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Present Technological Options for Water Use and Treatment in the Context of the Ecological Integrity Approach

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SUMMARY

Today, with the rapidly increasing (urban) population and water resources becoming more and more scarce, there is a strong need to reconsider our consumption patterns and the way we use our water resources. The ecological integrity approach is a way of sustainable thinking and is characterised by three elements, which may complement each other: 1) differentiate, 2) cascade, 3) closing cycles. All three elements require water and energy saving environmental technologies. Technologies, such as rainwater harvesting, water saving devices and decentralised wastewater treatment and re-use systems, may be feasible for houses, hotels, holiday resorts and industries, usually with high levels of water consumption. Examples from these technologies can be found at different places in the Netherlands and may also be feasible in the Egyptian situation, both from economic and ecological integrity perspectives.

CHAPTER 1 INTRODUCTION

Already in 1958 the UN Economic and Social Council stated that “No higher quality of water, unless there is a surplus of it, should be used for a purpose that can tolerate a lower grade”. Today, with the rapidly increasing (urban) population, industrialisation and water resources becoming more and more scarce, there is an even stronger need to reconsider our consumption patterns, our assumptions and how we use our water resources. Especially in regions with limited fresh water resources and low annual rainfall, the problems of water scarcity and water pollution should not be overlooked. In the Middle Eastern and Northern African regions the water consumption accounts for more than 40% of the available water resources, while in other regions (such as sub-Saharan Africa and South America) only less than 10% of the available resources is consumed. Currently, 14 countries in Africa are subject to water stress (1700 m3 or less per person annually) or water scarcity (1000 m3 or less per person annually), with those in Northern Africa facing the worst prospects (1).

The French philosopher Jacques Ellul has characterised the (western) society that “it tends to concentrate the benefits, while at the same time it deconcentrates the drawbacks”. In this context benefits can be formulated as production, consumption and welfare; the drawbacks are, for example, pollution, exhaustion of natural resources and waste generation and disposal. This means that people are not or only little involved with the impact of their behaviour on the environment and society. Due to this low involvement they don’t feel priority for their environment. The increasing individualism in society is another symptom of the same phenomenon. Recently the World Bank stated that “the ability to provide for and protect oneself and one’s immediate family has become a given in modern urban life, undermining the impetus to lobby for changes that will benefit society as a whole”(2). This character of the modern society leads to a situation where each individual claims the benefits for oneself and transfers the drawbacks to the community. It may lead to pollution and environmental degradation for which nobody, besides the government perhaps, feels responsibility.

CHAPTER 2 THE ECOLOGICAL INTEGRITY APPROACH

The threatening water scarcity and increasing degradation of the environment means that there is a need for a new approach in the water supply and sanitation sector that creates responsibility both on the consumption side as well as on the disposal side. This approach for the water supply, sanitation and wastewater treatment sector that can be summarised with the words: ecological integrity. Ecological integrity means more than the application of sustainable technologies in the processes of water consumption and (waste) water treatment. Before implementing sustainable water treatment and reuse technologies it is necessary to reconsider the existing water consumption patterns and the impact of this consumption on the environment. This reconsideration should be realised through a thorough analysis of the need, the present situation and the possible adjustments or solutions, in which the following principles must be taken into account:

1) One should not use a higher quality or larger quantity of water than is actually needed in order to save water resources and to minimise negative ecological impacts. This principle calls for measures of responsible water consumption. One can think of water saving technologies, changes in behaviour or water companies offering water with different qualities for different purposes.
2) One should consider wastewater as potentially a valuable product in order to save energy and avoid destruction of organic matter, nutrients and minerals[1]. The emphasis of this principle lies primarily on the disposal side. Wastewater from laundry and showers (still containing some soap) can be used for toilet flushing, car washing or cleaning the floor, while sewage (containing human excreta and thus fertiliser) can be reused for landscape irrigation or agricultural purposes.

An analysis in the context of the ecological integrity approach is characterised by three elements, which may complement each other:

1) Differentiate. Differentiation is an analysis of which water quality and how much is needed for which purpose. In general it can be said that only food preparing (and other kitchen uses) and bathing / showering require the highest drinking water quality. Other uses such as toilet flushing, car washing, landscape irrigation and even laundry can do with a lower quality of water. The differentiation of water uses gives a clear view on the required quality and quantity of water for different uses.

2) Cascade. Cascading the different types of uses, means that water used for a certain purpose, can be re-used for another purpose which requires water from a lower quality. It results in a hierarchy of the different types of water use. The wastewater from the highest category in the hierarchy can, for example, be applied in the third or fourth category without (much) treatment. This type of reuse requires less energy and saves high quality drinking water.

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[1] This is the case for domestic wastewater. The principles are also valid for industrial wastewater, but one should be aware of the fact that industrial wastewater often contains more inorganic (and probable toxic) components. The possibilities for reuse are determined by the composition of the wastewater and the processes in which it should be reused.

3) Close. The closing of different cycles, aims on a total re-use of all components of the wastewater, i.e. water, organic matter, nutrients and minerals. It is not possible, however, to close the different cycles with the idea that “what goes in, must come out”. For example, during the cycle water and nutrients are “lost“ by respectively evaporation and plant uptake. Also, the closing of cycles requires always energy to keep the process going. A risk of closing cycles is that contaminants will build up in the cycle and that the energy consumption will increase.

CHAPTER 3 ENVIRONMENTAL TECHNOLOGIES

3.1 approach

All three elements of the ecological integrity approach require, to a different extent, water and energy saving environmental technologies, although these technologies should not be applied without a thorough analysis of the whole (household) water supply system and the purposes and options for water treatment and reuse. Technologies, such as rainwater harvesting, water saving devices and decentralised wastewater treatment and re-use systems, may be feasible for hotels, holiday resorts and industries, who usually consume considerable amounts of water. Examples from these technologies can be found at different places in the Netherlands.

Alternative water resources
In order to save the existing ground water resources for drinking water purposes one may consider the use of alternative sources, such as rainwater harvesting and the use of surface water. Several domestic activities do not require the highest drinking water quality. Rainwater, e.g. collected from roofs, can be stored in tanks or large plastic bags, until it is used for toilet flushing or laundry. In several projects in the Netherlands surface water is used, after some treatment (bank infiltration), for toilet-flushing and yard taps. This has resulted in a decreased consumption of the highest quality drinking water. It also may save energy that in the former situation was needed to upgrade the water quality to drinking water standards.

3.2 Water saving technologies

There is increasing awareness for the fact that for certain purposes one can do with much less water than always has been the case. This process has been increased by the development of new technologies, such as new toilet designs that still function with up to half the amount less water than was needed before, and new types of sewer systems, such as smart drains. At present there are a lot of water and energy saving technologies available and there are numerous examples of the application of these technologies. For example, in The Netherlands the law prescribes a water saving device for each new toilet.

A theoretical example based on several experiments, which has been developed by several boards and organisations in the Netherlands (3), illustrates that on the water consumption side, savings of 30% water and 20 % energy are possible with relatively simple measures. Technologies that have been applied in this example are:

- water saving devices in the showerheads
- devices for flow limitation on taps
- toilets with water saving devices
- limitation of leakage from the pipes

The costs for realisation of these four measures were estimated on 50 guilders (~32.5 US$). The average water consumption in the Netherlands is about 130 litre per person per day. The average water price (in 1995) was 2.10 guilders (~1.3 US$) per m^3. Application of the above mentioned measures resulted in a water saving of 35 – 40 m3 and an energy saving of 75 – 100 m3 natural gas (CH_4) per year, which was an annual cost saving of 100 guilders (~65 US$) per household. This example makes clear that in The Netherlands situation, at relatively fair prices (1995) for water and energy, these water saving measures can be gained back in less than one year. With the expected increasing water scarcity the prices of water may increase in the near future; a development that will increase the feasibility of water saving technologies.

3.3 Water reuse technologies

Another aspect of the ecological integrity approach is to find out what options there are at the “end-of-the-pipe”. Water that has been used for a certain purpose is not necessarily wastewater that has to be disposed off. Especially in regions where water is scarce and thus expensive, it is worth to consider the opportunities for the use of water that has already been used.

3.3.1 Scale

More and more it is recognised that decentralised wastewater treatment and reuse systems can compete with centralised systems in the context of the ecological integrity (4). Decentralised systems can function with less water than the centralised systems, because it is not necessary to dilute the waste in order to enable transport over large distances. Centralised treatment usually involves higher costs, because wastes must be transported over long distances with frequent pumping stations to lift wastes, and plant facilities typically involve capital-intensive technologies and high recurrent costs (5). Furthermore, decentralised systems enable the reuse of organic matter and nutrients. The users of decentralised treatment and reuse systems are more involved with their waste production and its impacts on the environment, than is the case with the centralised “flush and forget” systems. An increased involvement with the treatment systems creates also more commitment in operation and maintenance.

Decentralised water treatment and reuse systems can be realised as individual or communal/community-based systems. Individual treatment systems have the benefit that the juridical constructions will be relatively simple, while communal systems require less time for operation and maintenance from each individual user. Based on examples from Pakistan and Brazil the World Bank has stated that decentralised neighbourhood and community-based systems with shallow sewers and basic community treatment facilities lower the unit costs significantly (2).

3.3.2 Type

The design of the wastewater treatment and reuse systems partly depends on the destination of the effluent. The effluent water quality of a system designed to reuse the water for laundry has to meet higher standards than a system designed to discharge its effluent into surface water. In general, the treatment processes in decentralised treatment systems are the same as those used in centralised treatment plants. Although there are a lot of different systems with different working principles, the examples of treatment technologies in this paper are limited to the so called ‘natural’ treatment systems. These natural treatment systems, such as vertical flow reedbeds, rootzone systems and other constructed wetlands, are relatively stable systems compared to the more compact systems. The operation and maintenance require no high skilled labour and can usually be done by the users themselves. Natural treatment systems require in general more space than the more compact systems, which can be seen as a drawback in densely populated areas. On the contrary, the natural systems are more visible systems and, as they are usually planted with reeds or other macrophytes, they may increase the esthetical value of the neighbourhood. These systems are applied for domestic wastewater as well as for wastewater from dairy farms, hospitals and oil industries.

3.3.3 Examples

Sewage fed swimming pool

Sewage from a small art centre and one household in a small village Delfstrahuizen, in the north of the The Netherlands is treated with a natural treatment system which has been designed and implemented by the Dutch consultant company RZN-TransForm. The system has been designed in harmony with the surrounding area and it emphasises the aquatic character of the neighbourhood. The sewage is collected in a septic tank for some pre-treatment. From the septic tank it is transported under gravity to a horizontal flow reedbed of about 50 m^2. The effluent is discharged into a shallow pond with different types of aquatic plants, such as lilies and bulrush. After these treatment steps the effluent meets swimming water quality standards and is discharged by an overflow mechanism into an open swimming pool which is private property of the owner. The system has worked now for 2 year since 1997 without any serious problem.

Grey water for laundry and toilet flushing

In the small town Bennekom in centre of The Netherlands, which is an urbanised area provided with a centralised sewer system, a grey water treatment and reuse system has been installed for one household (8 persons) (6). Grey water from bathing and showering is treated in a grease tank followed by a vertical flow reed bed (~6 m^2) which is placed in the garden surrounding the house. Most plants used are common reed (*Phragmites*), but also some flowering plants have been used resulting in a nice looking corner in the garden. After treatment in the reedbed the effluent is stored in a tank below ground level where it is mixed with rainwater collected from the roof. The water from this tank is used for toilet flushing and the washing machine. Inside the house this water is transported by a separate network. The pipes of this network have been painted bright green, to avoid unintended use for other purposes and illegal connections with the drinking water network. The first tests have shown that the system works well. The system has been designed to achieve a maximum saving in annual drinking water consumption with approximately 200 m^3, which is 20% of the annual water consumption for toilet flushing, washing machine and other laundry purposes. At expected drinking water prices this is equivalent with 800 guilders/yr. (~400 US$/yr.). It can be seen as an example of a cascade of uses.

Process water recycling on a chicory farm

In 1997 RZN-TransForm has realised a horizontal flow reedbed as a full scale pilot project for the recycling of process-water on a chicory farm in Espel, The Netherlands. The chicory is grown on racks in dark rooms where water, containing nutrients and pesticides, circulates around the roots of the plants. Recent developments in environmental law prohibit the discharge of this process water into surface water. The pilot system is designed to receive all the process water and recycle it into the process after treatment. The system does not receive the sewage from the farmer's household, in order to avoid the introduction of plant pathogens in the cultivation process.

Process water (15 – 20 m^3/week), containing some clay, is led to a sedimentation tank where the major part of the suspended solids is removed. From this sedimentation tank the water is lifted by a pump to a higher level at the beginning of the horizontal reedbed. The reedbed (approximately 100 m^2) is designed to treat 30-m3 process water per week. This results in a hydraulic retention time of 7 days. The main objective of the reedbed is the removal of plant pathogens and pesticides. In this system contaminants can be removed from the process water by different mechanisms, such as:

- adsorption on clay particles and sedimentation in the sedimentation basin,
- die off of viruses and other pathogens as a result of a long retention time in an unhealthy environment for pathogens,
- adsorption on soil particles in the reedbed (clay, peat, humus),
- conversion by micro-organisms in the reedbed,
- seasonal uptake by reeds
- a chemical reaction with the root extricates from the halophytes

Nitrogen and phosphorus removal were not part of the design criteria, because these plant nutrients can be recycled without any problem. After treatment in this reedbed the effluent is collected in a storage tank of 8 m^3, from where the water is reused for the cultivation of chicory.

Although the Chemical Oxygen Demand (COD), Suspended Solids (SS) and Kjeldahl Nitrogen (Nkj) were already quite low in the influent (respectively 90, 35 and 6 mg/l), the system achieved for all these parameters a removal percentage of more than 65% (7). The removal capacity for the bacteria *Erwinia Chrysanthemi* and the fungus *Phytophthora Cryptogea* has been tested by artificial infection of the influent and the analysis at three points in the system (sedimentation tank, influent reedbed, effluent reedbed). The results have shown that both *E. Chrysanthemi* and *P. Cryptogea* are effectively removed. Only in case of very high concentrations of *P. Cryptogea*, this fungus has been found in the effluent of the reedbed. Testing the removal capacity for pesticides, the results show that the reedbed is able decrease the concentration with 50 up to more than 90%, depending on the type of pesticide. The removal capacity for pesticides is not a crucial factor, because the remaining concentration in the process water may help to prevent for diseases in the chicory. Research also showed that the pesticides used did not affect the rootzone of the reedbed.

An economic evaluation of the system has been carried out, which reveals that each m^3 wastewater results in a net benefit of 2.20 guilders (~1.10 US$). This is due to savings in water and nutrients by re-circulation. The economic evaluation has been based on the assumption of a pay back period of 20 years for the reedbed and an annual standing crop evapo-transpiration of 3 mm. It has been calculated that even with a more than twice as large standing crop evapo-transpiration and a pay back period of 10 years the system can be realised at net zero costs.

CONCLUDING REMARK

Considering recent developments in environmental law (for example in Egypt, but as well in many other countries in the Middle East, North Africa and Western Europe), the possibilities to decrease the water consumption (and thus the costs for drinking water), and the options for esthetical improvement of the environment, the implementation of environmental technology mentioned above may be feasible, both from economic and ecological integrity perspectives.

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