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WATER, SANITATION AND HYGIENE: CHALLENGES OF THE MILLENNIUM

# Wastewater treatment for reuse

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THE ST. KIZITO Hospital in Matany, located in the centre of Karamoja district in Northern Uganda, is a private institution which covers the function of a District Hospital since the 1970's. Drinking and irrigation water is supplied from two boreholes and a daily volume of app. 20 m³ of wastewater is produced. Originally this wastewater was treated in an overloaded pond system which served the local population partly for watering animals before infiltration. This dangerous and unsatisfying situation together with the water scarcity - last years total annual rainfall of 625 mm lies well within the average annual rainfall (United Nations, 1989) but is unequally timely distributed - and the desire to enable reuse of the wastewater formed the bases of the described project.

## Objectives and requirements

The project is based on two main objectives:

- Reduction of the health risk due to direct human contact with untreated wastewater and
- Reuse of wastewater as a non-conventional water source for irrigation.

The main requirements to achieve these aims can be summarised as follows:

- Avoiding direct contact between people and disease-causing organisms in wastewater is the goal in reducing health concerns (Mancl and Rector, 1997). Several approaches can be used to avoid direct contact. Amongst others the reduction of pathogens by treatment of the wastewater is one of the possibilities. Another possibility is to technically avoid the possibility of direct contact with wastewater as far as possible. Another risk connected to the old treatment system was the presence of a free water surface serving as a potential breeding place for mosquitos. The elimination of any free water surface in the treatment process was required (Cairncross and Feachem, 1983; Krameter, 1995).
- Reuse of wastewater for irrigation requires first of all meeting of the national standards. For Uganda the National Environmental Management Authority demands treatment of wastewater before discharge on land up to the limits given in Table 1.

**Table 1. National environmental standards for the discharge of effluents or waste water into the water or on land (Uganda, 1998; in parts)**

| Parameter | limit | unit |
|---|---|---|
| $BOD_5$ | 50 | mg/l |
| COD | 100 | mg/l |
| $NO_3$-N | 20 | mg/l |
| $NO_2$-N | 2 | mg/l |
| $NH_4$-N | 10 | mg/l |

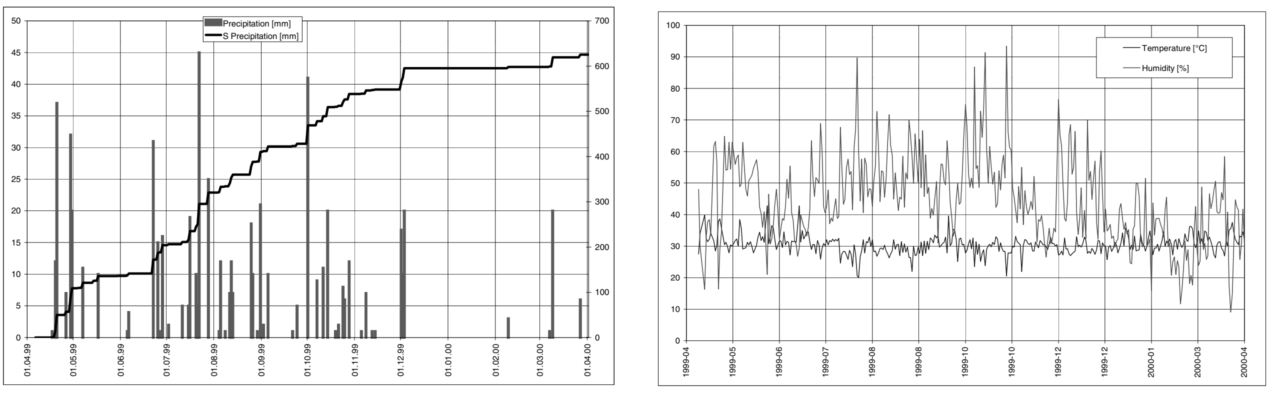


**Figure 1. Precipitation, humidity and temperature (max.) daily - period 1.4.99 to 1.4.00**

Nevertheless before reuse of wastewater due to the vicinity of the proposed area for reuse pre-treatment to reduce odour would have been required.

An additional aspect is that the quality of the water should be sufficient to allow for proper operation of the irrigation equipment, especially as drip irrigation has been proposed to reduce the risk of direct contact with wastewater. The required purification level would not be as strict as the standards shown in Table 1 but average literature values lie within the same order of magnitude (DeBoer, 1985; Ertuna, 1985).

## Solution

To achieve these aims a vertical flow constructed wetland system has been designed and constructed between October 1998 and March 1999. The design parameters were specifically chosen according to the requirements mentioned above and basic conditions as e.g. wastewater characteristics, pre-treatment and climate. The effluent is reused for irrigation of a fruit plantation.

The reasons to prefer a constructed wetland to a pond system, which is commonly applied for this purpose (Cairncross and Feachem, 1983; Arlosoroff, 1985; etc.), are amongst others

- the treatment efficiency,
- the possibility to regulate the degree of removal of nitrogen (partly) and
- the reduction of breeding places of vectors (Krameter, 1995).

Figure 2 shows the cross section of the filter bed of the constructed wetlands.

The beds are planted with locally available elephant grass which serves to feed cattle. The most important functions of the plants in relation to the treatment of wastewater are the physical effects. They stabilise the surface of the beds, provide good conditions for filtration, prevent the beds from clogging and provide a huge surface area for attached micro-organisms within the rootzone. Macrophyte-mediated transfer of oxygen to the rhizosphere by leakage from roots increases aerobic degradation of organic matter (Armstrong et al., 1990). The filter media is the critical point as only locally available material could be used. Generally the substrate of the main layer has to fulfil the following two criteria:

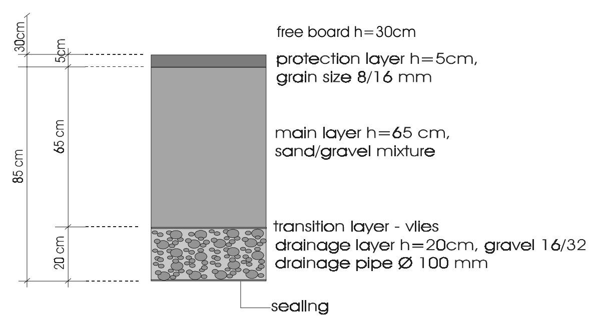


**Figure 2. Cross section - filter bed**

- Hydraulic conductivity, $k_f = 10^{-3} - 10^{-4}$ m/s and

$$U = \frac{d60}{d10} \leq 4$$

The available filter material was tested first on site according to the sand drainage test (Grant, 1995) and secondly in the laboratory in Vienna.

While the calculated conductivity value ($k_f = 0{,}0025 \times (d_{10} \times 1000)^{1{,}75} = 4{,}5 \times 10^{-4}$, Fair and Hatch's formula; $k_f = d_{10}^{\,2} \times 1000 = 7 \times 10^{-4}$, Hazens formula) was within an acceptable range, the high amount of material with a diameter smaller than 1 mm was considered problematic. Nevertheless no other material was available and screening to remove the fine share due to the quantity required not possible.

The dimensioning of the required area was based on the most common used design model for constructed wetlands, the first order k-C* areal model (Kadlec and Knight, 1996).

$$A = \frac{Q}{k}[\ln(Ci - C^*) - \ln(Co - C^*)]$$

A = area [m²]
Q = quantity of wastewater [m³/d]
k = first order areal rate constant [m/d]
Ci = concentration of inlet [mg/l]
Co = concentration of outlet [mg/l] - to be 50 mg/l
C* = background concentration [mg/l]

The chosen design parameters are $C^* = 3$ and k = 0,13 m/d (Brix, 1994). The required surface areas was calculated to A = 1063 m², which is equivalent to 1,76 m²/PE (1 PE = 60 $gBOD_5$/d; 80 l/d).

## Results

First investigations on the efficiency of the whole system exceeded all expectations and showed still significant potential for optimisation especially regarding construction costs.

Figure 1 shows first results after one year of operation. The purification efficiency is high, the elimination rate for COD is 93 per cent on average.

In total during this one year of operation an amount of app. 7000 m³ of wastewater has been treated and mostly reused for irrigation.

## Proceedings

Further research, including among others investigations on appropriate design parameters (reduction of construction costs), pathogen reduction, oversalting and the definition of the long-term stability of the system, is presently being carried out.

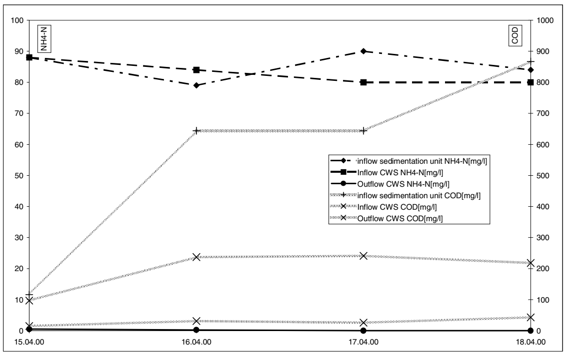


**Figure 3. Inflow and outflow oncentrations sedimentation unit and constructed wetland system**

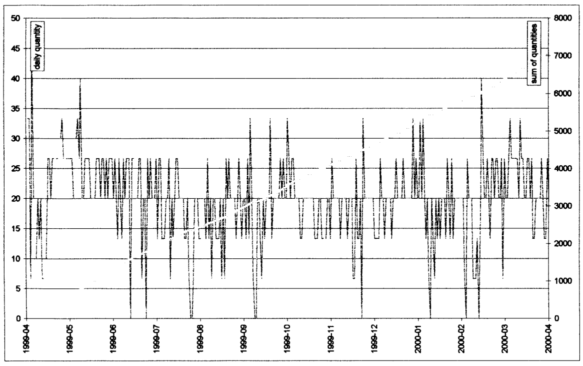


**Figure 4. Quantities of daily treated water and annual sum of quantities**

## References

ARLOSOROFF, S. (1985): Wastewater reuse for irrigation and agriculture, in non-conventional water resources use in developing countries, proceedings of the interregional seminar Willemstad, Curaçao

ARMSTRONG, W., ARMSTRONG, J. and BECKETT, P. (1990). Measurement and modelling of oxygen release from roots of Phragmites australis, Constructed wetlands in water pollution control, P. F. Cooper and B. C. Findlater, Eds., Pergamon Press, Oxford, UK, 41-53.

BRIX, H. (1994). The role of wetlands for the control of pollution in rural areas. Design and use of constructed wetlands. Centro internacional de altos estudios agronomicos mediterraneos, Zaragoza, Spain.

CAIRNCROSS, S., FEACHEM, R.G. (1983): Environmental health engineering in the tropics, John Willey and Sons, Chichester-NewYork-Brisbane-Toronto-Singapore

DEBOER, J. (1985): Overview of water reuse for developing countries, in non-conventional water resources use in developing countries, proceedings of the interregional seminar Willemstad, Curaçao

ERTUNA, C. (1985): Wastewater reuse and its application in Western Asia, in non-conventional water resources use in developing countries, proceedings of the interregional seminar Willemstad, Curaçao

KADLEC, R. and KNIGHT, R. (1996). Treatment Wetlands, CRC Press, Boca Raton, FL, 893pp.

KRAMETER, P. (1995): Effects of agricultural development on vector-borne diseases; irrigation and health, Landbouwuniversiteit Wageningen

MANCL, K., RECTOR, D. (1997): Reuse Of Reclaimed Wastewater Through Irrigation For Ohio Communities, Bulletin 860, The Ohio State University

UNITED NATIONS (1989): Groundwater in Eastern, Central and Southern Africa, Natural Resources/Water Series No. 19, New-York

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