Case study of sustainable sanitation projects

Three examples of wastewater reuse after reed bed treatment, Dubai, Industrial Zone

Fig. 1: Project location

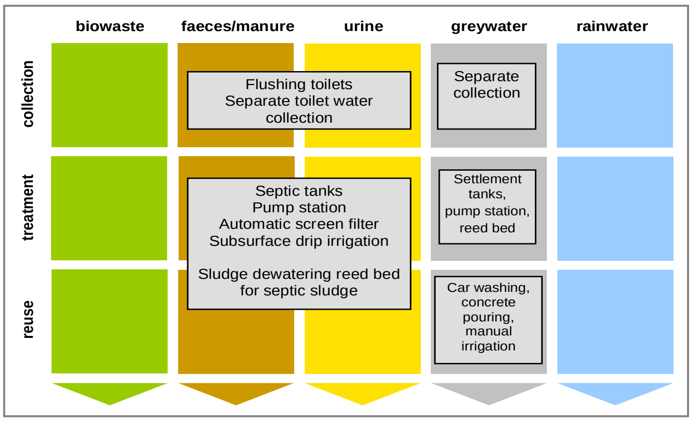

Fig. 2: Applied sanitation components in this project

1 General data

Type of project:

Treatment and reuse of wastewater of commercial buildings (workshops, offices, car washing) – full-scale

Project period:

Start of planning: 2005 / 2006
Start of construction: 1 month after planning start
Start of operation: 2-6 months after planning start

Project scale:

60-270 persons/day, and 10 cars/d for Example 1b
Investment costs of the 3 examples in the range of € 4,500 to € 21,000

Address of project location:

Example 1: Waagner Biro Gulf, Al Awir Ind. Area, Dubai
Example 2: The Lagoons Sama Dubai, Ras Al Khoor, Dubai
Example 3: Dubai Municipality Jadaf, behind ship yard, Dubai

Planning institution:

Waagner Biro Gulf

Executing institution:

Respective owners / Waagner Biro Gulf

Supporting agency:

None

2 Objectives and motivation of the project

Waagner Biro Gulf is a construction company specialized in steel, bridge and marine constructions with a special branch for environmental technologies, and has demonstrated innovative solutions in the field of closed loop wastewater treatment to its clients in different settings. The main aims of a range of different projects are:

- Demonstration of generally applicable wastewater reuse options for private companies and municipalities in sub-tropical, arid climates.
- Climate-specific testing of reed bed treatment for greywater (reed beds are a specific type of constructed wetland, see Section 5), sludge dewatering with reed beds and sub-surface drip irrigation with pre-treated blackwater.

Key information from three typical project examples is provided in this document.

Fig. 3: Project sites (clockwise): Example 1a, 2, 3, 1b (source: Waagner Biro Gulf)

3 Location and conditions

Dubai has a sub-tropical, arid climate with infrequent and irregular rainfall, totalling less than 130 mm per year. Temperatures range from 10°C to 48°C. Both industries and the population in Dubai and the surrounding Emirates is growing very fast and public infrastructure is unable to keep up with the exploding volume of sewage. On newly built developments and industrial sites, which are not (yet) connected to a public sewer, temporary or self-contained solutions for waste and wastewater management are needed.

Presently, wastewater is often either:

- discharged via long sewer networks to the main sewage treatment plant; or, if the site is not connected to sewers:
- stored in storage tanks and later transported by tanker to a central sewage treatment plant or
- pretreated in septic tanks and then infiltrated into the ground with soakaways.

Whilst the latter approach causes problems through increased road traffic, additional unplanned loadings to sewage treatment plants, soil contamination and possible groundwater contamination etc., the installation of huge sewer lines is technically demanding and costly.

Moreover, the high water demand in this hot, dry region is in conflict with its extremey limited availability, and thus innovative technical solutions are required. To some degree this high water demand can be met through the reuse of treated wastewater as service water.

4 Project history

Waagner Biro Gulf LLC is a multi-national turnkey contractor and facility manager of bridges, steel structures, waste recycling, wetland wastewater treatment plants, wetland systems and marine works with "in-house" design, manufacturing and installation capacities. It also serves as partner for public authorities in a variety of maintenance and upgrading contracts.

The introduction of innovative wastewater treatment options to the clients has become one of the company´s key environmental activities in the Gulf region.

5 Technologies applied

Reed beds are an example for a constructed wetland treatment process (vertical or horizontal sub-surface flow, soil filter planted with *Phragmites communis* or other marsh plants). Reed bed technology is used in Dubai for treatment of car wash wastewater, greywater, blackwater and septic sludge. In the following project examples, diverse technology components were applied:

Example 1a:
Domestic wastewater at the Waagner head office (270 staff members):

Transport by separate gravity sewer lines for grey and blackwater. Treatment and reuse of both greywater from showers / bathrooms and blackwater from toilets and the kitchen.

- Greywater: After settling in a 2-chamber tank, it is pumped in turns onto two vertical flow sand filter reed beds, each with an area of 250 m². The outflow of the greywater reed beds is directly used for different purposes as explained in Section 7.
- Blackwater: After passing through a 3-chamber septic tank, the pre-treated blackwater is pumped through a mechanical self-backwashing filter into a 700 m² sub-surface drip irrigation, watering a gardening area, thus avoiding any direct exposure of people to blackwater.
- Settled solids from the pretreatment units of greywater and blackwater (settlement tank and septic tanks): They are pumped every two months onto a 200 m² sludge dewatering reed bed for mineralization. This is a further development of sludge drying beds in the form of a sealed earth basin with a shallow vertical flow reed planted sand filter and 1 m freebord above the filter layer to accumulate the sludge over the next 10 years.

Example 1b:
Waagner company´s car washing wastewater (10 cars / day):
3-step pretreatment by gravity, three chamber oil separator without chemicals, 20 m² horizontal flow sand filter reed bed treatment of oil separator outflow, additional treatment of reed bed outflow in reed bed for greywater treatment.

Fig. 4: Car washwater reed bed Alawir (source: Waagner Biro Gulf)

Example 2:
Domestic wastewater of SAMA Dubai site office (200 staff members):

- 3-chamber septic tank and 100 m² vertical flow sand filter reed bed treatment for toilet blackwater
- Reuse of treated blackwater in 400 m² sub-surface drip irrigation (gardening)
- 2-chamber settlement tank and 40 m² separate vertical flow sand filter reed bed treatment for greywater
- 20 m² sludge dewatering reed bed (reed-planted sand filter bed) for mineralization of septic tank sludge

Example 3
Conversion of conventional septic tank with soak away at Dubai Municipality (60 staff members):

- Use of septic tank as pretreatment

- Conversion of soak away to a pump station and pumping of outflow to a 170 m² vertical flow sand filter reed bed for biological and tertiary treatment of pre-treated wastewater. Analyses proved sufficient quality for drip irrigation.
- Optional additional UV treatment of stored effluent with UV lamp in stainless steel pipe.

Fig. 5: Greywater reed bed Alawir (source: Waagner Biro Gulf)

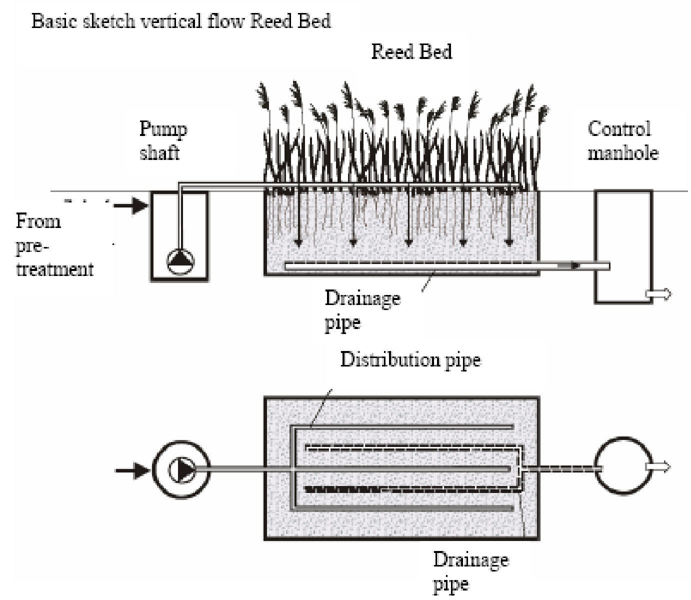

Fig. 6: Basic sketch of a vertical flow reed bed (source: http://www.entsorgungsverband.de/uploads/media/Vortrag-Bleif.pdf)

6 Design information

The designs are in accordance with the German guidelines for reed beds and the Dubai Municipality Guidelines for septic tanks as well as guidelines for drip irrigation systems (see Section 13).

The reed bed (or constructed wetland) treatment system combines both aerobic and anaerobic decomposition processes in a sand layer up to 1 m thick. The polyethylene-lined and refilled basins are planted with “Phragmites Communis” and other regional marsh plants. The wastewater percolates the filter substrate vertically or horizontally to the floor drains.

Along with the microbial and fungal decomposition of organic matter and pollutants in the rooted sand matrix, chemical and physical precipitation, adsorption and filtering processes occur due to sand constituent clay-like minerals and humus particles.

Through intermittent loading of the reed beds a radical change in the oxygen regime can be achieved. After water saturation of the sand through feeding the distribution system, a drainage network at the base collects the treated wastewater. The water in the pore space of the substrate is replaced during drainage by air, thus enabling aerobic decomposition processes to begin. Further oxygen transfer into the rhizosphere from the air occurs through a special helophyte tissue in the plant stems and roots (aerenchym).

Clogging of the filter substrates (sand, gravel) is prevented by the continuous growth and decay of the roots and rhizomes of the aquatic macrophytes and the resulting soil macropores. In this way, long-term use and transport of pre-treated water into the soil matrix is guaranteed.

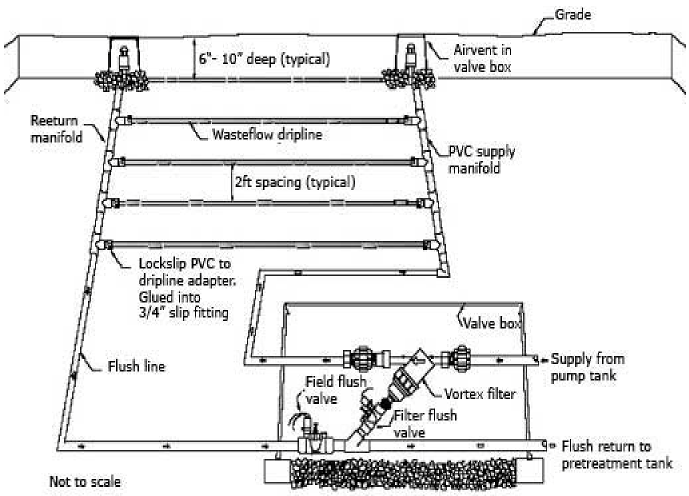

Fig. 7: Typical drip field layout (source: Geoflow)

7 Type of reuse

For Example 1:

- Storage of treated greywater (including water from car washing) in an elevated tank and a pond for reuse for concrete mixing, soil watering, car washing and a fish ponds.
- Sub-surface irrigation of different plants including tomatoes, melons, cucumbers, date palms, flowers, bushes and grass areas. Analyses of the plants have complied with WHO Standards.

Fig. 8: Sub-surface irrigated plants (source: Waagner Biro Gulf)

For Example 2:

- Storage and reuse of treated greywater for manual garden irrigation and for car washing
- Sub-surface drip irrigation system for gardens using treated blackwater
- Mineralised septic tank sludge used as a soil improver and fertiliser in landscaping.

For Example 3:

Storage of treated greywater for irrigation and for boat washing (after additional hygienisation using UV-radiation).

Plants irrigated with treated greywater and blackwater show excellent growth (e.g. pumpkins, oleander, palm trees). However no sub-surface plants such as onions or carrots were cultivated in order to avoid contact with the blackwater. The safest plants to minimize human exposure to the soil during planting and harvesting works are long term ornamental plants such as palm trees, grass and bushes.

8 Further project components

- Continuous analyses of the treated wastewater of project Example 1.
- Plants and soil are monitored, especially in the projects located at the constructors´ site (Example 2) and at the Municipality site (Example 3).
- Analyses have confirmed WHO Standard for the sub-surface blackwater irrigated crops.
- The sludge dewatering process is being monitored, and tests using sludge from other project sites are being carried out to define the maximum load.
- Experience has shown an enormous potential of this type of sludge dewatering technology in arid regions, as the drying and mineralization process is much faster than in Europe (dewatering and mineralization of sewage sludge with reed-planted sand filter). Further long term tests are necessary to find new design guidelines for arid regions.
- A greywater reed bed is divided into several parts to test the maximum loading in this climate.
- Advantages of decorative aspects of storage ponds in gardening are integrated into designs.

Fig. 9: Greywater garden (source: Waagner Biro Gulf)

9 Costs and economics

Depending on the exact circumstances, the actual construction investment for reed bed systems in this region is equal to conventional systems (activated sludge plants) for up to 15,000 persons (for larger installations, the conventional systems may have lower cost than red beed systems). While Dubai is in middle of the desert, the main problem is to get the right filter sand for the system, as the construction is booming and all the crushers are sold out for years and the price for sand is enormously high.

On the other hand, the operational costs of reed bed systems in this region are about 10-30 % of activated sludge plants. This is an important advantage for clients, as often for conventional sewage treatment plants no capital is provided for operation and maintenance, leading to malfunctions and poor efficiency. The reed bed technology provides a long lasting, low-maintenance and high performance, robust alternative solution with very low O&M costs compared to e.g. activated sludge treatment plants.

It is clearly the long term economic benefits of such systems that have persuaded companies to opt for the technology. The reliable performance potential is an added bonus.

<u>Cost examples:</u>

Example 1a: Investment: €4,500

Example 1b: Investment: € 36,000. Payback could be achieved within one year by saving fresh water and tanker disposal cost.

Example 2: Investment: € 13,000

Example 3: Investment: € 21,000, yearly running cost: € 200 (electricity and labour)

Average cost break-down of reed bed systems:

On average 90% of the investment costs are civil works, like earth movement and installation of filter material and distribution and drainage pipe works. Therefore the installation costs depend mainly on the prices of filter material and day rates of earth movement equipment. The remaining 10% of the investment costs are typically for the mechanical parts, mainly submersible pumps and valves.

As the mechanical equipment is a minor part of the system, also the maintenance, running and spare part costs for the system are very low - they are the same as for a pump station.

10 Operation and maintenance

Constructed wetlands in general, and reed beds in particular, are simple to operate without chemical additives or complex electronic controls. They require minimal staffing levels due to their very low maintenance requirements. Consequently, operational costs are very low, whereas system lifetimes are very long.

O&M is normally done by skilled workers of the owners which can be trained by the constructors within a few days. The operation of the system consists of the following tasks:

- Daily tasks: Visual check of the system
- Weekly tasks: Change of the distribution from one bed to another (opening and closing a valve); remove reed shoots from the service ways around the beds; visual check of the pump station.
- Every three months: Discharge sludge from the pre-treatment; flush distribution and drainage system, clean pump stations

The cut reeds can be:

- disposed of on the sludge dewatering reed bed as structure material and carbon donor for the mineralisation process.
- composted with other organic waste, used as litter for animals or as organic structure material in agriculture.
- If a high enough volume is produced: used to produce ecological building materials or biomass for biogas production.

Fig. 10: Reed bed plant for wastewater in Jadaf (source: Waagner Biro Gulf)

Sludge disposal from septic tanks is done every two to six months by vacuum tankers which dispose of it in the municipal sewage treatment plant. Alternatively, the sludge is pumped with a mobile pump and flexible hose onto a sewage sludge dewatering reed bed. This monthly effort takes less than 1 hour.

In the case of the gravity oil separator (in Example 1b) the oil has to be removed once a year.

11 Practical experience and lessons learnt

- The continuous availability of a large volume of stored and treated greywater in a pond makes some processes in the construction and maintenance works much easier.
- The vertical flow reed planted sand filter achieves results in the treatment of domestic sewage which allow a direct reuse for irrigation of the treated sewage without any further treatment.
- The treatment in such hot climate leads to even better results than in Western and Northern Europe (some results indicated in Table 1 below).
- Regarding manual reuse, the acceptance of treated greywater is much higher than that of treated blackwater, whereas sub-surface irrigation with blackwater is well accepted for gardening purposes due to the non-exposure to the water. However, it should be handled with care with regard to surface drainage and leakages, and well trained staff should run and maintain such a system.
- The gardens and fishponds created with the onsite treated wastewater from workers' accommodations and staff cabins have a great social value for the people there who otherwise mostly have no greenery around their work places and accommodation.
- Larger reed beds also contribute to biodiversity by serving as reserves for birds and small water animals.

Table 1: Typical average pollutant concentrations of reed bed effluents in the U.A.E. (source: Waagner Biro Gulf – based on 3 years of experience, approx. 20 plants treating a variety of wastewaters, and operating temperature range 25-50ºC)

COD	BOD	NH_4-N	TSS	pH
25	10	1	< 5	7.5

Note: Average influent parameters for raw sewage in the region: COD 400-600 mg/l, BOD 200-400 mg/l.

12 Sustainability assessment and long-term impacts

A qualitative sustainability assessment is provided below:

- Technical sustainability: As described above, the treatment results are even better than in colder climates. Once started, the system does not need additives, has low energy input and requires little maintenance.
- Ecological sustainability: Beyond the practical issues related to wastewater treatment, a reed bed system does consume only little energy but saves natural resources, it produces biomass as valuable by-product, it can serve as biotope and – because it is clearly visible - it often raises awareness concerning the subject of wastewater.
- Financial sustainability: Preconditions for the system are an available area of a certain size, some design and coordination efforts in the beginning to adapt the solution to the particular context, and an investment comparable to a conventional activated sludge treatment plant (for this region and for sizes up to 15,000 people). The cost benefits become evident after some years through power saving and low maintenance. Hence, a mid term financial perspective is necessary to compare possible solutions.

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As long as ecological education and awareness as well as consideration of macro-economical terms are not sufficiently developed on the decision making levels, the most powerful means to support sustainable systems are political and legislative regulations.

A basic assessment (Table 2) was carried out to indicate in which of the five sustainability criteria for sanitation (according to the SuSanA Vision Document 1) this project has its strengths and which aspects were not emphasised (weaknesses).

Table 2: Qualitative indication of sustainability of system. A cross in the respective column shows assessment of the relative sustainability of project (+ means: strong point of project; o means: average strength for this aspect and – means: no emphasis on this aspect for this project).

	collection and transport			treatment			transport and reuse		
Sustainability criteria:	+	o	-	+	o	-	+	o	-
• health and hygiene	X				X			X	
• environmental and natural resources	X			X			X		
• technology and operation	X			X			X		
• finance and economics	X				X		X		
• sociocultural and institutional	X			X			X		

Sustainability criteria for sanitation:

Health and hygiene include the risk of exposure to pathogens and hazardous substances and improvement of livelihood achieved by the application of a certain sanitation system.

Environment and natural resources involve the resources needed in the project as well as the degree of recycling and reuse practiced and the effects of these.

Technology and operation relate to the functionality and ease of constructing, operating and monitoring the entire system as well as its robustness and adaptability to existing systems.

Financial and economic issues include the capacity of households and communities to cover the costs for sanitation as well as the benefit, e.g. from fertilizer and the external impact on the economy.

Socio-cultural and institutional aspects refer to the socio-cultural acceptance and appropriateness of the system, perceptions, gender issues and compliance with legal and institutional frameworks.

For details on these criteria, please see the SuSanA Vision document "Towards more sustainable solutions" (www.susana.org).

With regards to the long-term impact of the project, the main expected impact of the project is improved public health (sewage overflow of septic and holding tanks is reduced), traffic by vacuum tankers is avoided and the reduction of freshwater consumption by the reuse of treated wastewater as service water. The idea of decentralised wastewater treatment and reuse is demonstrated.

13 Available documents and references

- Drip irrigation limits of Dubai Municipality http://www.environment.gov.ae/environment/major/informationbulletins
- Project references and results of reed bed treatment in sub-tropical climate: w.sievert@gmx.de
- Information about sub-surface drip irrigation system: www.geoflow.com http://ecotube-concept.com/index.html

14 Institutions, organisations and contact persons

Dubai Municipality:
Eng. Rashid Nassir Al Suwaidi
Head of Planning & Design Section Drainage & Irrigation Department
P.O.Box 67
Dubai, U.A.E.
E-mail: rnsuwadi@dm.gov.ae

Sama Dubai:
Marina Antonopoulou
Environmental Specialist Projects Management Department
P.O.Box 72527
Dubai, U.A.E.
E-mail: marina.antonopoulou@sama-dubai.com
www.sama-dubai.com

Construction:
Waagner Biro Gulf
P.O. Box: 8542, Dubai
wabidxb@emirates.net.ae
www.waagner-biro-gulf.com

Design of System:
Dipl.-Ing. (FH) Wolfram Sievert
P.O.Box 296017
Dubai, U.A.E.
E-mail : w.sievert@gmx.de

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Authors: Wolfram Sievert supported by Jana Schlick (jana.schlick@planco.org)

Editing and reviewing: Carola Israel, Elisabeth v. Münch (GTZ ecosan program – ecosan@gtz.de)