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From rain to grain: A model integrated water management system

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Abstract

Integrated water management in the Middle East is becoming extremely important due to water scarcity. A demonstration project has been undertaken to use water in the most efficient and economical way. The main purpose of this project is the establishment of a money-saving water catchment system and a non-polluting wastewater recycling system. In addition, it is expected to serve as a learning tool and a starting point for similar projects.

In an area with no government installed fresh water or sewer connections, rainwater is collected for use in irrigation and human use. Due to the nature of rainfall in the area, rain is stored in large (450 m^3) concrete containers during the winter months and used extensively over the summer months. The collecting surface (928 m^2, concrete slab) is used as a basketball field and the water collected is of excellent quality. This established project supports 2000 campers and visitors to the camping site over the course of the year.

In order to avoid pollution of ground water caused by open bottom pits, gray and black water were separated at the source. Grey water is used for irrigating recently planted forest trees and sample vegetable crops without treatment. Black water is used for irrigating non-edible useful plants with minimal processing. The plants raised on black water, such as bamboo, reeds, and luffa, support the nature of activities performed at the camping site.

A complete integrated environmentally friendly water management system is established that provides sustainable water resources and a zero effluent system. A practical and educational system is presented that can become typical for areas with similar water and sewer shortages. Campers and local citizens are already being introduced to the system and educated about the importance of water collection and the hazards of wastewater dumping into the ground.

1 Introduction

The Middle East in general suffers from a chronic need for water. This need is becoming critical with the increased population and the reduced amounts of rain falling every year. This situation promises to make water the main cause of wars in the Middle east in the coming years. The Jordan River, Euphrates and the Wazzani River are already hot issues being discussed now.

Lebanon in specific has been suffering from increasingly dry rainy seasons. This situation is affecting crops, potable water reserves and underground water reserves. Due to its nature and location, Lebanon receives a relatively large amount of rain when compared to its neighbors. However, these rains fall mainly over the winter months and flow rapidly and uncontrollably to the sea while the summer months are hot and dry. Many dams and water collection systems are still under consideration but the water shortage is becoming more critical every year.

Within this context, the following project has been undertaken in order to study the feasibility of making the utmost use of water. The general perception that grain comes from rain seems to be a waste of natural resources and thus is being challenged; a far more efficient use of water is being presented.

2 Framework of the project

The project is located in a rural area where the average annual rainfall is around 600 mm. Most of this rain falls in the months between October and April (Table 1). Accordingly, the area suffers from severe water shortages during the summer months. Residents used to depend on local small springs but in the past decade or so, and due to expanding human population in the area, these small springs have become unsuitable because they have either dried up or provide little water of questionable quality. Residents have turned to underground water resources and deep wells were excavated to fulfill the needs of the village. Due to the geological nature of the area, water percolates very quickly through the ground and is not retained underground until it is close to sea level (the village is 450m above sea level).

In addition to the lack of water supplies, this area has no sewer system; accordingly, residents have had to resort to dumping their wastewater in open-bottom pits. Due to the extensive fissures present in it, the ground tends to absorb large quantities of wastewater rapidly which seems to please the residents but tends to pollute the ground water they use.

A camping site was initiated in the area and the need for water became quickly evident. Hundreds of campers and visitors came to the area for educational, recreational, athletic and entertainment purposes. Water was needed for drinking, washing, showering, in addition to irrigation. Due to the no-profit nature of the organization running this project, no fees were collected for use of the site. Any water management system had to be highly efficient and cheap. The users were mainly youth organizations, boy scouts, or athletic teams.

Table 1: Monthly precipitation in the study area.

Month	Precipitation (mm)
September	24
October	70
November	61
December	174
January	63
February	144
March	33
April	8
May	5
June	0
July	0
August	0

No medium size integrated water management system had been undertaken in the area, therefore the need existed for a system that would both fulfill the needs of the camping site and serve as an example for similar projects. A complete feasibility study plus a return on investment estimate would be available for interested parties.

3 Water sources

Since the only available natural source of water is rain, a large water catchment system was constructed with a surface area of 928 sq. m. This surface is sufficient to fill the collection tanks even in the dry years. Various studies have indicated the importance of such systems (Haller [1], Gould [2]). This surface is used as a basketball playground that had an inclination of 1 cm per 4 m (0.25%) which served two purposes: the players did not feel the inclination and the water flew smoothly to the collection filter from which it was directed to the collection tanks. The water is collected in 3 large reinforced concrete tanks. These tanks were built underground with each having the following dimensions: length: 15 m, width: 5 m, height: 2 m. at a total cost of $ 20,000. The system is very practical but due to the nature of the weather in this area of the world, it could only fill once and then during the period of highest use, there were no natural sources for replenishing it. At current local water prices, the 450 m^3 tanks were saving $1200 per year. At that rate, the system will have a 17 year return on investment period not accounting for interest on the initial investment. If one was to consider the interest, this project will never pay for itself.

Potable water is available at a cost of $2.67 per cubic meter delivered to the site. This price has remained constant in the past few years. The process is extremely practical and the camping site used up all the rainwater collected and needed an extra 350 m^3 at a cost of $934.

The water is used for irrigating recently planted forest trees, fruit trees, selected assortment of vegetables and flowering plants that are made available for educational and beautification purposes. Campers also need the water for drinking, cooking, washing, and showering.

4 Water disposal

Due to the expenses incurred by purchasing water, every effort was made to make sure no water was being wasted. Bearing this in mind, all water outlets were monitored in order to design a receiving system that would best utilize the resulting effluent. The expansive area of the camp (20,000 m^2) made it uneconomical to connect all the small point sources to the overall plumbing system installed. A decentralized system had to be implemented in order to reduce waste. The following are some examples of individual solutions for secondary water use at various locations. Part of the kitchen water was directed to a reed stand, chicken are then allowed to go through picking through any kitchen leftovers that might have passed through. Spilled drinking water was directed to a walnut tree.

The bulk of the gray water generated from washing, was redirected to a small 0.5 m^3 tank which was used to water small forest trees planted recently to provide some shadow for the campers. The rest of the water was used to water sunflower, corn and other vegetables. At times of heavy use, the centralized gray water system was flooded so the spilled water was directed to a bamboo grove. This water was used as is without any pretreatment. No ill effects have been observed on the plants or the soil. It is plausible that any salt accumulation during the summer period would be washed away in the rainy season when little gray water is produced (due to minimal camping activities) and a lot of fresh rainwater rinses the soil. The gray water produced contained only soaps and organic matter that readily decomposed in the soil.

The showers and bathrooms were built next to each other with the same water disposal system so the separation of the water from each was not possible. Water produced from around 40 showers and 40 bathrooms flew through one system until they reached a wastewater disposal hole. That system functioned properly and no odors or water was being emitted. Accordingly, it was difficult to convince the project managers to abort this "proven" system and resort to a new untried system. Cost was the major issue, and pollution of ground water was not as tangible so the system had to provide an edge that would prove beneficial to the camping concept. This system also had to emit no annoying odors or insects. Since black water has not been approved for use in irrigation of edible crops especially with no prior treatment, our attention was directed to beneficial plants with direct impact on camp life. The plants of choice were bamboo (Bambusa vulgaris), common reed (Arundo donax) Overman [3], and

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loofah (Lufah cylindrical) . Previous studies have already indicated that some of these plants show great potential in treatment of wastewater (Rizk [4] and Zurayk [5]). Local varieties were used as they would be hardier. Bamboo and reed could be used by campers to make several artifacts, and lufah could be used for showers and cleaning. Two containers (each container having an area of 10 sq.m. and a depth of 80 cm) were built so that the effluent from one poured into the second one. The containers were designed with an inclination of 5%. The effluent from the second one poured into a plastic collection tank from which the water, which was clear, was used on highly water consuming poplar trees. Better than 90% removal of pathogenic bacteria has already been established using this method (Zurayk [6], Gerba [7]). The initial results obtained from this system are very encouraging. Bamboo would be preferred due to the high quality of wood it produces but tends to take more time to establish its roots (Del Porto [8]). Reeds grew to more than three meters and produced seeds. Lufah also grew considerably and produced fruit but some were attacked by caterpillars. Bamboo did not produce shoots during the first summer. Poplar trees survived in an otherwise hostile environment that they normally would not grow in.

Most previously done studies have suggested an initial pretreatment and settling of black water before use in any type of irrigation (Quin [9], Gloyna [10], Overman [11]). Constraints on money and space allocated for the system and our need to have minimal odors and insects generated have prompted us to use this system, which has proved to have all the desired characteristics. The use of a closed plastic container for the collection of the (twice) filtered effluent and the rapid water infiltration through the soil 19 cm/hr did not allow any water pools to form and accordingly no significant odors or mosquito larvae were observed. One has to admit that the knowledge of the effluent contents and the lack of any industrial or toxic effluents is a large factor in the success of this project. The system served as a biofilter and as a water absorbing system. The absence of heavy activity midweek and the concentration of camps on weekends have helped the soil dry in between heavy wastewater loads.

This system needs minimal maintenance and the layer of solid waste accumulating on top of the soil only needs to be re-mixed with the soil (for the first year) to improve soil characteristics, or be removed and dried for use as fertilizer once at the end of the summer. This system accommodated approximately 125 m^3 during the summer months of its first year of use. Needless to say that the system was overloaded but it has proven its worth. Plans to expand the system and to have two alternating sets of treatment beds are already in progress. Water may then be directed to one set or the other. Such a system will allow better drying of the soil in-between heavy loads and a larger crop yield. In addition, as the groves grow thicker, they will tend to absorb more water and nutrients.

5 Project returns

Economically, at a very modest 6% interest rate on the initial investment ($20,000) one could actually purchase potable water on a yearly basis without the hassle of storing it based on the local circumstances (price, availability of water, etc.). From a strictly economical point of view, large storage systems are not worth the trouble. The wastewater part of the project has proven its worth rapidly as it immediately produced a product of value: loofah and reeds. These two products were directly used in the campsite and aided in the preservation of biomass that would have been otherwise needed to support camp activities.

From a different perspective, the project has shown a great educational value. Campers and visitors are being educated about the importance of the preservation of valuable resources like water. The use of wastewater has also added to the feeling of satisfaction stemming from the realization that nothing is being wasted. This project has impressed visitors of various backgrounds and has initiated interest in resource management.

From the Environmental point of view, we have been successful in reducing water demand by collecting almost half of our water needs. We were able to have a positive effect on the biomass as we have almost balanced our needs with what we are generating. We have reduced the pollution of ground water by implementing a zero-wastewater generating system.

Around 2000 campers and visitors benefit from this system each year. It is expected that with the future expansion plan of the wastewater receiving area, we will reach a level where the wastewater will be used to its utmost value. Studies are already underway to determine the possibility of complete consumption of wastewater either to fulfill plants' growing needs or through evapotranspiration. Only then can we claim that we have the reached a perfect system.

In conclusion, a pioneering system has been implemented in a real life situation for the first time in Lebanon. Direct use of wastewater without pretreatment is being conducted. Tentative results show no ill effects but further, more detailed, long term studies need to be done to understand the drawbacks (if any) of this system.

Rain is being completely utilized to support life and activities before it is sent on its natural course of increasing vegetation and grains. Such efficient use may hold the key to solving critical water shortages in the rural areas of Lebanon and the region.

References

[1] Haller, D.H., Rain Water – An alternative source in developing and developed countries. *Water International*, **14**, pp. 27-36, 1989.

[2] Gould, J.E. & McPherson, H. J., Bacteriological quality of rainwater in roof and ground catchment systems in Botswana. *Water International*, **12**, pp. 135-138, 1987.

[3] Overman, A.R. Effluent irrigation of coastal Bermuda Grass. *Journal of the Environmental Engineering Division* February, pp. 55-60, 1979.

[4] Rizk, C. *Performance of Pilot Scale Hydrophyte Beds For Municipal Waste Water Treatment.* Thesis submitted to the American University of Beirut 1993 (Supervised by Dr. Rami Zurayk)

[5] Zurayk, R., Nimah, M., Geha, Y. & Rizk, C. Phosphorous retention in the soil matrix of constructed wetlands *Commun. Soil Sci. Plant Anal.* **28 (6-8)** pp. 521-535, 1997.

[6] Zurayk, R., Rizk, C., Nimah, M. & Acra, A. "Performance of pilot scale hydrophyte beds for wastewater treatment under various operating conditions" Proceedings of the WEFTEC '94. Water Environment Federation 67th annual Conference and Exposition, Water Environment Federation: Alexandria, USA, pp. 7-18, 1994.

[7] Gerba, C.P., Wallis, C. & Melnick, J.L., Fate of wastewater bacteria and viruses in soil *Journal of the Irrigation and Drainage Division* September pp. 157-174, 1975.

[8] David Del Porto "Zero effluent-discharge systems prevent pollution: conserving, separating and using up effluent on site". http://www.ecological-engineering.com/zeroD.html

[9] Quin, B.F. Surface irrigation with sewage effluent in New Zealand – A case study *Progress in Water Technology*, **11 (4/5)**, pp. 103-126, 1979.

[10] Gloyna, E. F. Wastewater Reuse – A Perspective *Water International*, **6**, pp. 33-36, 1981.

[11] Overman, A.R., Evans, L.E. Effluent irrigation of Sorghum X Sudangrass and Kenaf *Journal of the Environmental Engineering Division*. December, pp. 1061-1066, 1978.