Waste Water System Kibbutz Lotan

Report on

Design Proposal for a Constructed Wetland for Water Reuse

ÖKOTEC GmbH, Belzig

Author: Dr. Emile J. Niklas

Belzig, Germany, March 2005

Tel +49/33841/3889-0

Fax +49/33841/3889-10

Kibbutz Lotan

Chevel Eilot

88855 ISRAEL

Tel 972-8-6356888

Fax 972-8-6356827

1 Introduction

The Kibbutz Lotan has decided to improve the waste water treatment system. The chosen treatment system is a constructed wetland. The CWs have different advantages compared to technical system.

Technical treatment plants in small systems are usually not reliable, especially with fluctuating population, and they need much electricity. Instead constructed wetlands are usually tolerant against load fluctuations and require a very low maintenance and energy effort.

There are different types of treatment systems, using plants and soil (sand) or gravel. The treatment principle is mainly of microbial nature, soil filters have additionally adsorptive features. The microbial activity increases with the surface area to be covered by the microbial biofilm. Thus the treatment performance is better in soil filter systems compared to open water bodies or gravel beds. Fine material performs better than coarse material. Water bodies with plants perform better than those without plants, because they provide root surface as growth area.

The treatment is almost exclusively of microbial nature. The uptake of nutrients by the plants is negligible. Even if the plants are harvested, they might have a contribution to the nutrient elimination of only up to 10 %. If they are not harvested, the incorporated compounds are released during die-off of the plant tissue.

In terms of increasing efficiency/area ratio the following systems are of major importance:

1.1 Surface flow

This system can be described as a shallow pond with helophyte vegetation (like a marsh). The stems of the plants are used by the micro organisms as substrate. These systems are mainly used in North America, where area is not of much concern, compared with Europe. Advantage of the system is the easy integration in landscape design. The shallow water allows for the development of a rich fauna and the system thus is of great nature conservation value. But it is recommended, to use the system only as tertiary treatment after the biological treatment, because of odour and vector problems for diseases.

1.2 Subsurface flow in gravel bed

The water flows horizontally through a gravel bed of 40 to 60 cm thickness, which is planted with helophytes. The microbial growth takes place on the surface of the gravel and the plant roots. The plants supply some oxygen by their roots, which is used by the micro organisms for aerobic breakdown of the contaminants. This type of treatment, using plants, was initially developed in Germany by Käthe Seidel and is now widely used in the US and partially the countries, which are historically under US scientific influence. In Germany this type of treatment plant is rarely in use anymore, because of the area consume and the limitations in performance.

1.3 Vertical flow soil filters

In the vertical systems the waste water is applied on the surface of the sand filter, which virtually becomes a soil filter by the accumulated organic compounds, which are partly converted into a humus surface layer. By the infiltration process air is sucked into the pores of the filter material, supplying oxygen for the bacteria, which are living as biofilm around the sand particles. This is the most important factor for the degradation process. So the cleaning effect is high with relatively low area requirement. By passing the 60 cm thick filter layer, the water is treated not only by microbial activity, but also by adsorption processes. The extraction and later decomposition of persistent organic compounds is best in this system as well as the removal of pathogens. This treatment system requires a balanced grain distribution of the filter material. The material should be fine enough to secure a good distribution on the filter surface, but coarse enough to prevent clogging.

1.4 Which System for which location

The different systems have different advantages and disadvantages. Vertical soil filters have higher investment and pumping costs, which have to be compared to the higher area consume of the horizontal systems. Concerning the effluent quality any system is ok, if properly designed. In the case of the desert site of lotan, a vertical system is not to be recommended, because of the fine particles, brought along by the sand storms, which could clog the filter surface.

2 Background and goals

Background of the expert visit was, to give recommendations in addition to the pre-designed system, concerning design, procedures and materials.

3 Present Situation

3.1 Location and waste water origin

Lotan is a growing community with a strong ecological approach. The ecological innovations, developed by the community will be exhibited in an ecological park which is also used as training center. The public interest in this project will increase and thus an enhancement of the tourism is to be expected.

Lotan is situated in the Negev Desert. The water is supplied by the local water authority. For drinking purposes the water is treated by reverse osmosis. The highest water consumer is the dairy farm. Here the daily waste water production is up to 130 m^3/day during summer. The water use by the households, including the tourist accommodations, is up to 90 m^3/day.

The waste water from the kibbutz flows by gravity into a septic tank. After mechanical pre-treatment (sedimentation), the water from the dairy is also connected to this sewer system.

The sedimentation of the dairy waste water is obviously not sufficient. A big amount of solids is washed out and contribute to clogging the sewer system.

The septic tank has a scum layer in which the solids from the dairy farm predominate. The water, treated in the septic tank, is meant to flow by gravity to the neighbouring kibbutz, where it is treated in lagoons. The sewage pipes are blocked often, because the pipe has not enough slope. The lagoons are of insufficient size and thus overloaded. The combined waste water is treated insufficiently.

The need for a new waste water treatment plant is obvious. The decision for a natural system fits the ecological aspect of the project as well as the nature of the waste water.

3.2 Preparative Work on a New Waste Water Treatment System

Water analyses had been made. Yet they can give only a rough estimate of the concentrations to be expected after a functioning sedimentation system. The reason is, that the suspended solids are not removed sufficiently in the existing sedimentation tank. Comparing data from other locations, the expected BOD-concentration of the dairy sewage should range between 1,000 and 1,200 mg/L and the corresponding value of the household waste water between 200 and 400 mg/L.

3.3 The Planning

The local consultant office, which will make the detail planning, is Elah Water + Ecology with sister company Ofra Aqua Plants. The planners have experience with planning horizontal treatment systems. Systems in operation have been visited by kibbutz members. The experience of the local consultants includes the handling of dairy waste water. During a short meeting there was not enough time to discuss the dimensioning approaches. The consultants claim a high reduction of BOD and faecal indicator organisms due to climatic reasons and due to a special media set-up and plant selection.

3.4 The grey water treatment plant at the Eco-Educational park

The dimensioning according to the estimated grey water BOD loads in Germany, which should not be much different to the local conditions, is 23 g O_2 /m^2. As the Ammonia content is negligible, this figure represents the actual O_2 requirement.

4 The Proposed System

4.1 Present Design - Comments

The Design was made by Eli Cohen, OFRA AQUA PLANTS. It combines a series of steps for mechanical and secondary and tertiary treatment. The system and the expected load and effluent quality is shown in fig. 1. In the following the different treatment steps are listed.

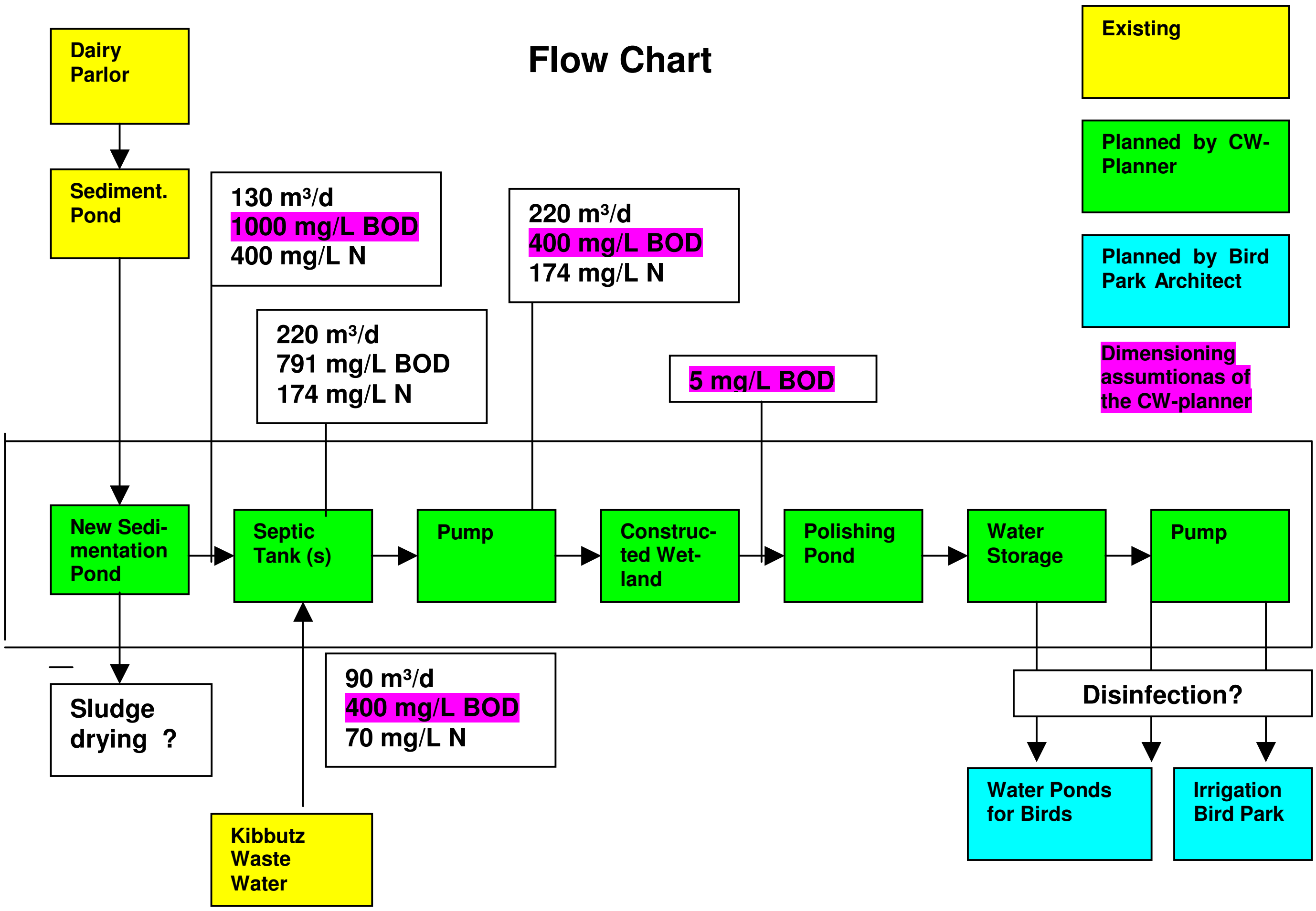


Fig. 1: The CW system design

The dimensioning is as follows: Septic tank 2 days retention time; 4-6 plant ponds, each 10 m x 10-14 m, depth 0.6 to 0.8 m; retention time about 6 days; BOD load 20 gO_2/m^2. Oxygen requirement, including Ammonia is about 60 g/m.

The old ***sedimentation pond*** has to be replaced by a new one, because the sedimentation is very insufficient. The definite design has not yet been worked out. The proposal of the planners is to separate the sludge in a structure similar to a wetland for water treatment.

Fig. 2: Sludge drying in reed bed (winter)

Sludge dewatering in reed beds (fig. 2 and 3) has been practiced since more than 15 years. The principle is similar to the normally used drying beds. They have a coarse sand layer of about 20 cm above a drainage layer. The plants provide additional evaporation. The capacity is about 250 kg/m²/a dry matter.

The practice in Lotan up to now is drying the sludge just on the natural sandy soil. In the existing climate this works fast. This shows, that only for drying, the plants are not necessary. This could have the advantage of using fly screens. With plants the bed can be charged up to a height of 1.50 m, without plants the dried sludge has to be removed after each application.

The suggested sludge bed should have about 440 m². This dimension derives from the assumption, that 250 cows are washed 3 times/day and leave 2 litres of dung with 20% dry matter each time. These figures have to be confirmed yet.

Fig. 3:Sludge bed (summer)

If a system like that is feasible, depends on the drying time in relation to the growth velocity of the locally abundant flies. Fly control is important!

To charge the beds with the total outflow, would be to much hydraulic load. So there has to be a separation before. The dimensions of the separation systems cannot be given now for this kind of waste water. For municipal waste water the retention time would be something about 2 hours. Assuming a maximum flow of 13 m³/h (d_{10}), this would result in a tank size of 26 m³.

These are rough figures, to give an impression, what could be done without a high energy requirement. Further discussion of the options should be done during design planning with the local planner.

The dimension for the ***new septic tank*** is given with 1,5 to 2 days, which is sufficient. The sludge from the septic tank has to be removed once and a while. It should be checked, if there is a possibility, to treat it along with the dairy sludge. Technically it would be possible in a drying bed and in other devices. But there could be legislative reservations.

The ***pump***, feeding the wetland, should be designed as a double pumping station to prevent overflow in case of malfunction of the pump and should be equipped with an alarm, which indicates too high water levels. It is important to protect the pump against blocking by solids. Alternatively a cutter pump can be installed.

According to the planners, the ***constructed wetland*** is pre-designed as a series of ponds, filled with gravel, sometimes with open surface and vertical passages, dimensioned with 4,500 m². It has a mixture of different plant species and is supposed to have a better performance com pared to the normal horizontal systems. Regarding to the use for irrigation the nitrogen should not be removed by the CW. In a horizontal system this is only possible in a limited extent. Concerning Phosphorus, there is an inconsistency between the requirements of the pond and the use for irrigation, because this valuable nutrient, which is derived from limited mining resources, is unwanted in the polishing pond. Remarks on the dimensioning are given in the next chapter.

The ***polishing pond***, dimensioned with 1,000 m², one meter deep and with additional 200-300 m² gravel filter at the outflow is meant for additional BOD reduction. The outflow of the CW should have already a fairly low residual BOD and Ammonia content, to avoid anoxic situations with possible danger to the fish. Low Phosphorus content is desirable for prevention of algae bloom, which causes anoxic situations, when the algae die off. For the water analyses it is important, to use filtered water to prevent wrong results due to a possible algae content of the sample. According to the planners, the outflow will be via a filter layer of sand. In this case the algae can be retained in the pond.

The water will be collected in a ***storage tank***, which is covered, to reduce evaporation. The design has to consider the later use of the water and the distribution of the pumping events.

The ***pump*** has to be selected according to the use of the water mainly concerning the irrigation of the bird park.

In the bird park a ***field*** for alfalfa production (or other cultures) is planned, which will be irrigated with the water from the storage tank and help to attract birds. This water use could be an important part of the system, because it can be dimensioned for total uptake of the nutrients. There are no estimations of the Phosphorus content of the waste water. But probably the phosphorus content will be the limiting factor for irrigation. For full nutrient uptake by the plants in this case the irrigation has to be planned according to the nitrogen content. A rough estimation gives a Nitrogen outflow of the CW of about 10-20 kg/d, which would be enough for fertilizing about 15 – 30 ha.

As remarked for the polishing pond already, the goals of nutrient reuse and using the water in a ***ponds for birds*** are somewhat contradictory. From the point of reuse of the nutrients as well as the water (evaporation), a pond does not seem favourable. As mentioned before, high nutrient concentration will have a negative effect on the water organisms, a low nutrient content will require additional fertilizer for the irrigation water.

In a desert Situation, a maximum regain of water and nutrients has a more important environmental effect, than ponds for migrating birds, which historically already have their natural water habitats on their route.

4.2. Remarks on the CW Dimensioning

The dimensioning of CWs has to consider different climatic conditions. The experience of the author with the performance of CWs in hot climates is restricted to treatment plants in India and Mexico. The limited data base suggest, that there is a remarkable increase of performance of CWs under higher temperatures.

If only designed concerning the BOD, the dimensioning would be under German conditions about 9.200 m². The temperature coefficients are known for different treatment technical treatment systems. If we adopt the coefficient to a natural system, we find a remarkable reduction in retention time for a given BOD reduction. If we assume a temperature difference of 15°C, the required area is supposed to be 5,400 m², which would be almost similar to the dimensioning of the local consultant.

Own experiences in Delhi show an area requirement even of only 4200 m². Citation from the final report: "It was also concluded by experiments that vertical beds can treat effectively as high as the BOD in the range of 100 to 125 gm/m^2/day whereas the horizontal beds the rang is between 35 to 50 gm/m^2/day which is greater than the limits being recommended currently." (Sirajuddin Ahmed: Performance Evaluation Study Of Root Zone Treatment Plant At Mother Dairy; Jamia Millia Islamia University, New Delhi, 2002). The corresponding value for a vertical system in Lotan would be 1700 m². But still there is the reservation of a somewhat limited data base and the given dimensions presuppose outflow concentrations of still 20 mg/l BOD, which would be too high for Lotan.

Concerning the BOD only, the dimensioning of the proposed system for Lotan thus seems to be adequate.

There is only one question mark: the Ammonia content, the treatment plant has to deal with. Up to the usual content of household waste water (60 mg/L) the treatment plants can handle the Nitrogen-Oxygenation "within the BOD-dimensioning". Higher Ammonia concentrations will lead to a competition between BOD and Ammonia removal. In Lotan we estimated an Ammonia concentration after the septic tank of 174 mg/L. This is only a very rough estimate, which has to be proved. If the Ammonia concentration to be expected is definitely above 100 mg/L, we recommend revision of the dimensioning according to the Oxygen consumption by the Ammonia-oxidation.

	Water Consumption [m³/d]	BOD-Concentration [mg/L]	N-Concentration [mg/L]	Oxygen Consumption [kg/d]
Households	90			
Dairy Farm	130			
Total	220	400	174	
Load [kg/d]		88	38,28	258,346
Load [g/m²]		20	9	57

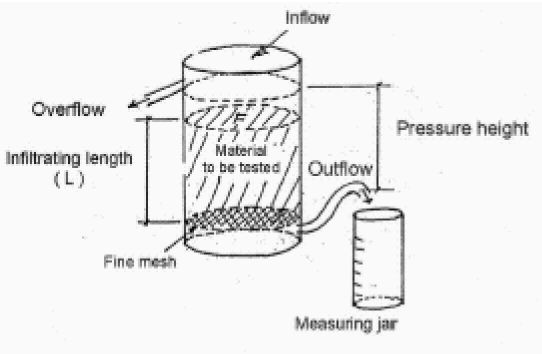
Tab. 1: BOD and Oxygen Consumption Loads

4.3 Proposals for the Material / Equipment

5.3.1 Sealing the soil

Usually the soil is sealed with a liner or a concrete plate. If there is clay soil or Bentonite available, it can be used as well. The sealing material can be mixed into the existing soil. A test mixture with the material and the existing soil should be made and checked by a construction material test lab. The percolation coefficient k_f has to be less than 10^{-8} m/s. The material should be mixed into the soil evenly in a depth of 60 centimeters. For the structures after the CW a less strict sealing is required. The soil then has to be condensed to 95% Proctor density. The resulting permeability should be tested at different places of the installed layer.

The material can be tested with the device, shown in fig. 4. The material should be compressed into a cylinder and given time for soaking from the wet side.



Count the time, in which the jar is filled !

Law of Darcy: k = V / i

Hydraulic slope: $i = \frac{\text{Pressure height, h [cm]}}{\text{Infiltration length, l [cm]}}$

Filter Velocity: $V\ [cm/s] = \frac{q\ [cm^3/s]}{A\ [cm^2]}$

Hydraulic Conductivity: $k\ [cm/s] = \frac{q\ [cm^3/s] * l\ [cm]}{A\ [cm^2] * h\ [cm}$

Fig. 4: Test Hydraulic conductivity; attention: k is given here in ***Centimetres/second***

5.3.2 Pumping

In spite of the not yet available data of the height, it can already be assumed, that the water has to be pumped from the ST into the CW. The other option would be to lower the CW, which would probably result in additional excavation of another 5 – 10,000 m³ of soil.

It should be checked, if using a solar pump would make sense. As the expected flow is not very high, the use of a solar pump should be possible. In fig. 5 an example for a solar pump is shown, which uses direct sunlight. Also a combination of solar panels with conventional pumps can be used.

Fig. 5: Solar pump

Disinfection

The water, leaving the system, according to the local consultant, will meet the national regulations for the quality of irrigation water. Nevertheless, the health authorites usually demand a disinfection device. This device from the view of the authorities preferably a chlorination unit, because Chlorine prevents the treated water from being re-infected. This is due to the level of the active agent in the water – compared to UV disinfection, where the few remaining bacteria can multiply again.

But Chlorine has different disadvantages: The handling requires trained personnel, because it is considered to be hazardous material. Chlorine molecules are attached to the killed bacterial biomass and other compounds and form the “bound Chlorine”, which can cause cancer. That means, that in the case of chlorination the water has to be perfectly clean (BOD below 5 mg/L), and, if taken from the polishing pond, the absence of algae should be guaranteed.

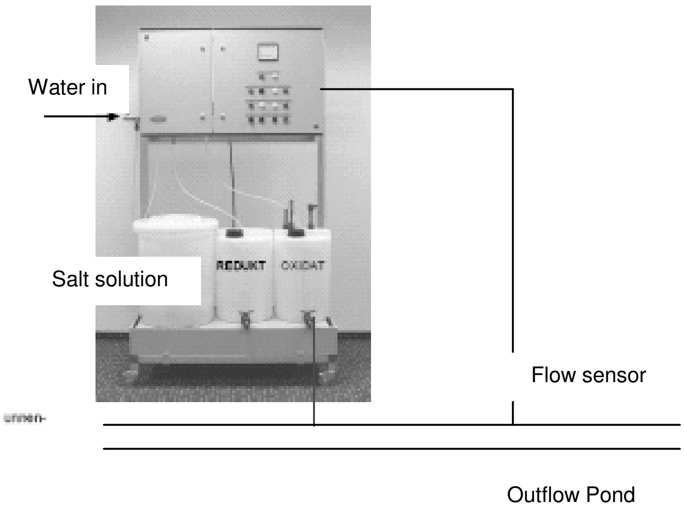


Fig. 6: Diaphragmaliser

In the following two alternative options are given. The first is the “Oximat” (fig. 6), which is a new development, used in hospitals, airports, etc. for disinfection of drinking water. It is based on a combination of electrolysis and membrane technology. It can be operated by solar power (60 W), and is ready for a water flow of 25 m³/h. The only material consumed for disinfection is cooking salt. The investment costs are about 120,000 NIS and the running costs are negligible. The equipment produces the disinfectant solution, which added to the water automatically according to the water flow. The harmless excess solution can be used in batch operation for manual disinfection of water tanks, floors, kitchen equipment etc.. The solution produced simultaneously is perfect as cleaning agent. Both products are commercially sold in Germany and can be shipped to Israel. A distributor in Israel does not exist yet. German health and environmental ministry approvals are issued.

Another option is the use of UV disinfection with improved performance – the Uvitt. At present, it cannot decided, if this system would make sense for the use in Lotan, but the relevant data have been sent to the supplier requesting an offer.

5 Evaluation of the results, assessments and recommendations

5.1 Recommendations on the treatment system

Besides the remarks on the material, which have to be checked, if they are feasible, there are two major points:

According to the comments on the dimensioning it is strongly recommended, to determine the Ammonia concentrations to be expected in the inflow into the CW and take them into account for dimensioning, if necessary.

At the inflow into the pond, the ammonia concentration should be less than 2 mg/L. Otherwise the oxygen consumption for conversion of the ammonia into Nitrate could cause a lack of oxygen, endangering the fish population.

5.2 Contract with the local consultant

In the contract there should be a guarantee of fulfilling the governmental regulations for treatment of waste water, which shall be used for irrigation. The expected BOD performance after the CW, given by the planner as 5 mg/L, should be fixed in the contract as an ***average*** value, which not has be met strictly all the time. The Ammonia concentration in the CW outflow should also be fixed at 2 mg/L in the contract as an average value. The hygienic performance of the system must meet the governmental regulations already in the outflow of the CW, if there is public access to the pond. This should also be clarified in the contract, as well as the guarantee period and the inflow conditions.

The contract should exactly define, who will cover the costs for additional investment ***and additional operation costs*** in case of necessary upgrade of the system.

The conversion of Ammonia into Nitrate (nitrification) should be almost complete after the CW (Ammonia-N < 2 mg/L), because otherwise the oxidation of Ammonia will happen in the following pond, thus possibly causing lack of oxygen and endangering the fish population.

5.3 Tendering/Contractor-Relation

A detailed specification should be part of the consultants achievement. Before signing the construction contract with the planner, the specification can be used, to obtain a reference offer from another contractor.