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A sustainable approach for reusing treated wastewater in agricultural irrigation in the West Bank – Palestine

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Abstract

There is a critical lack of sanitation in the West Bank (Palestine). Most domestic sewage is disposed of into unlined cesspits or septic tanks, or directly discharged to the environment without treatment. Water resources in the West Bank are limited, and nearly 70% of the water is used for agricultural irrigation. Reuse of treated (reclaimed) wastewater has great potential to alleviate these problems and improve crop yield, but there are many challenges to implementing wastewater reuse. This paper presents a case study in the West Bank town of Tubas, which currently has no sewage collection system or treatment. This study includes traditional engineering design and will address socio-cultural issues through a detailed survey of public perceptions about reclaimed wastewater and an education plan for the various stakeholders in the town. This approach should lead to a wastewater reuse system that is beneficial to Tubas as well as sustainable.

Keywords: Palestine; Wastewater reuse; Agricultural irrigation

1. Introduction

The West Bank (Palestine) is a predominantly agricultural area with limited water resources. The population is 2.5 million people and the average water usage rate is 65 L/capita/day [1], which is well below the WHO recommended level of 150 L/capita/day. Eighty-eight percent of households are connected to a water supply network, while only 45% of households are connected to a sewage collection system [2]. About 31 million cubic meters (MCM) of wastewater is collected per year, and 75% is discharged directly into the environment without any treatment due to a lack of functioning treatment plants [3]. Wastewater from the 55% of households not connected to a sewer system is discharged to cesspits and percolates into the ground.

The total agricultural area in the West Bank is around 165,000 hectares (62% fruit trees, 11% vegetables, and 27% field crops) [4]. Around 93 MCM/yr of water is used for irrigation, or 70% of the total water resources. Irrigated agriculture represents 37% of total agricultural production compared to only 24% from

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rain fed agriculture [5]. The use of properly treated wastewater would represent a significant increase in available water, and would be much better for the environment than the direct discharge of raw sewage. However, there are still many unknowns about this practice, such as the short-term effects on human health and the environment, types of crops that can be safely grown with treated wastewater, appropriate on-farm irrigation methods for the application of treated wastewater, and long-term effects on agricultural soils, and surface and groundwater quantity and quality. These important questions need to be addressed to ensure sustainable implementation of reuse projects.

2. Background

While reuse projects in America and Europe typically have very high standards for wastewater treatment, wastewater reuse in developing countries often "just happens" in an effort to compensate for shortfalls in water supply [6]. Quantifying reuse is difficult, but the UN estimates that 20 million hectares (10% of all irrigated land) are irrigated with raw, partially treated, or fully treated wastewater [7]. The key concern is human health hazards such as infection from helminth eggs [8–10] and other enteric infections [10–14]. There are also worries about the presence of bacterial pathogens [15,16] and chemical contaminants on irrigated food [17,18]. For a thorough review of advantages and disadvantages of wastewater reuse in developing countries, see reference [19].

An additional factor to consider in the Middle East and North Africa is that some Muslims believe that the use of treated wastewater is forbidden by Islam. The Council of Leading Islamic Scholars issued a *fatwa* (ruling) in 1978 decreeing that treated wastewater could be considered pure if it was treated properly, thus paving the way for reuse [20,21]. Nevertheless, some people still object to wastewater reuse on religious grounds.

While regulations vary across the developing world, most are based on the World Health Organization standards [6,22]. The most important definitions from these standards are 'unrestricted irrigation' (using treated wastewater to grow crops that are normally eaten raw) and 'restricted irrigation' (using treated wastewater to grow crops that are eaten cooked). Because cooking food will presumably reduce microbial contamination, wastewater of lower quality can be acceptable for restricted irrigation.

2.1. Wastewater reuse in the West Bank

Standards for wastewater effluent quality for various uses have been established by the Palestinian Ministry of the Environment, but they are often not enforced [23]. The regulations establish four classes of water from Class A (high quality) to Class D (low quality). Multiple barriers (zero to four) are needed depending on the class of effluent water and type of reuse. Fourteen kinds of barriers are listed, including disinfection, distance between irrigation water and crops, and inedible peel/shell on the crop (citrus, nuts, etc.) [24,25].

Proper treatment of wastewater is challenging due to limited funding, lack of infrastructure, and the depressed economy. The situation is further complicated by the ongoing Israeli occupation. Israel controls the planning and permitting process for new facilities, and restricts the movement of Palestinian people and supplies. Israeli military incursions often damage water and wastewater infrastructure, and many Israeli settlements discharge their untreated wastewater onto Palestinian lands [1].

Raw wastewater in the West Bank also contains higher concentrations of contaminants and pollutants than typically encountered in the USA. For example, a survey of wastewater characteristics of major West Bank cities found biochemical oxygen demands (BOD) of 500–1000 mg/L, chemical oxygen demands (COD) of 1000–3000 mg/L, and total nitrogen of 70–280 mg/L [5]. These are all higher than even the "high strength" wastewater in the USA, with BOD = 350 mg/L, COD = 800 mg/L and total nitrogen = 70 mg/L [26].

Nevertheless, there are some promising wastewater treatment–reuse projects being funded by international organizations such as the United Nations Development Programme (UNDP), US Agency for International Development (USAID), and various European Union countries:

- The Al-Bireh wastewater treatment plant (WWTP) treats 5750 m^3/d (50,000 population equivalents, P.E.) using extended aeration. The effluent is used to irrigate ornamental plants, olive trees, fruit trees, date palms, flowers, grape stocks, and greenhouse-grown eggplant [5].

- Birzeit University has a contact stabilization wastewater system (6000 P.E.) with effluent being used for restricted irrigation (vegetables that are eaten cooked) [27].
- Al-Quds University has an activated sludge system (350 P.E.) with pilot-scale ultra-filtration and reverse osmosis treatment to irrigate chick-peas [28].
- The Ein Sinya pilot plant, which treats 10 m^3/d using a two stage anaerobic–aerobic system [29] began operation in October 2007. Effluent will be used for various irrigation purposes.

A recent survey of rural West Bank villages found that 75% of people were opposed to using treated wastewater for agricultural irrigation. Seventy-five percent of respondents said their refusal was because reuse interfered with local customs and 63% said reuse was contrary to local cultural tradition [30]. In contrast, a similar survey in Jordan, where 14% of all agricultural irrigation water comes from treated wastewater, found that 56% of Jordanian farmers are willing to use treated wastewater for restricted irrigation, while 75% were willing to use it for unrestricted irrigation. Nevertheless, Jordanian farmers still listed concerns including health impacts, mistrust of water quality, worries about crop marketing, and religious prohibition [31]. It is anticipated that an education plan regarding the benefits of wastewater reuse will significantly improve public attitudes towards wastewater reuse.

2.2. Tubas study area

The Town of Tubas, located in the northeastern part of the West Bank, is the home to 23,000 residents and is a largely agricultural area. Tubas currently has no centralized wastewater collection or treatment; all wastewater is disposed in cesspits. In November 2007, Tubas initiated a comprehensive wastewater management project to investigate the development of a wastewater collection system, wastewater treatment plant, and a reuse system. The treated effluent will be used on local farmland, primarily citrus trees, vegetables, and fodder crops.

The water supply for Tubas comes from two culinary wells, which produced 525,000 m^3 in 2006. Forty-two percent of the produced water is unaccounted for, so the 306,000 m^3 of metered water yields an average per capita daily water consumption of only 38 L. A new well and other infrastructure improvements are being developed that should allow an increase in water supply to 100 L/capita/day. There are also some agricultural wells in the area, although most farmers rely on rainfall during the winter and also on untreated greywater (water from the kitchen, bath, and/or laundry).

3. Methodology

Topographic data were obtained from the municipality of Tubas and site visits were conducted to the area. Based on information available and the analyses of topographic data, the extent of the wastewater collection system was investigated. Possible locations of treatment plants were also investigated utilizing information about the area, site visits, and reuse potential. Treatment methods were also investigated based on quality and quantity of wastewater in addition to the socio-economic conditions of the residents. Possible locations of reuse areas and possible crops that could be irrigated were also investigated. The following sections summarize the results of the investigation and evaluation for the alternatives in wastewater collection, treatment and reuse in the area.

4. Results

Tubas is bisected by two watersheds, with 40% of the water draining to the southern Faria watershed and 60% draining east into the Malih catchment. The initial phase of this project concentrates on the Malih watershed, which allows a regional treatment plant that includes the nearby town of Tayaser (population 3300). Using the population growth rate of 3.5%, the projected population of the service area in 2025 is 49,000. It is assumed that by that time, 95% of the population will be connected to the sewer network, and 80% of the culinary water is converted to wastewater. The estimated wastewater production will be 1.3 million cubic meters (MCM) per year.

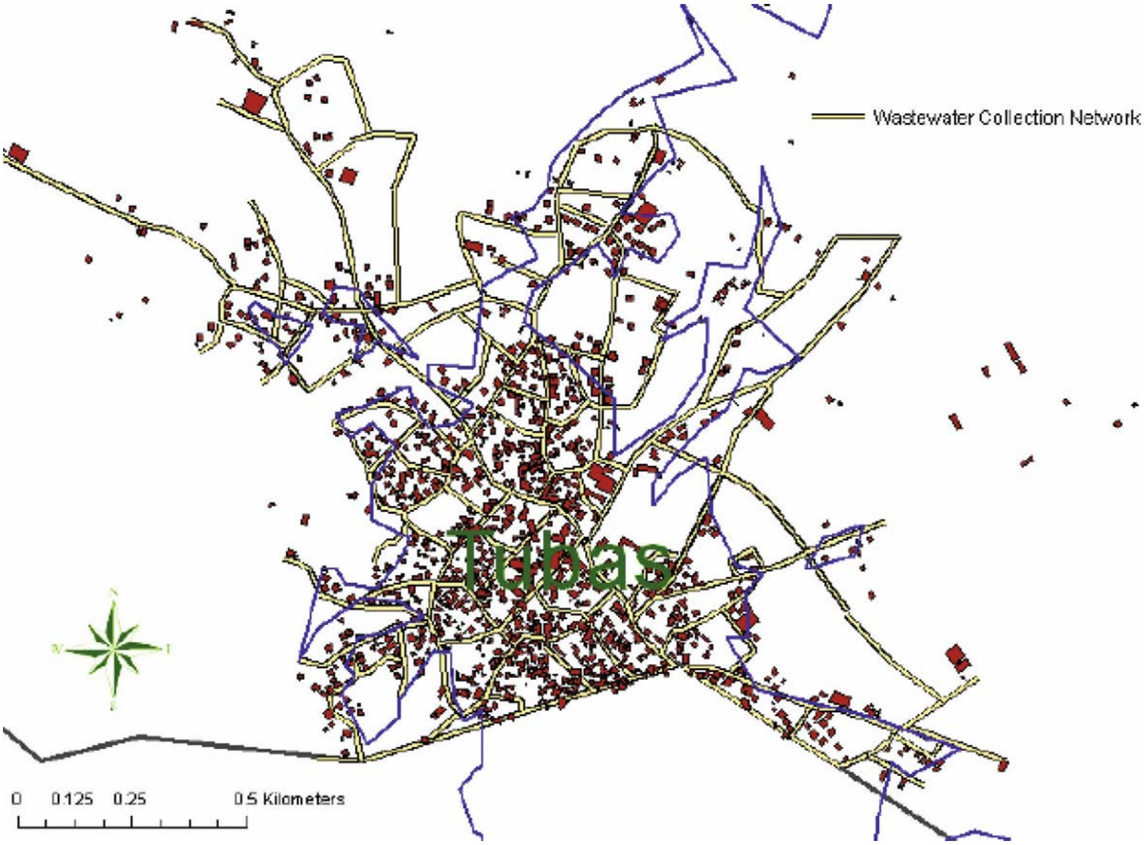

Fig. 1. Proposed sewer collection system for Tubas.

4.1. Wastewater collection and treatment

The preliminary delineation of the wastewater collection system for Tubas includes a total pipe length of approximately 23 km and 230 manholes (Fig. 1). An additional 3 km of pipeline is required for wastewater transmission to the planned treatment plant site. The final treatment process design will depend on the outcome of pilot-scale testing, but the preliminary proposal includes: screens for preliminary treatment, primary clarification, a complete-mix activated sludge system with secondary clarifier, and a slow sand filter for disinfection. Residual solids will be digested and land applied. Trickling filters are a possible alternative to the activated sludge system, although there is concern about their performance during the winter (cold) season. Lagoons will not be feasible due to the large land requirement and poor effluent quality.

4.2. Crop irrigation

In the early stages of the project, we recommended using treated wastewater for restricted irrigation. This will allow time for the municipality to gain experience in maintaining treatment plant efficiency, and will allow implementation of education plans to increase public acceptance. Thus, olive trees and fodder crops such as alfalfa will initially be irrigated. As confidence increases, other crops such as citrus, grapes, date palm trees and bananas may be included.

To estimate crop water requirements in the Tubas area, climatic data were obtained from the nearby Nablus weather station. Reference crop monthly evapotranspiration rates were calculated using the Penman-Monteith method as utilized by the FAO CROPWAT model. During the winter rainy season (November through March), most irrigation needs can

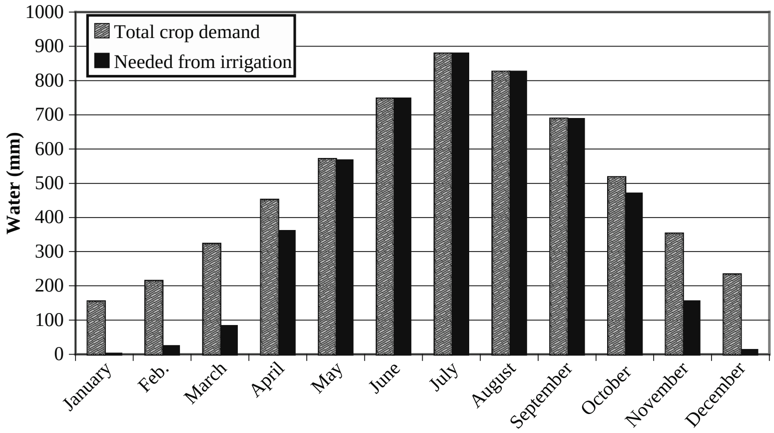

Fig. 2. Water demands for crops in the Tubas area.

be met by rainfall and irrigation is not required (Fig. 2), so the treated wastewater could be stored or discharged. However, there are over 300 hectares of farmland near the proposed treatment plant site that currently have no access to irrigation wells, so the use of treated wastewater will greatly increase the amount of land in production during the dry season (April through October).

A storage tank or pond is recommended to stabilize flows. Trickle irrigation systems are ideal because of high application efficiency and minimal exposure of plants and workers to water. Microsprinklers, which are common for irrigating trees, also have high efficiency and are allowable in fields at least 200 m away from homes and roads. Surface irrigation has the lowest efficiency among irrigation systems but it is the cheapest. It is anticipated that farmers may use surface irrigation during the initial stages of the project until they become comfortable enough to invest in infrastructure for trickle or sprinkler systems.

4.3. Key steps for sustainable implementation

Sustainable implementation of a wastewater treatment and reuse project must address technical as well as social, cultural, and economic factors. Consumers, farmers, and other stakeholders must be involved in the decision making process. One good example is the AQUAREC framework developed in the European Union [32,33]. Accordingly, ongoing tasks for this project include:

1. A survey of public opinion of consumers, including attitudes towards various reuse options, knowledge about the processes, and willingness to pay tariffs for sewage collection.
2. A survey of public opinion of farmers, including attitudes towards reuse and willingness to use and pay for treated wastewater for irrigation.
3. Development of a public awareness campaign and education plan to encourage acceptance of treated wastewater by consumers. Many consumers are not aware that some of the crops they currently consume are irrigated with untreated greywater, so properly treated wastewater represents an improvement over the status quo.
4. Development of an agricultural cooperative to encourage farmers to use of treated water, as well as to provide technical assistance in selecting appropriate crops, irrigation methods, and safety practices to minimize health hazards to workers and contamination of crops. This step should involve the Ministry of Agriculture.
5. A detailed Environmental Impact Assessment (EIA) study will be conducted to investigate the environmental and social impacts of the wastewater treatment plant and the reuse scheme.
6. Operation of a pilot-scale treatment plant to evaluate treatment processes and design the full-scale treatment plant.
7. An economic analysis to ensure proper tariffs for wastewater collection and irrigation water.

5. Conclusions

The Town of Tubas and neighboring communities do not have any infrastructure for centralized collection and treatment of wastewater. The current utilization of cesspits for wastewater disposal has a negative impact on the underlying groundwater resources, so the construction of a wastewater collection network and treatment plant is imperative. The area is heavily reliant on agriculture, but suffers from water scarcity. The reuse of treated wastewater can greatly improve environmental conditions and enhance agricultural activities. Successful implementation of the reuse project requires proper engineering design as well as consideration of social and cultural factors. A detailed survey of public opinion and development of an education plan to encourage acceptance of treated wastewater by farmers and consumers will improve stakeholder participation.

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