

Impacts Assessment of Treated Wastewater Use in Agriculture Irrigation in Amran Area, Republic of Yemen

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Abstract

This study deals with assessing the impact of treated wastewater use in agriculture irrigation in Amran area, Yemen. Chemical and biological wastewater and soil samples in accordance with the local and international standards were analyzed and evaluated. Analysis of the effluent in the facultative pond showed that the fecal Coliforms were present at $>2,400$ cfu/100ml. Nematode Ova were absent, but pathogenic protozoa (*Entamoeba* and *Giardia*) were found in significant numbers. It was revealed from this study that treated wastewater in the study area was moderately saline (2.4 ds/m) and contains high sodium bicarbonate, and high contents of nitrogen and phosphate. The soils analytical data indicated that the soils are highly saline ($SAR > 15$). This may be due to the over quantity of wastewater used for irrigation, which exceeds the irrigation requirements (40-100%). The quality of the effluent is important, not only for compliance with the regulations to protect farmers irrigating with effluent and consumers of the crops, but also to protect local inhabitants and other users of the valley from incidental contact.

Keywords: *Agriculture, Treated Wastewater, Irrigation,*

1. Introduction

Yemen still faces an acute problem with the shortage of water resources where there are no water resources except for rain and groundwater. For the purposes of drinking, agriculture and industry, there's a semi-entire reliance on groundwater. About 93% of water is consumed by the agriculture sector while 7% is allocated for other purposes (WEC/TNO, 2010), (Alderwish, 2009). It is estimated that the per capita of water in Yemen is $150 \text{ m}^3/\text{year}$ compared to $1250 \text{ m}^3/\text{year}$ in the Middle East and North Africa and $7500 \text{ m}^3/\text{year}$ globally (Rageh, 2012).

Water availability is the principal factor which is, and will, increasingly, constrain development in Yemen. It is well recognized that this is a resource that is being exploited at a much faster rate than natural replenishment and the actions to achieve control of the situation are slow to be imple-

mented. The use of novel sources of water, such as treated effluent, is one of a number of necessary immediate actions to provide short-term mitigation of the increased demand for water. The water shortage the situation and effluent reuse will be a small but essential component of the long-term solutions to sustainable water resources (Naji Abu-Hatim, 2009). The development of the groundwater level in the potable well field is unknown, but an overall decline, according to the regional trend, can be assumed. According to DHV (1993) and FAO (1996), the alluvial aquifer at Amran could be exhausted by 2040. In order to at least slow down the rate of the massive groundwater mining of the alluvial aquifer at Amran, artificial recharge could be considered.

Sanitation and health have been identified as crucial issues and, as a result water supply, sewer-

age systems and wastewater treatment facilities have been, or are now being, installed in many towns and cities in Yemen. This will control, or at least reduce, surface and groundwater contamination of water supplies for towns and downstream users of water.

Wastewater is a major factor in the transmission of disease and pollution, and the treatment and safe disposal (preferably by reuse) of the products of treatment are crucial for the protection of public health and the environment.

The aim of this study was to assess the impact of treated wastewater use in agriculture irrigation and its impact on soil and water resources in Amran area, Yemen. Moreover, analysis and evaluation of the chemical and biological wastewater and soil samples in accordance with the local and international standards (IPP, 2001) were conducted.

2. Materials and Methods

2.1 Study Area

Amran (Figure 1), capital of Amran Governorate, is located approximately 50 km north of Sana'a at the junction of the roads to Sa'dah and Hajjah. The old town was built on the banks of the valley. Similar to many towns in Yemen, the city has been expanding rapidly in recent years. In 1996, the population of the town was 29,000 inhabitants and increased to about 54,500 by 2005. The town is located in an extensive agricultural area, with small villages and farmhouses scattered over the wide valley that is used extensively for rain-fed and irrigated farming. The area is bounded by mountains to the north and south. The valley has an average elevation of more than 2,200m above sea level (MWE, 2003).

2.2 Significance of the Study

The study area is considered as one of the areas that suffer from the degradation of natural resources, particularly soil and water in both surface and groundwater sides as well as plant or vegetation cover.

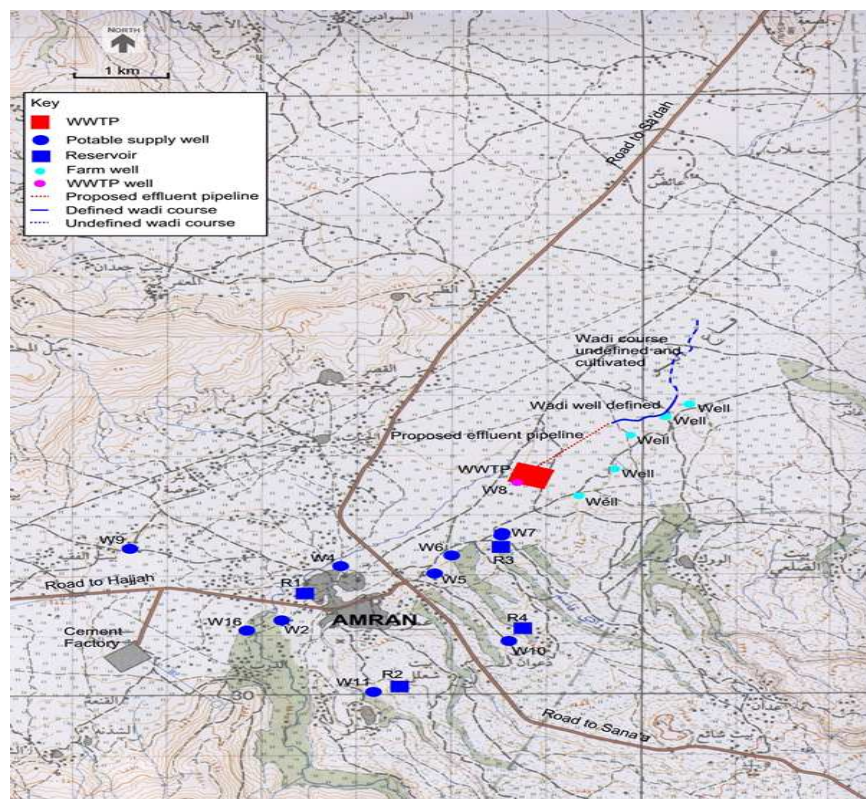


Figure 1: Map of Amran and Location of WWTP

Poor farmers, who don't have the water resources to irrigate forage crops to feed their livestock, especially during winter season, still suffer from big health and environmental problems as a result of using sewage water, as well as health damages on livestock drinking stagnant water or being fed with forage which has been irrigated using this water. It also floods the lands near the wells, either surface or groundwater, causing a chemical pollution in aquifers and a biological pollution which infects human. For these reasons, this study was conducted to determine the environmental and healthy damages caused by using wastewater in its present state, and to evaluate its effect on renewable resources as well as on the human being. The role and effect of sewage water in degradation of renewable natural resources in the study area was studied.

2.3 Methodology

Diagnostic study included the following steps of data collection and analyses were conducted:

- 1- Secondary data were collected and revised. This was achieved by (1) visiting the branch of water and sanitation in Amran (2) meeting with officials of sanitation station section and the laboratories, (3) briefing them on the importance of the current study, and (4) obtaining the necessary data from them.
- 2- Visiting the field of the sewage treatment station in Amran for the purpose of identifying the reality and the mechanism of work stations, energy absorption capacity and compilation of initial information.
- 3- Taking the necessary measurements such as the drain inside and outside of the station and assessing the results of the analysis available by comparing them with local indicators and recommended specifications.
- 4- Administering the proposed field survey among the sample farmers in the region by specialists on the panel which included the following:
 - A- Questionnaire of treated wastewater (its importance, management, acceptance or satisfaction, problems and suggested solutions).
 - B- Questionnaire of forages or crops irrigated with treated wastewater (kinds - ways of

irrigation, problems arising, and suggested solutions).

- C- Questionnaire on cattle in the region (kinds, diseases and causes, & suggested solutions).

3. Results and Discussion

3.1 Quality of Water Flowing out from the Station

To assess the quality of treated water, needed analyses should be done on sewage water and compared with the specifications at local and internationally accepted standards. The data collected from the Enterprise Branch in Amran available until the year 2007 as well as data available in previous studies which included the Physical, chemical and microbiological analyses is shown in table (1). It is clear that the range allowed in Yemeni standards for waste water use for irrigation purposes exceeded the international standards as follows:

- The total stuck materials are 50% greater of the maximum.
- The amount of phosphate is 31% higher.
- A slight increase over the range allowed by the concentration of Sodium by 2.3 %.
- Lack of agreement on biological standards due to not using of the chlorination process.

3.2 Problems and obstacles Based on the results of this study the following obstacles were obvious:

- Lack of drain water measurement devices for measuring the inflows and outflows of water to the station.
- The absence of regular and systematic analyses to assess the performance of the station continuously.
- Lack of facilities for managers of the laboratory like devices and supplies in addition to the old age of the chemical materials, as most of them exceed ten years, and almost expired.
- Insufficiency of the skilled stuff as there is a specialist in chemistry and another technical one.

- Lack of devices of transferring materials from the laboratory to the station, which is about 6 km. -Absence of the established mechanism for managing and maintaining the station to ensure the preservation of the efficiency of the performance of the station.
- Lack of electric power in the site of the station.
- The violations committed by some shops and workshops of car oil to the network.
- The use of raw wastewater by farmers through blocking the main network connected to the station and diverting water to agricultural lands, which lead to problems for the station and farmers as well as the soil and plants.
- The inefficiency of the box for blocking strange materials and repositories.

Table 1

Analysis results of treatment station in Amran compared with standard specifications standards authority (No. 150 of 2001), Environment Bylaw (No. 148 of 2000)

Parameter	Unit	Inlet water sample	Outlet water sample	Standard measurements (Yemeni)
BOD ₅	mg/l	356	81,5	150
COD	mg/l	810	157,5	500
EC	μ/cm	2630	2400	700 - 4000
TDS	mg/l			450 - 3000
TSS	mg/l	78,3	67,8	30 - 45
PH		7,4	8	6.5 - 8.4
Ca	mg/l	76	56	
Mg	mg/l	33,6	21,5	
SO ₄	mg/l	62,4	33,6	
PO ₄	mg/l	45	39,5	30
K	mg/l	107,25	68,25	
NH ₃	mg/l	68	16,9	
Toxic Ions				
Na	mg/l	269,1	204,7	200
Cl	mg/l	355	159,75	400 - 1000
HCO ₃	mg/l	610	610	150 - 850
Toxic Elements				
Total N	mg/l			5 - 30
NO ₃	mg/l	93	8.6	5 - 30
Biological analysis				
T.Coli	cfu/100mL		>2,400	1000 WHO (1989)
F.Coli	cfu/100mL		>2,400	1000

3.3 Mechanism for the Management and Use of Treated Wastewater

Based on the questionnaire prepared to determine the mechanism for the management and use of quality of water, the following results were obtained:

- There were no specific mechanisms to manage the use of wastewater as in some cases, farmers open the crude water before it arrives at the station since the existing land leading to the station is higher than the main slot at the end of each treatment basin in the station.
- Opening the water in the station is random rather than organized through secludes.

3.4 The Most Important Perspectives Gained From Interviews of the Farmers

The neighboring farmers receive water from the station until the saturation point which is then moved to other farmers who are far from the station. Therefore, farmers who stay at the end of the valley depends only rain during winter seasons

- Water is divided between two villages (Amran) because of the nature.
- There are conflicts of water distribution among the farmers because of the lack of a specific mechanism for distribution.
- Irrigation is also random and is not carried out according to the need of water irrigation and scheduling. Moreover, large quantities of water enter the station which leads to deposition of salt and emergence of weed causing soil salinization in a short time destroying its productivity in the future.
- Non-use of security and safety precautions when using water.
- The absence of interference from the local institution in managing and using water.
- Lack of the community's participation in managing and using this water.

3.4 Soil Damages Due to Random Uses of Treated Wastewater

The results of analyzing surface soil samples (Table 2) which have been collected from three farm fields that vary in irrigation period with treated wastewater in Amran area.. These results

showed that the pH of the samples is within average alkaline range (7.6-7.9). The results also showed that the time of irrigation had a slight impact on the value of this indicator, as it decreased in the third field (irrigated for a long time) to 7.6. This may be due to the rule of acidic compounds among the results of treating wastewater, like sulfur compounds which turn into sulfuric acid and thus lead to a decrease in pH values.

For electronic connection, which is reflect of soil salinity degree, it varied gradually as it was 250 micro Siemens/cm in soil sample not irrigated with wastewater. Then it increased to 1100 micro Siemens/ cm in soil sample irrigated for three years. In the last sample (irrigated for more than ten years), EC reached the highest level of 11900 micro Siemens/cm (Figure 2).

It was noticed that the accumulation level in the last field has increased significantly and this may be due to the heavy soil type, which hinders the washing process and the dissolved salts movement. The content of calcium carbonate, the values were low generally and close to each other and ranged between 3.3 - 4.5%. The effect of irrigating using wastewater on calcium carbonate indicator is considered as low effect for the long term.

The contents of organic substance varied between 0.49% in the first field and reached 0.59 and 1.04% in the second and third fields, respectively.

This variation might be due to the fact that the first field is planted under rain-fed irrigation, while the second planted with trefoil which increases organic substance content. In the third field which contains the highest salinity degree, reduced the percentage of the organic substance as a result of its disintegration and decomposition into less complex and coherent compounds (Haidar, 2005).

It was noticed that the content of available phosphorus varied between 9.4, 13.0 and 26.0mg/kg in the first second and the third fields, respectively. It is clear that the increase was positively correlated with the duration of irrigation with wastewater. This indicates that the irrigation

water content of phosphor is considered relatively high, or the water amount added is higher than crop's needs causing the cumulative effect.

Exchange Sodium followed the same pattern of Phosphor. It was noticed that its amount has increased increasingly with the duration of irrigation (0.30, 1.2 and 5.2 cm/kg) in the three fields. Therefore, the increase in the amount of the exchange sodium affected the values of exchange sodium ratios which increased from 1.0% in the witness field (not irrigated) to 28.9% from the field irrigated for over ten years.

In the third field, it reached the danger level, when proper treatments should be set before it exacerbates more. This accumulation is due to heavy field soil as it was noted that there was severe stiffness in the field and a difficulty of water penetration despite the presence of side drains around the field.

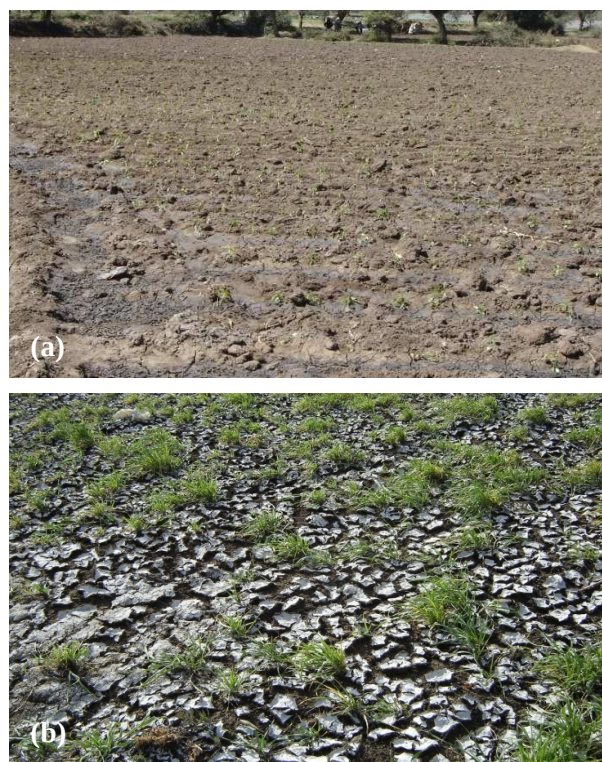


Figure 2: (a) Soil irrigated (2-3 years); (b) Soil irrigated (more than 10 years)

Table 2

Shows the values of chemical analyses of surface soil from different fields in Amran valley

Farmer's field	Depth of soil cm	Exchange capacity cm/kg soil	% For Exchange sodium	Exchange bases			
				Na+	K+	Ca++	Mg++
Saleh Al-faki field (unplanted)*	0 – 30	30.0	1.0	0.3	-	-	-
Saleh Al-Faki field (planted with trefoil)**	0 – 30	20.0	6.0	1.2	-	-	-
Ahmed Al-wajeeh field (planted with barley)***	0 – 30	18.0	28.9	5.2	0.67	-	-

* = a field not irrigated with wastewater; ** = a field irrigated for 2-3 years; *** = a field irrigated for over ten years

4. Conclusions

- Treated wastewater is considered one of the most important renewable and unconventional resources for irrigation.
- The content of water out flowing from the sewage stations is considered acceptable to some extent as a result of not using Chlorine in eliminating microbes..
- The study showed that the amounts of inflowing sewage water have exceeded the absorptive capacity at a rate of almost doubled from 5000 m³, the year of construction to almost 1000 m³ now. This affected the poor quality of this water due to the incompleteness of the required treatment process. Noted that a basin has been added to absorb the expansion in the sewerage network, the station is still unable to correct treatment.
- There is no specific mechanism to manage and use waste water, and raw water is sometimes opened by farmers before it reaches the station because the lands located before the station are higher than the level of main hole in the end of treating basins.
- The quality of sewage water from the station is not suitable to irrigate vegetables, especially those eaten fresh, while it is suitable to irrigate forage crops for grazing livestock or sale in markets and it helps the farmers get an economic return.
- The use of untreated wastewater plays a significant role in spreading diseases, bacteria that are harmful and environmental pollutant, either among humans or animals. Grazing farm animals on the banks of canals, streams and water bodies and the animals drinking directly from this water may lead to infecting animals with many diseases.
- It is clear from this study that there are some diseases that are permanent, presenting a problem for farmers and livestock breeders.
- The absence of awareness and guiding means, among farmers about the quality of wastewater and its dangerous health and environmental effects leads to putting consumers' health at risk, as getting infected with dangerous diseases and degradation of natural resources.
- It was noted that the amount of water added to irrigate crops is much more than their needs. In addition, the use of solid waste as a fertilizer with no treatment threatens to cause soil salinity, pollution and degradation rapidly making very expensive treatment.

Recommendations

Considering the results of this study the following recommendation can be made:

1. Chemical and microbiological water analyses of the water coming in and out from the station must be done periodically to monitor the elements that are considerably increasing.
2. Chemical and microbiological analyses of soil, surface and groundwater and plants must also be tested periodically to determine the damage

- caused by using sewage water and to set the appropriate solutions.
3. To set restrictions on dealing with sewage water flowing from the station and the way of using it in surface irrigation using protective clothes and footwear.
 4. To introduce forages which is resistant to salinity and have high productivity.
 5. Increase the farmer's awareness of treated wastewater use in useful fodder production (barley, trefoil, maize).
 6. Increase treatment times to decrease the percentage of herbs transported with the water.
 7. Set training programs for researchers and specialists in the field of fodder production using wastewater.
 8. Run detailed and laboratory studies to determine the pathogens of the most spread diseases and which presented a problem for farmers, and to identify the proper medicines for these diseases.
 9. Make rules and strict controls on the use of untreated wastewater in agriculture and livestock breeding.
 10. Set periodic guiding programs about the dangers of animals drinking from the canals and streams and water bodies, or grazing on lands that pass by untreated wastewater.
 11. Expand the treating station is a priority of the tasks for the concerned authorities who need to treat the water well and with high quality that matches its use in agricultural irrigation in accordance with local standards.

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