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The Effect of Education Level on Accepting The Reuse of Treated Effluent in Irrigation

Husam Al-Najar✉, *Basel EL Hamarneh*

[1]Faculty of Science, Disaster Management Master Program. The Islamic University of Gaza, P.O. Box 108 Gaza Strip, Palestine.

✉ Correspondence: E-mail: halnajar@iugaza.edu.ps

ABSTRACT

Gaza strip suffers from a serious shortage in water resources due to the continuous increase in population, life changes, political conditions, and drought caused by climate change. Due to demands for water for domestic use, it resulted accumulation of large quantities of wastewater in the treatment plant in Rafah. Therefore, reuse of treated wastewater is one of the most recently accepted approaches to save groundwater or domestic use. The aim of this research is to study the treated effluent quality from Rafah Treatment Plant, in addition to the effect of education level of the farmers on reusing treated wastewater for irrigation. A questionnaire was distributed to farmers to investigate the acceptance of using treated effluent for irrigation, meanwhile the effluent parameters tested were BOD, COD, TKN, NH_4, NO_3, and P, accounted for 110, 250, 108, 127, 0.23, 17.9 mg/L, respectively. The concentration of Cd, Pb, and Cu must be <0.003, <0.001, and 19.9 µg/L, respectively. Most of reuse parameters were higher than the recommended levels for the effluent reuse based on the recommended Palestinian Standards for irrigation. About 80% of farmers accept using treated wastewater in irrigation since there is a close relationship between the educational level of farmers and the acceptance of using of treated wastewater in irrigation, as long as it is safe and healthy.

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1. INTRODUCTION

Mediterranean regions are characterized by serious water imbalance. The imbalance between water demands versus supply is due mainly to the limited resources and uneven distribution of precipitation, high temperatures, and expanding needs for water demand (Fatta *et al.* 2005). According to the Population Reference Bureau, seeing world's fastest growing populations is in the Gaza Strip, where the population growth rate is 4.5% per year, and their demand for water is increasing every time (Martin, 2015). In the Gaza Strip, over 50% of freshwater consumption is devoted to agricultural activities. Over exploitation of the aquifer diminished seriously the quantity and quality of groundwater badly needed for human consumption as well as for agriculture as one of the main sources of income in the Gaza Strip. The reuse of treated wastewater could be an essential option to solve the water deficit crisis in Gaza Strip (PWA, 2015).

Irrigation using treated wastewater is considered as a priority in Rafah due to various factors, including the depletion of groundwater resources and actually, reuse would increase the available freshwater resources for domestic and industrial use, in addition the rainfall in Rafah is 250 mm/year in comparison to 450 mm/year in the north of the Gaza Strip. Moreover, agriculture is the main job for income for most of Rafah residents since the residents of Rafah have high unemployment records due to the lack of water resources for agriculture.

Assuming that 80% of the water used for domestic usage returns as wastewater, the potential wastewater produced from Rafah Governorate will be more than 16,000 m3/day of the year 2020. This situation will increase along with the increase in population and demand for water supply.

The wastewater that is generated in Rafah is currently discharged into the sea; a small amount infiltrates into the soil and contaminates the groundwater. The efficient treatment and reuse of such considerable quantity of wastewater in areas characterized by water crisis becomes a priority at a local and national level to meet increasing agricultural water demand, which was identified as one of the main objectives of the Palestinian water sector. However, the soil in west Rafah is characterized by its sandy texture with high infiltration rate (Abu Jabal *et al.* 2018), irrigation by partially treated effluent could increase the input of pollutants to the groundwater. In addition, the farmers acceptance to use the treated effluent in irrigation is doubtful. Therefore, the aim of this research is to study the potential of reusing the treated effluent from Rafah wastewater treatment plant for irrigation and the effect of farmer education on acceptance of reuse.

2. MATERIALS AND METHODS

2.1. Quality Measurement

The samples were taken from outlet of Rafah wastewater treatment plant (RWWTP), due to the importance of the wastewater properties on agricultural practices, it is necessary to determine its characteristics before consumption. The samples were collected before winter seasons on Tuesday 10/10/2017.

2.2. Sample Collection Method

A composite sample device was used to take samples from RWWTP effluent. This device programmed to take 200 milliliters per hour during a 24 hours of period which is considered standard for most determinations.

The samples were collected from RWWTP effluent in a clean 2-liter plastic bottle. After mixed sample collected by sampler device and put in ice box, samples for microbiological, chemical, and heavy metal analysis were collected in sterile bottles and then sent to the laboratory of Islamic university. The waste

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water was analyzed according to the American Public Health Agency (APHA, 2005).

2.3. Tested Parameters

The tests were performed by using the following parameters: BOD_5, COD, NH_4, TKN, NO_3, P, Cl, TSS, FC, TDS, pH, EC, Cd, Pb, Cu, Na, Ca and Mg.

2.4. Questionnaire Design

A questionnaire according to Saunders *et al.* (2009) is a method of collecting data that consists of a series of questions and other prompts for the purpose of gathering information from respondents. According to Johnson and Duberley (2000), a questionnaire is a structured technique for data collection that includes a series of questions, written or verbal, that a respondent answers.

The questionnaire focused on the target group "People working on agriculture", their ability to fill out questionnaires was so simple that they had to stay away from difficult terms and clarify several words with examples. The researcher asks closed questions, answers are chosen as examples (yes or no) or closed multiple choice and open questions. Answers that follow open questions require additional information from the respondent.

2.5. Sample Size

Study sample is a subset of the population selected to participate in a research study and its size refers to the number of the elements to be included in a study (Tayie, 2005; Zikmund *et al.,* 2009). The aim of determining an adequate sample size is to estimate the population prevalence with a good precision (Naing et al., 2006). It is an extremely rare possibility to conduct full population surveys. Therefore, a sample can be chosen from the study population that is commonly referred to as the 'target population' (Malhotra and Birks, 2007). The principles of statistical sampling, which guarantee a representative sample are employed for economy and speed (Fellows and Liu, 2008).

Several factors can influence the size of the required sample for a study, including the purpose of the study, population size, sample sizes used in similar studies, the risk of selecting a "bad" sample, and the allowable sampling error and resource constraints (Malhotra and Birks, 2007). A statistical calculation approach has been used in this study to calculate the required sample size. The following formula was used to determine the sample size of unlimited population (De Vaus, 2002).

To calculate the sample size for this study, a statistical calculation was used. The following formula was used to determine the sample size of unlimited population (Creative research system, 2008).

$$SS = \frac{Z^2 \times P \times (1-P)}{C^2}$$

where

SS = Sample Size.

Z = Z Value (e.g. 1.96 for 95% confidence level of $\alpha = 0.05$).

P = Percentage picking a choice, expressed as decimal, (0.50 used for sample size needed). Its value taken as 50% or 0.5 as it would lead to a larger sample size (Naing *et al.* 2006).

C = Often, an 'acceptable' margin of error used by survey researchers falls between 4% and 8% of the 95% confidence level (DataStar, 2008). Since the population is not high, a maximum error of estimation (0.08) is a reasonable choice.

On the basis of the mentioned reasons, sample size for this study can be calculated as follows:

$$SS = \frac{1.96^2 \times 0.5 \times (1-0.5)}{0.08^2} = 150$$

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The above sample size formula is valid if the calculated sample size is smaller than or equal to 5% of the population size (n/N ≤0.05) If this proportion is larger than 5% (n/N >0.05), we need to use the formula with finite population correction (Bartlet *et al.*, 2001; Naing *et al.*, 2006) using the following formula:

$$New \quad SS = \frac{SS}{1+\frac{SS-1}{pop}}$$

where

New SS = Corrected sample size.

Pop = Population size.

The population was "3452" agricultural holder (PCBC, 2016), and the ratio between the obtained sample size and the population equals to (150/3452) = 0.043, which is less than 0.05. As a result, in this study, 150 questionnaires need to be distributed to farmers in Rafah governorate, but researchers, distributed 160 questionnaires, because some questionnaires were defect.

2.6. Statistical Analysis

The data should be presented in a well-structured and easy way (Biggam, 2015). Kothari (2004) defined data analysis as "the computation of certain measures along with searching for patterns of relationship that exist amongst the data-groups".

The overall goal of data analysis is to arrive at a general understanding of the phenomenon under study (Tayie, 2005). The computerized programs EXCEL and SPSS were used as the data analysis tool to help tabulate data and analysis.

3. RESULTS AND DISCUSSION

The main objective of this study is to investigate the quality of RWWTP effluent, and to evaluate the impact of using treated wastewater on quality of resources and efficiency of farming activities. To achieve the objectives of the study, the national and international reuse guidelines were reviewed and compared with the case in RWWTP.

3.1. Quality Measurement

The average daily flow quantities received from RWWTP reach 12,000 m3/d, existing RWWTP provide only partial treatment of the wastewater concerning organic matter, due to inadequate treatment system performance, inadequate design and limited electricity supply. The influent BOD, COD, TSS, TKN, NO3, pH, and EC account for 600, 1300, 596, 182, 0.4 (mg/L), 8.1, and 4600 µs/cm.

A range of concentrations of treated effluent wastewater were tested (Physical, chemical, biological, and heavy metals) for samples taken from RWWTP effluent. The results shown in **Table 1** were evaluated according to the guidelines and standards of local, regional and international references (FAO, 1992; PWA, 2005) guidelines.

3.2. Physical Properties

3.2.1.Hydrogen Potential (pH Value)

Natural water usually has a pH value between 6.5 and 8.4 (Pescod, 1992), but is seldom a problem by itself. Normally, pH is a routine measurement in irrigation water quality assessment.

3.2.2. Salinity hazard

Salinity is the saltiness or amount of dissolved salt in a water which is derived from conductivity. The salinity of the effluent could be measured by two parameters TDS and EC. According to (EPA, 2003) EC values are still in the usual range of salinity where the critical value of applied water should not increase 3000 µs/cm.

The current salinity of treated effluent from RWWTP has a severe degree of restriction on use. Recommended EC of 2500 µs/cm for treating wastewater is used for irrigation. Then, excessive salinity may damage some crops. Salt concentration improves soil absorption, reduces plant

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uptake of soil nutrients, and reduces soil fertility (*Mbarki et al., 2017*).

3.3. Chemical Properties

3.3.1. Sodium (Na) Hazard

Sodic water is water with high concentration of sodium, which is relative to the concentration of calcium and magnesium. Result of effluent RWWTP showed that sodium Na^+ level of the applied water concentration of RWW (543 mg/L) exceeded the maximum level assigned according to the (FAO, 1992) guidelines showed that the concentration of calcium and magnesium are 460 and 900 mg/L, respectively (FAO, 1992).

According to PS-742-2003, type of TWW is unsuitable for irrigation due to the high Na content. The higher concentration of Na in wastewater is due to household products for laundry, kitchen, bath, and cleaning (Shomar *et al.*, 2005). Also, sodium concentration is associated with chloride (Cl) concentration which is originally high in the Gaza Strip ground water due to seawater intrusion (Shomar *et al.*, 2010).

Table 1. Quality parameters of effluent wastewater from RWWTP compared with local and international standards

Parameter	Unit	TWW effluent of RWWTP	FAO 1992	PS 742/2003*
BOD_5	(mg/L)	110	20-30	45-60
COD	(mg/L)	250	50-60	150-200
NH_4	(mg/L)	126.8	40	NA
TKN	(mg/L)	107.7	NA	50
NO_3	(mg/L)	0.225	50	50
P	(mg/L)	17.9	30	30
Na^+	(mg/L)	543	900	460
Ca^{++}	(mg/L)	89	400	400
Mg^{++}	(mg/L)	88	60	60
Cl	(mg/L)	786	1000	500
SAR	(meq/L)	9.73	0-15	9
TSS	(mg/L)	137	50	50
FC	(CFU/100 mL)	620,000	<1000	<1000
pH	Value	8.2	6.5-8.4	6-9
EC	(µs/cm)	4650	0-3000	2500
Cd	ppm***	<0.003	10	10
Pb	ppm***	<0.001	93	100
Cu	ppm***	19.9	43	200

* PS-742-2003 for dry fodder irrigation. *** ppm = (mg/L) = 1000 ppb NA: cannot give a relevant.

3.3.2. Sodium Adsorption Ratio (SAR)

SAR was widely accepted by researchers to evaluate the potential soil degradation caused by relatively high sodium content in the soil profile. Sodium hazard is also usually expressed in terms of the sodium adsorption ratio (SAR). SAR is calculated from the ratio of sodium to calcium and magnesium by using the following equation:

$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}} = 9.73$$

where

Na = 543/23 = 23.61 meq/L

Ca = 89/20 = 4.45 meq/L

Mg = 88/12 = 7.33 meq/L.

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SAR is an important parameter for the determination of the suitability of irrigation water because it is responsible for the sodium hazard. High Sodium Adsorption Ratios reduce the infiltration rate of water into the soil. The value of SAR for TWW of RWWTP was 9.73 meq/l, slightly exceed the maximum allowable value 9 meq/l, acceptable according to FAO (1992) guidelines standards.

Sodium content is an important factor in irrigation water quality evaluation and excessive sodium leads to development of an alkaline soil that can cause soil physical problems and reducing soil permeability. The concentration of the sodium permissible limit of the treated wastewater for irrigation is about 10.87 meq/L (250 mg/L) (Shakir *et al.,* 2016).

3.3.3. Nitrate (NO3)

Nitrate is naturally occurring ions that are part of the nitrogen cycle, the nitrate ion (NO_3) is the stable form of combined nitrogen for oxygenated systems (Tyagi et al., 2018).

Results indicated that Nitrate NO3 values was 0.225 mg/L for TWW lower than usual limits 50 mg/L, stated by (FAO, 1992).

The reason nitrate exists in TWW is because they are at the permissible level and lower than source water. During the biological treatment process, total nitrogen is converted in cell synthesis by ammonification, then removed during the sedimentation process (Horan, 1989).

3.3.4. Total Kjeldahl Nitrogen (TKN)

According to the EPA definition, Total Nitrogen equals to Total Kjeldahl Nitrogen (TKN) plus nitrate plus nitrite (Redmond *et al.* 2014). The values of TKN were 107.70 mg/L for TWW effluent of RWWTP. These results are in excess of the acceptable range assigned as PS 224/2003 that the reference standard for irrigation water quality is reported to be 50 mg/L.

3.3.5. Ammonium (NH4)

It was clearly noticed NH_4 value for TWW effluent was 126.80 mg/L. These results were higher than FAO (1992) standard reaching the value of between 0 and 40 mg/L.

3.3.6. Phosphorus (P)

Phosphorus is absorbed by plant roots in the orthophosphate form, the values of phosphorus was 17.9 mg/L for TWW of RWWTP. According to (FAO, 1992), the maximum permissible Phosphorus value is 30 mg/L. Results indicated that P was within guidelines values, these values indicate low degree of detergent exist in TWW within allowable range.

3.4. Biochemical and Chemical Oxygen Demands (BOD5 and COD)

The BOD_5values for TWW of RWWTP was 110 mg/L, Also COD values was 250 mg/L. In comparison to both value of BOD and COD to meet (FAO, 1992), these results is excess the acceptable range.

3.5. Biological Parameters

Fecal and total coliform (FC) was investigated as indicator parameters for biological characteristics of wastewater. Results of treated wastewater of RWWTP show that fecal Coliform Bacteria equal 620,000 CFU/100 mL. That means high risk of pathogen presence, and it is much higher than FAO (1992) standards.

3.6. Heavy Metal (HM)

Apart from Petrol, lead (Pb) in wastewater comes from recycled batteries, storage tank linings and corrosive liquid tanks paints, and antibacterial and wood preservatives. On the other hand, Cadmium (Cd) comes from industrial sources such as galvanizing. Household sources include disposal batteries, traffic sources such as tires and oil, and farming sources because cadmium is used to treat poultry infected by parasitic worms (Dojlido and Best, 1993). The results of effluent Cd, Pb, Cu are in the range of FAO (1992) standards.

Khaskhoussy et al. (2015) stated that Treated wastewater (TWW) may contain toxic chemical constituents that pose negative environmental and health impacts. The TWW irrigation increased significantly ($P \leq 0.05$) on the soils' EC, Na, K, Ca, Mg, Cl, SAR, Cu, Cd, and Ni and had no significant effect ($P \leq 0.05$) on the soils' pH, Zn, Co, and Pb contents. EC, Na, Cl, SAR, Zn, and Co increased significantly with soil depth. These elements are important to be clarified for gaining good analysis results.

3.7. Relationship between Education Level and Acceptance of Using Treated Wastewater for Irrigation

Table 2 shows the relation between education levels and acceptance of using treated wastewater for irrigation. Based on the Chi-square test analysis, there was an assumption that two variables are independent. The result showed that P-value =0.00095 < α= 0.05, so the null hypothesis (variables are related) was rejected. This means that there is a close relationship between the educational level in Rafah governorate and acceptance of using treated wastewater in irrigation, as long as they are safe and healthy, as supported by Deek et al. (2010). There are differences in statistical significance that people with more education have more acceptance of using treated wastewater.

Table2. The relation between education level and acceptance of using treated wastewater for irrigation

Acceptance of using treated wastewater for irrigation		Yes		No		Total
		Freq.	Perc.	Freq.	Perc.	
Education Level	Uneducated	12	17.1%	11	10.7%	23
	Elementary School	14	12.0%	7	25.0%	21
	Preparatory School	28	17.1%	3	39.3%	31
	Secondary	29	24.8%	4	14.3%	33
	Diploma	26	22.2%	2	7.1%	28
	University graduate and over	8	6.8%	1	3.6%	9

3.8. The Relation between Participating in Environmental Awareness Programs to Reuse Treated Wastewater and Educational Level

Table 3 shows the relation between participating in environmental awareness programs to reuse treated wastewater and educational level by using Chi-square test analysis with the assumption of two variables are independent. P-value =0.0015< α= 0.05, so the null hypothesis (variables are related) is rejected. This means that there is a close relationship between participating in environmental awareness programs to reuse treated wastewater and educational level. Adewumi and Oguntuase (2016) stated that environment programs was very useful to enhanced wastewater reuse where wastewater reuse will form an important component of water sources in addition to surface and groundwater sources. It will also eliminate the pollution effects of indiscriminate disposal into sensitive ecosystems.

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In conclusion, The reuse of RWW is a major priority to meet the increase water demands of the agricultural sector due to water scarcity in Gaza Strip.

Current wastewater effluent from RWWTP is unsuitable for irrigation due to the higher concentration of BOD, COD, TKN, Na, Mg, Cl, SAR, TSS, FC, and TDS these concentrations are above the permissible limit according to the Palestinian standards, but parameters (NH_4, NO_3, P, Ca, pH, Cd, Pb, and Cu) still in allowable range. The use of treated wastewater for irrigation of all social, cultural, and environmental aspect is feasible but in contrast with a technical standpoint because RWWTP needs improvement to meet PS standards. However, after installing a sand filter, it will be technically possible. The researcher found that most of the farmers, about 80.70%, would accept using treated wastewater in irrigation. The highest yield was the most relevant reason for accepting the use of treated wastewater because of increasing salinity level in the local agricultural wells, increasing fuel price, and maintenance cost. Robbie *et al.* (2017) stated that water treatment plus reuse in urban farms can enhance GHG mitigation and also directly save groundwater. However, very large amounts of land are needed to extract nutrients from dilute effluents.

Moreover, there is a close relationship between education level and acceptance of using treated wastewater for irrigation. The researcher believes that these public awareness campaigns contribute to the sustainability of the treated wastewater projects and reuse of the treated wastewater for irrigation. There is also a close relationship between participating in environmental awareness programs to reuse treated wastewater and educational level.

Table3. The relation between participating in environmental awareness programs to reuse treated wastewater and educational level

Participating in environmental awareness programs to reuse treated wastewater		Yes		No		Total
		Frequency	%	Frequency	%	
Educational level	Uneducated	18	15.8%	5	16.1%	23
	Elementary School	15	13.2%	6	19.4%	21
	Preparatory School	17	14.9%	14	45.2%	31
	Secondary	28	24.6%	5	16.1%	33
	Diploma	27	23.7%	1	3.2%	28
	University graduate and over	9	7.9%	0	0.0%	9

4. CONCLUSION

The BOD, COD, TKN, NH_4, NO_3, and P accounted for 110, 250, 108, 127, 0.23, 17.90 mg/L, respectively. Then, the concentration of , Cd, Pb, and Cu were <0.003, <0.001, and 19.90 µg/L, respectively. Most of reuse parameters were higher than the recommended levels for the effluent reuse based on the recommended Palestinian Standards for irrigation. About 80.70% of farmers accept using treated wastewater in irrigation and the Chi-square test analysis showed that at P-value =0.00095 < α = 0.05, there is a close relationship between the educational level of farmers and the acceptance of using of treated wastewater in irrigation, as long as they are safe and healthy.

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6. AUTHORS' NOTE

The authors declares that there is no conflict of interest regarding the publication of this article. Authors confirmed that the data and the paper are free of plagiarism.

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