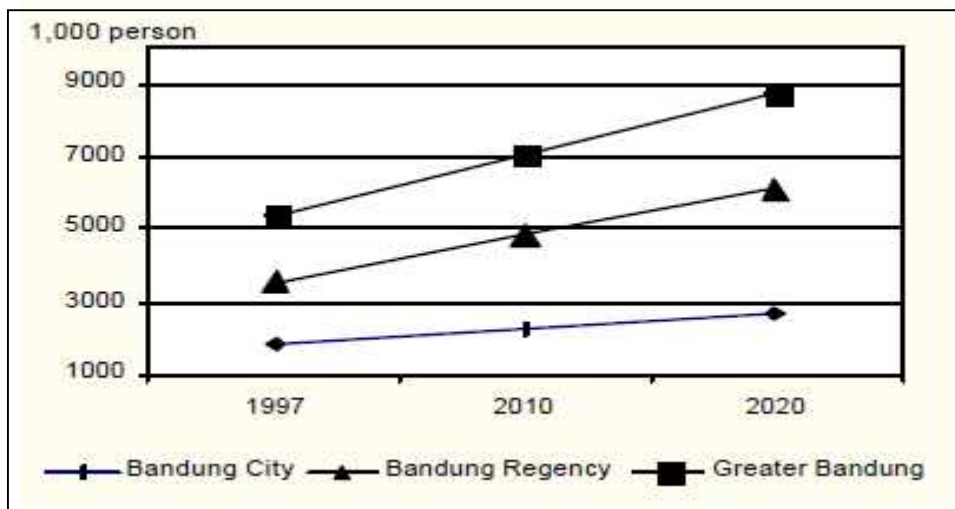


Figure 2.4 Population growth prediction in Bandung city, Bandung regency and Greater Bandung

2.1.3 Urban water system in Bandung city

The water system which consist of drinking water and wastewater is become the responsibility of the Bandung city water company or Perusahaan Daerah Air Minum (PDAM). This is a government owned company. As a consequence, the local government must grant this company certain amount of subsidies for supporting the operational and maintenance of the company. However this subsidy is only cover some part of the operation and maintenance cost. And unfortunately, the rest of the cost is charge to the water company's customers. The customer of the water company is including household, industries, office buildings and agriculture.

2.1.4 Watershed in Bandung city

Citarum watershed is the only watershed that straddles in Bandung city. Citarum watershed is also one of the biggest watersheds in west java province. Citarum River is straddling the west java province, flowing from the southern java to northern java which finally goes to Java Sea. Total area of the watershed is 6,614 km² with 269 km length, as can be seen at figure 2.6. The spring of the watershed is located in Wayang Mountain, 40 km from Bandung city. And the estuary of the watershed is in Tanjung Karawang. This watershed is the feeder for three artificial dams;

- Saguling, constructed in 1986, 982 million m³
- Cirata, constructed in 1988, 2165 million m³
- Jatiluhur, constructed in 1963, 3000 million m³

This watershed is also become the water source for agricultural field where it is able to irrigate around 300,000 ha of agriculture field. This watershed is also use as one of drinking water resource for several big cities along the watershed such as Bandung city, Jakarta city, Purwakarta, Bekasi, Karawang, Cianjur and Cimahi. Some of these areas are the key rice producer in Indonesia.

2.2 Wastewater system

To complement the urban water system, Bandung city's water company also constructed a centralized type of wastewater system. And the available water transportation system is mainly combined type of sewer system. The scheme of the wastewater system in Bandung city is given in figure 2.5 bellow.

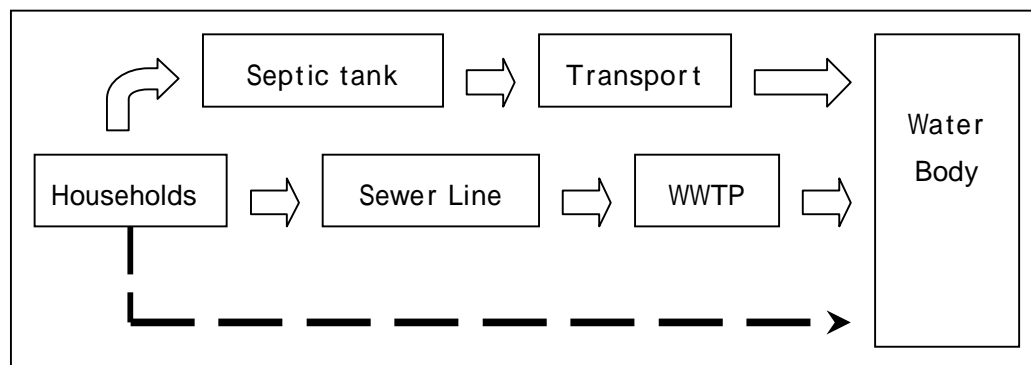


Figure 2.5 The scheme of wastewater system in Bandung city

2.2.1 wastewater distribution system

Since it started the operation in 1992, the sewerage system is able to cover only 30% of the total population. It includes eastern, central and southern area of the city. In order to cope with this problem they already construct two types of distribution system:

a. Main sewer line

The main sewer line only covers some part of the city. Everyone who is customer of the water company is supposed to discharge their wastewater into the main sewer line. As a matter of fact, not every one is able to receive this service, since the sewer line remains covered some part of the city.

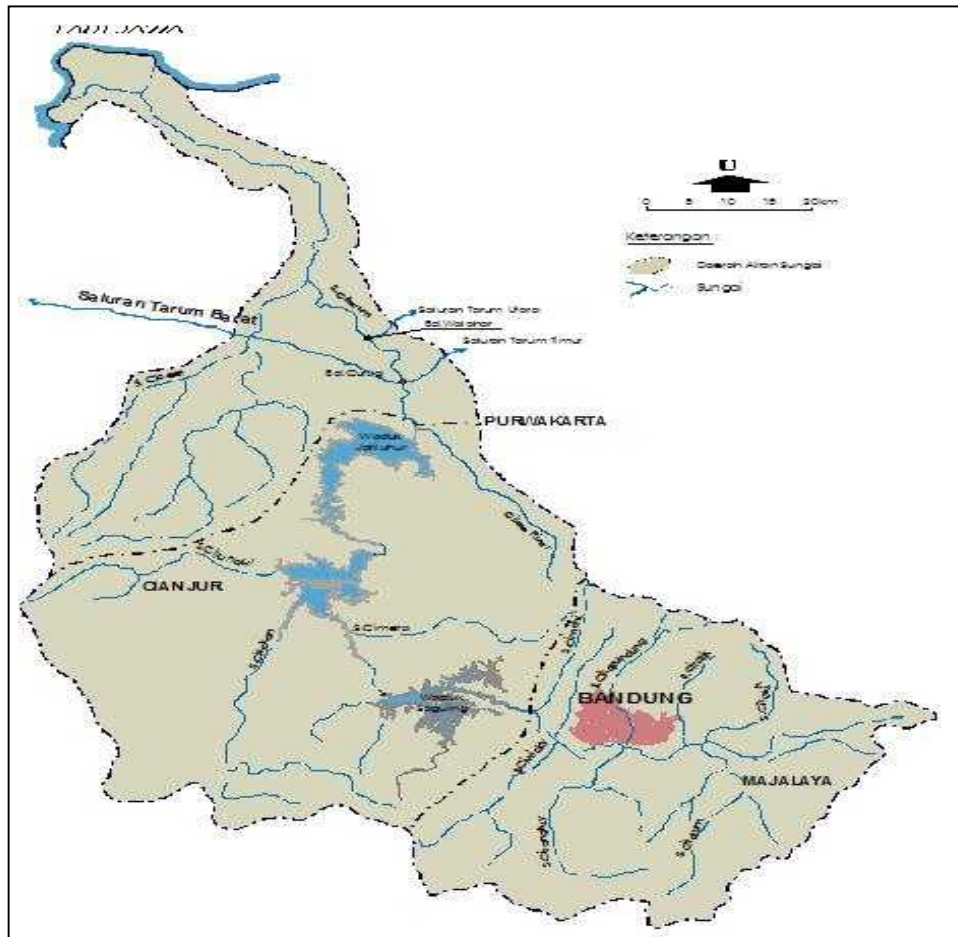


Figure 2.6 Citarum watershed in West java province (source: west java EPA)

b. Septic tank

This septic tank system is expected to cover some part of the city which is not covered by the main sewer line. There are two kinds of septic tank; the individual septic tank and communal septic tank. However in many cases, the septic tank is poorly controlled and poorly managed. This condition is even worsened by the fact the wastewater division, as the division who responsible for this issue, only provide 2 tanks for septic tank service across the city. This number is definitely not sufficient to do a regular operation such as pumping and delivering wastewater from the septic tank to the wastewater treatment plant.

2.2.2 wastewater treatment plant

To fulfill the needs of high quality of watersheds, the wastewater treatment plant is then constructed to reduce emission of pollutant from domestic wastewater before it discharged to the watershed. Using the financial aid from ADB, the Bandung city government established a wastewater treatment plant together with the sewerage line across the city. The wastewater treatment plant is located in Bojongsoang district of Bandung regency.

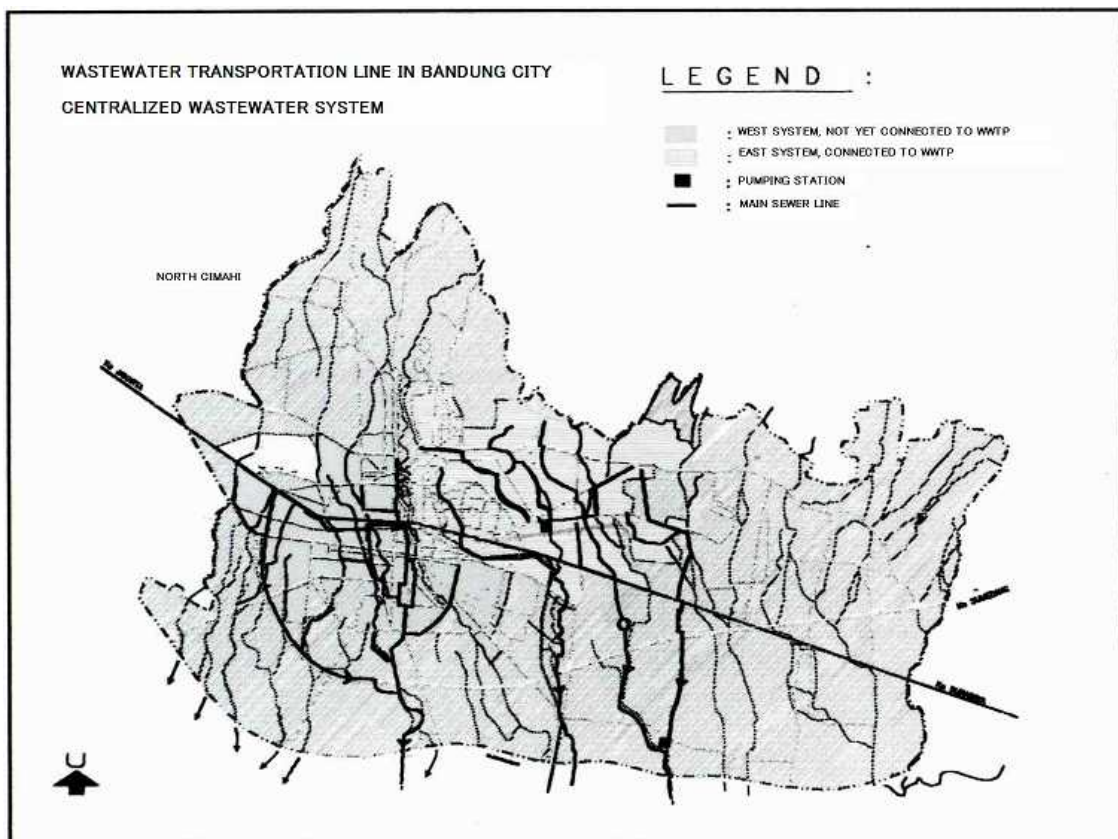


Figure 2.7 Sewerage line in Bandung city wastewater system (source: PDAM Bandung)

2.2.2.1 the existing wastewater treatment plant

The existing wastewater treatment plant is operated using oxidation pond process. The capacity of the pond is very high around 80,000 m³, with retention time is around 10-12 days. Unfortunately with that large amount of capacity is not supported by a good wastewater distribution system, which made not all wastewater from the city can be delivered to the wastewater treatment plant.

The treatment process of this wastewater treatment plant is consisting of physical and chemical treatment including:

- Bar screen, to filtrate large size solid waste (>50 mm)

- Screw pump, pumping water out of the sump well to grit chamber
- Mechanical bar screen, for small size solid waste separation (20mm-50mm).
- Screening press, to solidify the remaining waste from the mechanical bar screen by pressing it.
- Grit chamber, where the sand and mud is separated.

The complete process of wastewater treatment is also explained by figure 2.8.

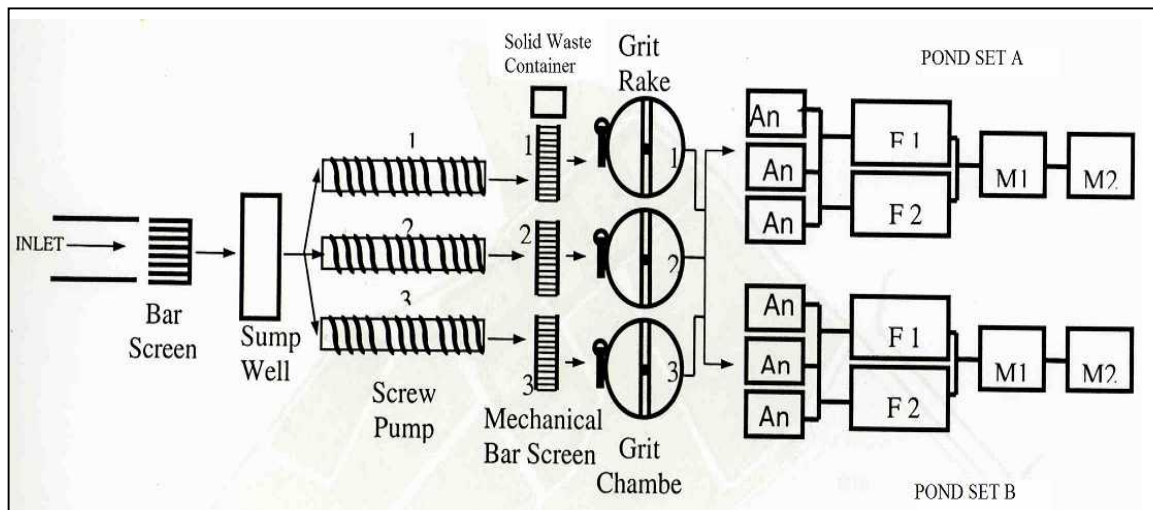


Figure 2.8 Wastewater treatment plant scheme (source: PDAM Bandung)

The biological process within the stabilization process including several steps such as:

1. anaerobic process, carried out in 3 anaerobic ponds
2. facultative process, carried out in 2 facultative ponds
3. maturation process, carried out in 2 maturation ponds

The ponds arrangement can be seen in figure 2.9. The effluent of the wastewater treatment process will go into the water bodies which also a part of the Citarum watershed. The effluent is definitely must fulfill the government minimum standard of water quality to watershed.

The technical design of stabilization ponds is described in table 2.1 below.

2.2.2.2 the new additional wastewater treatment plant

In order to reach other areas that has not yet covered by the existing system, the water company has been trying to develop a new infrastructure for additional sewerage line and additional wastewater treatment plant. The western and northern part of the city had been discharging their wastewater to watersheds. Both the government and the water company did not consider the situation in this area seriously because most of the areas are used for settlement or real estate. But as the economic and

population keep on growing, many houses, offices and real estate had been developed in this western and northern area.

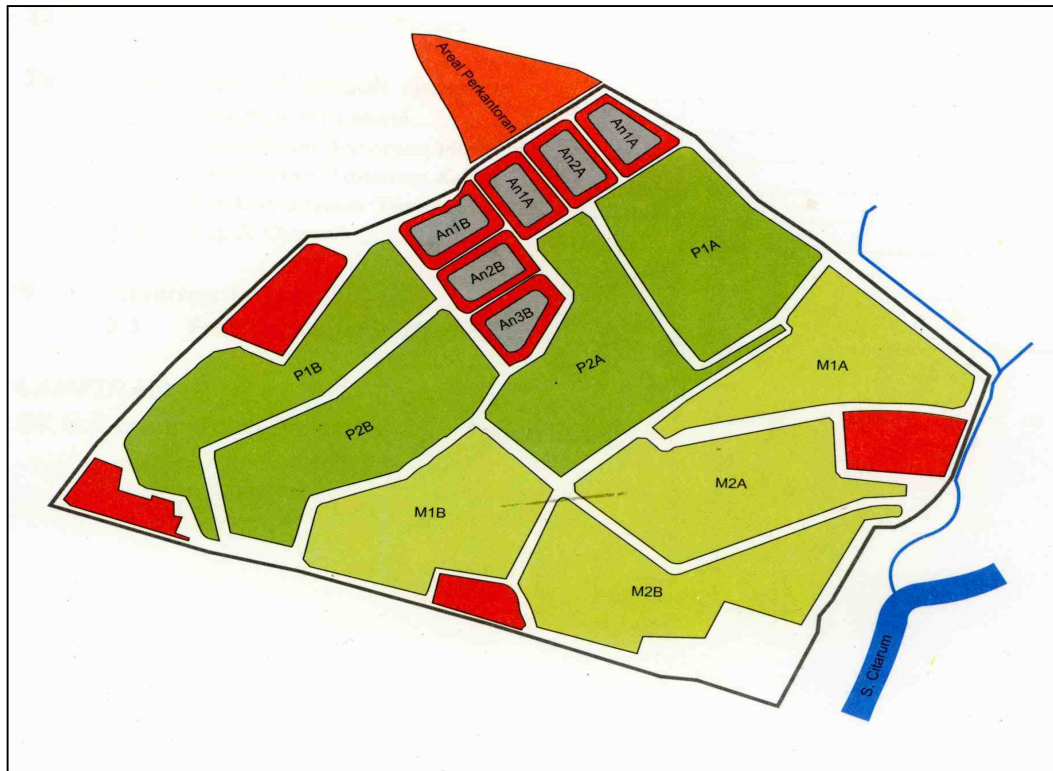


Figure 2.9 Pond Arrangement in Bojongsang WWTP, Bandung (source: PDAM Bandung)

The new additional treatment plant is actually the wastewater treatment plant that used to be operated more than 30 years ago. That old wastewater treatment plant was constructed by the Dutch during the colonialism period. Around 30 years ago, the Bandung city local government remains operated this plant. Nonetheless, lack of maintenance because lack of knowledge to do maintenance, had made the wastewater treatment plant can not performed in satisfy level. That old wastewater treatment plant had been stopped their operation for the last 30 years. And now, the Bandung city government wants to reconstruct the plant so this plant can be used to treat wastewater from some other areas.

As a consequence of this plan, they must install a new sewer line in some areas which suppose to cover by this new wastewater treatment plant. This plan for installation of new domestic sewer line is also confirmed by the wastewater division of the water company. They have expectation that the renovation of the old wastewater treatment plant and the installation of the new sewerage line across the city could be accomplished within several years ahead.

Table 2.1 the technical design of Stabilization ponds in Bojongsoang WWTP

Parameter	Type of Pond			Unit
	Anaerobic	Facultative	Maturation	
Debit	80,835	80,835	80,835	M3/day
Volumetric	275	300	-	gr.BOD/m3/day
BOD influent	360	144	50	mg/l
Total organic matter	20,100	11,640	-	gr.BOD/m3/day
Retention time	2	5-7	3	Days
Depth	4	2	1.5	M
Area	4.04	29.8	32.5	Ha
Temperature	22.5	22.5	22.5	oC
BOD effluent	144	50	30	Mg/L
Fecal coli	108	-	5,000	Mpn/1000ml

(source: PDAM Bandung)

2.2.3 sludge handling

As well as other wastewater treatment process, sludge always emerged as by product and another problem yet to be solved in this place. This treatment plant owns several large ponds for the treatment process, and these ponds produced a lot of sludge as by product of the process. Normally the wastewater division will dig the sludge out of the pond whenever the amount of sludge is over the limit. The complete process of sludge handling is described in figure 2.10 bellow.

After collecting the sludge, they mainly dry it and then pile it up in the municipal solid waste final disposal site. Based on the lab analysis of heavy metal content within the sludge, this sludge as the by product from the wastewater treatment process is not recommended as fertilizer for certain type of plants such as rice or any kind of vegetables. For non-consumption plants such as flowers or any kind of decorative plants, the sludge may be used as fertilizer. These pictures (figure 2.11 and figure 2.12) bellow depicted the utilization of sludge from the treatment plant for flower in areas of the treatment plant in Bojongsoang, Bandung.

In Bojongsoang wastewater treatment plant also established a place to cultivate some kinds of plants by using the sludge from the treatment plant, which can be seen from figure 2.12. They also have a greenhouse for cultivating some types of plants. All of this effort is considered as an attempt to reuse the sludge from the plant.

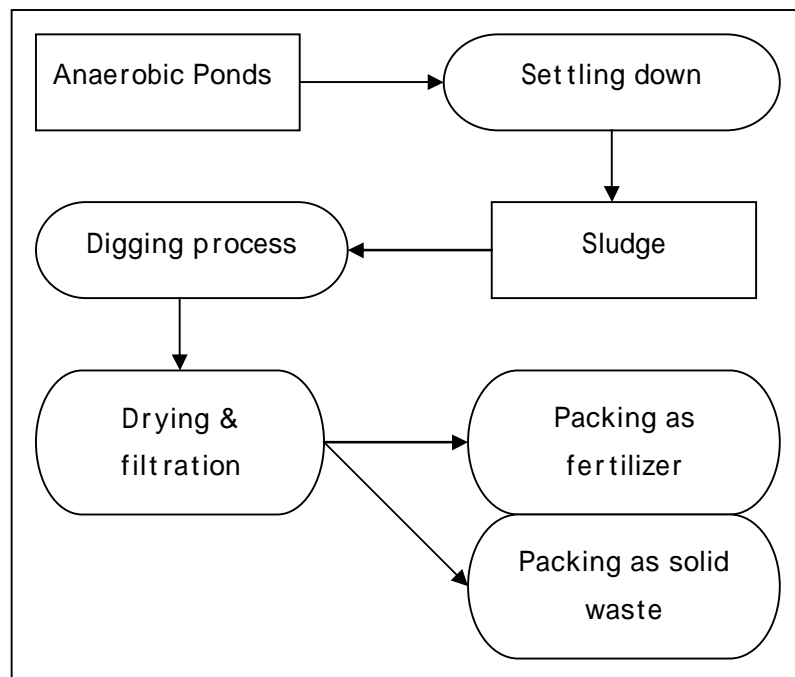


Figure 2.10 the scheme of sludge handling process in Bojongsoang wwtp



Figure 2.11 Decorative plants in Bojongsoang WWTP



Figure 2.12 Sludge reuse for plants in Bojongsoang treatment plant

2.3 Problems in wastewater system in Bandung city

Bandung city wastewater system is actually a developed system, so the system has not yet well established. That is why, during that process, the Bandung city face a lot of issues related to wastewater system, as follows.

2.3.1 service reliability

Service reliability is the ability of the water company especially wastewater division to provide a sufficient or a better service for the entire city. In terms of service reliability there are three problems which have been emerging since the wastewater system started its operation.

a. service coverage

As been mentioned above, the water company is only able to cover around 30% of the total population of the city. This fact came with several consequences, as follow;

- untreated domestic wastewater to watershed

One consequences of not become a customer of water company is they are not able to discharge

their wastewater to the domestic sewer line. The cheapest and instant way to solve this problem is by discharging their wastewater to the nearest water body, as can be seen in figure 2.13 bellow.



Figure 2.13 discharging their wastewater to the nearest water body

- groundwater exploitation

Since there are numerous people who are not belong to the water company, these people mainly provide their daily water need by extracting the groundwater using water well. The uncontrolled groundwater extraction activity has been threatening the availability of groundwater as one water resource. The typical well which used in household for pumping out the groundwater can be seen in figure 2.14 bellow.



Figure 2.14 the groundwater well in one house in Bandung city

b. treatment performance

The treatment plant is basically one important part of the wastewater system. This existence of this plant is aim to reduce the emission of pollutant within the wastewater before releasing it to the water body. However, the Bojongsoang wastewater treatment performance is not stable enough to perform a good operation. Up and down of wastewater influent is often claimed as one major caused of the ineffectiveness of the wastewater treatment plant.

c. domestic sewer line coverage

The water company admitted that they have difficulties in spread the domestic sewer line all over the city. That is why, the current domestic sewer line only cover some parts of the city. Unfortunately some people who are not suppose to discharge their wastewater to that sewer line; able to release their wastewater to the sewer line, yet some other who is the customer of the water company could not receive that service that they suppose to get because they live far from the main sewer line. And oftentimes, to connect your house to the nearest sewer line may cost you a lot of money and lot of times.

2.3.2 sanitary

One component of the sanitation system in Bandung city is septic tank. Since the sewerage line can not cover the entire city, and then the use of septic tank is very common in this city. However, the septic tank is sometimes is poorly controlled and maintenance. This condition often times blamed for the high number of water borne disease in the city, especially during rainy season.

2.3.3 inappropriate sludge handling

Regular maintenance upon the ponds in oxidation pond technique is necessary. An important kind of maintenance is sludge removal from the pond, in order to avoid overload of the pond to happen. Nevertheless, the water company is not able to perform a regular sludge digging out of the pond. One officer in the water company blamed the lack of finance that the wastewater division currently faced. To remove the sludge from one pond will cost a lot of money whereas they have 13 ponds to be cleared regularly. This issue perhaps will not influence the water quality right away, yet whenever the pond can not endure the sludge and the wastewater, then the water quality issue could emerged.

2.3.4 Untreated wastewater reuse for agriculture activity

The wastewater treatment plant is located in Bojongsoang district in Bandung regency area. This treatment plant area is located very close to agricultural field. As can be seen from figure 2.x above that the water body as the receiver of effluent from the treatment plant is located pretty far from the agricultural field. This paddy field highly depends on rain water to irrigate their field. So when dry season comes, the farmer will face difficulties in finding water to irrigate their field. Then the farmers pumped out the untreated wastewater from the sewer channel into their field. This situation is taking place during dry season, which made the wastewater treatment plant has to stop their operation due to no influent to be treated.

This choice that had been made by the farmer is inevitably gives two impacts; for the farmer itself and for the wastewater treatment plant. The utilization of raw wastewater into agricultural field will cause health risk issue for the farmer and for the consumer of the agriculture product. As we know, the untreated wastewater contain many microorganism including virus or bacteria that may cause disease, if it exposure to human. The heavy metal content within the raw wastewater could be absorbed by the plant and deposited it inside. So any time we, human, consumes rice from that agriculture field, there is a chance that the rice would contained some heavy metal from the untreated wastewater and obviously caused health problem.

The water company has been trying to explain the dangerous risk of using the raw wastewater for irrigation. Yet since every dry season the farmer face the same problem over and over then they felt that they have no other choice than pumping out the raw wastewater from the domestic sewer channel into their field. Otherwise they can not growth their plants during dry season. Lately the water company already give up and let them use their untreated wastewater for their field and received the consequences that they must stop their operation during dry season which cause their ponds to be dry during that season.

2.3.5 Illegal discharge of industrial wastewater system to domestic sewer

Economic development in Bandung city is marked by the growth of home industries in the city. Though the existence of home industries has important role in economic aspect of the city, yet it is difficult to perform a monitoring toward their activity since most of them are not registered or an official company. Most of these industries are textile industries or handcraft industries.

It is been quite long time since the water company realizes that there is an infiltration of untreated industrial wastewater into the domestic sewer. This can be traced by the high concentration of some heavy metal in the sludge and in the effluent. Yet they hardly do anything, since it is difficult to state who should responsible for the heavy metal concentration in sludge and water body. Since Pb and Cd concentration is found quite high within the sludge and water body, we could say that this metal came from the dye that used in these home industries.

The existence of raw industrial wastewater in domestic sewer perhaps will not give a huge impact on the treatment performance of the plant. Yet since the wastewater treatment plant is not aimed to treat wastewater with heavy metal, then the heavy metal content will not treated but will goes into the river and the sludge, which cause inability of sludge reuse and watershed quality deterioration.

The description of issues in 2.3.4 about raw wastewater reuse for agriculture and in this part can be seen in chart of figure 2.15 bellow.

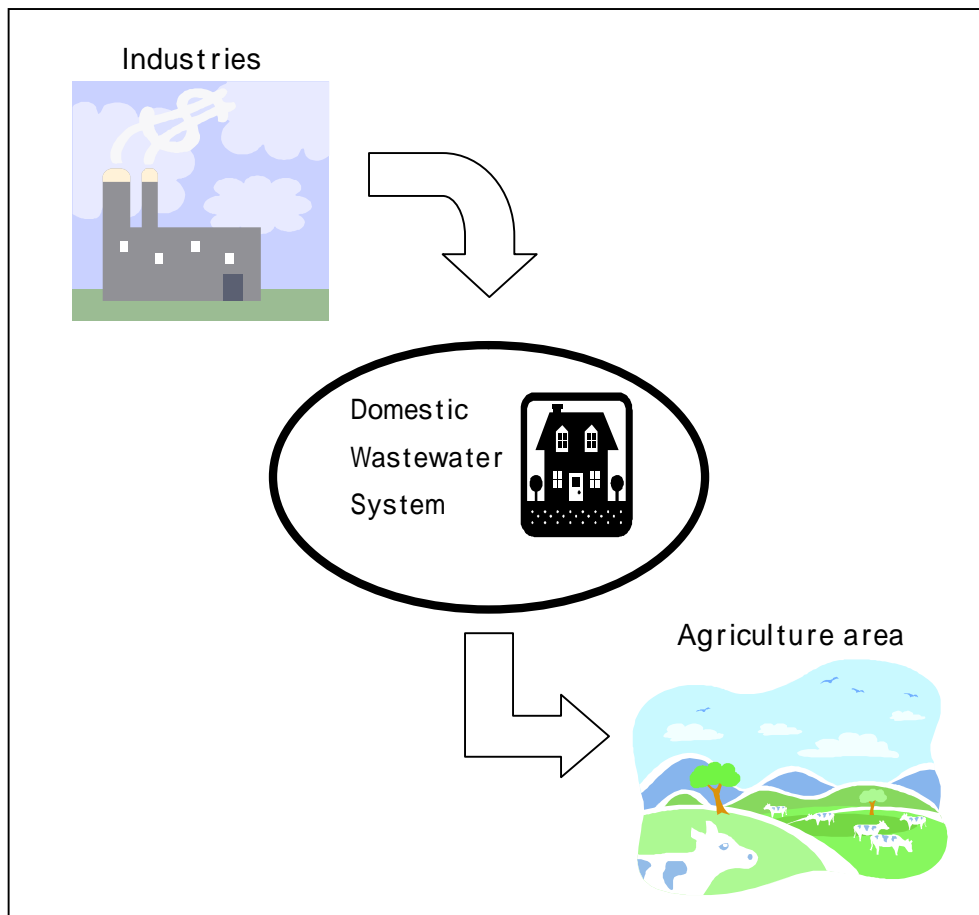


Figure 2.15 The scheme of Issues in wastewater system in Bandung city

2.3.6 Watershed quality deterioration

Bandung city as well as Bandung regency is currently attempt to cope with watershed quality issue. In Bandung city itself, the Cikapundung river as a a part of Citarum watershed, has been suffering from water quality deterioration for the last twenty years. The river that used to be clean and healthy now changing into its color into brown and sometimes spread unpleasant smell whenever we getting closer to the river. This watershed quality deterioration has lead to many issues including health risk issue since a lot of people who remains live at the river bank. There are a lot of factors which suspected for these problems such as land use change in the city and such practice like discharging the untreated domestic wastewater to the watershed is still very common. The situation of the watershed in Bandung city can be seen by the following pictures in figure 2.16 and figure 2.17.



Figure 2.16 Satellite photo of Cikapundung, used as campaign for cleaner cikapundung river by the west java EPA (source: west java EPA)



Figure 2.17 the figure of cikapundung river in Bandung city

Chapter III

SUSTAINABLE DEVELOPMENT EVALUATION

3.1 Sustainable Wastewater Management

Since the WCED published their report in 1987, we have witnessed a rapid increase of sustainability concept being adopted and adapted to many disciplines and sectors. In that process, although some people regard sustainability concept as the vaguest paradigms of contemporary society (Lopez-Ridaura et al, 2005), many NGOs, research institutions, or development agencies include sustainability in their agendas and design many alternatives which aimed at improving sustainability.

3.1.1 Sustainable development

The term “sustainability” and “sustainable development” suddenly emerge and become widely used for the last 20 years. This term is often used to illustrate an intended vision for development that provides solutions to current and future problems. Since a sustainable condition itself is a dynamic process, so “sustainable” definition will also different from time to time and place to place. Everyone could have their own version of “sustainable” and “sustainability”. Foxon et al for instance, he defines sustainable development as an attempt to ensuring a better life in for today and future. Yet the most popular and widely accepted definition of “sustainability” and “sustainable development” was coming from OECD’s version. According to Brundtland report made by OECD, sustainable development define as development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

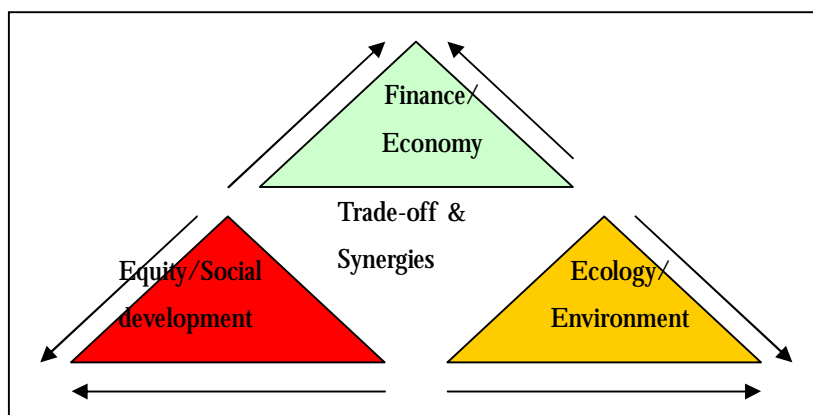


Figure 3.1 sustainability trilogy

Initially the term “sustainable” had an economic connotation relative to growth. But later on, it spread among other academic circles, and this term eventually used as an expression in economic, social and environment aspect as well. The WCED version of sustainability emphasizes many dimensions of it, such as natural resource exploitation, economic growth, security against environmental hazard and a fair share of resources around the world. And nowadays addressing sustainability concept can no longer be separated from the economic, environmental and social aspect.

3.1.2 Sustainable wastewater system

Technology has become an answer to many problems, including environmental issue by providing many alternatives for solution. We could easily recognize the advantages of the technology we implement, however oftentimes we miss some aspects which were not so obvious, hence less acknowledged. Yet afterwards, these aspects have a huge impact for the entire environment and the community as well. Take the conventional wastewater technology, covered centralized system and combined sewer system for instance. It often considered unsustainable because in this technology, water, energy or nutrient recovery is pretty hard to do. Besides In addition, dilution of wastewater streams containing pathogens and toxic compounds such as heavy metals and organic micro pollutants makes treatment more complex and requires higher levels of resources such as energy, money, space, and expertise, while still posing pressure on the environment through emissions (Balkema et al, 2002).

Sustainability concept offers a range of alternatives of how to attain a sustainable wastewater management, from improving the existing technology to substitute with a more sustainable technology (Kaarman, 2003). A constructive way of working with wastewater system is to formulate a set of operational sustainability criteria and indicator. In order to make it more operationally understandable, then some guidelines would be necessary.

The concepts of what sustainable wastewater management exactly is, describes as follow:

- Sufficient environmental protection by reducing the emission of pollutant to maintain the quality and the diversity of ecosystem.
- Wastewater and sewerage management must provide at least the minimum service to the community
- Low or no health risk of infectious disease or any toxic matter.

3.1.3 Sustainability evaluation

There are various ways of doing the assessment or evaluation of sustainability of a system as well as the wastewater system. There are two widely accepted methods for evaluating a sustainability of a system:

1. Single indicator

Although there are some limitations in using the single indicator for evaluating the sustainability of a system, yet many researchers still consider that using this single indicator is somehow more convenient. There is a lot of single indicator that has been used for evaluating sustainability such as:

- Exergy analysis

Energy can only be converted into different forms. The conversion of energy in a process occurs by the consumption of the quality of the energy. Thus, energy could be regarded as a carrier of quality, and it is this quality that is consumed during the conversion of energy (Wall, 1977). The quality of a flow of energy could be define as the useful part of the energy i.e. that part that can perform mechanical work. The term for this part of the energy is exergy, which is strictly defines as that part of the energy that convertible into all forms of energy (Wall, 1977).

The concept of exergy could be illustrated by using an example from Holmberg (1995) discussing the turnover of energy in a waterfall. In a waterfall the particles are moving in the same direction and a turbine could be used to extract mechanical work. If this is not done, when the water reaches the bottom of the waterfall, its kinetic energy is converted into heat. The particles are then no longer movin in the same direction but they move individually in different directions. The energy conserved but the energy is the heat is not available for work like the kinetic energy of the failing water i.e its exergy is lower (Hellstrom & Karrnan, 1997).

The advantage of the exergy analysis is when the sustainability concept is used to compare several systems then the whole comparison is based on a single unambiguously quantifiable indicator, namely exergy. Consequently, no weighting of different indicators is involved. Whilst this property makes this analysis straightforward, it is at the same time its limiting factor, as insight is only gained into the efficiency of the processes but not into the different environmental impacts (Balkema et al, 2002) .

- Economic analysis

The economic theory also suggests a single indicator approach. The central thought behind a sustainability assessment based on economic theory is that sustainability could easily be integrated into decision-making if expressed in terms of money. Tools such as: cost-benefit analysis, life

cycle costing, and total cost assessment, all balance the expected costs and benefits, and are often the first step in a project. In theory, all kinds of costs and benefits can be included, however in practice these tools are mostly used as a one-dimensional techniques incorporating only financial costs and benefits. The obvious reason is that most social and environmental costs are difficult to quantify (Balkema et al, 2002).

It is essential to realize that the translation of environmental and socio-cultural indicators into monetary values is a part of the decision-making process since it includes normative choices such as fixing values and weighting factors of different indicators. In a perfect market-economy, prices would reflect the value of things as perceived by society. However, no perfect market economy exists and especially in the water sector prices are regulated by governmental organizations with taxes and subsidies. As such, an in-depth economic analysis of the sustainability of water supply and wastewater treatment could provide a valuable insight in the real cost of water service (Balkema et al, 2002).

2. Multiple indicator

Methodologies using multiple indicators in order to evaluating the sustainability of one system which frequently used by many researchers are:

- LCA (life cycle assessment)

LCA is especially developed to assess different environmental impacts encountering during a product's lifetime. LCA is a structured methodology starting with defining the goal and scope of the study. Thereafter, a life cycle inventory of environmental aspects is made, based on mass and energy balances. Finally, these environmental aspects are categorised in environmental impact categories, such as depletion of resources, global warming potential, ozone depletion, acidification, ecotoxicity, desiccation, eutrophication, landscape degradation, etc. These categories can be normalised and weighted to come to a final decision whether to choose one technology or the other (Balkema et al, 2002).

The advantage of LCA is the well-described and standardized structure and the fact that it is applied to a wide range of products and services including the different parts of the urban water cycle. However, LCA has some drawbacks; the assessment of a complete life cycle requires a large quantity of data. Aggregation of the data into the standardized environmental impact categories means loss of insight into the emissions that are of particular relevance to wastewater treatment. Furthermore, additional indicators are needed to measure sustainability as LCA limits itself to a restricted set of technical and environmental aspects (Balkema et al, 2002).

The fact that LCA is mostly applied to the operational phase of wastewater treatment only, using adapted environmental categories, or additional categories such as reuse potential, social impact, etc, clearly reflects the mentioned disadvantages of LCA. If it is only the operational phase that is being assessed one should no longer speak of a LCA, but of a chain analysis or environmental impact analysis (Balkema et al, 2002).

- General system analysis

The general approach followed in a sustainability assessment of water services is a system analysis based on mass and energy balances providing an indication of material use, emissions, costs, and required land area. In principle, LCA is a type of system analysis, based on mass and energy balances and using indicators to assess the environmental impact.

LCA is usually applied to compare a few technologies on environmental impacts only, while the system analysis, as a rule, assesses more generally and abstractly by capturing the nature of the system in a mathematical description. In the case of urban water systems, the systems analysis focuses on the comparison of whole systems, often on a large number of systems, and uses a multi-dimensional set of sustainability indicators. Both looking at whole systems and using a multi-dimensional set of indicators, is essential to sustainability assessment. Looking at the whole system, one can find integrated solutions that may not be visible when looking at smaller parts of the system. Similarly, optimising in one dimension, for instance the environmental dimension, will improve this aspect of the system but may have unwanted effects in other dimensions, for instance the system may become unaffordable (Balkema et al, 2002).

3.1.4 Sustainability evaluation using indicators

Sustainable development evaluation provides necessary information for any related stakeholders. Sustainable development is accepted as vision for managing the interaction between environment and economic progress together with the social acceptance. But experts are still struggling with the practical problem how to implement and measure it. More often than not, they are faced with an information dilemma. On the one hand, information and information sources are proliferating at an astounding rate. On the other hand, they seldom seem to have the specific information required for decision making and effective management (Walmsley, 2002).

The use of sustainability indicator is one good method to overcoming this dilemma and also as an attempt to utilize the concept of sustainability in more practical way. Indicators provide a means of communicating information about progress toward a goal in significant and simplified manner

(Hammond et al, 1995). As one of accepted method, indicator offers numerous uses and potential for improving environmental management, such as (Hammond et al, 1995 and Walmsley et al, 1996):

- monitor and assess conditions and trends on a national, regional and global scale
- compare different situations
- assess the effectiveness of policy making
- mark progress against a stated benchmark
- monitor changes in public attitude and behavior
- provide early warning information
- forecast and project trends

OECD proposed following criteria to select a set of appropriate indicators (Walmsley, 2002):

- a. due to policy relevance and utility for users, indicators should be;
 - provide a representative picture of environmental conditions, pressure on the environment or social's response
 - be simple, easy to interpret and able to show trends over time
 - be responsive to changes in the environment and related human activities
 - provide a basis for comparisons
 - be either national in scope or applicable to issue of national significance
 - have a target or threshold against which to compare it so that users are able to assess the significance of the values associated with it.
- b. due to analytical soundness, indicators should be
 - be theoretically well founded in technical and scientific terms
 - be based on international standards and consensus about its validity
 - lend itself to be linked to economic models, forecasting and information systems
- c. due to measurability, the data required to support the indicators should be:
 - readily available or made available at a reasonable cost
 - adequate documented and of known quality
 - updated at regular intervals in accordance with reliable procedures

3.2 Research Work Scheme

In this figure 3.2 bellow shows the structure or the work scheme of the present study. I started by conducting the case study survey to Bandung city. Data used in this study is not only in form of statistical data but also based on field observation and interviewing several officers from institutions

that related with this wastewater system issue.

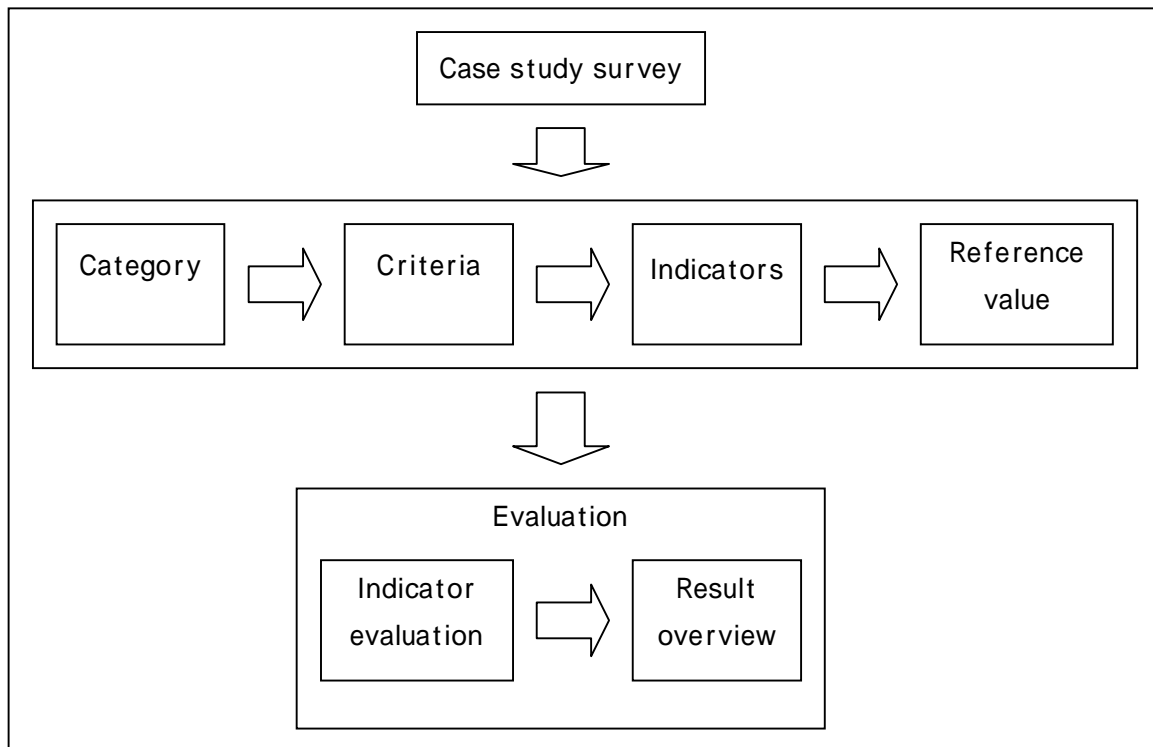


Figure 3.2 Research work scheme

After collecting some data and had a direct observation over Bandung city wastewater management, I tried to develop the category which broken down into criteria and resulting indicators. This set of indicator together with reference value, will then used as tool to evaluate the sustainability level of Bandung city.

3.3 Data for Evaluation

Unlike many other researches in sustainability, this study's first step is doing the survey in the case study, which in this study is Bandung city. In order to get some information and data from the city, there are three ways that have been done, as follows:

- Interview

By having a dialog with some officers in Bandung city's water company as the company who responsible in handling this wastewater issue. And also I have got a chance to contacted some people in west java EPA and have interviewed some of them. Some interviews also had been made with some city dwellers in Bandung city. Some information about the financial arrangement within the water company (which I explained more details in the institutional

management indicator), sludge handling information and also some information about problems that they currently faced (the illegal discharge of industrial wastewater and the pumping of raw wastewater from the sewerage channel into the nearest agriculture field).

They also informed me about their future plan to develop a wider service area by installing the sewer line all over the city and the plan to reconstruct the old wastewater treatment plant they used to have in order to cover some area of the city which has not covered yet.

- Asking for the data to institution related to wastewater issue

Before coming to Bandung city, I had set some data that I wanted to collect from the Bandung city. And also I have made some contacts with both the Bandung city's water company and the west java EPA and the Bandung city statistic agency, to confirm the availability of the data that I asked for.

Some data related to wastewater influent, effluent, wastewater quality and technical information about the wastewater treatment plant was gained from the Bandung city' water company. And other data about the watershed quality and groundwater quality was granted by the west java EPA. They gave me some data that also used by Dr. Setiawan Wangsaatmaja (the head of the west java EPA) for his dissertation.

Other data such as population, precipitation, humidity, water consumption was gained from the Bandung city statistic agency (BPS Bandung) and from the internet. And the geological information about Bandung city was obtained from the Bandung city geological agency.

Some other information was also obtained from the internet. From the local and national newspaper who published story about Citarum watershed quality deterioration. Information about environmental status of Bandung city could be obtained from the annual report made by the west java EPA which routinely published their report on their website. Some other information about Bandung city was also got from the official website of Bandung city.

- field observation

In order to get an accurate view about the sanitary and wastewater system in Bandung city, I got my self downtown Bandung city, visiting some places to other places. By this field observation I could get some visual data and facts which would strengthen the access to wastewater service indicator and confirm the fact that the direct discharge practice of untreated wastewater into the watershed is indeed taking place. Places that I visited are some area in

southern Bandung, central and northern Bandung city. I also had a chance to visit the Bojongsoang wastewater treatment plant in Bandung city and visiting the laboratory for examines the effluent quality of the wastewater treatment.

3.4 Sustainability Development Indicator

Based on some data that had been gathered, we are able to develop some indicators which can be grouped to some criteria and category. There are five categories which proposed in this research; technical, health, economic, environmental and social. After define each category, and then we could derive the indicators based on principles on each category and principles of a sustainable wastewater management.

The set of indicators selected were based on (Muga et al, 2007) :

- (1) The relevancy of the indicators to the wastewater treatment technologies
- (2) Their ability to indicate progress towards balanced sustainability or away from it, that is equal inclusion of economic, environmental and social aspects.

The system is represented by a number of dimensions broken down into indicators. The sustainability criteria that have been proposed in this research which used to derive the indicators can be broken down into five categories. And these criteria have been selected on the basis of five criteria:

- *Technical*
Water and sewerage management must provide at least minimum service to the community
- *Health*
Sustainability approach must ensure minimization of health risk from infectious disease or any toxic matters to human being.
- *Economic*
Efficient and effective allocation distribution of scares resources for a sustainable community's quality of life and a sustainable institution as a part of the stakeholders.
- *Social*
Sustainable atmosphere will encourage harmony relationship between stakeholders, which are marked by community awareness and professionalism of each stakeholder.
- *Environment*
The long term viability of the natural environmental should be maintained to support long term development by supplying resources and taking up emissions. This should result in protection and efficient utilization.

Based on the principles of a sustainable wastewater management and definition on each category above, each category is broken down into several criteria which later yield in indicators and reference value for every category and every criterion. The table 3.1 bellow shows the complete list of the indicators and reference value that proposed to assess the sustainability of wastewater system in Bandung city.

Table 3.1 Set of indicator for sustainability evaluation which developed in this study for evaluating the sustainability of Bandung city wastewater system

<i>Category</i>	<i>Criteria</i>	<i>Indicator</i>	<i>Description</i>	<i>Data availability</i>	<i>Reference value</i>
Economic	Water cost/capita	IDR (Indonesian Rupiah)	Most cases the problem in running the system is not lies on the construction cost [beginning cost] but at operational and maintenance cost. And the water company tries to earn more money by charging the entire customer for this service.	Available	Regional Income per capita per month
Health	Health risk of toxic matter exposure	<ul style="list-style-type: none"> - E.coli in groundwater - E.coli in waterbody 	- Groundwater is one of the major drinking water resources in this city. Poor septic tank controlled is often claimed as the poor quality of groundwater	Not available	Not exceeded the health department threshold
Environment	Water quality	BOD	BOD value could indicate that many untreated domestic waste	Available	At least meet the local and national standard

			still discharged to the water body. This could be either the insufficient wwtp performance or direct discharge of domestic waste		
		Heavy metal concentration	Heavy metal concentration indicate more on the infiltration of untreated industrial sewer to domestic sewer channel	Partly available	
		DO	One of important/clear indicator of water pollution, commonly use in indicating water pollution.	Available	
	Energy consumption	Litre gas/year	Water pollution relation with energy consumption is described in graph bellow.	Not available	As efficient as possible
	Sludge quality	heavy metal concentration	Indicate the number of untreated industrial wastewater in domestic sewer	Available	

			and indicate		
Social	Accessibility to sanitary facilities	High/low	Indicate the uneven accessibility to wastewater system from the local citizens. This accessibility to wastewater system has created many problems such as economy, social and environment.	Available	High
	Institutional management	High/low	The way the institutional in charged, arrange or manage the issues within them including the financial arrangement.	Partly available	High
Technical	Wastewater treatment performance	% removal	%removal would easily indicate the performance of the wwtp itself.	Available	
	Septic tank performance	- septic tank capacity - coverage area	Both indicators would indicate whether the septic tank could work as it supposed as one	Not available	

		of the wastewater distribution.		
System sensitivity	Volume of wwtp influent	Indicating the fluctuation in influent because of precipitation and illegal dumping. While the population increasing within the service area would have influence the wwtp performance also. Although the wastewater influent could also indicate the population rate or precipitation but by show the population and precipitation data we could also indicate any other aspect that might caused the wastewater raised.	Available	
	Precipitation			
	Water lost (Volume of untreated water being pumped)	Since the illegal pumping of raw wastewater quite often, this would an easy tool to	Available	

			<p>indicate how often and how serious this kind of occurrence happens.</p>	
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Chapter IV

EVAUATION RESULT

4.1 Sustainability development indicator evaluation

The sustainability evaluation is conducted in two sections; the individual sustainability indicator evaluation which explained bellow and another part is the overview of the evaluation result of the individual sustainability evaluation. Using sustainability development indicators, this part tried to give details about the current situation in Bandung city wastewater system, the trend that currently occur and future risk that might come about ahead. The result of this evaluation will be afterward used as a base for general overview analysis.

4.1.1 Economic

The economic aspect is a subject that aims to distribute the scares resources in effective and efficient allocation for a sustainable community's quality of life and a sustainable institution as a part of the stakeholders. The major issues in economic aspect of the wastewater management in Bandung city are the affordability of the local community to afford the water price and the ability of the water company to provide a sufficient amount of money to support the operational and maintenance cost of the wastewater facilities. Providing a sufficient fund for new construction is seemed to be not a big problem anymore, because they can gain sponsors from local or central government investment, foreign aid and etc. Although the ability of the system self supporting is one essential point to achieve the sustainable system, yet the core problem is begun to emerge when they have to deal with the operational and maintenance cost.

As a government own company, the Bandung city water enterprise's financial basis is supposed to be supported by the local government. The Bandung city local government is already granted this company with subsidizes which can cover certain part of the total cost to run the system. However, the amount of subsidize for drinking water division is somehow higher than the wastewater division. This situation made the wastewater division must push their effort harder to earn more money for their daily operation. Oftentimes this company experience deficit in selling their water. Since the operational and maintenance cost is keep increasing yet the amount of subsidize is not increasing, so they decided to let the customer bear the financial burden by charging more to the customer.

As regulated in the local government policy for water, the water cost in this city can be divided into three types of cost; drinking water cost, wastewater cost and cost for new construction or new connection. The arrangement of water cost in Bandung city is describe as bellow in table 4.1

Table 4.1 Water cost arrangement in Bandung city

Type of cost	Amount of cost
Drinking water	500 IDR/m3 (¥ 6.7/m3)
Wastewater	5000 – 38000 IDR (¥ 67 – 567)
Construction cost	800,000 IDR (¥ 10,700)

(Source: PDAM Bandung)

Originally the wastewater division did not charge anything to the customer for their service. But later then, when there is an inequity in government subsidize and profit shares between this division with drinking water division, had forced the wastewater division to earn some finance from the customers. Although many peoples in the city were against this plan, the wastewater company sticks to their plan and this regulation will be implemented soon.

Using this arrangement table above, we can estimate how much money is spent for water for each person by using an assumption. Let us assume that water consumption in Bandung city is around 200 /cap.day. Then, the result of the calculation can be seen from the table 4.2 bellow

Table 4.2 Calculation of monthly water cost

Type of cost	Amount of cost	Reference value
Drinking water	200 m3 x 0.01x30x500=3000 IDR	Income per capita per month: 1,023.059 IDR (¥ 10,700)
Wastewater	5000 IDR	
<i>Total</i>	<i>8,000 IDR (¥ 107)</i>	

If we compare the amount of monthly water cost with the income per capita per month in Bandung then we can say that everybody should be able to afford water with this price. But if we include the cost for new construction or new connection from the household to the nearest water pipe and again compare it with the income per capita per month of the city, then we can see how expensive it is.

The number of customer of the Bandung city water enterprise remains 30% of total population. This high price of new connection cost is often complained and blamed by the local citizens as the reason why they refuse to become the water company customer.

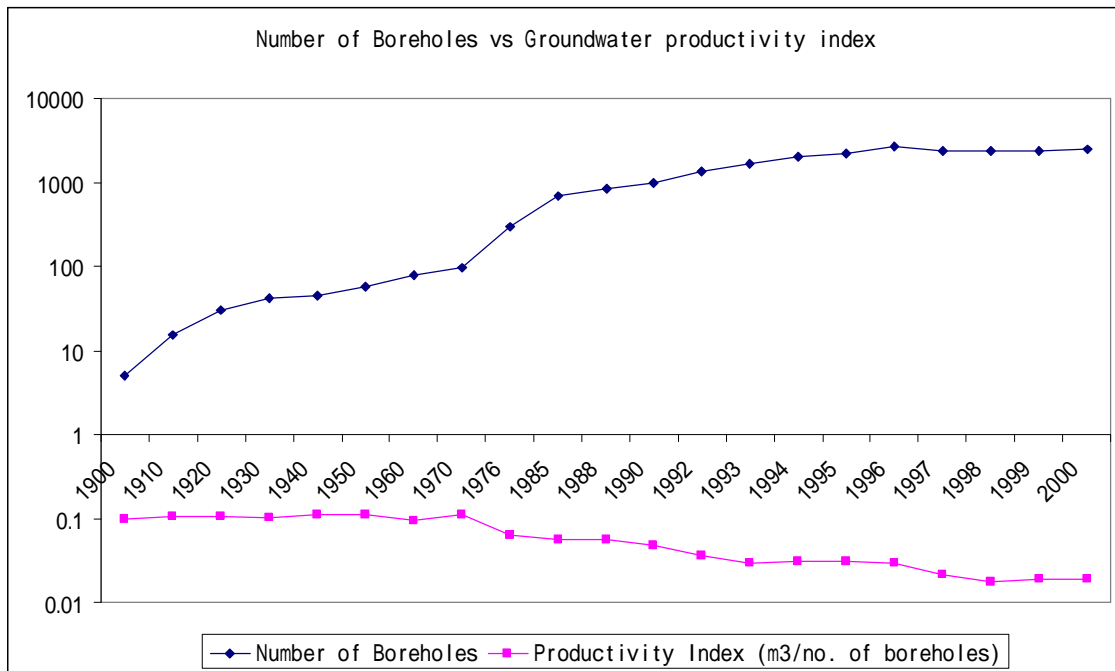


Figure 4.1 Groundwater productivity index and growth of boreholes (source: Wangsaatmaja, 2004)

Another thing is the high price for the connection does not come together with a good service from the water company, such as the long waiting time for construction of new connection which normally could takes like months, unstable daily water supply and many others. These have been the reason why so many people chose to not become the customer of water enterprise, instead they prefer to use groundwater as their daily water supply and discharge their wastewater to the nearest water body.

This has been taking place quite long, as we can see from the figure 4.1, which depict the trend of groundwater extraction for domestic purposes for the last several years. From that figure can be seen the increasing number of borehole for groundwater extraction in Bandung city, regardless the existence of water company to provide their water needs. If we do not take any action to counter this menace, then this situation will continue years and years later until they face a water crisis situation.

This kind of situation would lead to several risks in the future:

- As the number of people who used the water company's service is decreasing, then it would might generate financial issue within the water company especially wastewater division to fulfill their finance need.
- Environmental aspect seems to be the next thing which receives the impact indirectly. The

obvious example as can already showed in figure 4.1. Since the number of groundwater extraction is increasing, this becomes the menace for the groundwater availability and quality. And the inability of wastewater division to cover the rest of the city, will also lead to deterioration of watershed quality, as there are numbers of households whom discharge their wastewater directly to water body.

4.1.2 Environment

In this environment aspect, the long term viability of the natural environmental should be maintained to support long term development by supplying resources and taking up emissions. This should result in protection and efficient utilization.

4.1.3 watershed quality

By browsing through the water quality data, we could see the current situation of bandung city water management and any other aspect related to it.

4.1.3.1 BOD concentration

BOD concentration plays an important role in determining the quality of water. By simply look to the BOD concentration we could easily judge the quality of water.

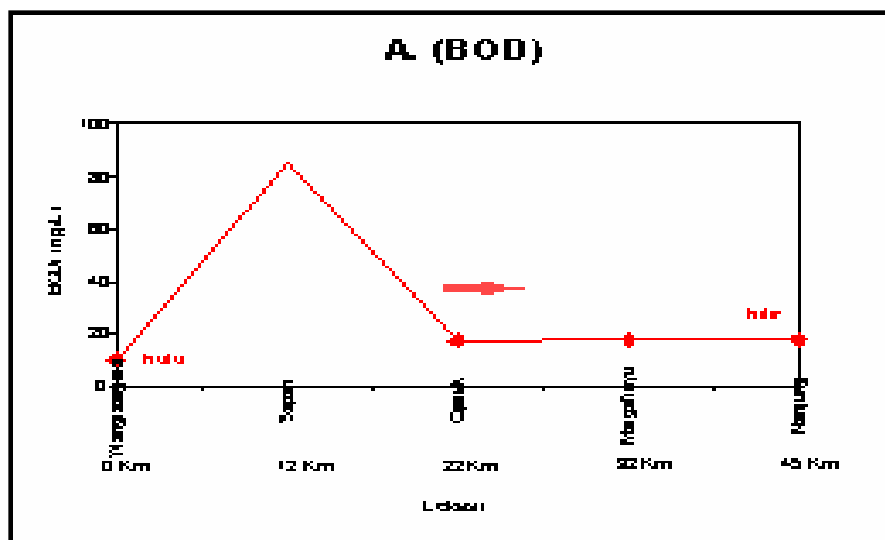


Figure 4.2 BOD concentrations ranging from upstream to downstream (Source: Wangsaatmaja, 2004)

Based on figure 4.2 bellow we could see the BOD concentration ranging from upstream to downstream. In the upstream area the BOD concentration is tend to increase, especially in Km 12 (Majalaya town) from the water spring. The reason for the high BOD level in this place is because in this area, there are lots of industrial activities and this situation is worsened by the fact that this

city has no domestic wastewater treatment plant, so that every household in this city mainly discharge their wastewater to the watershed. Meanwhile, in Bandung city, which located around 40 km from the spring, although BOD level is had significantly decreasing compare to the upstream level, BOD concentration remains above the threshold.

There are two possible reasons behind this fact of high BOD concentration in Bandung city, as follows:

- The water quality in downstream [including Bandung city] is also influenced by the water quality from the upstream level. BOD concentration in upstream is very high, then the further the water flow from the upstream to downstream, the BOD concentration will decreasing, due to the nature ability of water to treat the pollutant. However since the BOD concentration in upstream is extremely high and the concentration is already exceeding the capacity of water to recover themselves from the existence of pollutant, then the remaining untreated pollutant keep flowing to the downstream.
- There are lots of people in Bandung city who are still refusing to become the customer of the water company. These people are mainly discharge their wastewater into the nearest water body which eventually will goes to the Citarum watershed.

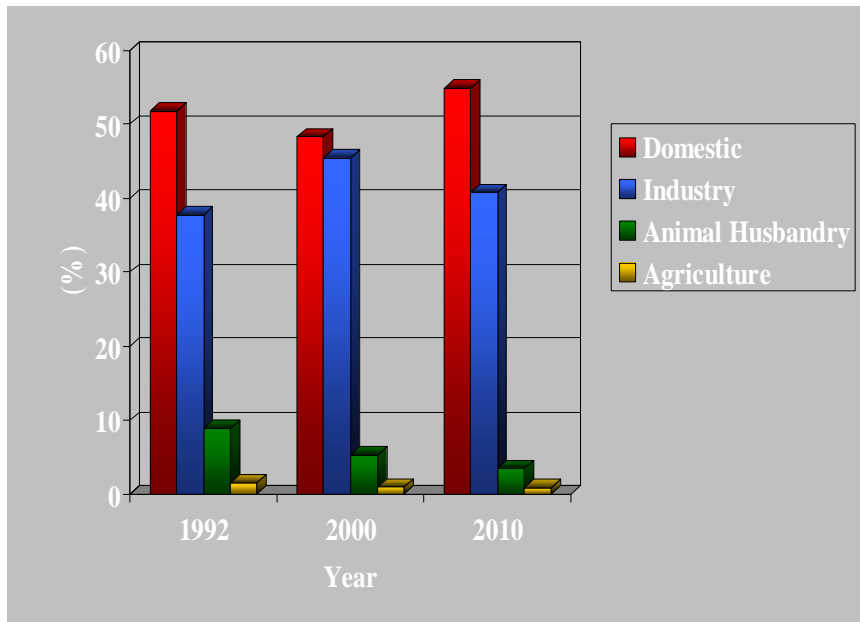


Figure 4.3 Contributors to BOD concentration in upstream of Citarum watershed (source: Wangsaatmaja, 2001)

In figure 4.3 we could see that domestic waste has major contribution for high BOD concentration in watershed. The good news from this picture is the BOD contribution from animal husbandry is

decreasing. And the bad news is both BOD contributors, either from industries or households have a tendency to increase. If we drag a line from 1992 BOD value to 2010 BOD value, we can there is a tendency of BOD from domestic waste to increase. And the similar thing is also occur when we try to connect the BOD value of industry's from BOD value in 1992 to 2010 then we can also see the tendency of the BOD from industries to increasing.

This curve forecast that the BOD concentration will increase from 2000 to 2010, as the population is also increase for several years ahead. This actually should be considered as warning for the many places in the downstream, including Bandung city. Since increase of BOD concentration in upstream area will influence the water quality in downstream area, and including Bandung city.

4.1.3.2 Heavy metal concentration

To show the trend of heavy metal concentration and its impact on the environment, here bellow is showed two curves; Cu and Pb concentration changes from upstream to downstream of Citarum watershed which described in figure 4.4 and figure 4.5 bellow.

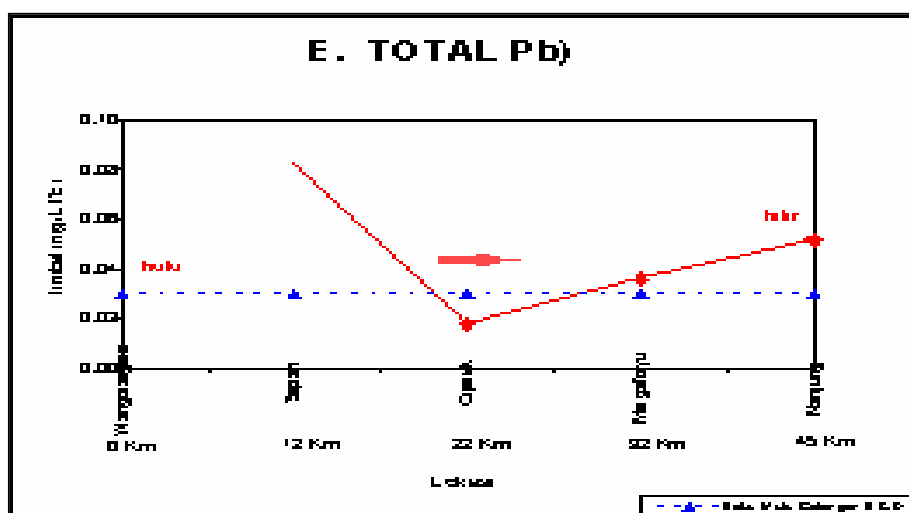


Figure 4.4 Total Pb concentrations in Citarum watershed (Source: Wangsaatmaja, 2004)

Based on the Cu concentration curve and Pb concentration curve in Citarum watershed, we can see the similar trend as the previous BOD curve, is also happen in here. In the upstream (at the same point where BOD concentration is significantly increasing), the Pb and Cu concentration are also high. Then if we move to further point to downstream, the Pb and Cu concentration tend to decrease and then increasing again as it reach the downstream area. The blue dotted line is the threshold for the allowed concentration of Pb or Cu in water body. Bandung city itself is located around 40 km from the spring. And as can be seen from the curve, the Pb and Cu concentration in

that point is above the allowed concentration of Pb and Cu in water body.

There are couples of things which can explain why the high concentration of Pb and Cu upper part of the watershed:

- In km 12 (Majalaya town), where the Pb and Cu concentration is suddenly increase, there are lots of industrial activity exist. And those industries are mainly textile industries, which their dye contain Pb and Cu. Lack of control over industrial wastewater in this city can be the reason for the high concentration of Cu and Pb in the water body
- Another possibility for the high concentration of Pb is coming from the smoke of vehicle. Because there is a high way road straddle, where busses and trucks always cross this road. And high industrial activity is also one factor that caused a lot of truck or buses to pass by that road.

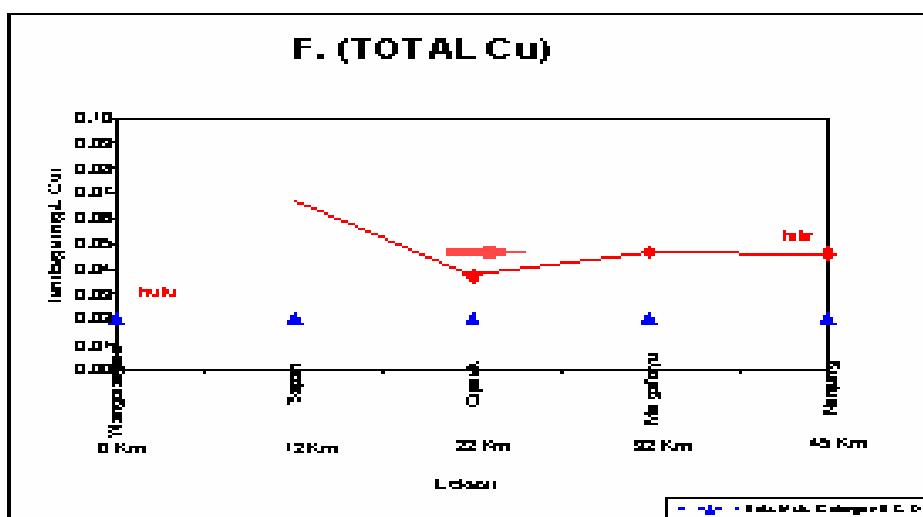


Figure 4.5 Total Cu concentrations in Citarum watershed (Source: Wangsaatmaja, 2004)

There are several things which can also describe the reason of the Pb and Cu concentration trend in Bandung city:

- the water body in Bandung city (40 km from the spring) as a part of the Citarum watershed, receive influence from the upstream of the watersheds
- The trend of Cu and Pb concentration in water body in Bandung city is also to increase. This is a sign of lack of control over industrial wastewater. In Bandung city, there are lots of textile industries, in terms of home industries and big factories as well. For big industries, it is easier to control their wastewater. But for home industries, it is difficult to control and trace downs their wastewater.

4.1.3.3 DO concentration

The third indicator for watershed pollution is DO (dissolved oxygen). This indicator was chosen

because the data availability and DO is always regarded as a widely accepted standard parameter in deciding whether water pollution is occurring or not.

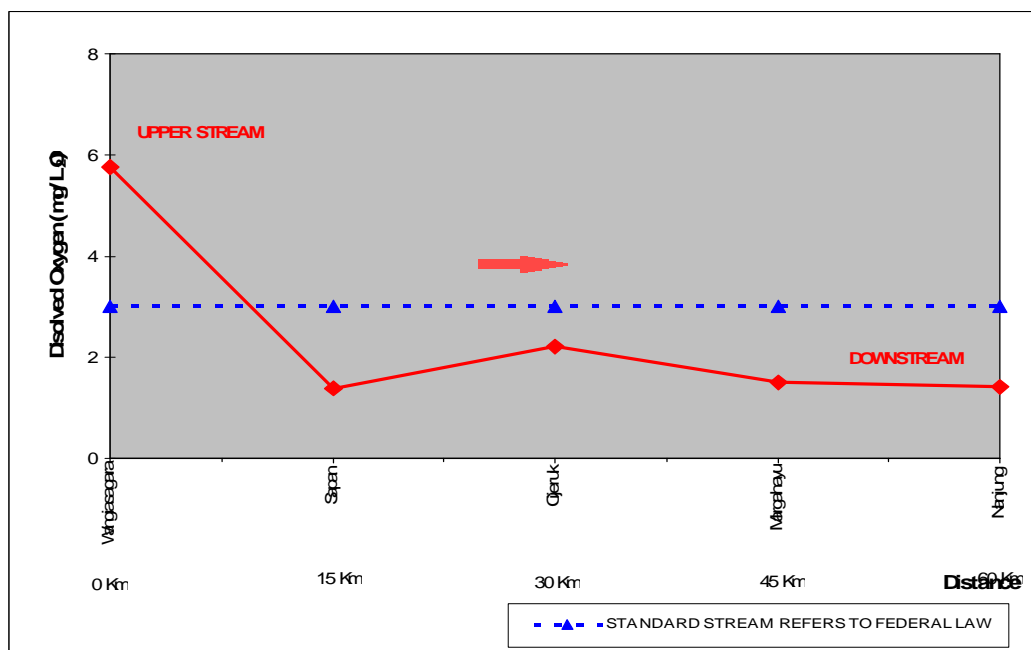


Figure 4.6 Dissolved oxygen range from upstream to downstream in Citarum watershed (Source: Wangsaatmaja, 2004)

DO or dissolved oxygen represents the amount of oxygen dissolved in water. A good quality of water is indicated by the high amount of DO concentration within the water. From the curve above we could see the tendency of DO from upstream to downstream is decreasing. The blue dotted line is minimum DO concentration in water body (threshold). This curve confirm the good quality of water only available several kilometers away from the spring, while the rest of the watershed, from upstream to down stream, the DO concentration is very low. As well as other curves above, in km 12 where the BOD and heavy metal concentration is pretty high, the DO concentration also very low. The trend of DO from km 22 is decreasing. Bandung city which located in the downstream (km 40), also experience a terrible quality of water body which indicated by a low DO concentration bellow the threshold for DO concentration in watershed. This DO concentration is seems to strengthen the fact how bad the water quality in Bandung city is and how necessary an action to be seriously taken in order to recover this situation.

But if we look at the situation in Bandung city closer, then we can say several things related to water quality issue in here.

- a. a deteriorated water quality of watershed in bandung city might be caused by:

- Service reliability issue
This is including population coverage, security and treatment performance. Lack of service reliability makes only few people, who are able to reach the wastewater facilities. And a good system protection [security] solely might not guarantee a good treatment performance. But a good system protection will support a good treatment performance. We still see some cases related to system protection such as infiltrated of industrial wastewater to the domestic waste and also illegal pumping of domestic wastewater from the wastewater channel to the agricultural field for irrigation; have some impact on the performance of the wastewater treatment plant.
 - Lack of control over industrial wastewater in upstream and within Bandung city itself.
Those curve of BOD, heavy metal and DO concentrations confirm how serious the water pollution in upstream and downstream is. From figure 4.3, domestic wastewater and industrial wastewater is the major contributor for high BOD concentration. And clearly industrial wastewater is responsible for the high concentration of Pb and Cu in the watershed. This high concentration of heavy metal in watershed is a sign of lacking of control from the government over the industrial wastewater.
 - water pollution in cities at the upstream part
Although we can not say for sure how far the water pollution in upstream may influence the water quality in Bandung city [downstream], but based on those fact shown by the above curves, we can say for sure that the water pollution from at the upstream gives some impact for the water quality in downstream.
- b. a deteriorated water quality of watershed in bandung city may cause:
- Water quality issue at some lakes or dams within the watersheds such as eutrophication or etc.
The trend of a high BOD concentration and low DO concentration confirm a poor or deteriorate water quality in water body in Bandung city. This situation might result in water quality issue in dams or lakes which receive water from the watersheds. Such case like eutrophication might occur. As reported by the local newspaper on july 4th 2007, where one of the dams [saguling] is suffered from serious eutrophication for the last several months. This phenomenon might be considered as a sign for a serious action demanded. Otherwise, there going to be more problem in health risk issue and ecosystem biodiversity in dams or lake.
 - Chemical use for water purification will be increasing [related to health risk issue].
Citarum watershed is the only and the biggest watershed in Bandung city and Bandung municipality. Water from rivers is also flowing to some dam or lake which later on use as water resources for drinking water. Since the water quality in downstream is deteriorated,

then there will be a water quality issue in dams or lakes which will result in increasing of chemical use for water purification for drinking water. This would have twofold effects; increasing in cost for chemicals for drinking water purification and health risk because of increase of chemical use for water purification.

- Contribution in water pollution at the downstream cities.

The water quality deterioration in Bandung city will give impact not only to dams or lakes within the Citarum watershed but also to other cities in furtherer downstream such as Jakarta, Purwakarta, Bekasi etc. Because those cities also rely on dams which is watered by the Citarum watersheds as their drinking water resources. So there will be a health risk issue in these cities. Since Bandung city located at the upper part of downstream while the rest of the cities are located at the furthest part of downstream, then a deteriorated water quality in Bandung city, might contribute to the deterioration of water quality in Jakarta, Bekasi and Purwakarta.

4.1.4 sludge quality

As a by product of wastewater treatment system, sludge handling and sludge quality is really important. Sludge quality determines what kind of treatment must be applied to it.

Table 4.3 sludge content

Heavy metal	Content (mg/Kg)
Pb	173.98
Cd	3.72
Mn	301
Fe	402

Source: PDAM Bandung

Sludge reuse is one alternative in sludge handling. This alternative is a good way in recycling nutrients which is an important aspect in sustainability. Nevertheless, with the available content of heavy metal in the sludge, it is not feasible to conduct sludge reuse. Besides health risk issue because of sludge's pathogen exposure to human is one important issue.

Bandung city water company (PDAM) does not apply an advance technique in handling their sludge. Normally they just dry then packed it and pile it up in final disposal site for municipal solid waste. And if this water company keeps using this inappropriate method in sludge handling, it would boost the solid waste amount in the final disposal site. This issue is really important because Bandung city and Bandung municipality have a difficulty in handling the municipal solid waste.

Since the explosion of the solid waste mountain in one final disposal site in Bandung city which cause death of several people, this city still bit traumatic with that. However the traumatic feeling does not reduce the municipal solid waste production where the continuity of producing solid waste in large amount may produce the same risk.

There is no real attempt neither from the local government nor the citizens to reduce the production of solid waste within the city, although they realize that the Bandung city needs that kind of program. In order to reduce the amount of sludge as a solid waste, a proper sludge handling is necessary. There are many technology alternatives for sludge handling available. Yet in order to run those technologies, a sufficient financial support is necessary.

4.1.5 Social

As an integrated part of sustainability, social aspect has become an inevitably part to evaluate when discussing about sustainability. Service reliability and accessibility to wastewater service are an essential part in creating a sustainable wastewater management. Both of these indicators are under the social category.

4.1.1.5 Institutional Management

Balkema et al, 2002 stated that different wastewater treatment systems will require different regulations and control mechanisms. These requirements should fit in the existing institutional infrastructure of the country or region. In this indicator, institutional management could be interpreted as the way the institution:

- manage the issues in the system within the institution
- financial arrangement among the part within the institution
- manage the job related on each aspect within the system
- And many others.

During my survey in Bandung city, I have met some officers in the Bandung city water company (PDAM) and doing some interviews. Based on the interview, I could catch a disappointment in terms of financial arrangement. Originally the water company has decided the arrangement of their finance, 30% from the annual benefit should be delivered for the wastewater division's operations and maintenance. Yet apparently this policy does not working really well, because the wastewater division felt that most of the annual benefit of the water company goes to the drinking water division. This lack of finance also has become the reason for inappropriate sludge handling in Bandung city wastewater treatment plant and also the inability for developing the domestic sewer line to cover the rest of the city.

Clearly the institutional management plays an important role in helping the wastewater system moving toward sustainable level. The key points in developing a good management especially in terms of financial arrangement are transparency and firmness. Having a transparent financial arrangement will encourage the responsibility to work the job efficiently, while a firmness way of leading an institution will help the institution become more solid and stronger.

4.1.1.6 Accessibility to wastewater facilities

To reach sustainability, we need to reduce the emission of BOD, phosphorous, nitrogen and any other organic matter to the environment. So, accessibility to wastewater facilities is really important. Because lack of access to wastewater facilities is one reason why many people remains discharge their wastewater to the nearest watershed.

There are two ways to evaluate this part:

1. Based on several facts that have been gathered during my survey in Bandung city, Indonesia.
 - a. Since the wastewater treatment plant established, they only constructed one major domestic sewer and some pipe which connected to that sewer. However, not everyone can receive that service. Some people who are originally not customers of the water company yet live very close to the sewer able to use that facility. And because of the need for more money to run the system is emerging then the water company decided to charge certain amount of money from the customer which is called as wastewater fee. Ironically, some people who are the customer of the water company yet does not receive or not able to use the facility because they live a bit further from the domestic sewer, forced to pay that fee. Meanwhile those who live very close to the sewer and able to use the facility but not a customer of the water company do not have to pay for the monthly fee. This unfair situation has driven some protest from customers to the water company.
 - b. Almost all new or nice residential area such as real estate, apartment or any other newly developed residential area is already become customers of the water company and automatically connected to the domestic sewer. Most people who live here are people who came from middle to high economic strata. This people obviously are able to afford the cost for new connection which is a bit expensive. Meanwhile the rest of the city are coming from middle to lower economic classes who might disapprove to pay for the construction of new connection. That is why; direct discharge of domestic wastewater to the water body is very common practice to do.
 - c. Besides obliged to pay certain amount of money, to construct a new connection normally took months. So sometimes in certain residential area, some residences conduct a fund

raising from the residences then pay some handy men to help them constructing a sewerage channel from their residential area to the nearest watersheds or the nearest municipal sewerage channel. These people are strongly against the water company's plan to charge the customer for the wastewater fee.

2. Based on those curves above, we can see that the amount of water consumption in Bandung city is way much higher than the amount of wastewater generated, which also confirmed by table 4.4 below.

Table 4.4 Water consumption vs Wastewater production (annual)

<i>FY</i>	<i>Wastewater production (m3)</i>	<i>Water consumption (m3)</i>
2002	6,466,705	35,828,311
2003	10,627,705	33,873,552
2004	13,214,460	33,065,526

(*Source: Bandung Annual Statistic Book and PDAM Bandung*)

This table 4.4 confirms that there is an inequality in water consumption and wastewater generated. This kind of event can occur because there is an inequality in access to wastewater facilities.

If there is no action is taken to tackle this occurrence, then that kind of situation may turn it into several risks:

- Social

Any decision over the drinking water and wastewater issue taken by the water company might give some impacts to the customer. If they takes a wrong decision or decide to do nothing then it would make such thing like crisis of trust toward the water company as the only institution which responsible for drinking water and wastewater issue is possible to occur.

- Environmental

Environment aspect might be the aspect which receives direct impact from these social problems within the system. If more and more people prefer to leave the water company's service as an impact of unreliable service and lack of access to wastewater facilities, and instead they chose to provide the drinking water from groundwater and discharge their wastewater to the watershed, then these things will yield in twofold:

- a. Increasing in groundwater exploitation because the water company is not able to provide a stable distribution of drinking water.

- b. Watershed's quality deterioration because of high load of untreated domestic waste to the watershed.

4.1.6 Technical

Technical aspect mainly concern about how to achieve a sustainable operation of the wastewater treatment plant, as the essential part of the wastewater system. A provision for a sustainable wastewater management under the technical aspect is water and sewerage management must provide at least minimum service to the community.

4.1.6.1 wastewater treatment performance

The Bandung city is currently served by one wastewater treatment plant which located in Bojongsoang. This wastewater treatment plant is built to treat collected wastewater. Their task is to reduce the amounts of pollutants in the wastewater before being released to the environment. Data on the performance of the wastewater treatment plant is important to know the effectiveness of the treatment process. And this data is available for BOD and COD removal as depicted in figure 4.9 bellow.

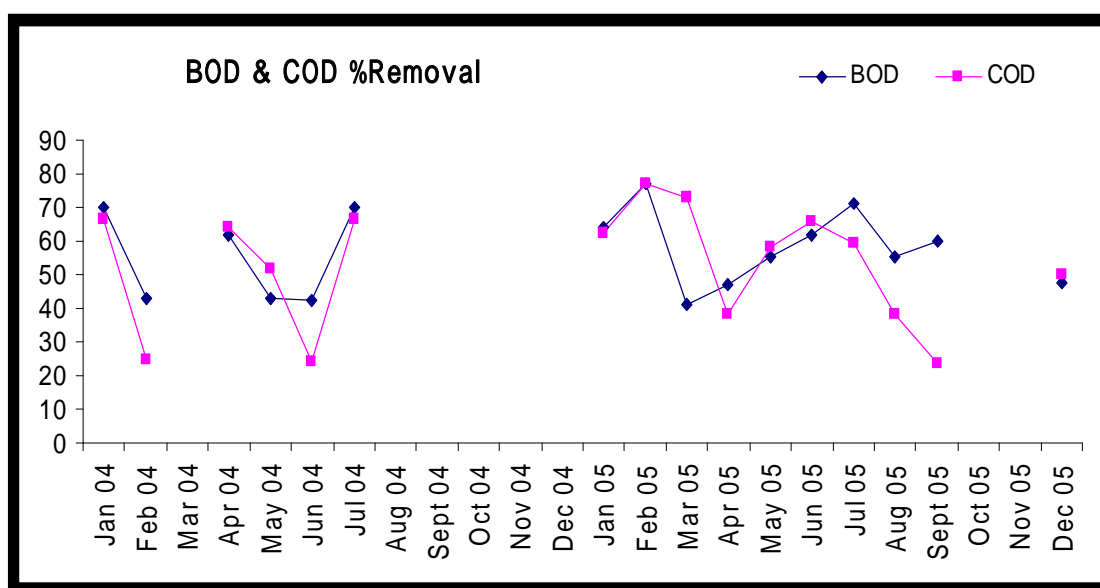


Figure 4.9 BOD and COD % removal of the wastewater treatment plant (Source: PDAM Bandung)

Based on the picture above, the removal of BOD and COD seem to have similar trend. There are certain months where the BOD and COD removal reach more than 60%. But there are several months where there is no data for BOD and COD removal. This thing could happened because during these months [August 2004 - December 2004 and September 2005 – November 2005], the

wastewater treatment plant must stopped their operation since all wastewater which suppose to enter the wastewater treatment plant were pumping out to the nearest agriculture field.

In certain other months, the removal was low and tends to decreasing. Let us take %removal from March 2004 to June 2004 for instance. From March 2004 to May 2004, there was a tendency to decrease as the amount of water which entered the wastewater treatment plant was also increasing. And later when the amount of influent in the wastewater treatment plant decreasing, as there is a season change from rainy season to dry season, the removal is also increasing.

One point we could see from this figure is that this wastewater treatment plant has not yet able to perform a stable performance of removing nutrient. The frequency for BOD removal bellow 60% is higher than above 60%. This fact confirms that the treatment plant also has not yet able to perform a good performance in reducing and removing organic matter from the wastewater. And this obviously will not lead to the sustainability of the plant as well as the entire system of wastewater management.

4.1.6.2 system sensitivity

In order to develop a sustainable wastewater management, at least the minimum service must be provided. And a frequent failure could be regarded as sustainable. These indicators are concern about system sensitivity over malfunctioning or fluctuation within the wastewater system.

a. volume of influent

There are several reasons behind the increase of wastewater production. It can be caused by an increase in water usage, increase in storm water volume into the sewer, illegal infiltration from industries and many others. That is why, the volume of influent that entered to the wastewater treatment plant can be a good indicator for many things, or in this case represents in terms “system sensitivity”. And the trend for wastewater production is illustrated in figure 4.10 bellow.

The wastewater treatment plant is currently serving only some part of the cities; eastern, southern and center part of Bandung city. The wastewater production received at the Bojongsoang wastewater treatment plant has been fluctuating, although the fluctuation is remains bellow the design capacity of the wastewater treatment plant.

The good news from this curve is that the daily influent of wastewater is remains bellow the design capacity. This influent could be keep bellow the capacity is because there is more than half of the population of the city which has not covered yet by the wastewater treatment plant. So one day if

they could successfully connect every house in Bandung city to the sewerage channel then a regular monitoring over the volume of influent of the wastewater treatment plant is a must-to-do thing.

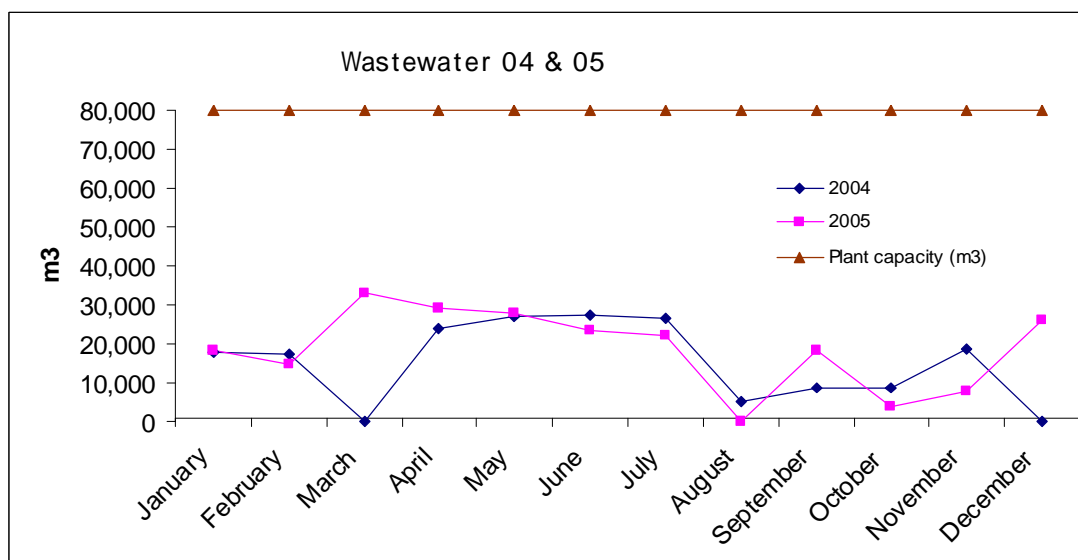


Figure 4.10 wastewater productions in 2004 and 2005 (Source: Bandung Annual Statistic Book)

But the bad news is since the rest of the population remains discharging their wastewater directly to the water body then water quality issue still becomes the problem that has not been solved yet. And the illegal pumping of the wastewater from the sewerage channel to the agricultural field may disturb the stability operation and the capability of the ponds to perform a good result.

b. Precipitation trend

Precipitation trend is also included in this research because this city using a combined sewage system, where surface runoff from impermeable areas [i.e. pavement and etc] is carried to the wastewater treatment plant. And the coming of storm water into the plant could increase the volumes received at the wastewater treatment plant during rainy seasons.

Let us take the wastewater production trend in 2004 as an example. As shown in figure 4.x bellow, the wastewater production tends to increase when the rainy seasons comes and the precipitation is high. There are two things as risk of the rise and fall in precipitation trend:

- When they successfully connected every house in Bandung city to the domestic sewer line, there is a high possibility that the wastewater treatment plant can no longer receive and treat the city's wastewater because there is a tendency for population to increase, due to high number of migration from rural areas to Bandung city.
- Since the operation used in this plant is oxidation pond where there are some ponds which

operated under anaerobic conditions while other operated under aerobic condition. These aerobic ponds are operated in open air situation which allowed rainwater to enter. During days where the precipitation is high, it may cause overflows, releasing untreated wastewater into the environment.

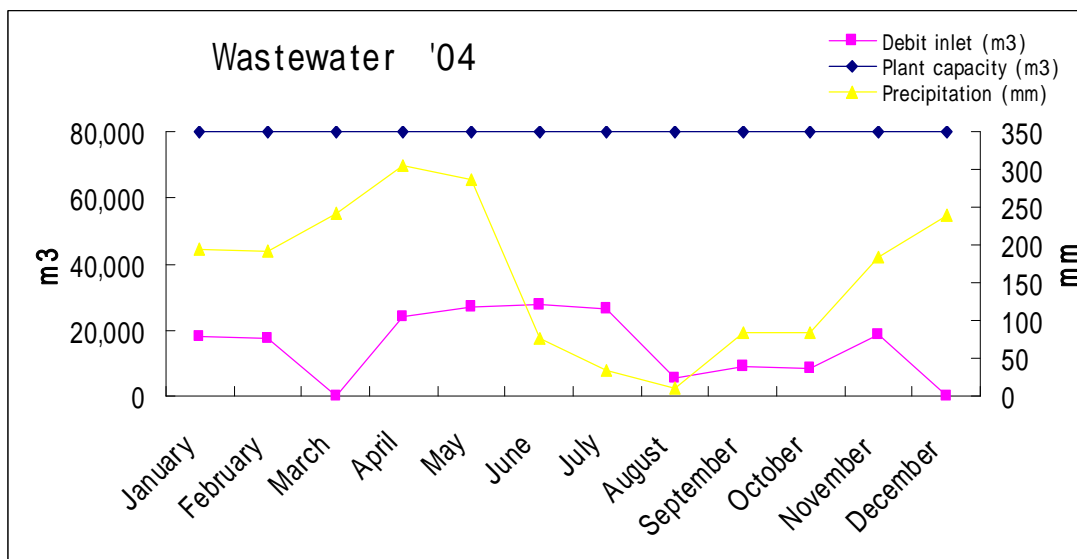


Figure 4.11 precipitation influences on wastewater production (Source: Bandung Annual Statistic Book)

Other than any other factors, this precipitation trend is also one indicator for effectiveness and efficiency of the wastewater treatment plant.

c. water loss

One important part of the wastewater system is wastewater distribution system. Security issue is the main issue in maintaining a good wastewater distribution from the source of wastewater to the wastewater treatment plant. In Bandung city, water loss as a part of the security aspect of the wastewater management is happened to be serious, as can be seen in table 4.5 bellow.

Table 4.5 Water loss during wastewater transportation

FY	Wastewater treated on the WWTP (m3/day)	Water Loss (m3/day)		total wastewater generation
		Pump station	open channel	
2002	9,664	3,221	4,832	17,717
2003	15,882	5,294	7,941	29,117
2004	19,748	6,582	9,874	36,204

(Source: PDAM Bandung)

Table 4.5 above confirms that nearly 50% water loss is taking place every day for the last three years.

This is obviously not good news for everyone in the city. Large volumes of wastewater are lost due to many reasons such as leakage in pipes, illegal pumping from the domestic sewer [open channel] for agricultural purposes. Leakage in pipes will leads to loss of pressure, increase in pumping cost and also increased risk of contamination by microorganism or any other harmful organic or inorganic matters to the groundwater. In the meantime, illegal pumping for agriculture activities might also lead to increase in health risk issue because of bacteria or any harmful organic or inorganic matter exposure to human. This pumping activity will also have a detrimental effect for the wastewater treatment plant since the plant must stopped their operation due to this pumping activity.

The ironic part of this case is this enormous water loss case has been going on for the last three years. And the water company as well as the local government seemed to be doing nothing any significant action to recover the situation. This lack of consideration over security issue in the wastewater system would not lead to a sustainable level of the wastewater management.

4.2 General overview

This part is intended to capture the real condition of the wastewater system in Bandung city in an easier way. Very often in Bandung city, we can not separate one aspect with another. One event could occur because another event has driven it to happen. Using an interconnected indicators bellow, we could visualize the real situation of Bandung city's wastewater management. And these indicators are derived from the result of sustainability indicator evaluation which previously accomplished.

From the previous individual evaluation result, we could pick up several criteria which correspond to the present situation of wastewater system in Bandung city. And those criteria are:

1. Water price

Water price means the amount of money that being paid by the customer of the water company for monthly water bill.

2. Affordability

The affordability means the ability of the customer of the water company to afford or to pay for the service. This affordability is closely related with water price.

3. Service reliability

Service reliability means the ability of the wastewater division or the water company to provide a good service. Good service including a good treatment performance, wide service coverage area, a safe water transportation from the source of the wastewater into the wastewater treatment plant and also an ability to secure the whole system so that any malfunction or failure will not occur (security).

4. Willingness to pay

Willingness to pay is the level of willingness of the customer of the water company to pay for the service.

5. Watershed quality

Watershed quality is obviously represents the quality of the watershed or the water body within Bandung city.

In figure 4.12 bellow, I tried to visualize the problems related wastewater issue in Bandung city. The wastewater system was established in order to reduce the emission of organic pollutant or any kind

of pollutant from the system into the environment, so they could maintain the watershed quality, as described in the most right box of the chart. And the watershed quality in this case is highly depend on how reliable the service that provided by the water company is. This relationship is represents by L-5. This means, the watershed quality and the service reliability have a linear relation, means the more reliable the service is, the better the water quality will be and vice versa.

Meanwhile the service reliability itself has a reciprocal relation with water price (R-1). It means there is a time when the water price influences the service reliability, so the higher water price is decided, the more reliable the service is. Yet in other times, the water price is determined by the service reliability. So the high service reliability is demanded, then as the consequence, the water price must be raised.

In between service reliability and water price, there are lots of things that affected both the water price and service reliability. Water price has a converse relation with affordability. If the water price is higher then the affordability will be decreasing, vice versa (C-2). Eventually the affordability has inevitably influencing such things like treatment performance, service coverage area, wastewater transportation and system security, which represented by number 3 in the chart. Those things will determine how reliable the service is. If all those criteria are in a better condition, which means a better treatment performance, the ability to cover the whole city as the service area, safe wastewater transportation and a good maintenance to secure the system, then we could say that the service reliability is also in a better level.

Nonetheless, the problem is if we want to provide a reliable service, it must be cost a lot of money. As mentioned in the previous part of this chapter, the water company will let the customer to bear the finance as a consequence of the better service they have received. The customer will always be against this plan, although oftentimes the water company ignore this fact and keep continuing their plan. This situation has been distracting the water company for a long time. And we obviously must find a way to get through this, because if we do not, it means we voluntarily put the watershed quality in a threatening condition, due to lack of ability to provide a good service and also the direct discharge of untreated wastewater into the nearest watershed practice.

And willingness to pay has come in the way between water price, affordability and service reliability. By mapping the relation between service reliability and willingness to pay, as will be explained bellow in this part, we would be able to bridge the gap between water price and service reliability. Willingness to pay will also help us to determine the amount of water price should be bear by the customer, which indicated by D-7 in the chart. Willingness to pay not only serve as a determine

factor on how much money they (the customer) want to spend for water every month, but also we could be able to know what kind of service are expected by the customer from the water company. That is why the relation between willingness to pay and service reliability is indicated by L-6, which means they both have a linear relation.

In some cases and for some people, they expecting a better service provided by the water company, in exchange for a higher cost they must spend for it. While in many other cases, there are many people who expecting a better service without raising the water price. Then the willingness to pay plays its function. By mapping the affordability of the customer with the level of how reliable the service that they are expected, we could define the willingness to pay. So if the water company wants to raise the water price to certain level, as consequences of that, they also have to improve the service they provide, so that every one would gladly spend their money on it.

The detail explanations about the chart and the criteria which shown in the chart, will be given in each fragment under this part, from 4. 2.1 to 4.2.3.

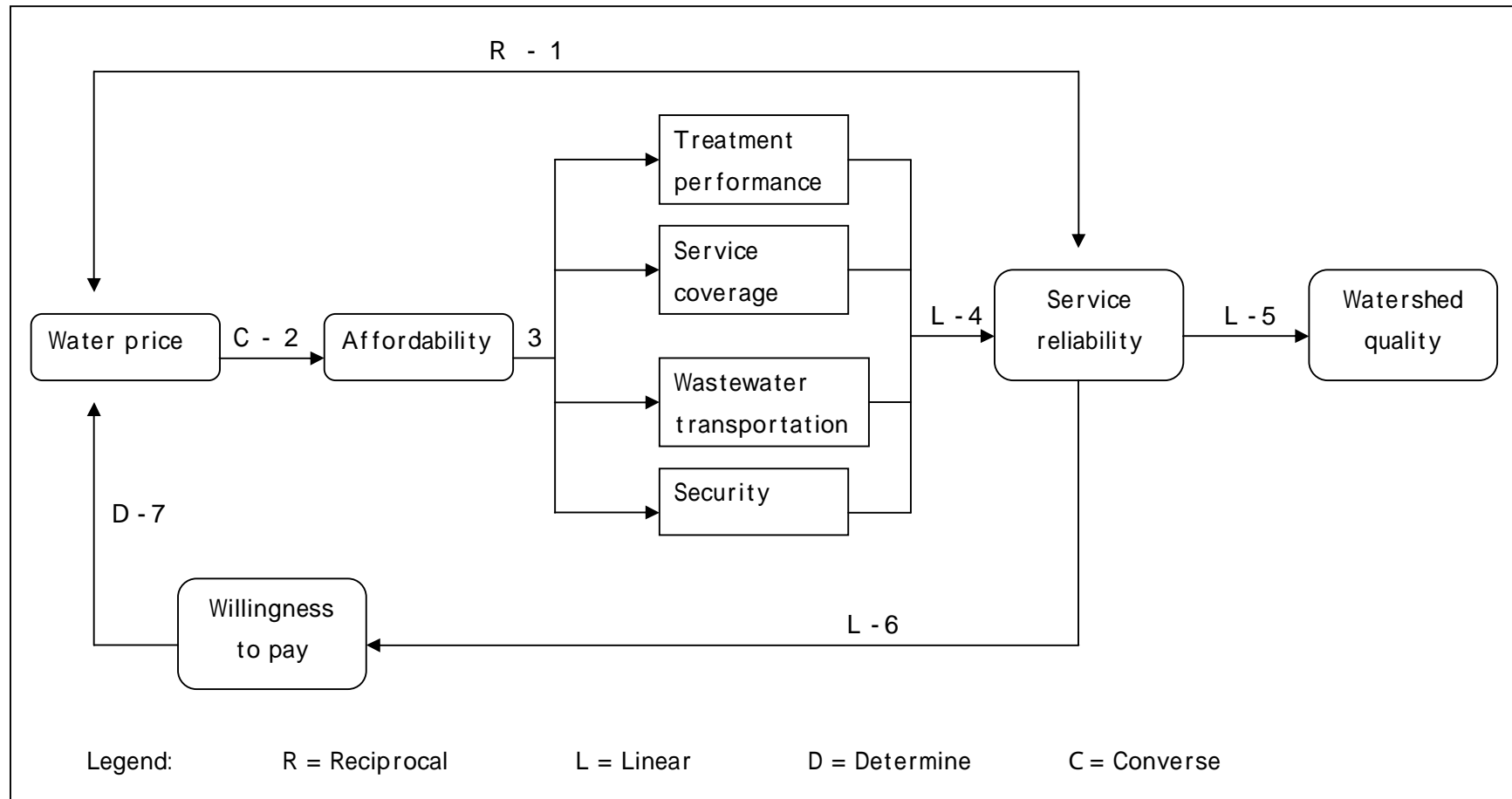


Figure 4.12 The scheme of wastewater problem in wastewater system in Bandung city

4.2.1 technical – economic

This part is aim to grab the economic and social aspects in one frame. There are three interconnected indicators shown here. The figure 4.13 bellow is describing the arrangement of the explanation on this part.

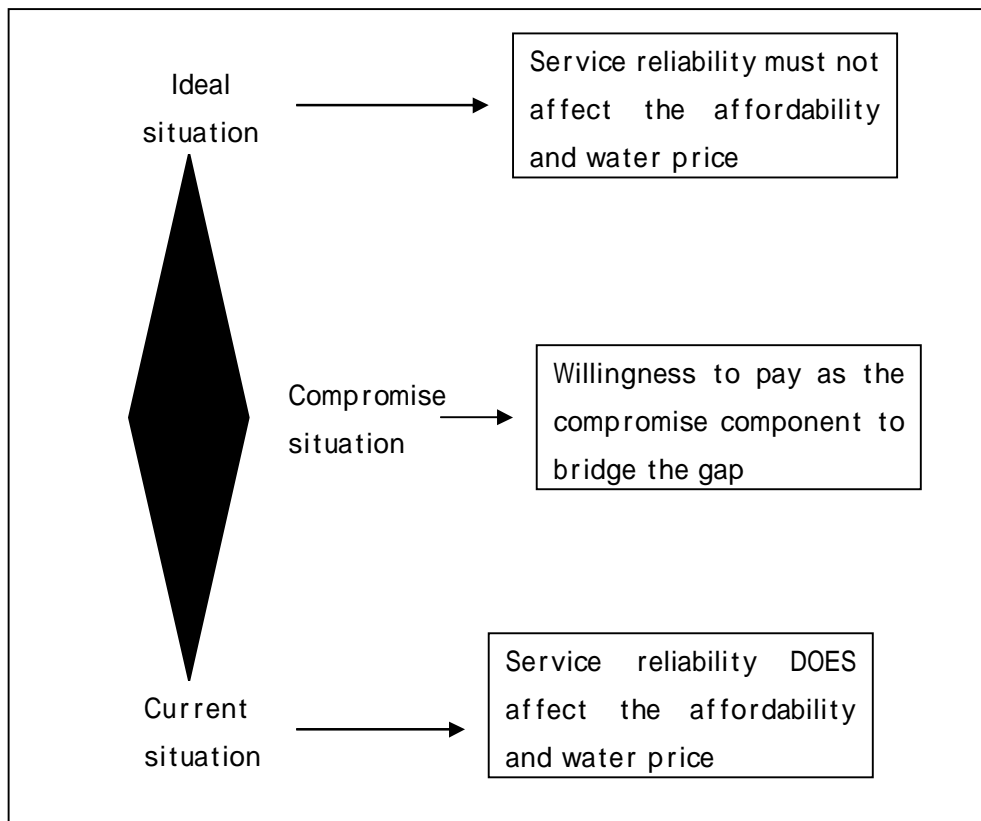


Figure 4.13 The relation scheme between service reliability, water price and affordability

As can be seen from figure 4.1.3, the way I am going to rationalize this part is by comparing the current situation (the reality) and the ideal situation between service reliability relation with water price and affordability. In the ideal situation, the service reliability must not affect water price as well as the affordability. While in reality the service reliability is actually determined the water price which affecting the affordability. This situation is explained in this 4.2.1.1 and 4.2.1.2 bellow. And there is another situation right in the middle of current situation and ideal situation which in this case called the compromise situation. The detail about compromise situation will be explained in 4.2.1.3 bellow. Basically this compromise situation is made as a reaction to connect the ideal situation pole and the reality situation pole.

4.2.1.1 service reliability and water price

Water price is refers to the price of water per unit which including both drinking water and wastewater. And service reliability is refers to the ability of the water company to provide a reliable service, including the service coverage, treatment performance etc. And the relation between water price and service reliability can be described in figure 4.14 bellow.

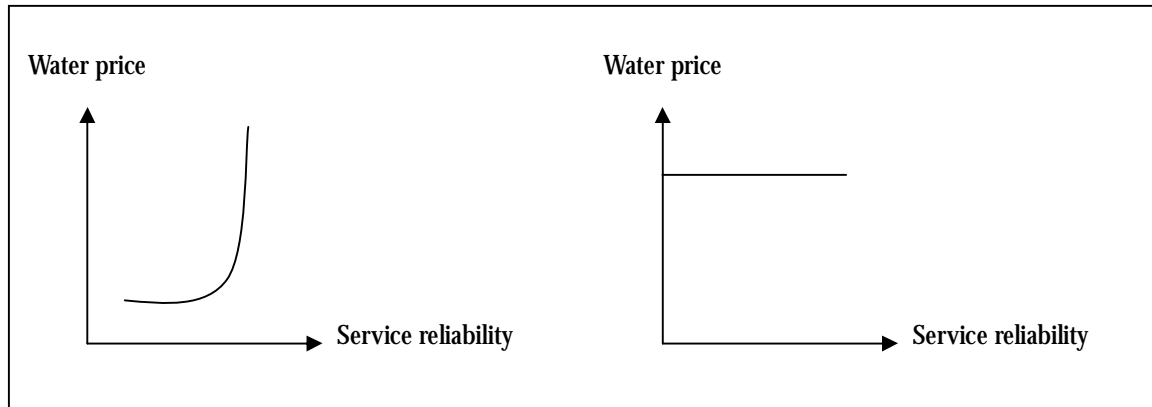


Figure 4.14 Water price vs service reliability in Bandung city (left) and the ideal relation between water price and service reliability (right)

The ideal relationship between water price and service reliability is depicted in the right picture of the figure 4.x above. This curve tries to tell us that in ideal condition, any development of service reliability does not influence the water price for the customers. However in the real situation in Bandung city, every time we tried to raise the service reliability then it would subsequently increase the water price. Since the less investment from government for wastewater divisions, so any increase in production cost will be bear by the customer. This would lead to social protest because of high water price which eventually will drive them to use other water resources and back to direct discharge practice.

4.2.1.2 Affordability and Service reliability

Service reliability is also related to affordability. Affordability refers to the ability of the customer to afford the service provided. There are many things which determine the affordability, but the major point is water price. The relation between affordability and service reliability is depicted in figure 4.15 bellow.

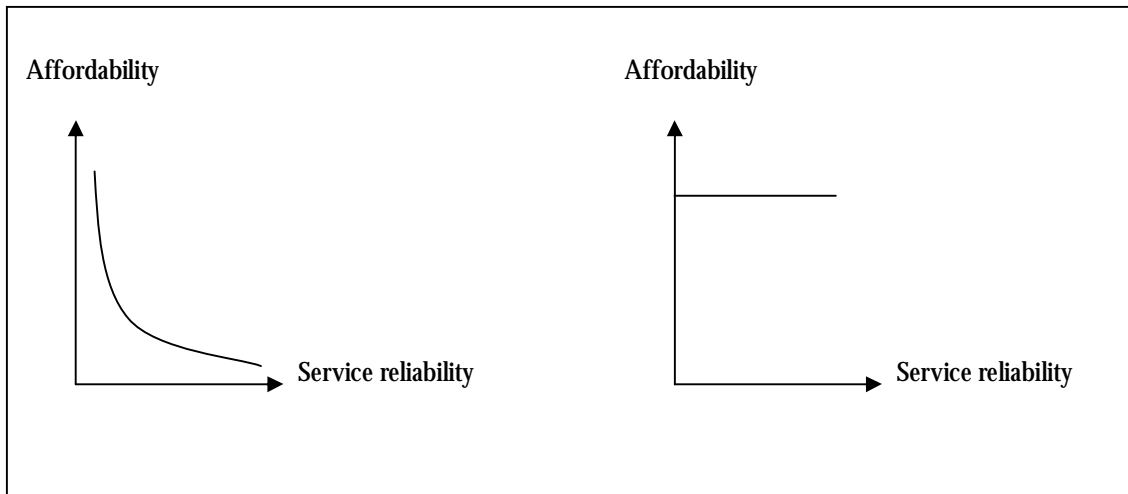


Figure 4.15 Affordability vs service reliability in Bandung city (left) and the ideal relation between affordability and service reliability (right)

Very similar to the behavior of service reliability relationship with water price, the ideal condition of service reliability relationship with the affordability is illustrated at the right picture of the figure 4.14 above. As sketched in the left curve of figure 4.15, the situation in Bandung city is a bit different. Further development of service reliability will demand more finance to support it. Since some of the financial for running the system is endured by the customer then this development in service reliability will also means that the customer has to pay more. If the water company raises the water price then it could reduce the affordability. However if you are focusing on enhancing affordability then the water company will face some problem in performing a good system. Because enhancing affordability means you have to lessen the water price which will cut down the cost for running the system then it would also reduce the service reliability.

In Bandung city, if you register as the customer of the water company then you are obliged to pay some money for registration and for installation new connection. For some people, the cost for constructing a new connection is very expensive. That is why; instead of paying that, some people are rather use borehole or well to extract groundwater as their water source. This is how the high service reliability requires high affordability works. Yet when they focus on develop the affordability, there are very limited amount of money available to run the system. In many cases, they reduce the service quality at one part and keep it good at the other part. Take piping leakage and water stealing as an example. Because lack of finance availability, they use a moderate type of pipes for water distribution but apply poor maintenance to it. This is the reason why leakage of pipe is pretty high in Bandung city [nearly 40%] and water stealing practice is also common. This is how the high affordability will result in low service reliability works.

4.2.1.3 willingness to pay and service reliability

The last series for this part is the relation between willingness to pay with service reliability. How they behavior toward each other is described in the figure 4.16 bellow.

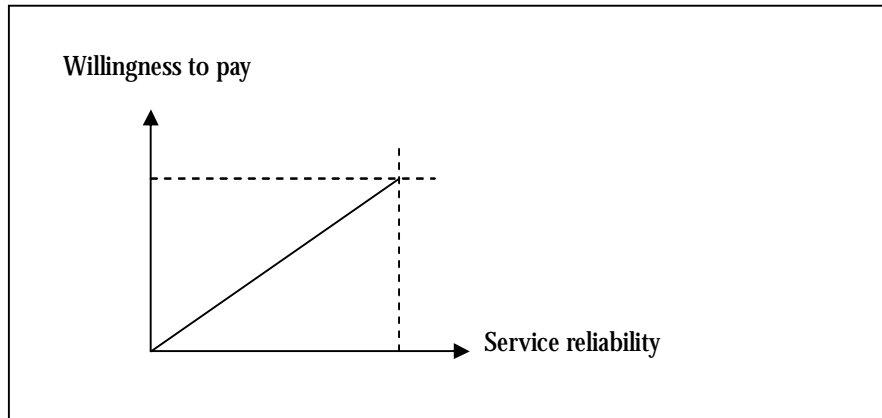


Figure 4.16 Willingness to pay for the service vs Service reliability

This figure illustrates service reliability and willingness to pay has a linear relations. Advancing the service reliability will boosting the willingness to pay. However both service reliability and willingness to pay are limited which in this figure symbolized by the dotted line. The maximum value for willingness to pay will cross in one point with the maximum service reliability. In other words, low service reliability will yield in low willingness to pay.

Take water distribution or domestic sewer connection case as an example. Since the water company unable to distribute a stable supply for drinking water for the rest of the city then many people are complaining about this. So when the water company felt it is necessary to raise the basic water price, then every one is show disagreement. The customer alibi is the water company is not supposed to raise the water price if they are not able to provide them with good service. Or in case domestic sewer, in some residential area in the city, some people are use their money to finance the construction of sewerage line from their house to the nearest sewer channel. So they think it is inappropriate if the water company still charge them for the wastewater fee because they did not receive sufficient service from the water company.

We can not neglect other aspects which determine the willingness to pay. This curve could also regard as the way out of the problematic situation that the water company is facing. They could put some value as the maximum willingness to pay and the maximum number for service reliability, the cross point of these two lines will be the target for the minimum satisfied service that the water company is able to provide. They can see where is their position in relation between the customer's

willingness to pay, service reliability and their target they wanted to achieve. So that they can work things out to achieve the target and what steps should be taken to reach the target.

4.2.2 environmental – economic

It is oftentimes becomes an inevitable situation that economic activity or economic growths might has influencing the quality of the environment. That similar relation is also happen in wastewater system as well.

4.2.2.1 water quality and affordability

Of many aspect which could describes the relation between environmental aspect and economic aspect is how affordability might affect the water quality of the watersheds as well as the groundwater quality. This relation is tried to be explained by the bellow figure 4.17.

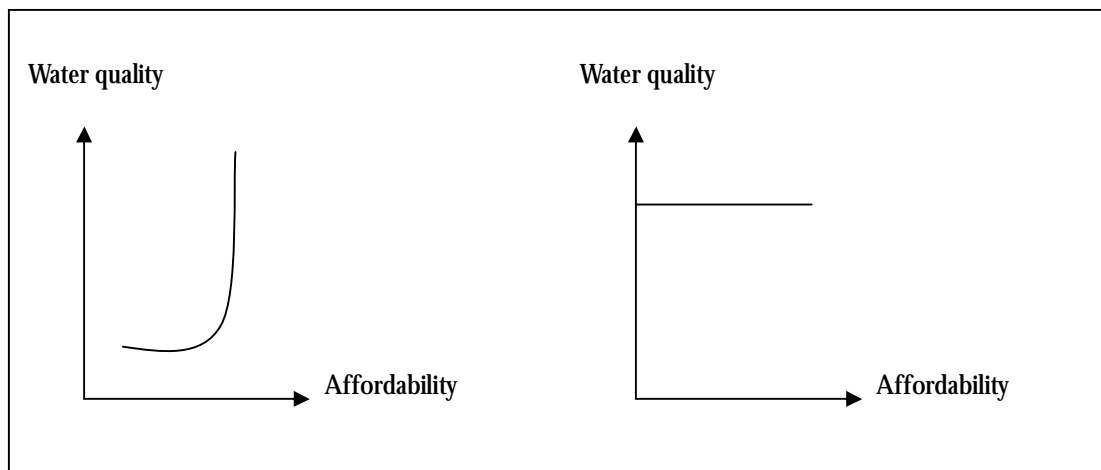


Figure 4.17 Affordability vs water quality in Bandung city (left) and the ideal relation between affordability and water quality (right)

The right image of figure 4.17 shows the ideal relation between water quality and affordability. In the perfect world the affordability has nothing to do with the quality of the watersheds or groundwater. But what currently taking place in Bandung city is the affordability or the ability of the community to access or to afford the wastewater service and also drinking water service plays a significant role in determining the quality of groundwater and also watershed, and that what the left image in figure 4.17 is about. If the water company tries to escalate the affordability which is imply as reducing the cost that the customer must pay for monthly fee or cost for construction of new connection then it means they also upgraded the water quality. In the contrary, if they only concern on how to collect more money to support their operation by charging more to the customer, it would lessen the affordability and no one will ever going to use the service. And instead, they will

prefer to provide everything they need with a way which would help the water quality to deteriorate.

Let us take the cost for new connection cases as the example. As I had told in the economic evaluation for sustainability in the first part of this chapter that one reason why there are many people who seem to be not interested to become the customer of the water company is because of the expensive cost for construction of new connection. These people are preferred to use groundwater as their daily water source, as indicate by the increasing number of borehole users which shown in figure 4.1 This condition is inevitably lead to groundwater quality issue and also become a threat for the productivity or the availability of groundwater in this city. The current picture of the Bandung city's water quality can be reviewed by data shown in Table 4.6 and Table 4.7 bellow.

Table 4.6 Groundwater quality in Bandung city in 2003

<i>Aquifer system</i>	<i>Quality</i>
Shallow (< 40 m)	Some parameters do not meet the drinking water standard (Indonesian Ministry of health 1990): Fe 3+ > 0,3 mg/L, Turbidity > 5 FTU, Mn 2+ > 0.1 mg/L, Organic compound >10 mg/L KMnO4
Middle (40-150 m)	Generally meeting the standard (Indonesian Ministry of Health, 1990) except Fe3+ > 0,3 mg/l
Deep (>150 m)	Meeting the standard

(Source: West Java Mining agency)

As a consequence of the choice, those who are not customers to the water company will not allow to use or access the wastewater service. And this forced them to release their untreated wastewater to the nearest water body. Since this practice is very common across the city for many years, watershed quality issue has been an issue yet to be solved.

Table 4.7 Groundwater quality in Bandung city in shallow level (2003)

<i>Parameter</i>	<i>Threshold value (mg/L)</i>	<i>Sample value [average]</i>
DHL	1000	0
COD	10	37.5
NO3	10	0
Fe	0.3	20.3
Mn	0.1	46.87

(source: West Java Mining Agency)

In this kind of dilemmatic situation it is a bit hard to find a way to please everyone. Any alternatives to be taken shall be different from case to case; it could be economic action or environmental action or neither of them. But regardless whatever choice will be made to clear things up, both the water company and the community and also the local government or any governmental institution related to the case, must sit together to discuss the issue. A good corporation between all stakeholders in the system is one good point to achieve sustainable wastewater management.

4.2.3 socio – environment

In several cases, there is hardly a relationship between social aspect and environment aspect within the system. Yet in this case, social aspect plays an important role in determining environmental quality in indirect way. Under this relation, there is a correlation between watershed quality and population coverage.

4.2.3.1 water quality and population coverage

The term of water quality used in this explanation is refers to watershed quality. And population coverage is the number of population covered or served by the water company for wastewater system. And this relation is illustrated in figure 4.19 bellow.

As we could observe from the figure 4.19, initially, increase in population coverage will improve the water quality. When the number of population covered is raised, it would also increase volume of wastewater influent which enters into the wastewater treatment plant. If the raising of wastewater influent exceeding the wastewater treatment plant capacity, then any increase in population coverage will not improving the water quality. It is even decreasing as the population coverage getting higher.

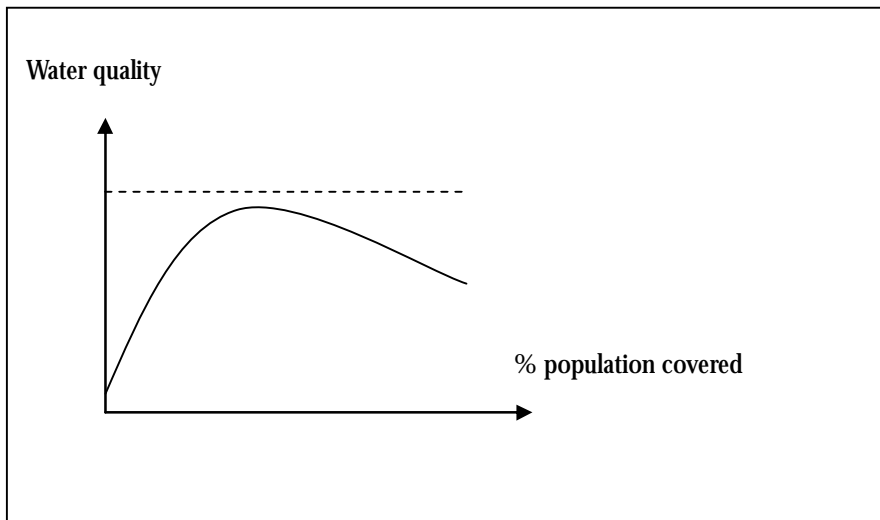


Figure 4.19 Water quality vs Population coverage

This kind of phenomenon has not yet to be happened. However it is important to be aware of such things might occur. Bandung city is the fourth largest city in Indonesia. And as any other big cities, migration rate is also high, so the population is always tend to proliferate.

4.2.3.2 water quality and security

System security has become an integrated part in developing a good system, including in wastewater system. System security means protection over malfunctioning and failure of the system, so the system could works normally. And the relation between this system security and water quality could be illustrated in figure 4.20 bellow.

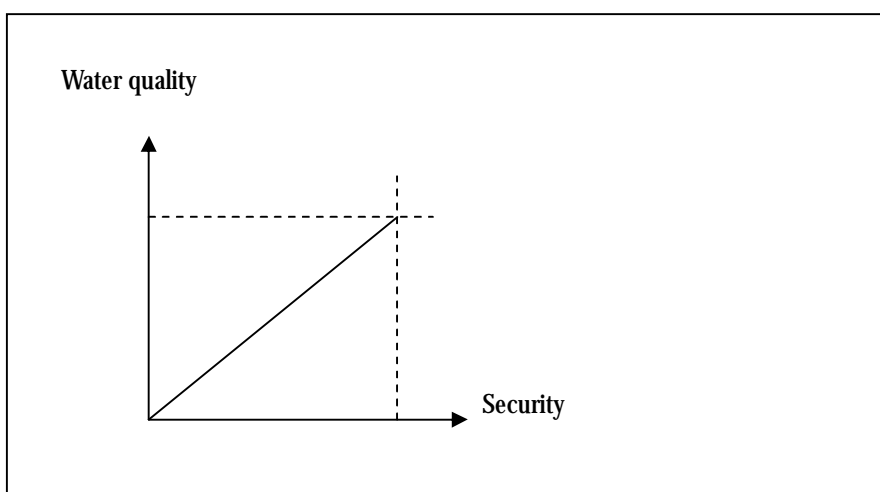


Figure 4.20 Water quality relations with system security

Figure 4.17 above confirm that a stronger and sufficient protection of the system has a linear relation with the water quality. It means a better security over wastewater system would lead to also a better water shed quality. And on the contrary, a weak protection of the system will generate problems in watershed quality.

There are several cases which had been a manifest of this theory. Infiltration of untreated industrial wastewater to domestic sewer and illegal pumping of raw wastewater to agricultural field are real examples of the hypothesis.

Routine and continuous monitoring on the system is one condition to secure the system which eventually would lead to a sustainable state. Lack of monitoring or control over things which has a risk for system failure or system malfunction is the case of infiltration of untreated industrial wastewater to domestic sewer. Most industries that carried out this kind of practice are home industries. Financially and technically incapable of treating their own wastewater made some industries decided to discharge their untreated wastewater to domestic sewer line. And since the wastewater treatment plant is not design to treat industrial waste, so this heavy metal contents are just passing through before finally goes to the water body. This condition is proved by the high concentration of some heavy metals on the water body and in the sludge as the by product of the wastewater treatment process.

Illegal pumping of raw wastewater case is pretty much the same. So during dry season, where rainfall intensity is low, it is going to be difficult time for agricultural field which highly depends on rainwater for irrigation. And the instant way that many farmers near by the wastewater treatment plant do is pumping out the untreated wastewater into their agricultural field. And the effect for this is the wastewater treatment plant decided to stop their operation during dry season. The instability on the operation of wastewater treatment plant will generate an instable treatment performance which eventually affecting the water quality of the water body.

A stable operation of wastewater system is one provision for a sustainable wastewater management. An efficient and effective treatment performance must be supported by a proper protection of the system. So a sustainable wastewater management is not only can be achieved by providing a sufficient and reliable service, an effective treatment performance, an affordable service but also by providing a sufficient maintenance and a proper protection for the system.

4.2.4 Epilogue for the general overview

From the figure 4.12 above we could see how things correlate to each other in the circle of wastewater system in Bandung city. Service reliability is the critical point among the criteria that determine the watershed quality, as the goal of the wastewater system itself. A better watershed quality is the final goal of wastewater system because the purpose of the establishment of wastewater system is to reduce the emission of the organic matter or pollutant to the environment.

A stronger ability of the water company to provide a reliable service will result in a better quality of treatment performance of the wastewater treatment plant, the wastewater transportation, service area coverage and more secure system. And that ability is strongly depending on the affordability of the customer or the city dwellers to pay for the service. Oftentimes, the high service reliability requires a higher financial basis which means the water price will be increased. The existence of willingness to pay criteria will help us to link between the demand of a reliable service and a reasonable price of water.

Institutional management is also one point to be improved in order to able to provide a better service from the water company. The poor institutional management in Bandung city wastewater system has been influencing the service reliability in indirect way.

Chapter V

CONCLUSION

5.1 Conclusions

Some conclusions can be drawn from the sustainability evaluation of wastewater system in Bandung city, Indonesia.

- The current situation of Bandung city wastewater system is not moving toward sustainability and some improvements are necessary in the operation of the system to make them sustainable such as:
 - Technical aspect are the core part of the system which need to be improved
 - Access to wastewater service must be increased. And promoting the use of wastewater facilities to the city dwellers
 - A better institutional management, especially in terms of financial arrangement
 - Develop a more appropriate way of sludge handling; otherwise it would lead to problems in treatment performance and municipal solid waste.

These improvements could give impact on the economic aspect. But soon as they use the willingness to pay indicator to connect the customers demand and the water company demand, then this could satisfy both parts.

- We have developed some important criteria for evaluating the sustainability of wastewater system in Bandung city which definitely can be used for other similar system in other places. And the criteria are:
 - Service reliability, which including the treatment performance, service area coverage, wastewater transportation and system security.
 - water price and affordability
 - watershed quality
 - willingness to pay
- Service reliability is the key point that determines whether the whole system could really work well or not. Improving the service reliability is one important thing to do to help the system moving toward sustainability.

- Comparing the new system which planned to be applied in the city with the current system and evaluating it using these indicators would help the decision maker to decide which one is the best for them.

5.2 Recommendation for future study

This study can be used as support for further research projects aimed at furthering the development toward sustainable wastewater system. There is still work to be done in this area. Some suggestions for further projects are summarized bellow:

- Health and hygiene criteria are very important for evaluate the wastewater system. Yet finding an appropriate indicator for health criteria is a bit tricky but challenging at the same time. And obtain a sufficient data for evaluating the health aspect is often becomes another issue in doing research in this field.
- The efficiency and the effectiveness of energy used for the system to work is one important point which is not able to be done in this research.

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