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| **Author(s)** | Petter D. Jenssen[1], Lau Seng[2] , B. Chong[3], T. H. Huang[4], Y. Fevang[1], I. Skadberg[1] |
| **Address** | Department of Mathematical Sciences and Technology<br>Agricultural University of Norway |
| **Telephone** | +47 6494 8685 |
| **Fax** | +47 6494 8810 |
| **Mobile** | +47 913 77 360 |
| **E-mail** | petter.jenssen@umb.no |
| **Short CV for Introduction Purposes ( 100 words max)** | Petter D. Jenssen is a full professor of environmental engineering and has developed a master program in «green» civil engineering. He is the foremost expert in Norway on nature based and alternative sewage systems. He has initiated and headed a 4 year, 6 million USD, national research program entitled «Natural systems technology for wastewater treatment». Several of these treatment alternatives are highly interesting in developing countries. Since 2003 he has organized an annual international in ecosan shortcourse with highly qualified lecturers from Norway and abroad. In 1999 he hosted the third international conference on “Ecological engineering for wastewater treatment”. |
| **Photograph attached ( jpg)** | |

1) The Norwegian University of Life Sciences (UMB), Ås Norway
2) The Universiti of Sarawak Malaysia (UNIMAS), Kuching Sarawak
3) Chemsain Consultants, Kuching Sarawak
4) National Environmental and Resources Board (NREB), Kuching Sarawak

## INTRODUCTION

Kuching, the capital of Sarawak Malaysia, is lacking a proper sanitary system. The sewage is discharged untreated to storm drains and gutters. The result is massive pollution of the Sarawak river which traverses Kuching City, and unsatisfactory health conditions due to potential close contact to raw sewer. A conventional centralized sanitary system is expensive (Mamit et al. 2005) and hence, the State Government is considering ecological sanitation.

In all buildings in Kuching the toilet waste is separated from the other household wastewater. This facilitates implementation of a source separating ecological sanitation (ecosan) system. In this paper technical and social implications of converting to an ecosan system are discussed. The greywater is treated using Norwegian technology and sizing (Jenssen and Vråle 2004). However, in a warm climate higher efficiency of the biological processes can be expected and a more compact design may be possible.

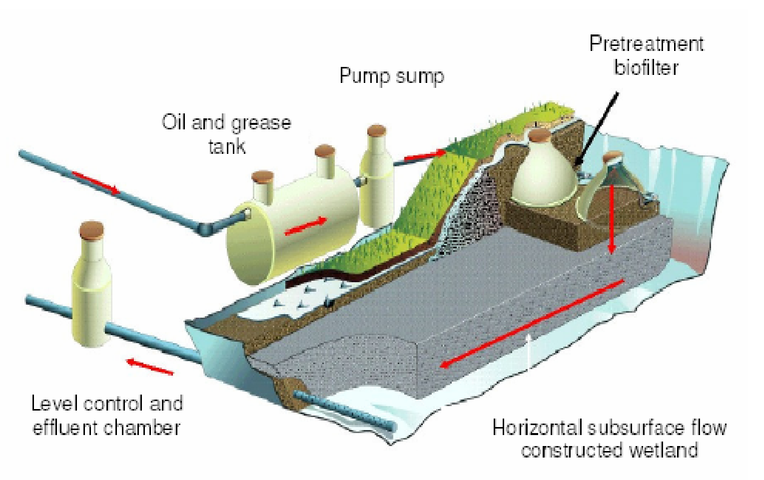
## THE HUI SING GARDEN PILOT SYSTEM

The system includes 9 single storey households with an average of 5 persons/household in a residential area called the Hui Sing Garden. The ecosan system consists of the toilet waste (blackwater) and the greywater (other household wastewaters) management facilities.

### The black- and greywater systems

The existing 6-9 litre/flush squatting toilet toilets are retrofitted with Scandinavian 2/4 litre toilet and the existing septic tanks are converted to holding tanks. The blackwater is currently transported to a sludge treatment plant. In the future the black water is intended for feeding a biogas facility to generate power and fertilizer (Mamit et al. 2005).

The new grey water treatment facility include collection pipes from the houses a common septic tank or oil and grease trap, a pump sump, the pre-treatment biofilters and the horizontal sub-surface flow constructed wetland, (Figure 1).



Source: Prof. Petter D. Jenssen, Agricultural University of Norway

**Figure 1**: **Schematic layout of the ECOSAN grey water treatment facility**

The biofilter is covered by hemispherical domes which facilitate spraying of the incoming grey water over the biofilter surface. The polyethylene domes of local manufacture (Weida®) have an inner diameter of 1830mm. The biofilter has a depth of 600 mm and is filled with light weight aggregate (LWA) of Norwegian make (Filtralite®) in the size range 2–4 mm, There were 4 domes installed in this facility.

The horizontal subsurface flow constructed wetland is filled with crushed limestone aggregate (5-8mm) from a local source and the depth is 600mm. The wetland is lined with geotextile benthonite-clay liner (GCL). The limestone is covered by a thin layer of coconut husk to prevent the top soil (100mm) from settling into the limestone aggregate The horizontal flow area is equipped with 16 sampling wells made of perforated polyethylene (PE) pipes, (Figure 2). The biofilter and the wetland is based on Norwegian design (Heistad *et al.*, 2001; Jenssen and Vråle 2004, Jenssen et al. 2005).

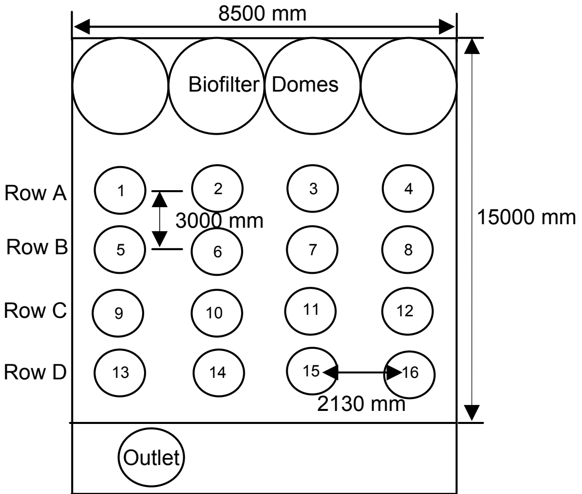


**Figure 2** : Layout of the 16 sampling wells in the ECOSAN facility

## Sampling and analyses

The the total water use is monitored by calibrated water meters for each household. Separate water meters are used to monitor the flow to the toilets.

The greywater flow can be calculated from the pumping frequency and a tipping bucket at the outlet of the wetland.

The water quality parameters analyzed were pH, temperature, oil and grease, electrical conductivity, BOD, COD, total suspended solids, ammonium nitrogen, total nitrogen, nitrate nitrogen, total phosphorus, calcium, magnesium, iron, aluminium, total coliform count (TCC), faecal coliform count (FCC) and *E.coli*.

Standard monitoring of the greywater treatment included sampling in the pump sump (inlet) and after the wetland (outlet). The samples from Row A of the sampling wells indicate the efficiency of biofilters, Sampling of the 16 wells were carried out on a less frequent basis to investigate the efficiency of the wetland. All the analyses were conducted according to the Standard Methods (APHA, 1992).

## RESULTS

## The Black Water System

The replacement of the existing toilets has reduced the blackwater production from 40 to 15 litre/person and day. In order to reduce disturbance to the homeowner when emptying the tank a pump-out pipe was fitted. The pipe was extended to the property line, thus no work on private property is needed to pump the tank. In additon a quick coupling terminates the pump-out tube reducing the time to empty the tank to 6 minutes for a 4 $m^3$ tank.

The first tank was of poor quality and sealing has not been totally successful. Groundwater intrusion is therefore unavoidable in periods of high rainfall. Since most of the remaining houses have extended floors directly over the septic tank that will greatly hamper the conversion into a holding tanks. As a result of these problems one holding tank for blackwater from all the 9 houses will be constructed.

## The greywater system

In table 1 average inlet and outlet concentrations are shown and in Fig. 3 and 4 the outlet concentrations are plotted versus time.

Table 1. Average (n=13) inlet, after biofilter and outlet concentrations of the greywater treatment system in Hui Sing Garden (mg/l).

| Parameter | In<br>(n=13) | Out biofilter<br>(n=6) | Out<br>(n=13) | % removal |
|---|---|---|---|---|
| BOD | 128,75 | <2 | <2 | >98,4 |
| COD | 212,42 | 11,93 | 10,61 | 95,0 |
| TSS | 75,95 | 6,01 | 2,66 | 96,5 |
| Total N* | 37,15 | 14,38 | 9,24 | 75,1 |
| Ammonia | 12,62 | 2,13 | 0,83 | 93,5 |
| Nitrate | 2,05 | 5,44 | 5,27 | -157,5 |
| Total P | 2,39 | nd | 0,33 | 86,2 |
| Fecal Coli. MPN/100ml | | 5596 | 646 | |
| E. Coli. MPN/100ml | | 576 | 389 | |

* Kjeldal + ammonia+nitrate

The average values show >90% removal of BOD, COD, TSS and ammonia. The effluent meets the WHO drinking water requirements with respect to nitrogen (<10mg N/l). Only two out of 13 samples of indicator bacteria (Faecal coliforms) are above the European standard for acceptable swimming water (1000FC/100ml) and only one sample of E.coli exceeds 1000/100ml and 10 are below 100/100ml (Fig 4).

The first 7 months the effluent values are very low and stable. From September 2004 to January 2005 outlet concentrations of BOD, COD and ammonia have increased. This may be due to an increase in incoming COD (Fig 3), but can also be an effect of the rain season washing more organic matter down from the soil layer covering the horizontal flow wetland. The soil layer has also been disturbed in the fall 2004 due to planting of the wetland filter. For bacteria the trend is different and the outlet concentrations are back to the low values again in January 2005.

The performance of the greywater treatment system in Hui Sing Garden is similar to the results that are obtained in Norwegian systems with similar design (Jenssen and Vråle 2004). However, in an urban setting space is restricted and part of this research is to investigate if the systems can be made more compact. The main removal of BOD, suspended solids, nitrogen and bacteria occurs in the biofilter and subsequent wetland section before sampling row A (Table 1 and Fig 5).

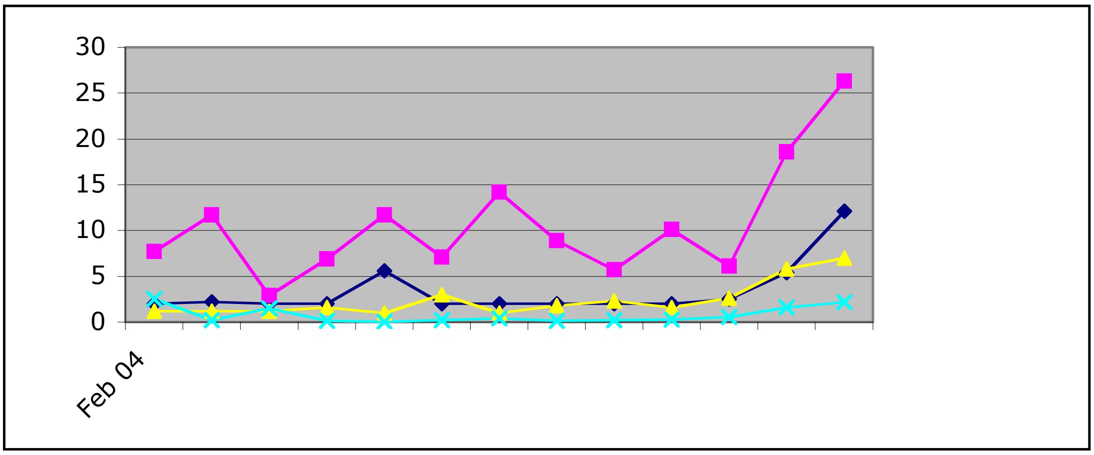


Figure 3. Outlet concentrations versus time for BOD, COD, TSS and Ammonium in mg/litre.

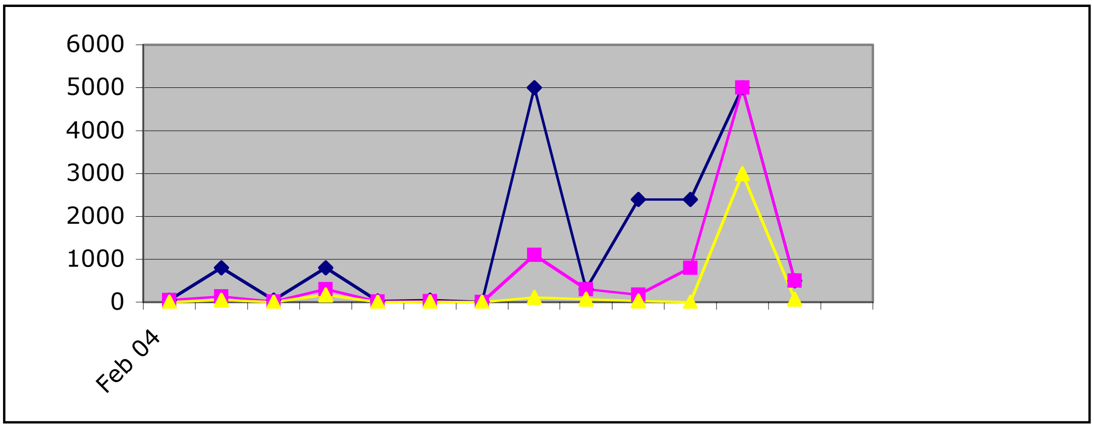


Figure 4. Outlet concentrations versus time for Total Coliforms, Faecal Coliforms and E. coli (MPN/100ml).

To achieve swimming water quality with respect to faecal coliforms the whole wetland section is needed. The horizontal flow wetland section is also essential to achieve very high phosphorus removal provided a material with a high P-sorption capacity is used (Jenssen et al 2005). If BOD and SS are the main design criteria and faecal coliforms above 1000/100 ml is acceptable from a risk perspective the horizontal flow wetland section can be made more compact reducing the overall size of the system from 2.8m$^2$/p to 0.7m$^2$/p.

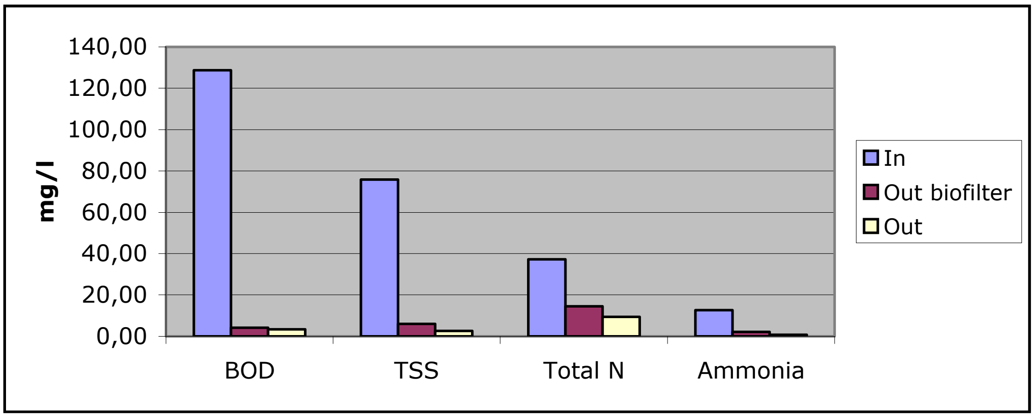


Figure 5. Effluent concentrations (mg/l) of BOD, TSS, Total N and ammonia in the septic tank effluent (in) out of the biofilter an final outlet of the wetland.

In Norway loading rates of up to 110 cm/d have been applied to greywater biofilters over a period of 5 years without clogging problems. In Hui Sing Garden the loading is 60 cm/d. Despite lower rate and warmer climate partial clogging of the biofilter has been observed in the fall of 2004. The greywater composition in Hui Sing Garden does not deviate much from Norwegian wastewater except for higher content of oil and grease and phosphorus. This difference may be the cause of clogging, however, earlier studies relate clogging to the content of BOD and TSS (Siegrist 1987) and these parameters does not differ much between Norway and Hui Sing Garden. Another cause of the clogging may be a suboptimal dosing frequency. Work is now being performed to optimize the biofilters through a more efficient dosing regime. Ausland (1998), and Emerick et al. (1997) showed that a dosing regime optimizing residence time enhance the perfomance of the biofilters.

## Social aspects of the ecological sanitation

A critical issue for the success of ecological sanitation is the residents acceptance of the system. In order to investigate the residents' opinion and experiences, a social survey was carried out and interviews were conducted with each family.

The greywater treatment in Hui Sing Garden is integrated into a park adjacent to the homes[1]. No residents reported problems with the physical appearance of the treatment system and many appreciated it: "*The area in the park is covered, you see nothing. The wetland is like a sign of environmental protection*" are some of the comments. Today, the little "hill" created by the biofilter is used as a play area.

The residents strongly feel that the project is an important initiative to minimise water pollution and thus, to provide them a better and healthier living environment. Many residents actually encouraged the government to proceed implementing this system on a larger scale, if "their" pilot project was a success. The clear and clean wetland effluent made the participating families feel proud. They all presented "their" pilot project to friends and relatives.

The pilot project collects all greywater via pipes and discharge of untreated effluent directly into drains is eliminated. The families recognise that the drains are clean and the problems with rats and flies that fed of the food residues from the greywater outlets have decreased noticeably.

The project has made the families aware of the connection between their wastewater discharge and the pollution of the river. However, they have yet to recognise the necessity of saving water. Kuching receive high rainfall and "water" is priced very low. Therefore, reducing water usage is not an obvious issue. They are, however, concerned with the service fee they have to pay for blackwater pump out, as new black water system requires more frequent emptying than the previous septic tank system. To reduce the cost for collection of black water, they realise that reduction of water to flush toilets is a key factor.

## Environmental aspects and upscaling

The ecological sanitation eliminates the blackwater discharge totally and the greywater is treated before disposal to the storm drains. This gives a considerable decrease in mass discharge (Fig.6).

Discharge of oil and grease is reduced from 43,3 to 0,2 g/p*day (99 %), $BOD_5$ from 36,6 to 0,5 g/p*day (99 %), COD from 50 to 1,7 g/p*day (97 %), Suspended Solids from 10,6 to 0,3 g/p*day (97 %) and total nitrogen is reduced from 6,2 to 0,5 g/p*day (92 %). These figures exceed the performance of conventional tertiary treatment plants and in addition reclamation of plant nutrients, for recycling. Based on the results from Hui Sing Garden, implementing ecosan on a large scale in Kuching will benefit the environment in general and improve river water quality.

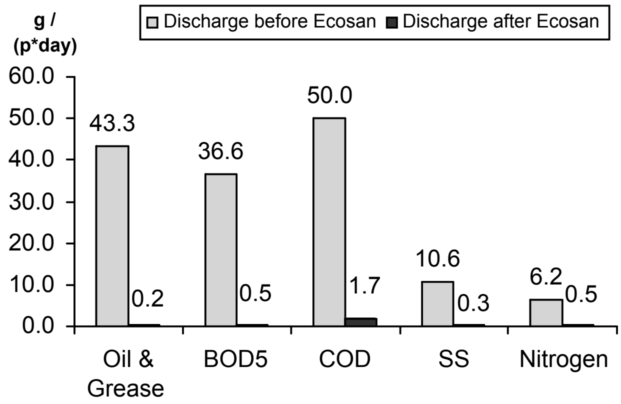


Figure 6. Mass discharge of oil and grease, BOD, COD, TSS and Total Nitrogen in Hui Sing Garden before and after implementing the ecosan pilot project (Fevang and Skadberg 2004).

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[1] In Kuching, housing estates with more than 1 ha, have 10% open space for green parks and playground.

Technically upscaling the ecosan system to the majority of Kuching city is feasible and mainly a logistics challenge. The investment costs are lower than conventional sanitation mainly due to eliminating the centralized piping system (Mamit et al. 2005). However the investment cost will depend on having compact efficient greywater treatment systems. The main factor influencing the operational cost is the desludging of the holding tanks for blackwater and the septic tanks for the greywater. Reducing the discharge of oil and grease to the greywater system will greatly increase the desludging intervals. A separate oil and grease collection should be evaluated. The oil and grease is normally beneficial for anaerobic digestion, but can also be processed to bio-diesel (Zhang et al. 2003).The frequency of blackwater collection depends on the toilet flush volume (Table 2).

Table 2. Blackwater volumes for different toilet alternatives. The table is based on 6 flushes per person per day.

| Water use/flush | Average volume urine+ faeces per person and day (liter) | Flushwater per person and day (liter) | Total blackwater per person and day (liter) | Total blackwater per family of 5 and day (liter) | Total blackwater per family of 5 and year (m3) | Total blackwater adjusted (m3)* |
|---|---|---|---|---|---|---|
| | | | | | | . |
| 6 | 1,5 | 36 | 37,5 | 187,5 | 68,4 | 47,9 |
| 2/4 | 1,5 | 14 | 15,5 | 77,5 | 28,3 | 19,8 |
| 1 | 1,5 | 6 | 7,5 | 37,5 | 13,7 | 9,6 |
| 0,4/0,8 | 1,5 | 2,8 | 4,3 | 21,5 | 7,8 | 5,5 |
| 0,2/0.8 | 1,5 | 1,8 | 3,3 | 16,5 | 6,0 | 4,2 |

* Adjusted for the presence (vacations time at work, school etc.) at home assuming 70% presence

The optimum size for a blackwater holding tank depends on the volume of the vacuum truck. If the holding tank is larger that the carrying capacity of the truck, blackwater will have to be stored longer or the truck has to come more than once to pump out the tank. Longer storage times may induce higher nitrogen loss and should be investigated. If the nine houses in Hui Sing Garden were equipped 0.2/0.8 litre dual flush vacuum toilets the total production of blackwater would be 38 m3. A 12 m3 truck would then have to come 3.2 times per year. Using a 2/4 litre dual flush toilet and a theoretical production of blackwater becomes 19.8 m3/year and family and for 9 families 99 m3/year. This would mean 8.2 times per year.

## ACKNOWLEDGEMENT

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