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Characterization of Grey Water from Country-Side Decentralized Water Treatment Stations in Northern Palestine

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Abstract

Fresh-water problem in Palestine dates back to the early 1900's due to various geographical settings and political turbulences. The problem is exacerbated by the ever-increasing demand on water by population growth and development. As pressures on freshwater resources grow in Palestine and as new sources of supply become increasingly scarce, expensive, or politically controversial, utilizing alternative options has become a must, to meet water needs. To reduce water demand by increasing the efficiency of water use and to expand the usefulness of alternative sources of water previously considered unusable. One option of supply is "greywater." The project seeks to treat and reclaim household grey water to supply irrigation water, and enhance crop production in patch gardens. The task results reveal that grey water from household activities has the potential for irrigating crops and offers many social and financial benefits to improve the residents' source of revenue. Various parameters were monitored and measured for a decentralized constructed wetland system yielding some interesting and promising data.

Keywords: Treated Grey Water, Irrigation, Agriculture.

1. Introduction

Scarcity and misuse of water are serious and growing threats to sustainable development and protection of the environment. Human health and well fare, food security, industrial development, and the ecosystems on which they depend are all at risk, unless water and land resources are managed more effectively than they have been in the past to meet the increasing population demands (Al-Jayyousi, O. 2003).

With increased population growth and development in Palestine (PCBS, 2010), the conventional groundwater sources supply is becoming increasingly vulnerable and scarce. This growth, combined with recent years of low rainfall, political turmoil, has resulted in increasing pressure on water supplies in Palestine(Amjad, 1999). To circumvent this problem, an alternative water resource plan is being advocated. Among these potential alternative sources of supply is grey water (Faruqui, N. & Al-Jayyousi, O. 2003).

Grey water from a single household, if treated appropriately, can be considered a resource and can be used on-site for garden and lawn irrigation, toilet flushing, washing machines, and other outdoor uses(Al-Hamaiedeh H., & Bino, M. 2010). Garden watering and toilet flushing, for example, do not require water with drinking quality (Bino, M., Al-Beiruti S., and Ayesh M., 2010). Grey water refers to the wastewater generated from kitchens, laundries and bathrooms, not black water, which is waste water containing human excrement. Grey water can be used untreated, or it can be treated to varying degrees to reduce nutrients and disease-causing microorganisms. The appropriate uses of grey water depend on both the source of grey water and the level of treatment. The potential health risks associated with grey water recycling when it has been sourced from a multi-dwelling or commercial premises are considered potentially greater than those associated with grey water recycling within single domestic premises. Therefore, grey water recycling must always occur in a safe and controlled manne (Al- Hamaiedeh, 2010). In the northern part of the Palestine

(West Bank), there are many communities with sparse population and large landscape area that have no permanent water resources. For domestic and agriculture purposes these communities get their water from either the seasonal rainfall or they resort to trucking water in tanks from a distant source. Those towns and villages lack proper sewage system. The reuse of grey-water at household scale has become an important tool to enhance water efficiency, which enables them to use for water for multi-purpose irrigation.

The aim of this project is to evaluate the grey water at decentralized rural treatment systems. Those stations were built within an area that has both low rainfall and low socio-economic status. Furthermore, our intention is to enhance public perception about grey water from negative to positive. This will help create better public awareness that will address the water problem effectively. Education and awareness-building campaigns play a critical role in building public knowledge and support for new water solutions. Poor water quality may negatively impact productivity due to illness, social and societal decay, and declines in public order. Also, increasing media attention, community pressure, and education on the impacts of poor water quality might lead to more support that is worth of capital investments to protect public health and water quality through the construction of grey water treatment stations.

2. Materials and Methods

2.1 Site selection

Remote, rural towns located in the Northern WestBank were considered in this project for various factors such as the amount of rainfall in the area, the willingness of the household and farmers to reuse treated grey water for certain crops, and infrastructure available at target site. Jenin and Tubas governorates, located in northern WestBank, are fertile land with rain-fed agriculture and limited water resources. Both governorates depend mainly on common rainfed crops such as wheat, barely, and some forage. Also, almonds and other rainfed trees beside olive trees are the most common fruit bearing trees found in this area of WestBank. The Eastern part of this area is considered a margin region with limited rainfall that does not exceed 300 mm annually. The areas have no permanent water resources, have no sewage collecting systems, and have very low income. They also represent areas that located near NARC center which makes it easy to visit, contact and follow up. As a result, three villages in Tubas Governorate were chosen (Tammon, Aqqaba, Tayasir) and in the Jenin Governorate five towns were slected (Deir Abu Da'if, Faqoua, Jalboon, Balama, and Arab-bounah).

2.2 Household selection

Several people showed a strong interest in the applying the safe and productive use of treated grey-water in their houses, however, some were selected because they fit within the required criteria. In each locality, two public awareness workshops were held for the selection process. A list of about 35 members each representing a household attended the workshop. Eleven households were chosen to apply the project after reviewing the surveys households filled out. The following parameters were considered in selecting households to engage in the activities leading to the safe use of grey-water in irrigation: Household is not connected to a sewage collection system; the number of person per household is more than 5 persons; has at least 500 m2 garden space close to the house; flexibility and interested in reusing of grey-water irrigation; the ability of grey-water separation from the domestic wastewater; the monthly consumption is more 15 cubic meter; presence of electricity source; and the landscape nature is easy to work in.

2.3 Grey water station construction

NARC research team built grey water treatment system to meet household needs. The constructed wetland system was developed by ICARDA, adopted and modified by NARC. The design of the treatment unit - “wetland system” is comprised of a gravel filter medium, mostly crushed, volcano rocks (Zeo-Tuff-2cm). The system was divided into four compartments as shown in **Diagram 1**:

- The grey water from the house is transferred to the manhole through a PVC pipe (diameter = 4 inches) for further gravity separation. The manhole contains two valves for maintenance and controlling overflow to cesspits, and is covered with a concrete lid (diameter 50cm, depth 50cm).
- Gravity separation: A 100 L tank which separates grey-water into three layers : solids in the bottom (if present), upper layer of grease and oils, and middle layer consisting of grey-water.

There is a filter connected to the end of the line to take the water to the next part. The other end is connected to a pierced horizontal 3˝ tube. The upper end of the U-tube is connected to a 50cm tube for sampling. The 3˝ U – pipe tube where used to transfer the middle layer (water) to the next part

- The third compartment is used as upflow tuff . This part has been constructed from concrete and cinder-blocks (Dimensions W=80cm, H=80cm, L= 4m). The compartment has slight ground slope of 1%. There is a layer of soft sand to adjust the slope and to protect internal black-plastic cover (thickness 600 micron). An insulating sheet of polystyrene (thickness 2cm) is placed between the walls of the compartment and the black-plastic cover. Finally, the volcanic tuff (diameter ~20 mm) was placed in the compartment.
- The fourth compartment (barrel = 100 liter) is a collection and a pumping stage. This drum is placed below the ground level by a 25 cm. A concrete slab is poured in the barrel to hold it in place. Holes of 0.5 cm are then drilled through the sides of the barrel to a height of up to 50 cm. Then, a submergible pump is installed within the barrel and an electric aeration unit is installed to pump the air from bottom of the barrel to the top (bubbling air).
- A drip irrigation system is connected with the setup to efficiently distribute the water to the garden trees.

2.4 Instrumentation and Chemicals

For measuring the BOD values, 250 mL of waste water of samples collected and stored in amber jars. The BOD sensor (VELP Scientifica) that fits on these bottles was used. Samples were incubated at 25-30 C for five days. This instruments reads the values over five days. An electric conductivity (E.C. 214, HANNA Instrument) meter was used for measuring the EC values from which the TDS values were calculated. A spectrophotometer (LABOMED, Inc.) was used for measuring the nitrates values at 220 nm. A flame photometer (spectrolab FP 102) was used for the determination of the sodium and potassium cations. Water hardness (magnesium and calcium) was measured using standard titrimetric method after buffering the samples with ammonia/ammonium chloride buffer. Eriochrom Black T (EBT) was used as indicator for calcium and magnesium EDTA titrations. The murexide indicator was used for calcium (pH at 13) EDTA titrations.

3. Results and Discussion

A water treatment system shown in (Diagram 1) can serve as an efficient, self-contained, wastewater treatment system. Because the system treats and dispose of household wastewater onsite, they are often more economical than centralized sewer systems in rural areas where lot sizes are larger and houses are spaced widely apart.

Water quality can be analyzed by tests designed to measure its suitability for agricultural purposes. Water that looks clear and pure may be contaminated with pathogenic microorganisms. For example, 105 (100 000) bacteria per milliliter of water is invisible to the naked eye. Therefore, even water that appears “pure” must be tested to ensure that it contains no microorganisms that might cause disease. On the other hand there are so many potential pathogens that it is impractical to test for them all. Because of this, tests have been developed for indicator organisms. These are organisms that are present in feces (or sewage), survive as long as pathogenic organisms, and are easy to test for at relatively low cost.

Indicator organisms signify that fecal pollution has occurred and microbial pathogens might be present. Total and fecal coliforms, and the enterocci - fecal streptocci are the indicator organisms currently used in the public health arena. Coliform bacteria include all aerobic and facultative anaerobic, gram-negative, nonspore-forming, rod-shaped bacteria that ferment lactose with gas formation. There are three groupings of coliform bacteria used as standards: Total Coliforms (TC), Fecal Coliforms (FC) and Escherichia coli. Total coliforms are the broadest grouping including Escherichia, Enterobacter, Klebsiella, and Citrobacter. These are found naturally in the soil, as well as in feces. Fecal coliforms are the next widest grouping, which includes many species of bacteria commonly found in the human intestinal tract. Usually between 60% and 90% of total coliforms are fecal coliforms. E. coli are a particular species of bacteria that may or may not be pathogenic but are ubiquitous in the human intestinal tract. Generally more than 90% of the fecal coliform are Escherichia (usually written as E. coli).

A decentralized modified-wetland water treatment system was adopted for several advantages. First, an extensive sewer system is not necessary. Second, low-cost solutions are possible. Third, the system is applicable in densely as well as sparsely populated areas. Fourth, Segregation of grey wastewater from “black” wastewater is possible. And fifth, Environmentally feasible grey water treatment and sustainable water management are possible.

The grey water treatment station collects, stores, treats and may disinfect grey water. Our stations were built and installed in residential households to provide treated grey water for use for irrigation (agricultural garden needs). Some measured parameters included the following indicators:

(a) Biochemical Oxygen Demand recorded over five days (BOD5)

(b) Total Suspended solids (TSS)—or Total Dissolved Solids (TDS)

(c) Thermo-tolerant Coliforms or E. Coli (an indicator of fecal contamination) forming units (cfu) per 100 mL.

(d) Anions such as Residual chlorine and carbonates

(e) Cations and water hardness such as sodium, potassium, calcium and magnesium cations

Table 1 shows mean values of the various testing parameters. The data indicate a significant reduction in all parameters, with the exception of EC and pH. The efficiency of treatment in the stations shown in Figure 1 that indicates the removal capacity of the treatment unit. Mean BOD_5 from five locations was lowered by 96.6 ppm. Average BOD5 over the entire period for all sampling stations was 126.6 mg/L (with a range from 86 mg/L-245 mg/L). We sampled the sites since March 2011. Although we are working with a limited data set, it appears that BOD_5 values fluctuated from period to period and from station to another. Typical BOD_5 values for grey water as reported in the literature range from 33-290 mg/L, while values for untreated domestic wastewater range from 100-400 mg/L (Siegrist, 1977).

Wastewater contains organic substances typically in the form of carbon, hydrogen, oxygen, and nitrogen and may contain other elements. Common concentrations of these organic materials in grey water in the forms of proteins (40 to 60 percent), carbohydrates (25 to 50 percent), and oils and fats (8 to 12 percent). The water may also contain small amounts of synthetic organic molecules (i.e., pesticides and solvents), which may range from simple to complex in structure. Biochemical oxidation reactions convert organic material using oxygen and nutrients into carbon dioxide, water, and new cells, which can be expressed as follows: Organics + O_2 + nutrients → CO_2 + H_2O + new cells + nutrients + energy

In this equation, one can assume that organisms use oxygen to breakdown carbon-based materials for incorporation into new cell mass and energy. As mentioned previously, the frequent measure of this oxygen use is biochemical oxygen demand (BOD). BOD is defined as the amount of oxygen used in the metabolism of biodegradable organics. If water with a large amount of BOD is discharged into the environment, it can deplete the natural oxygen resources. Heterotrophic bacteria utilize deposited organics and O2 at rates that exceed the oxygen-transfer rates across the water surface. This can cause anaerobic conditions, which leads to noxious odors and degradation of water quality. BOD5 in grey water sampled just prior to discharge to gardens averaged 30 mg/L with a range of 29-79 mg/L, TDS ranged from 400-2400 mg/L with a mean of 987 mg/L.

Many of the microorganisms that exist in wastewater might be beneficial. In fact, many wastewater treatment technologies are dependent on these beneficial microorganisms for remediation of wastewater so that it won’t destructively impact the environment. One of the primary purposes of water treatment system is to remove organic matter from wastewater so that excessive oxygen consumption won’t become a problem when it is released to the environment.

Another aim of these treatment systems is nitrification/denitrification. Nitrification is an aerobic route in which bacteria oxidize reduced forms of nitrogen (NH_4^+,NO_2^-, NO_3^-). Denitrification is an anaerobic route by which oxidized forms of nitrogen are reduced to gaseous forms (NO_3^-, NO_2^-, N_2O or N_2), which can then escape into the atmosphere. This is important because the release of nitrogen to the aquatic environment can also cause eutrophication, which is really not so important in our case, since the water will be used in direct irrigation rather than release into streams.

However, the specific health problem associated with increased levels of nitrogen is methemoglobinemia or blue-baby syndrome. This disease is a direct result of elevated concentrations of nitrite in water. In this project, it was observed that stations decreased concentrations of nitrogen as shown in Figure 3. Nitrate values ranged between 12-83 mg/L with a mean of 38 mg/L. Nitrate values were lower in effluent than in the raw grey water with reduction of 53.99%. This indicates that a significant amount of de-nitrification occurred, which is shown clearly in Figure 3.

The pH values averaged 6.1 before sampling (range 5.04-7.01) and 7.6 after sampling (range 7.1-7.99). The lower pH values may result from the use of water without any alkalinity adjustment, whereas the high figures indicate the presence of bleach. Total Coliform counts generally were high and exceeded our dilution ranges. Guideline (Dixon, A., Butler D., & Fewkes A., 1999) for Fecal Coliforms in reclaimed water for irrigation is set at 200 cfu/100. Jefferson *et al*. (2001) published data showing suggested appropriate values for domestic wastewater recycling of <10,000 and <2,000 cfu/100 mL for TC and FC, respectively. Our results show that greywater samples occasionally exceed these values. This suggests that direct human contact with greywater should be avoided, unless the wastewater is disinfected.

TDS values were reduced by 7% as represented in Figure 2. Total coliforms were lowered by 11.5% which was good considering that these microbes occur in large quantities in the soil. E. Coli detected in the effluents by 55% lower than in the raw grey water. This indicates a high efficiency of the stations in removing pathogens. Data showed a considerable variation both within and between different sites.

The interesting result shown in Figures 2 and 3 gives efficiency of 76% for BOD, 7% for TDS, and 54% for NO_3^{--} which falls within the standards approved by the Palestine Standards Institute recently and by the Palestinian Authority (2012). The institute classifies the water quality according to A (high quality), B (good quality), C (medium quality), D (low quality) system. As an example, the institute gives the specifications for BOD5 as 20 mg/Liter (A-quality), 20 mg/Liter (B-quality), 40 mg/Liter (C-quality), and 60 mg/Liter (D-quality) respectively. With respect to NO3-, the institute gives 20 ppm for high quality, 20 ppm for good quality, 30 ppm for medium quality and 60 ppm for low quality. The TDS values were 1200, 1500, 1500, and 1500 ppm for high, good, medium and low quality respectively.

4. Conclusions

Various treatment processes are suggested in the literature, but since on-site grey water recycling is a relatively new practice in Palestine, only few systems can be constructed in this area due to it geographical location. The treatment stations build are based on physical process that diverts water after treatment and allows immediate use of water for landscape and garden irrigation or storing it temporarily in a tank. Overall, the grey water stations worked well, and interviews with community members indicated wide community interest in, the grey water stations.

Grey water reuse might serve as a promising strategy in terms of the significant local water saving, reducing the risk of water borne diseases, especially in marginalized rural areas. However, some important questions may arise regarding grey water reuse such as acceptability with regard to religious and cultural values; affordability and financial benefits; difficulty; and ability to improve access to sufficient quality and quantity of water. Answers to such questions can be addressed by in public awareness seminars and training activities related to such projects.

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References

Al- Hamaiedeh , H.D. (2010). The Impact of Greywater Reuse in Irrigation on Public Health and Safety. *Electronic Journal of Geotechnical Engineering*, 15(K), 1131-1138.

Al-Hamaiedeh, H.D., and Bino, M. (2010) "Effect of treated grey water reuse in irrigation on soil and plants”, *Desalination*, **256**, Elsevier, 115-119.

Al-Jayyousi, O.R. (2003), "Greywater reuse: Towards sustainable water management", Desalination **156**, Elsevier, 181–192.

Amjad, U. Q. (1999), "Water, Conflict, and Cooperation: Ramallah, West Bank" *M.S. Thesis*, Virginia Polytechnic Institute and State University.

Bino M., Al-Beiruti S. and Ayesh M. (2010) “Greywater use in rural home gardens in Karak, Jordan” In: *Greywater Use in the Middle East*, McIlwaine and Redwood (eds). IDRC.

Dixon, A.M., D. Butler, and A. Fewkes (1999) “ Guidelines fro greywater reuse: Health issues” *Water and Environmental Management* **15**(5): 322-326.

Faruqui, N., and Al-Jayyousi O. (2003) “Greywater Reuse in Urban Agriculture for Poverty Alleviation.” *Water International*, 27 (3): 387–394.

Jefferson, B; Laine, A.L.; Stephenson,T. and Judd S.J. (2001) “Advanced biological unit processes for domestic wastewater recycling” *Water Science and Technology* **43**(10): 211-218.

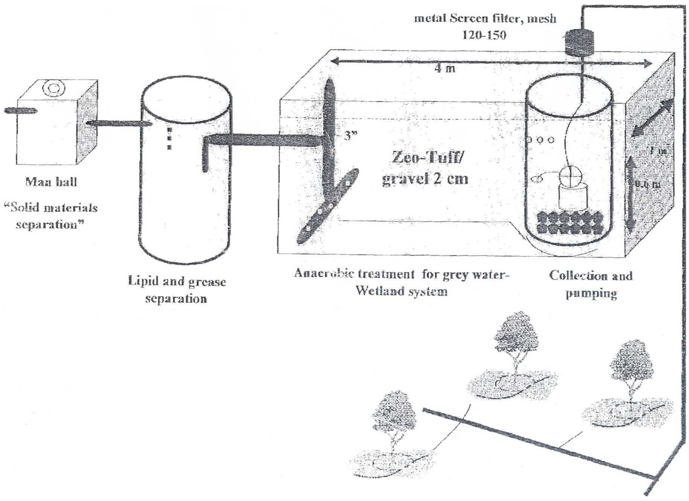
Palestinian Central Bureau of Statistics-PCBS,(2010) *Palestinians in Figures* 2009, p. 11

Palestine Standards Institute (2012) Palestine National Authority. <http://www.psi.gov.ps> accessed 12 January, 2012

Siegrist, R.L. (1977) " Waste segregation as a means to enhance onsite wastewater management" *Journal of Environmental Health* July/August: 509. *In* National Small Flows Clearinghouse, 1998, Greywater Technology Package WWBKNG 82:2-6

Table 1. The Summary of Averaged Data Acquired from the Stations for Raw and Treated water

Parameter	Raw water	Treated water	Difference
pH	6.1	7.6	1.4
Ec(mmohes)	1.5	1.5	0.0
HCO3(ppm)	476.1	441.8	-34.3
Hardness (ppm)	770.0	605.7	-164.3
TDS(ppm)	987.3	917.3	-69.9
Na^+ (ppm)	330.8	297.8	-33.0
Ca^{2+}(ppm)	89.5	78.4	-11.1
Mg^{2+} (ppm)	132.2	99.6	-32.6
Cl^- (ppm)	297.5	334.2	36.7
K^+(ppm)	37.3	32.1	-5.2
NO_3^-(ppm)	38.0	17.5	-20.5
BOD (ppm)	126.6	30.0	-96.6
E-coli (cfu/100ml)	395.0	176.4	-218.6
T.Coliform (cfu/100ml)	232.3*	208.3*	-24.0



The Diagram 1: Sketch of the Grey Water Treatment Station.

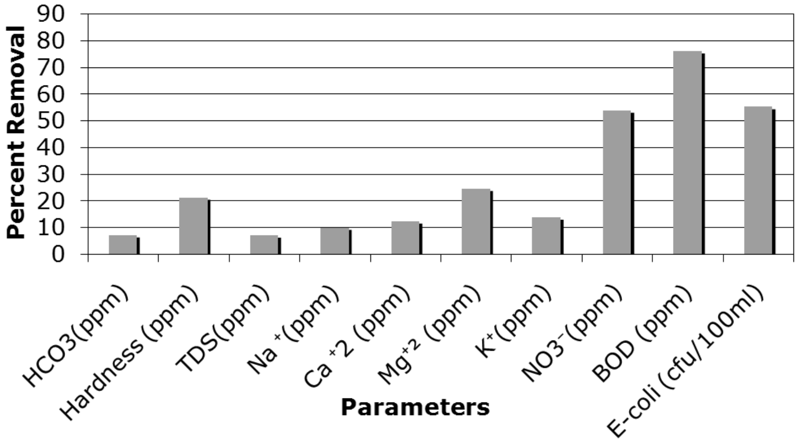


Figure 1: Efficiency of Treated Grey Water System as Percent Removal

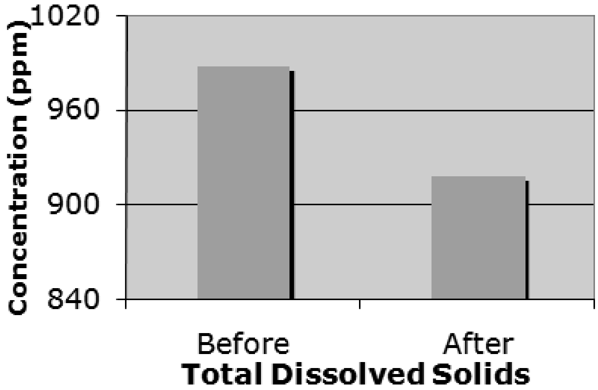


Figure 2: Lower TDS Reading in the Treated Water than Untreated Water.

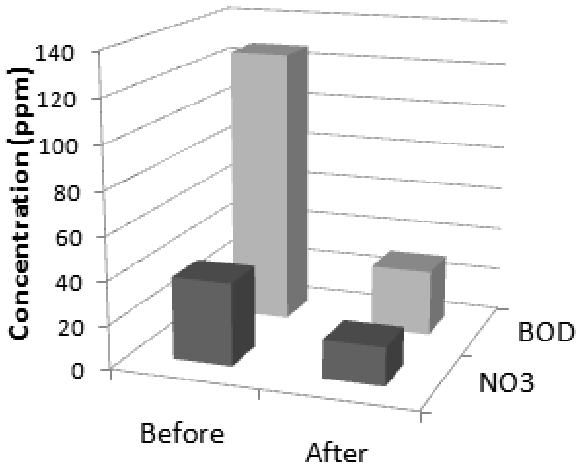


Figure 3: Values of Measured Nitrates and BOD_5 prior and after treatment.