Cost Benefit Analysis for Centralized and Decentralized Wastewater Treatment System (Case study: Surabaya-Indonesia)

Maria Prihandrijanti[1], Almy Malisie[2], Ralf Otterpohl[2]
[1]Centre for Environmental Studies, University of Surabaya, Raya Kalirungkut, Surabaya 60293, Indonesia
[2]Institute of Wastewater Management and Water Protection, Hamburg University of Technology (TUHH), Eissendorferstrasse 42, 20173 Hamburg, Germany
Email Address: prihandrijanti@ubaya.ac.id, almy.malisie@tu-harburg.de

Keywords: ecosan, centralized, cost-benefit-analysis (CBA), DEWATS, sensitivity-test, wastewater

Introduction

Around three million inhabitants of Surabaya, the second largest city in Indonesia, still dispose their wastewater to water bodies. This is mainly caused by the lack of adequate wastewater treatment system. In order to have a sustainable wastewater treatment system, having an integrated assessment of each alternative based on its economical, environmental, social, health and institutional aspects is necessary. This study explores the economical aspects of three scenarios of wastewater treatment system, with Kalirungkut sub-district, a densely populated urban area in Surabaya, as a case study area. The costs and benefits of alternative interventions are evaluated using the Cost benefit analysis (CBA) method in order to support the decision maker by bringing elements of transparency and objectivity.

As Surabaya does not have a functioning sewerage system and its treatment, the existing system is mainly pour-flush toilet with septic tank. This system requires that the settled sludge in the septic tanks periodically desludged with a septage hauler truck and then transported to the septage treatment plant. Septage is collected from septic tanks all around Surabaya by fleets of tankers operated predominantly by private companies. Unfortunately, not all tankers discharge at the sewage treatment works. There are also direct discharge points along the Surabaya River which provides no treatment to the septage at all. The river water in the vicinity of the outfalls is predominated by the septage.

Like the general sanitation condition in Surabaya, there is currently insufficient sanitation infrastructure in the case study area (Kalirungkut sub-district) and no sewerage networks or sewage treatment for domestic wastewater, except the on-site systems. The range of options available for improving access to sanitation is wide, especially in low-income settings where large proportions of the population have access to only the most basic facilities. For developing countries, WHO favours intervention options that are low cost, feasible and do not require heavy maintenance.

Centralized wastewater treatment system

Surabaya SSDP (Sewerage and Sanitation Development Programme) has done a study on the sewage treatment works in Surabaya (SSDP, 1997). Surabaya has one sewage treatment work, which is located in Keputih (Sukolilo district, east Surabaya). It is a public works operated by Dinas Kebersihan, treating septage from household septic tanks from all areas in Surabaya. The overall appearance of the works was poor due to badly maintained inlet works and the casual use of any spare land for sludge drying. The mechanical and electrical plant was working and the oxidation ditches were apparently operating although failures and faults do exist. The works were probably suffering from overloading and so could not be expected to meet the design quality standards.

In 1996, a master plan for sewerage and sanitation development was written for the city of Surabaya. In this Master Plan for the year of 2020, the wastewater would be treated in off-site modules by using shallow sewerage as conveyance system and Imhoff Tanks as the treatment technology. Unfortunately, this master plan has not been implemented yet due to some constraints and lack of funds. In addition, large-scale centralized wastewater treatment is not an economical option particularly for people living in low income urban areas. Decentralized wastewater treatment systems that are more affordable are being developed. In order to solve water pollution from domestic wastewater, decentralized wastewater systems have been constructed in some areas.

Decentralized wastewater treatment system (DEWATS)
The DEWATS-Indonesia project is publicly funded private cooperation between the German and Indonesian non profit organizations, Bremen Overseas Research and Development Association (BORDA) and Institute for Rural Technology Development (*Lembaga Pengembangan Teknologi Pedesaan*). DEWATS is based on the principle of low-maintenance since most important parts of the system work without technical energy inputs and cannot be switched off intentionally. DEWATS applications provide state of-the-art-technology at affordable prices because all of the materials used for construction are locally available. DEWATS applications are based on basic technical treatment modules which consist of baffled upstream anaerobic reactors for greywater treatment and anaerobic digester for blackwater treatment.

Another decentralized wastewater treatment alternative that this study considers is Ecological Sanitation (Ecosan) that follows similar ideas as DEWATS. In addition, Ecosan aims to full reuse of nutrients. Another Ecosan principle is to prevent mixing of pathogenic bacteria from human waste with the wastewater that are going to be returned to the environment. Furthermore, Ecosan is able to recover valuable nutrients from domestic wastewater, particularly in human urine and faecal matter. These nutrients would not recoverable if they are diluted with large amounts of domestic wastewater in the conventional sewerage systems.

The Ecosan pilot plant in the case study area separates wastewater into blackwater (human faecal+flushing water), yellowwater (human urine+flushing water) and greywater. Blackwater is contained and treated separately into compost using worms (vermicomposting), while yellowwater is stored separately for 6 months to have a hygienisation process. Greywater, which originates from bathing and washing activities contains less organic matter, and is treated with horizontal flow sub-surface constructed wetland.

Cost Benefit Analysis (CBA)
According to the 2001 Census, kecamatan (district) Rungkut has a population of 111,286 people, who live in 6 kelurahans. It has an area of 21.02 km^2, thus the population density of this district is 5294 people/km^2. The Surabaya Industrial Estate Rungkut (SIER) is located in this district. This industrial estate houses 371 companies and has an area of 332 hectare. Kelurahan (sub-district) Kalirungkut, with a population of 35,090 people and an area of 2.58 km^2, has the highest population, because a big university and several industries are located in this sub-district. Therefore, in this sub-district there are a high percentage of non-permanent residents, who came here from other towns or villages to work, study or live there.

Considering the location profile (e.g. population, density, etc.), it would be better and easier to divide the wastewater management scheme into smaller modules to make it easier to manage and minimise the need for expert operation and maintenance. With smaller modules, the operation and maintenance of the facilities would not be so complex as bigger plants and the community or someone from the community who acts or paid as a caretaker could be trained to manage the facilities. As the smallest neighbourhood coordinating organisation, Rukun Tetangga (RT) would be very suitable to facilitate community-based sanitation management, because it takes care of the social and administrative matters of a neighbourhood. The base scenario is based on the empirical study, which has been done in kelurahan (sub-district) Kalirungkut, kecamatan (district) Rungkut in Surabaya-Indonesia.

The case study area, Kalirungkut sub-district, has 35,090 population (in 2001), which is divided into 83 RTs. With an assumed average growth rate of 1.57%/year it is projected that the population would be 50,000 people in 2020. This study is based on implementation of two alternative sanitation systems in comparison to conventional wastewater treatment (household connections to the sewerage system and partly-centralised wastewater treatment of domestic wastewater). Thus, there were three different alternatives for this study, which were:

Scenario 1
Ecological Sanitation system alternatives integrated with Decentralised Wastewater Treatment Systems (Dewats) technologies in order to rendering domestic wastewater safe and using the safe products of sanitised human excreta for agricultural purposes, as follows:

a) Communal toilet for a part of the RT's population who does not have their own/private WC, with source separation (yellow-, brown- and greywater) followed by urine (yellowwater) storage in Urine Tank (UT), treatment of faecal material (brownwater) with pre- and vermicomposting in Rottebehaelter (RB) and treatment of greywater with Horizontal Subsurface Flow Constructed Wetland (HSFCW) or Baffled Septic Tank (BST);
b) Decentralised domestic wastewater treatment for the rest of the RT's population who have their own WC with BST for greywater treatment. The brownwater and urine are treated/stored in every household. Thus, only the greywater from every household are sent to the decentralised treatment unit. For the decentralised alternative, BST is preferred instead of HSFCW because HSFCW would require very large area for the whole population served.

Scenario 2

Decentralised Wastewater Treatment Systems (Dewats) technologies in order to rendering domestic wastewater safe and using the biogas product for cooking purposes, as follows:

a) Communal toilet for a part of the RT's population who does not have own/private WC with partly separated treatment of grey- and blackwater (wastewater from WC). The greywater is treated with Baffled Septic Tank (BST), and the blackwater is treated with Anaerobic Digester (AD) on-site.
b) Decentralised wastewater treatment for the rest of the RT's populations who have their own WC with Baffled Septic Tank (BST) for greywater treatment and Anaerobic Digester (AD) for blackwater treatment.

Scenario 3

Household connections to the sewerage system and off-site wastewater treatment of domestic wastewater from the community according to the Surabaya SSDP (Sewerage and Sanitation Development Programme) Master Plan 2020. Based on this Master Plan, the wastewater in this scenario would be treated in off-site module by using shallow sewerage as conveyance system and Imhoff Tank as the treatment technology.

Shallow sewer was chosen because it can be laid to flatter gradients and lower depths than conventional sewers and is placed in non-trafficked areas. This renders it suitable for small community systems in low-income kampung type areas. Shallow sewer could be utilised in conjunction with a conventional system. Small low-income areas could be connected to a conventional sewer in a nearby street by a shallow sewer network. Imhoff-tank works similar to communal septic tank. Imhoff tank provides minimum wastewater treatment facilities for household influents. Due to the underground construction, land use is very limited. An Imhoff tank can be constructed under roads or other public areas. Construction costs are higher than septic tank. Manual or vacuum desludging is required more often than septic tank. Reduction of BOD is about 30-40 %; very moderate reduction of infectious organisms and quite effective sedimentation of coarse particles.

Few studies measured the costs and benefits of alternative interventions to provide policy makers with the information to choose the most efficient intervention from the viewpoint of society or the health sector. Generally, it would seem that there has been inadequate attention to economic issues in water and sanitation interventions (Hutton in WHO, 2001), but especially in the field of sanitation system alternatives (other than sewerage system).

The purpose of this study was to explore the costs and benefits of the sanitation system alternatives/scenarios, with Kalirungkut-Surabaya as case-study area. This work was not meant to state or declare that an alternative sanitation system is the best or the only option for every low-income urban area in general, because the choice of a best sanitation system for a certain area/community depends on various aspects; so that it might differ very much from one to the other.

The viewpoints of this analysis were:

- economical (building, operation and maintenance costs), and
- society (direct expenditures avoided due to less illness from diarrhoeal disease)

This financial CBA will include available information related to:

i) An analysis of the costs of constructing each sanitation system alternative for case study area in monetary terms
ii) An analysis of the benefits obtained from implementing the sanitation system alternatives expressed in monetary terms

However, as in other CBA in water and sanitation field, there are many intangible costs as well as benefits, which are not constituted or represented by a physical object and very difficult to measure, such as the impact (in monetary terms) of different effluent qualities from several wastewater treatment systems, benefits from the reduction of soil infertility through usage of human excreta as fertiliser/soil conditioner, etc.

Costs for each scenario have been compiled and presented below:

Table 1 **Total Investment and Operation and Maintenance costs of each scenario**

System	Construction (€)	Land (€)	First cost (€)	O & M (€)
Scenario 1	4.203.528	562.500	4.766.028	68.750
Scenario 2	5.037.007	800.500	5.837.507	68.750
Scenario 3	6.173.838	included in Construction	6.173.838	308.692

Due to problems in measurement and quantification/valuation, and also because of substantial variability between settings and absence of adequate data, only the averted health expenditure from the private point of view and revenue from user fee will be valued as benefits in this study. Further, as in the case also in other studies on Cost-Benefit of sanitation interventions, this analysis also makes use of some general assumptions for all scenarios. The averted health expenditure incorporates:

a) treatment and transport costs
b) income gained due to days lost from work avoided
c) opportunity cost of days of school absenteeism avoided
d) productive parents' days lost avoided due to less child illness

The benefits have a general characteristic, which could result from all sanitation interventions. Therefore, they are assumed the same for each scenario. Total annual benefit for each scenario were 658,125€.

The results of cost benefit analysis were presented in the following tables.

Table 2 **Net Present Value of the three scenarios**

Scenario	PV Cost (€)	PV Benefits (€)	NPV (€)	B/C ratio
1	4,896,635	5,397,481	500,846	1.10
2	5,870,717	5,397,481	-473,236	0.92
3	8,144,312	5,397,481	-2,746,831	0.66

For this analysis, the present value of costs and benefits are combined in Table 2 to calculate the Net Present Value (NPV) and Benefit-Cost ratio (B/C). The flow of costs and benefits were discounted at 10% discount rate. It can be seen from the table that Scenario 1 has a positive Net Present Value (NPV) and a B/C ratio greater than one, whereas the others have not. Nonetheless, this does not mean that the others are not practicable, because the results above are only based on calculations on a given aspects of costs and benefits. Scenario 2 could also have a positive net benefits if, one of the parameters changes. Scenario 3 is obviously the most expensive option in comparison to Ecosan and Dewats systems, especially if the costs of clean water wasted through its utilisation as a means of wastewater conveyance are also calculated. Still it is apparent that the Ecosan scenario has more benefits than the other systems, such as the added benefit from urine and faeces as fertiliser or soil conditioner, its closing-the-loop concept and simple technology. Nevertheless, not all benefits could be valued in this study because a wide range of further studies are still needed, such as how to optimize the fertilizer value of human excreta as well as its marketing strategy.

A number of sensitivity tests were carried out to show how changes in certain parameters would affect indicator values. The results for the NPV values and B/C ratio are in Table 3 and 4 respectively. The parameter changed are: discount rate 8% and 12%, construction cost 30% higher, O & M cost 30% higher, user fee 30% higher and benefit start delayed by one year.

Table 3 **Net Present Values from sensitivity tests result**

Scenario	Base case	r=8%	r=12%	Construction +30%	O&M +30%	User fee +30%	Benefit start delayed 1 yr
1	500.845	1.110.639	17.147	-134.214	331.693	746.884	-97.456
2	-473.236	118.557	-939.577	-1.119.245	-642.388	-227.197	-1.071.538
3	-2.746.831	-2.441.540	-2.979.370	-5.190.120	-3.506.329	-2.500.792	-3.345.133

Table 4 **Benefits/Costs ratio from sensitivity tests result**

Scenario	Base case	r=8%	r=12%	Construction +30%	O&M +30%	User fee +30%	Benefit start delayed 1 yr
1	1,10	1,22	1,00	0,98	1,07	1,15	0,98
2	0,92	1,02	0,84	0,83	0,89	0,96	0,82
3	0,66	0,72	0,62	0,51	0,61	0,69	0,59

The results showed that if the discount rate was changed to 8%, B/C ratio of scenario 1 and 2 will be higher, but Scenario 3 still has B/C ratio less than one. If the discount rate was changed to 12%, than only Scenario 1 which still has positive NPV, even though it is very small (B/C ratio = 1,00). If the operation and maintenance cost was increased by 30% or the user fee was increased by 30%, only Scenario 1 which still has positive NPV. All scenarios will have negative NPV or B/C ratio less than one if the benefit start was delayed for one year and if the construction cost was increased by 30%. Sensitivity tests show that these results are very sensitive especially to changes in construction cost and benefit start.

Conclusions and Recommendations

The results of cost benefit analysis in this study showed that the decentralized system was more feasible economically for this case study, since the centralized wastewater treatment system had the highest net present value cost and the lowest cost benefit ratio. In order to support decision making regarding the sustainable wastewater treatment system for this area, further assessment on environmental, health, social, and institutional aspect are recommended.

References

1. Hutton, G. and L. Haller, *Evaluation of the Costs and Benefits of Water and Sanitation Improvements at the Global Level,* WHO, Geneva, Switzerland, 2004.
2. Indonesian Water Supply and Sanitation Policy Formulation and Action Planning Project (WASPOLA), *Sanimas: Sanitasi oleh Masyarakat*, Water and Sanitation Program, Jakarta, Indonesia, 2002.
3. PT Indulexco Consulting Group, Mott MacDonald Ltd. and PT Dacrea, *Final Report Master Plan Surabaya Sewerage and Sanitation Development Programme 2020*, Surabaya, Indonesia, 1997.
4. Sasse, Ludwig, *DEWATS: Decentralised Wastewater Treatment in Developing Countries*, BORDA, Bremen, Germany, 1998.
5. Snell, Michael, *Cost-Benefit Analysis for Engineers and Planners*, Thomas Telford Services Ltd., London, England, 1997.
6. Sugden, R. and A. Williams, *The Principles of Practical Cost-Benefit Analysis*, Oxford University Press, Oxford, England, 1978.
7. Sukarma, R. and R. Pollard, *Indonesia: Overview of Sanitation and Sewerage Experience and Policy Options*, Water and Sanitation Program for East Asia and the Pacific, Jakarta, Indonesia, 2001.

8. WHO and UNICEF, *Access to Improved Sanitation: Indonesia,* WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation Coverage Estimates 1980-2000, 2001.
9. WHO and UNICEF, *Global Water Supply and Sanitation Assessment 2000 Report*, 2000.