# REVIEW OF
# THE DECENTRALIZED SANITATION PROJECT
# IN KAFR EL SHEIKH GOVERNORATE, EGYPT

**Report on a visit to Egypt**

**12−27 February 2005**

**by**


**Professor Duncan Mara**

**Duncan Mara Associates**

**Leeds, UK**


**28 February 2005**

## INTRODUCTION

I visited Egypt during 12−26 February 2005 to review the work -to-date by RODECO Consulting Gmbh and ALDAR Consulting Engineers (Cairo) on the GTZ-funded Decentralized Sanitation Project in the Governorate of Kafr El Sheikh, specifically to review the sewerage and wastewater treatment implemented in the village of El Mofty El Kobra and the facilities designed (but not yet implemented) for the village of Om Sen. Visits were made to both these villages and to four others which may be selected for inclusion in Phase II of the Decentralized Sanitation Project.

I also visited Cairo for discussions with ALDAR Consulting Engineers; unfortunately meetings with the National Organization for Potable Water and Sanitary Drainage (NOPWASD) and the Social Fund for Development (SFD) were cancelled by these organizations. I gave guest lectures on “Low-cost sewerage and low-cost wastewater treatment: appropriate technologies for use in rural Egypt” at Zagazig University, the American University in Cairo, Alazhar University and Ain Shams University. An electronic version of this lecture was given to each of these organizations.

## DECENTRALIZED SANITATION PROJECT

The concept of decentralized sanitation has been very successfully applied to the village of El Mofty El Kobra. Project staff have worked very closely with the community which has established an active Community Development Association (CDA). The CDA is the formal owner of the sewer network, pumping station and waste stabilization ponds. It collects a monthly fee from every household in the village and this income is used to employ a young man from the village to operate and maintain the system, as well as to purchase any spare parts needed in the future and to pay for the interceptor tanks to be desludged. A set of very well illustrated booklets has been produced for distribution to each household to provide information on the sanitation system and how it can be best used by the householders and their families.

An extremely interesting technical aspect of the sanitation system for El Mofty El Kobra is the use, for the first time in Egypt (and indeed in the Middle East and North Africa), of settled sewerage (also called small-bore sewerage). The adoption of low-cost sewerage systems is clearly very important in rural Egypt as it provides, from the users’ perspective, the same level of service as conventional sewerage but at lower cost. Close monitoring of the system at El Mofty El Kobra is required so that the next generation of designs can be based on local full-scale experience.

The next village to be sewered through the Decentralized Sanitation Project is Om Sen. This village is similar in size to El Mofty El Kobra and a conventional sewer network, with wastewater treatment in waste stabilization ponds, has been designed for it. It is anticipated that this scheme will shortly go out to tender and construction completed in 9−12 months. Thus there will be the opportunity to compare the costs and performance settled sewerage and conventional sewerage in these two villages.

Phase II of the Decentralized Sanitation Project will commence on 1 April 2005. Designs for sewerage and wastewater treatment in a further eight villages will be prepared during this Phase.

# A. EL MOFTY EL KOBRA

## A1. Settled sewer network

The settled (or "small bore") sewer network for El Mofty El Kobra has been very well designed. The solids interceptor tanks (Figure 1) are very satisfactory. The sewer diameter varies between 100 and 250 mm and there is an appropriate mix of clean-outs and manholes (Figure 2). The wastewater is pumped from the village to the waste stabilization ponds, and the pump house is also well designed. Construction of the sewer network and the pump house appears to have been done to a very high standard by the contractor, Markaz El Omara Co.

Construction was completed in September 2004 but the system could not be commissioned then as there was no electricity supply to the pump house. This was done in early February 2005 and the system stated functioning on 4 February.


***Figure 1. Interceptor tank serving a single household at El Mofty El Kobra***

***Figure 2. Clean-out chamber in the settled sewer network at El Mofty El Kobra***

## A2. Waste stabilization ponds

Two main points have to be made:

(1) As the wastewater entering the WSP at El Mofty El Kobra has been settled in the interceptor tanks, anaerobic ponds should not be have been used.

(2) The design criteria used for these WSP are less than wholly satisfactory. Annex I details a redesign and an evaluation of the design adopted.

The WSP were constructed to a high standard by the contractor (Figures 3−5).

***Figure 3. Anaerobic pond at El Mofty El Kobra***

***Figure 4. Sludge drying beds at El Mofty El Kobra***

***Figure 5. Facultative and maturation ponds at El Mofty El Kobra***

## B. OM SEN

### B1. Conventional sewer network

No problems are anticipated with the design, construction and operation of the conventional sewerage system for Om Sen. The system is described as a “shallow conventional” system as the depth of the sewers in the upper reaches is only 50 cm; however, strictly speaking, it is not shallow sewerage (which is the early term for simplified or “condominial” sewerage) (see Section C below).

### B2. Waste stabilization ponds

The waste stabilization ponds for Om Sen were redesigned as shown in Annex II. The system comprises an anaerobic pond, a secondary facultative pond and two maturation ponds. The total mid-depth area is 6583 $m^2$, which is perfectly satisfactory for the available area of 2 feddans (8400 $m^2$). [ALDAR Consulting Engineers has been provided with an electronic copy of the *Design Manual for Waste Stabilization Ponds in Mediterranean Countries* (Mara and Pearson, Lagoon Technology International, Leeds, UK, for the European Investment Bank, 1998).]

## C. RECOMMENDATIONS FOR PHASE II

Simp sew in Village xx.
REUSE?

# ANNEX I

# Review of waste stabilization pond design for El Mofty El Sheikh

## 1. REDESIGN OF THE WSP SYSTEM FOR EL MOFTY EL SHEIKH

The design presented below is based on the general design procedures given in *Design Manual for Waste Stabilization Ponds in Mediterranean Countries* (Mara and Pearson, Lagoon Technology International, Leeds, UK, for the European Investment Bank, 1998; http://www.leeds.ac.uk/civil/ceri/water/tphe/publicat/pdm/med/medman.html).

### (a) Secondary facultative pond

No need for anaerobic ponds (the interceptor tanks fulfil this function). Assume a BOD removal of 50% in the interceptor tanks and a winter design temperature of 18°C. Thus:

*Design BOD loading* ($\lambda_s$, kg/ha d):

$\lambda_s = 350(1.107 - 0.002T)^{T-25}$ = 217 kg BOD/ha d at 18°C.

*Mid-depth area* ($A$, $m^2$):

$A = 10L_iQ/\lambda_s$ (where $L_i$ = BOD of influent wastewater, mg/l and $Q$ = wastewater flow, $m^3/d$)

For $L_i = (0.5 \times 530) = 265$ mg/l and $Q = 316$ $m^3/d$:

$A = (10 \times 265 \times 316)/217 = 3860$ $m^2$

For a depth (d, m) of 1.5 m, mean hydraulic retention time ($\theta_f$, days) (ignoring evaporation) is:

$\theta_f = AD/Q = (3860 \times 1.5)/316 = 18$ days

The unfiltered effluent BOD ($L_e$, mg/l) is given by

$L_e = L_i/[1 + (0.1 \times 1.05^{T-20} \times \theta_f)] = 265/[1 + (0.1 \times 1.05^{18-20} \times 18)] = 100$ mg/l

## (b) Maturation ponds

Assume the number of faecal coliform bacteria in the influent wastewater ($N_i$) is $1 \times 10^7$ per 100 ml (i.e., allowing for a small decrease in the interceptor tanks and sewers from $5 \times 10^7$ to $1 \times 10^7$ per 100 ml), and that the required number in the final effluent ($N_e$) is 3000 per 100 ml.

The general equation of faecal coliform removal in the series of ponds is:

$$N_e = N_i/[(1 + k_{B(T)}\theta_f)(1 + k_{B(T)}\theta_{m1})(1 + k_{B(T)}\theta_m)^n]$$

where $k_{B(T)}$ is given by $k_{B(T)} = 2.6(1.19)^{T-20} = 1.84\ \text{day}^{-1}$ at 18°C; $\theta_{m1}$ is the retention time in the first maturation pond, days; and $\theta_m$ is the retention time in the second and subsequent maturation ponds of which there are *n*. A more convenient form of this equation is:

$$\theta_m = \{[N_i/N_e(1 + k_{B(T)}\theta_f)(1 + k_{B(T)}\theta_{m1}]^{1/n} - 1\}/k_{B(T)}$$

The retention time in the first maturation pond ($\theta_{m1}$, d) is determined on the basis that the BOD loading on it is 75% of that on the preceding facultative pond. Thus:

$$\theta_{m1} = 10L_{e(f)}D_{m1}/0.75\lambda_{s(f)}$$

where $D_{m1}$ is the depth, m. Thus:

$$\theta_{m1} = (10 \times 100 \times 1)/(0.75 \times 217) = 6.1 \text{ days.}$$

Thus:

$$\theta_m = \{[10^7/3000(1 + 1.84\times18)(1 + 1.84\times6.1]^{1/n} - 1\}/1.84$$

i.e., $\theta_m = 5.9$ d for $n = 1$. Thus there is a single secondary maturation pond with a retention time of 5.9 days.

### *Comments*

This design is significantly different from that used for the El Mofty El Kobra ponds. However, it is a more precise design based on modern design procedures and with a more realistic winter design temperature.

The WSP design for El Mofty El Kobra is now evaluated to determine its likely performance both now and at the end of the design period.

## 2. EVALUATION OF THE EXISTING PONDS AT EL MOFTY EL KOBRA

The pond system constructed at El Mofty El Kobra comprises:

(1) an anaerobic pond (mid-depth area, 970 $m^2$; depth, 5 m),
(2) a secondary facultative pond (area, 2070 $m^2$; depth, 1.5 m), and
(3) a single maturation pond (area, 1490 $m^2$; depth, 1.5 m).

These sizes are divided in two equal series.

### A. Design flow

#### "Anaerobic" pond

The anaerobic pond is likely to act as an underloaded anaerobic pond or an overloaded facultative pond (as the interceptor tanks provide anaerobic treatment). The BOD loadings on this pond are:

(a) volumetric loading ($\lambda_v$, g/$m^3$ d):

$\lambda_v = L_i Q/V = (265 \times 316)/(970 \times 5) = 17$ g/$m^3$ d (i.e., very underloaded as the design loading for 18°C is 260 g/$m^3$ d).

(b) surface loading ($\lambda_s$, kg/ha d):

$\lambda_s = 10\, L_i Q/A = (10 \times 265 \times 316)/(970) = 863$ kg/ha d (i.e., very overloaded as the design loading for 18°C is 217 kg/ha d).

Assuming ~20% BOD removal, the effluent BOD is ~(0.8 × 265) = ~212 mg/l.

#### Facultative pond

The surface loading on the facultative pond is:

$\lambda_s = 10\, L_i Q/A = (10 \times 212 \times 316)/(2070) = 324$ kg/ha d (i.e., overloaded).

### B. Current flow

The current population is ~2760, with a wastewater flow of ~32 litres/person day and an assumed BOD contribution of ~30 g/person day. Thus the flow $Q$ = 88 $m^3$/d and the BOD $L_i$ = 940 mg/l; the latter is reduced in the interceptor tanks to ~470 mg/l.

### "Anaerobic" pond

(a) volumetric loading ($\lambda_v$, g/m$^3$ d):

$\lambda_v = L_i Q/V = (470 \times 88)/(970 \times 5) = 9$ g/m$^3$ d.

i.e., very underloaded.

(b) surface loading ($\lambda_s$, kg/ha d):

$\lambda_s = 10\ L_i Q/A = (10 \times 470 \times 88)/(970) = 426$ kg/ha d.

i.e., very overloaded.

Assuming ~20% BOD removal, the effluent BOD is ~(0.8 × 470) = ~376 mg/l.

### Facultative pond

The surface loading on the facultative pond is:

$\lambda_s = 10\ L_i Q/A = (10 \times 376 \times 88)/(2070) = 160$ kg/ha d.

i.e., slightly underloaded as the design loading for 18°C is 217 kg/ha d).

### <u>Redesigned facultative pond</u>

Use the existing anaerobic and facultative ponds as a secondary facultative pond (this would necessitate partially filling the anaerobic pond and redesigning the pond feed pipework). Thus:

(a) Current population:

$\lambda_s = 10\ L_i Q/A = (10 \times 470 \times 88)/(2070 + 970) = 136$ kg/ha d − *satisfactory*.

(b) Design population:

$\lambda_s = 10\ L_i Q/A = (10 \times 265 \times 316)/(2070 + 970) = 275$ kg/ha d − *slightly overloaded.*.

### *General comments*

At this stage no remedial action is recommended as it is better to wait for a year or so to determine actual performance. Effluent quality may be poor in winter, but the loadings at the current flow rate may not give rise to significant nuisance − however, there could be a little odour from the overloaded facultative ponds (but not from the underloaded anaerobic ponds). Both ponds may be purple/red/pink in colour due to the growth of photosynthetic bacteria; if the facultative ponds are this colour, then odour release is unlikely.

The data obtained by routine monitoring during this period will be extremely useful for any subsequent upgrading of the system.

# ANNEX II

# Waste stabilization pond design for Om Sen

The design presented below is based on the general design procedures given in *Design Manual for Waste Stabilization Ponds in Mediterranean Countries*.

## Design parameters

Population = 4000; wastewater flow ($Q$) = 300 $m^3$/day; BOD ($L_i$) = 533 mg/l (40 g/person d); FC ($N_i$) = $5 \times 10^7$ per 100 ml; and temperature ($T$) = 18°C.

## (a) Anaerobic pond

Design BOD loading ($\lambda_v$,) = 260 g/$m^3$ d at 18°C

Mid-depth area ($A_a$, $m^2$) for a depth ($D_a$) of 5 m:

$A_a = L_i Q/\lambda_v D_a = (533 \times 300)/(260 \times 5) = 123\ m^2$

Retention time ($\theta_a$) = $A_a D_a/Q = (123 \times 5)/300 = 2$ days

BOD removal = 56% at 18°C

Effluent BOD = 0.44 × 533 = 235 mg/l.

## (b) Secondary facultative pond

Design BOD loading ($\lambda_s$, kg/ha d):

$\lambda_s = 350(1.107 - 0.002T)^{T-25} = 217$ kg BOD/ha d at 18°C.

Mid-depth area ($A_f$, $m^2$):

$A_f = 10 L_i Q/\lambda_s = (10 \times 235 \times 300)/217 = 3250\ m^2$

Retention time ($\theta_f$) for a depth ($D_f$) of 1.5 m = $A_f D_f/Q = (3250 \times 1.5)/300 = 16$ days

The unfiltered effluent BOD ($L_e$, mg/l) is given by

$L_e = L_i/[1 + (0.1 \times 1.05^{T-20} \times \theta_f)] = 235/[1 + (0.1 \times 1.05^{18-20} \times 16)] = 96$ mg/l

### (b) Maturation ponds

Assume the required number of faecal coliform bacteria in the final effluent ($N_e$) is 3000 per 100 ml.

The general equation of faecal coliform removal in the series of ponds is:

$N_e = N_i/[(1 + k_{B(T)}\theta_a)(1 + k_{B(T)}\theta_f)(1 + k_{B(T)}\theta_{m1})(1 + k_{B(T)}\theta_m)^n]$

where $k_{B(T)}$ is given by $k_{B(T)} = 2.6(1.19)^{T-20} = 1.84$ day$^{-1}$ at 18°C; $\theta_{m1}$ is the retention time in the first maturation pond, days; and $\theta_m$ is the retention time in the second and subsequent maturation ponds of which there are $n$. A more convenient form of this equation is:

$\theta_m = \{[N_i/N_e(1 + k_{B(T)}\theta_a)(1 + k_{B(T)}\theta_f)(1 + k_{B(T)}\theta_{m1})]^{1/n} - 1\}/k_{B(T)}$

The retention time in the first maturation pond ($\theta_{m1}$, d) is determined on the basis that the BOD loading on it is 75% of that on the preceding facultative pond. Thus:

$\theta_{m1} = 10L_{e(f)}D_{m1}/0.75\lambda_{s(f)}$

where $D_{m1}$ is the depth, m. Thus:

$\theta_{m1} = (10 \times 96 \times 1)/(0.75 \times 217) = 5.9$ days.

Thus:

$\theta_m = \{[5 \times 10^7/3000(1 + 1.84\times2)(1 + 1.84\times16)(1 + 1.84\times5.9)]^{1/n} - 1\}/1.84$

i.e., $\theta_m = 4.8$ d for $n = 1$. Thus there is a single secondary maturation pond with a retention time of 4.8 days.

Area of M1 $= Q\theta_{m1}/ D_{m1} = 300 \times 5.9/1 = 1770$ m$^2$

Area of M2 $= Q\theta_m/ D_m = 300 \times 4.8/1 = 1440$ m$^2$

### Total mid-depth area

The mid-depth areas are as follows:

| | |
|---|---|
| Anaerobic ponds | 123 $m^2$ |
| Facultative ponds | 3250 $m^2$ |
| Primary maturation ponds | 1770 $m^2$ |
| Secondary maturation ponds | 1440 $m^2$ |
| **Total mid-depth area** | **6583 $m^2$** |

Thus the WSP system will fit into the available area of 2 feddans (8400 $m^2$).