Title	INTEGRATING CONVENTIONAL AND ECOLOGICAL SANITATION IN URBAN SANITATION FOR THE FUTURE
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1.0 Introduction

1.1 Background

Improving urban sanitation is going to be one of the largest and most expensive challenges for the environmental quality and hygiene of our cities in the coming years.

In general the concepts used for urban sanitation has not developed much for the last 100 years. Flush toilets, sewer networks and centralized treatment of mixed sewage and wastewater from all types of sources have all through the years been the only solution seriously considered. However, the costs of centralized sewage are prohibitive for large part of the world's urban areas. Increased demands for improved treatment further add to the costs. At the same time, issues related to disposal of contaminated sludge from treatment of mixed sewage and percolation from leaking sewers raises environmental and health concerns.

The growing demand for sustainable solutions includes recycling of the nutrients to the soil, reducing the CO_2 emission by utilizing the energy content in the sludge and reducing the amount of water utilized as medium for transporting the waste in the sewage system.

In Kuching, Sarawak, Malaysia, a study has been conducted to assess the possibility of integrating conventional centralized sewage treatment with non-piped ecological sanitation. The study is still at a very early stage. However, already at the present stage, it can be concluded that ecological sanitation for urban areas is certainly a concept that should be considered seriously for any urban wastewater planning. This paper presents the background, contents and findings from the study.

1.2 The Location of study area

Kuching is the capital of the Malaysian State Sarawak located at the northwestern part of the island of Borneo. The city is located along both sides of Sarawak River approximately 40 km from the river mouth. Large tracts of the city are founded on unstable ground comprising of peat swamp and soft estuarine and riverine deposits, while the old

Figure 1: Location of the city of Kuching, Sarawak

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historical city centre is located on mineral soil. The city has a population of about half million, found fairly widespread on flat terrain along the surrounding rivers and streams.

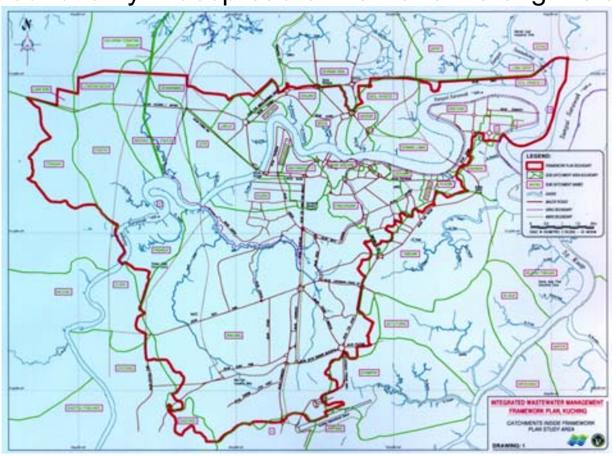


Figure 2: Kuching city study area

The Sarawak River is strongly influenced by tidal flushing which improves the removal of pollutants from the river system. In 1998, the State Government has established a gate system to control water level especially in front of the city centre. However the gate system has reduced tidal flushing, thereby causing deterioration of water quality of the river and distributaries. Controlled flushing of the gates has only partly compensated for the deterioration. To enhance water quality of Sarawak River, the State Government has initiated a series of studies on possible improvements of the wastewater management. The studies have been confined to the parts of the city discharging to the river upstream of the gates. This study area is 98 km2 with a population estimated at 220, 000 inhabitants or 36,000 households (refer to ***Figure 2***). Within the study area, the residential areas are typically well delineated, with only few businesses discharging non-domestic wastewater within the areas. The commercial activities are located in dedicated commercial centers. The total population equivalent (PE) in the area is 580,000.

2.0 Present Wastewater Management in Kuching City

In 2001 a survey was conducted to determine the main contributors to the pollution of the river. The survey indicates that households are by far the main sources of pollution, followed by food outlets**. *Table 1*** shows pollution load from different sources for Kuching City.

Plate 1: Black water outlet (left channel) and grey water (right channel) outlets to storm water drain in central Kuching

Most residential households are equipped with two separate wastewater outlets systems, one outlet for **black water** (toilet water) and a number of outlets for **grey water** (washing, bathing, kitchen and cleaning). Black water is treated in individual septic tanks at each premise, though few housing estates are covered by communal treatment facilities (Imhoff tanks). Overflows from the septic tanks are directed to the stormwater drains (refer to ***Plate 1*****).** The septic tanks are generally properly sized with retention time of 16 to 32 hours. However, even well functioning tanks will only be able to reduce the content of organic matter by 40% and can only ensure a minor reduction in pathogens. In 1998, the State Government introduced a desludging regulation requiring desludging of household tanks every 4th year and established a sludge treatment plant based on drying

Plate 2: Tanker Truck at Matang Sludge Treatment Facility

(screwpressing), stabilizing (lime mixing) and landfilling of the stabilized sludge. Among the issued encountered in the operation of the new collection system, was that about 20 to 30% of the septic tanks are inaccessible due to inconvenient location of the tanks or house extensions and some septic tanks are of poor quality and collapse when desludged. In addition only a minimal biological activity has been encountered in the tanks as reflected by a low total coliform count of approx. 10^5, probably due to extensive usage of chemical cleaning agents.

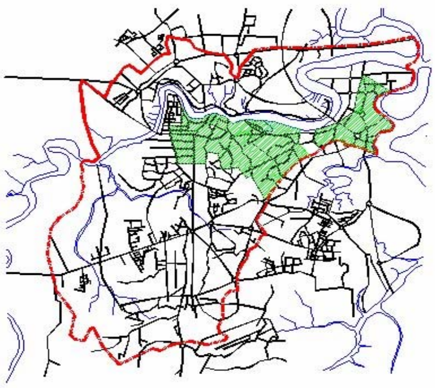
Greywater from households is discharged directly to the stormwater drains without any treatment and flows into Sarawak River or its distributaries. Similarly, only about one third of about 650 food outlets in the city are installed with oil and grease traps, which furthermore are grossly undersized (*between 50-200 liters capacity*). The remaining food outlets are discharging directly into storm water drains. The studies also indicate that grease trap with the size of 1000 liters and above are required to trap these wastes. Though oil and grease constitutes only about 5% of total organic matter discharge, oil and grease clogs the drains, and is a cause for foul odour.

In ***figure 3***, the parts of the study area where the food outlets discharge more than 70% of the oil and grease load are presented.

Table 1: Load from different sources

	Household (kg/day)	Food outlets (kg/day)	Industries (kg/day)
BOD	5900-9700	650	15
COD	19900-26000	800	40
TSS	5400-8000	260	60
Tot-N	2600-3400	30	5
Tot-P	500-600	10	3
Oil and grease	200-350	60	2

Figure 3: Areas of Kuching City where more than 70% of the load of oil and grease is from food outlets



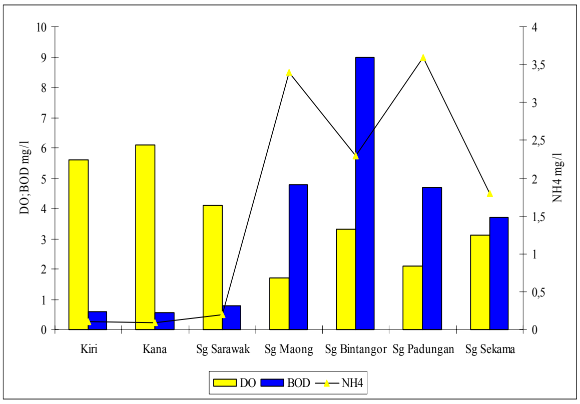
3.0 River water quality

The water quality of Sarawak River varies considerably, with high level of dissolved oxygen upstream (Kiri and Kanan), declining to about 4mg/l as the river passes through the city center. In the urban tributaries (Maong, Bintangor, Padungan and Sekama) the oxygen lecvel is further reduced. As seen in ***figure 4***, low oxygen level corresponds to high level of ammonium and BOD. Similarly, bacterial counts are very high, more than 16,000 MPN/100ml in the city center and in the tributaries (***Table 2***). Initial studies on the development over time show among others increase in organic matter in the river bed sediment and a decline in biodiversity.

Figure 5 illustrate the increase in organic matter in the bottom of the sediment of the river 2000-2003 and ***figure 6*** illustrate the development in biodiversity in the same period.

4.0 Wastewater management improvement strategies

Figure 4: Mean concentration of dissolved oxygen, BOD and ammoniacal nitrogen (NH_4-N) in 2000 in different zones of the Sg. Sarawak as defined below.



A feasibility study carried out in 2001-03, documented that a conventional piped wastewater system for the study area will cost the government about 3 billion MYR[6]. Out of this, approximately 2 billion MYR refer to installation and construction of sewers and pumping stations.

As a follow up, the government is carrying out a comparative study to assess and recommend on other emerging ecological non-piped wastewater systems to complement conventional wastewater systems in an environmental and economic viable way[7]. The overall concept applied is based on source sorting of grey and black water from households. As the grey water from kitchen and bathrooms constitutes more than 90% of the wastewater but contain less than 1% of the pathogens, this wastewater fraction can be treated locally without involving any health risk. The black water, however, contains nearly all pathogens and is therefore critical to treat locally in an urban setting. The fraction, however, contains less than 10% of the wastewater, and it may therefore be relevant to assess the environmental and economical feasibility of transporting this fraction to centralized treatment and recycling of nutrients and energy. The first step of the comparative study was to determine the criteria for selecting the components of a possible ecological sanitation system for the city. With a large number of pilot project implemented worldwide, especially in the last 5 to 10 years, a variety of concepts and approaches have emerged. Most of the projects are rural and therefore not relevant for the urban setting. Other projects are however, actually developed for urban areas or can be adapted to urban conditions. Therefore, before proceeding with the planning, criteria have to be set for selecting the most suitable ecological sanitation system. The criteria selected include:

(i) No change in habits to be required

For ecological sanitation to be functional as general solution for larger urban areas, the system has to recognize the different motivations, attitudes and habits of the residents. It was therefore considered important that the system should not require any change in habits. For the individual households, the kitchens, bathrooms and toilets should be functioning exactly as before the system was introduced. This let to rejection of urine separation systems. Another reason for this rejection of course was the additional costs imposed by the dual piping from the toilet & dual collection system.

(ii) Simple maintenance of local facilities

The ecological sanitation system should be able to function without any increased environmental impact even if the operation and maintenance system is not fully up to par. This criterion implies among others, that local treatment of black water was rejected. The system therefore has to be based on hauling the black water to a centralized recycling facility. The criterion further implies that the grey water system have to be simple gravity based systems. More advanced compact indoor systems like the German Lokus design was therefore rejected at this juncture for individual residential premises.

[6] currency rate for Malaysian Ringgit to US dollars : 3.8 MYR = USD 1

[7] Sarawak Government-DANIDA UEMS Project: "Framework plan for Integrated Wastewater Management for the City of Kuching, Sarawak". Henrik Lynghus and Ib Larsen, COWI Denmark, (UEMS_TEC_02-05) NREB, Kuching 2004.

Table 2: Mean bacterial counts in the different zones of the river Sarawak in the year 2000

Zone	Mean conc. of Total Coliform (MPN/100ml)	Mean conc. of Faecal coliforms (MPN/100ml)
Zone A Sg. Sarawak Kanan	9400	5100
Zone B Sg. Sarawak Kiri	11800	7500
Zone C (Batu Kawa to Satok bridge)	4300	-
Zone D (Satok to Barrage)	> 16000	> 16000
Zone E (Sg. Maong)	> 16000	> 16000
Zone F (Sg. Bintangor)	> 16000	> 16000
Zone G (Sg. Padungan)	> 16000	> 16000
Zone H (Sg. Sekama)	> 16000	> 16000

Figure 5: loss of ignition. Sarawak River

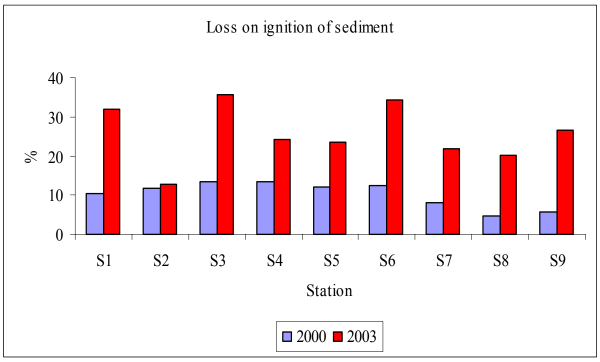
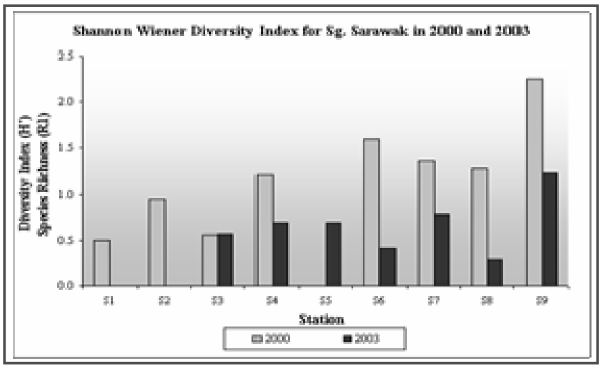


Figure 6: Biodiversity, fish and prawns. Sarawak River



(iii) Simply construction of local facilities
The grey water technology has to be simple and based on components which could be produced locally. This criterion points towards compact combined vertical and horizontal wetland solutions.

(iv) Generally accepted design
In the urban setting a large number of grey water facilities would be required. It is of course crucial that the presence of the facilities in the neighborhood is accepted by the residents as part of the urban landscape. This implies that the facility should be designed so as to be accepted as a green feature without any negative impact like odour, noise on unpleasant design.

The concept of the greywater system was adopted based on a system developed by the University of Life Sciences (UMB) in Oslo, Norway. The compact design using nozzles to spray the wastewater at the vertical wetland and the possibilities to integrate the facility in parks and open areas was persuasive.

For the black water system, the wastewater has to be hauled away for centralized treatment. Reduction in water consumption for toilet flush was therefore crucial. The system design for the study was based on substituting existing toilets with 2–4 liters low flush toilets. However, in the future, the economy of the ecological sanitation may be further improved by implementing even less water-using toilets or vacuum systems. The treatment of the black water was to take place in a biogas plant to produce fertilizer and energy. The study therefore presupposed an upgrade of the existing sludge treatment plant to a biogas plant to treat black water and other organic wastes from markets, abattoirs, food industries, oil and grease traps at food outlets etc.

The study had to take into consideration the specific features of the city, advantagous or disadvantagous for implementing the different treatment systems. The city has some specific features of huge important for the economic feasibility of ecological sanitation:

- **Source sorting of grey and black water**

As describe above all premises in Kuching are already equipped with separate outlets for grey and black water. In many countries houses only have one wastewater pipe combining grey and black water. Separating the grey and black water is therefore one of the major constrains for implementing ecological sanitation in urban built-up areas. However, in Kuching this is not the case, the costs for separation of grey and black water have already been paid. This feature is actually not a requirement according to the local building regulations. It seems merely to have developed as building practice due to lack of requirement to treat grey water. This shortage in the present sewage management system may now prove to be a huge advantage for the city.

- **Local treatment of grey water**

According to the local building regulations all new housing developments larger than 1 hectare have to include 10% open areas for public purposes. Upon completion of the development this area is handed over to the local councils. This means that a huge part of the city already encompasses areas available for grey water treatment. As mentioned above a precondition for successfully utilizing this advantage is, that the design of the facilities is accepted as a component of the public green areas.

At the same time that the conditions for implementing ecological sanitation are very favorable compared to many other urban areas worldwide, the conditions in certain areas of the city are clearly infavourable to conventional piped wastewater systems:

- **Instable ground**

The instable ground at the extensive peat swamp and soft clay areas implies increasing cost for conventional piping. In many areas piling of pipes will be a requirement. Subsiding of the peat swamp areas following laying of the sewers might further increase the risk for breaking sewers or for the gradient of the sewers to reverse.

- **Low lying level areas**

The risk for reversing the gradient is further increased in the huge areas, which are low lying and with very minimal gradients. To ensure a continuous flow in sewer in such areas extensive pumping will be required.

- **High ground water level**

The ground water level in many areas is less than 1 meter below surface. The high ground water level implies high risk for ground water intrusion into the sewers and therefore overloading of the sewage system and the treatment plant.

5.0 Integrating conventional and ecological sanitation

5.1 Characteristic of conventional and ecological sanitation

The main objective for integrating different wastewater management systems is to ensure the largest environmental improvement for the available resources. To optimize the possible distribution of the two systems the characteristic and advantages of each system have to be identified and assessed. The two systems each have potential advantages and disadvantages.

Conventional systems generally have the following main advantages:

- Efficient removal of wastewater ensuring a high hygienic standard in the sanitized areas;
- Highly robust towards composition of the wastewater discharged into the sewers. Main limitations are solids that clog the sewers and substances that corrode the sewers;

The disadvantages include:

- Extremely high capital costs;
- High consumption of water as medium to transport the pollutants to the treatment plant;
- Low sludge quality due to the mixing of wastewater types in the sewers;
- Health issues related to percolation of sewage from breaking or leaking sewers.

The main advantages of ecological sanitation include:

- Low capital cost;
- High environmental performance with a very low discharge of pollutants and high level of recycling of nutrients and energy.

The main disadvantageous are:

- High sensitivity towards composition of wastewater. The wastewater has to be clean fractions that can be treated in grey water facilities and that can be accepted as fertilizer on agriculture or land after the treatment respectively;
- A high number of local grey water facilities that need to be managed and maintained;
- Increased road traffic from collection of black water;

Conventional systems would therefore often be the only realistic solution for major business districts, industrial areas and other areas where the sources and the composition of the wastewater discharge are difficult to determine and control. For areas where the robustness of the conventional wastewater system is not required due to uniform composition of the wastewater, the environmental and economic benefits of ecological sanitation may be substantial. This will often be the case for residential and many commercial and institutional areas.

Based on these criteria and principles the study aims to identify areas where conventional wastewater management and ecological sanitation respective will be feasible. The study encompasses 3 steps:

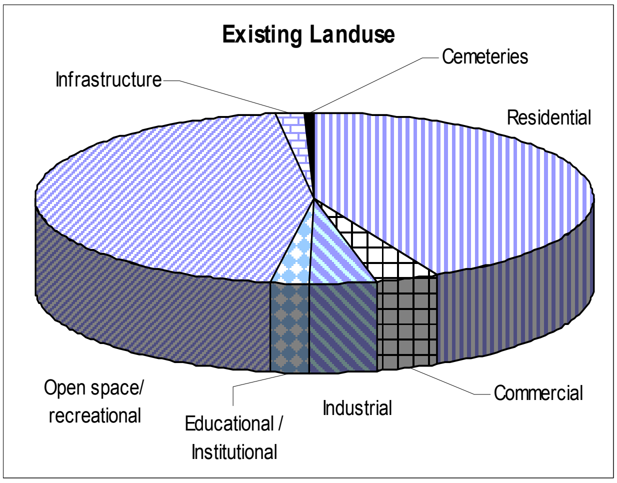
- Land use survey
- Wastewater type survey
- Area suitability survey

5.2 Area suitability survey

The first step of that survey was to identify the land use within the study area. The findings are presented in ***figure 7***.

The recreational areas constitute 45% of the area. Residential areas with no or very little mixing with commercial or other activities constitute 43% of the areas. Commercial and industrial areas in total only constitute approximately 8%.

Figure 7: Existing land use figure



The next step was to determine the wastewater composition within the different areas. Wastewater was divided The next step was to determine the wastewater composition within the different areas. Wastewater was divided into:

- **Domestic wastewater**
  Water that only content non-toxic organic matter and nutrients.

- **Non-domestic wastewater**
  Mixed wastewater from industries and workshops etc., which typically contain toxic substances that are not suitable for recycling or may hamper or prevent the function of the grey water facilities.

- **Mixed wastewater**
  Domestic wastewater mixed with very small amounts of non-domestic wastewater from dispersed garages and other small businesses.

Finally an area suitability analysis was carried out, adjusting the findings from the land use and wastewater composition analysis for factors such as location, congestion etc. The final area suitability map is presented in ***figure 8***.

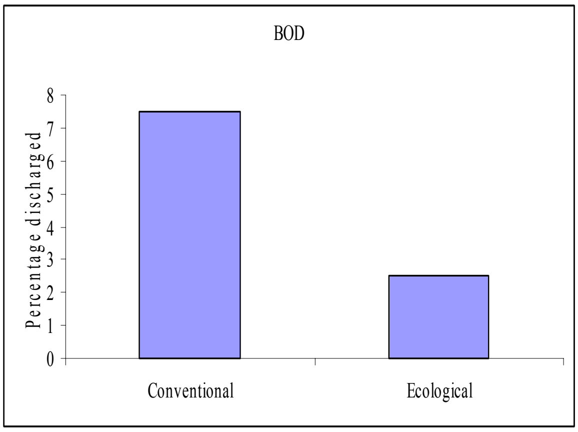
Figure 8: Area suitability for ecological sanitation systems

The surveys documented that 89% of the study area were suitable for ecological sanitation (green/light grey areas). For 8% of the area ecological sanitation was not considered suitable (grey areas). Areas conditionally suitable for ecological sanitation (red/dark grey areas) were defined as areas discharging mixed wastewater. In these areas, a small amount of non-domestic wastewater would have to be separated from the domestic wastewater by simple mechanical means and by a reasonable level of enforcement to allow for ecological sanitation. These areas include a number of commercial centers and sprawl areas with workshops, garages, backyard industries, etc.

5.3 Environmental assessment

Following this, an environmental assessment study[8] was carried out comparing the discharge of BOD and nutrient from conventional sanitized area with ecological sanitation.

Figure 9: BOD_5 discharged from areas with conventional and ecological sanitation systems



The discharge of BOD from the ecological sanitized area would be approximately 1/3 of the discharge from the conventional sanitized areas (Refer to ***figure 9***) while the difference in discharge of nutrients were even bigger. The discharge of nitrogen from the conventional system was expected to be approximately 10 times higher (50%) than from ecological sanitized area.

This difference is due to the conversion of black water into fertilizer for the ecological sanitation system, while all domestic wastewater in the conventional wastewater system are discharged into the sewage system.

The ecological sanitation system further implies a substantial recycling of the nutrients from the black water for agricultural purpose, as approximately 90% of the nitrogen and 55% of the phosphorus is contained in the black water. ***(Refer to table 4)***

The mean values are estimated as follows:

Table 4: Estimated amount and content of pollutants in black and grey water in Kuching

Pollutant	Black water	Grey water
Organic matter (BOD)	25 g/cap/day	35 g/cap/day
Nitrogen (Tot-N)	13 g/cap/day	1.5 g/cap/day
Phosphorous (Tot-P)	1.8 g/cap/day	1.0 g/cap/day
Bacteria (E. coli)	10	10
Grease	0	25
Wastewater quantity	40 l/cap/day	140 l/cap/day

To confirm the environmental quality achieved by ecological sanitization under the local tropical climate and the local culture and habits, an ecological sanitation demonstration project was established for a row of 9 terraced houses in the centre of Kuching. The demonstration project has revealed very impressive treatment rates. The demonstration project has further revealed that the grey water facilities, when properly designed, are accepted by the residents as a positive green feature in the urban landscape[9].

5.4 Economic assessment

A series of surveys has been initiated to obtain figures on the costs for establishing and operating the black and grey water for ecological sanitation. As shown in Table 5 below, the first preliminary costing assessment on capital costs, under the hypothetic situation that ecological sanitation is suitable for 100% of the study area, is approximately MYR 600 mill.

[8]Sarawak Government-DANIDA UEMS Project: “Estimation Methods for Discharge from Treatment Facilities”, Erling Povlsen COWI Denmark, (UEMS_TEC_03_02), NREB Kuching, 2004

[9] Jenssen, Petter et al. 2005. “An urban ecological sanitation pilot study in humid tropical climate”. Paper for the Third International Conference on Ecological Sanitation. Durban RSA, May 2005

Table 5 : Capital Cost – Ecological Sanitation for the Kuching Study Area (Mill MYR)

Grey water facilities and house connections	300
Low flush toilets and holding tanks	150
Tanker trucks	35
Biogas plant	40
Others	75
TOTAL	**600**

Most of the capital costs are related to the installation of the grey water treatment facilities. Based on detailed calculations for a demonstration project[10], the installation of a grey water facility for 160 PE, including house connections and oil and grease trap, amounts to 100,000 MYR. Upscaling this amount to 500,000 PE will amount to 300 million MYR. This amount is considered conservative as future grey water facilities are expected to cover a larger number of households. The black water system includes conversion of all toilets in the study area to 2 – 4 liters low flush toilets and installation of communal holding tanks. The study area contains an estimated 60,000 toilets to be substituted. An estimated 1,000 grey water facilities and 1,000 black water holding tanks have to be installed.

To transport the black water from the holding tanks to the future biogas plant an estimated number of 70 units of $10m^3$ vacuum tanker trucks are required.

The estimated total capital cost of 600 mill MYR for ecological sanitation as presented above, is obviously lower than the the conventional wastewater system (3 billion RM). Eventhough the area suitability analysis has shown that 100% ecological sanitation of the study area is not possible, the findings still reveal some extremely interesting perspectives for the future direction of urban wastewater management. The preliminary findings indicate a capital cost for ecological sanitation in built-up areas at 20% of the cost for conventional sanitation.

The above discussion refers to sanitizing of built-up urban areas. The preliminary survey has documented even more exciting data when ecological sanitation is encompassed in new housing development from the design stage. The preliminary findings indicate that the additional cost for installing ecological sanitation is as low as 10% of a conventional sewage system.

The capital costs per PE are illustrated in ***table 6***.

Table 6: Comparison capital costs

	Built-up areas	**New Housing Estates**
Conventional	6,000 MYR/PE	4,500 -5,500 MYR/PE
Ecological Sanitation	1,200 MYR/PE	500 MYR/PE

5.4.2 Operation costs

For the operational costs, however, the preliminary findings do not point in the direction of major savings. The findings indicate a yearly operational cost per PE for conventional as well as ecological sanitation at 100–150 MYR. Not surprising 95% of the operational cost for ecological sanitation is related to the black water collection and recycling the black water. A major issue

[10] "Estimation cost for 32 units of houses (160 PE) for Dusun Bayu Ecosan Project at Sejingkat, Kuching", Chemsain Konsultant Sdn. Bhd., Kuching, March 2004

for the next phase on the study therefore is to reduce the amount of the black water. The conversion of the existing toilets to 2–4 liters low flush toilets as included in the present study will reduce the amount of black water from 17% to 5% of the domestic wastewater. Refer to ***table 7*** below.

Table 7: Water consumption l/person/day

	Grey water	Black water	% of Black water
Standard flush toilet	200	40	17%
Low flush toilet	200	10	5%

However, it should be carefully considered, if even less water consuming toilets or vacuum toilets system could be implemented in the future.

5.5 Wastewater recycling

The study presupposes upgrading of the existing septic sludge treatment plant to biogas production. It is expected that the upgrade will reduce the current treatment costs considerably by eliminating the costs for disposal of the treated sludge, for electricity and for stabilizing agents. Currently, the calculations have not included income from the produced fertilizer or energy. At the moment it is not considered likely that the product can fetch higher price than the cost for the necessary concentration. It is anticipated that the degassed black water will be sufficiently hygienized to be used for specific agricultural purposes. A study has been conducted on the possible use of the product in a 24 km^2 large oil palm plantation located approximately 25 km from the plant. The feasibility of transporting the product to and distributing it at the plantation in raw liquid form and at different levels of concentration has been surveyed. The calculation was based on a 100,000 ton/year biogas plant, corresponding to 10% of the expected future full-scale capacity.

The study has further assessed the amount and fertilizing value of the product from the biogas plant for the plantation. The study has revealed that the product from a 100,000 ton/year biogas plant only partly can substitute conventional fertilizers at the plantation. Refer to ***table 8*** below.

Table 8: Supply of recycled fertilizer vs. demand for nutrients, at an oil palm estate, Sarawak[11][12]

Demand	N	P	K
Demand	254	125	424
Supply (100% N efficacy)	237	33	70
Surplus / deficit	(17)	(92)	(354)
Supply (70% N efficacy)	166	33	70
Surplus / deficit	(88)	(92)	(354)

The assessment indicates that the product may nearly fulfill the requirement for nitrogen. However, for phosphorus and most certainly for potassium, the product cannot meet crop requirements. Depending on the techniques used for fertilizer application, it is, however, likely that the bio-availability of the phosphorus by far exceeds that of the reference fertilizer (reactive rock phosphate), and therefore the phosphorous deficiency may not be severe or may even not occur at all. Furthermore, it is likely that a fertilization scheme can be developed by which the plantation managers will not need to supplement the crop annually, but may do so every second or third year, thereby cutting costs.

[11] Sarawak Government/Danida, UEMS Project: "Proposed Matang Biogas Plant Discharge Product Disposal and Handling on Oil Palm Plantation". Bent Mahler, SPD Innovative Technologies Sdn. Bhd. Kuching, Sarawak, 2004

[12] Sarawak Government/Danida, UEMS Project: "Proposed Matang Biogas Plant Discharge Product Disposal and Handling on Oil Palm Plantation". Bent Mahler, SPD Innovative Technologies Sdn. Bhd., Kuching, Sarawak, 2004

Cooperation between the University Malaysia Sarawak (UNIMAS), the Royal Danish Agriculture University (KVL) and University of Life Sciences (UMB) in Norway has been established to undertake research in the performance and improvement of ecological sanitation system under tropical climate, including the appropriate and safe use of the product at oil palm estates.

6.0 Perspectives

The study on integrating conventional wastewater management and ecological sanitation in Kuching is still at a very early stage. During the coming 12 months much more substantiated data are expected to be derived. However, already at the present stage, it can be concluded that ecological sanitation for urban areas is certainly a concept that should be considered seriously in any urban wastewater planning.