Evaluation of the Efficiency of Wastewater Treatment Plants in Taiz City and their Suitability for Irrigation

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https://doi.org/10.20428/JST.25.1.1

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Abstract:

A field study was carried out for influent and effluent wastewater from Two treatment plants in Taiz city. The aim of the study is to evaluate and increase the efficiency of the treatment plants in Al-Buriahy and Nadfood factories (Al-Qurf), in order to ensure the safe and suitable use of wastewater for irrigation. Four samples of sewage were collected from influent and effluent of different locations within the areas of Al-Qurf, Al-Hawjlah, Hidran Al-Dabab and Al-Buraihy. The results of the chemical analysis showed that the samples of the partially treated wastewater compared with the untreated wastewater were higher in total dissolved solids. The values of the trace elements remained at the level of the sewage influent before and after the treatment plant in Al-Buraihy, the level of treatment did not decrease the concentration of a number of these elements. The results of the study indicate that the concentration of Biochemical Oxygen Demand (BOD_5) for effluent wastewater from the treatment plants recorded a significant decrease in their values. In contrast the results were close in the concentration of the BOD_5 influent from the treatment plant in Al-Buraihy with the BOD_5 concentration effluent from the treatment plant in the Nadfood has, reached 457mg/l, because the influent of the sewage from the industrial processes in the treatment plant of the Nadfood was too high, reaching an average of 7791 mg / l compared with 553 mg / l in the municipal influent sewage at the treatment plant in Al-Buraihy. The results of bacteriological analyses showed that the treated wastewater recorded a significant reduction in the number of fecal coliform compared with the number of fecal coliform at influent from treatment plant at Al-Buraihy area.These indications for treatment in wastewater stabilization ponds in Al-Buraihy, and treatment plant for industrial wastewater, that include the aeration and sedimentation units in Al-Qurf Nadfood factories, indicate that the degree of treatment is below the required level and still exceeds the limit allowed for irrigation purposes according to Yemeni and International standards. This suggests an action of rehabilitation of existing sewerage system, completion of the sewerage network and the establishment of the new treatment plant by using stabilization ponds with floating surface aerator in the facultative ponds at north of Taiz City. In addition, increase the efficiency of the current

https://doi.org/10.20428/JST.25.1.1

treatment plant by division of wastewater stabilization ponds in Al-Buraihy, into anaerobic, facultative and maturation ponds, providing each pond with two devices/tools to measure the flows, and the establishment of the new treatment plant at the Nadfood factories. It should consist of screening, oil /fat removal, primary and secondary clarifiers, high rate trickling filters (1st and 2nd stage), sludge digester, sand drying beds, and chlorination.

Keywords: Taiz city, sewage, biochemical oxygen demand, fecal coliform, treatment plant, efficiency, municipal, industrial.

تقييم كفاءة محطات معالجة مياه الصرف الصحي في مدينة تعز ومدى ملاءمتها للاستخدام في الري

الملخص:

تم تنفيذ دراسة ميدانية لمياه الصرف الصحي الداخلة والخارجة من محطتين للمعالجة إحداها سكنية والأخرى صناعية في مدينة تعز. تهدف الدراسة إلى تقييم كفاءة محطتي المعالجة في البريهي ومصانع الأغذية في القرف بما يضمن الاستفادة من مياه الصرف الصحي بطريقة آمنة وسليمة. تم جمع أربع عينات من مياه الصرف الصحي في مواقع مختلفة : الخارجة من محطة معالجة مياه الصرف الصناعي بالقرف، مياه الصرف الصحي الخام من شبكة المجاري بالحوجلة، مياه الصرف الصحي المعالجة من نقطة التجمع بمنطقة حذران الضباب والخارجة من مياه الصرف الصحي من محطة البريهي. بينت نتائج التحاليل الكيميائية أن عينات مياه الصرف الصحي المعالجة جزئيا بالمقارنة مع مياه الصرف الصحي غير المعالجة كان غالب زيادة تركيزها من الأملاح الذائبة الكلية، بينما ظلت قيم العناصر الثقيلة عند مستواها في مياه الصرف الصحي الداخلة إلى محطة المعالجة في البريهي، إذ لم تخفف المعالجة من درجة تركيز عدد من هذه العناصر. تشير نتائج الدراسة أيضا أن تركيز الأكسجين المتص حيويا لمياه الصرف الصحي الخارجة من محطتي المعالجة في البريهي والقرف سجل انخفاضا في القيم، فيما كانت النتائج متقاربة في تركيز الأكسجين المتص حيويا الداخل إلى محطة المعالجة في البريهي مع تركيز الأكسجين المتص حيويا الخارج من محطة المعالجة في القرف، والتي تبلغ 457ملجم / لتر، بسبب أن مياه الصرف الصحي الناتجة عن العمليات الصناعية الداخلة إلى محطة القرف كانت كبيرة إذ تصل في المتوسط إلى 7791ملجم / لتر بالقياس مع 553 ملجم / لتر في مياه الصرف الصحي البلدية الداخلة إلى محطة المعالجة في البريهي. أظهرت نتائج التحاليل البكتيريولوجية أن مياه الصرف الصحي المعالجة سجلت انخفاضا ملحوظا في عدد بكتيريا القولون بالمقارنة مع عدد بكتيريا القولون في الداخل إلى محطة المعالجة البريهي. إن هذه المؤشرات للمعالجة في برك تثبيت المخلفات السائلة في البريهي ومحطة المعالجة لمياه الصرف الصناعي التي تشمل وحدتي التهوية الميكانيكية والترسيب في مصانع الأغذية بالقرف، تدل على أن درجة المعالجة دون المستوى المطلوب وما تزال تتجاوز الحد المسموح به لأغراض الري بحسب المواصفات اليمنية والدولية. تم اقتراح إعادة تأهيل شبكة الصرف الصحي ومحطة المعالجة الحالية في البريهي بتقسيم أحواض المحطة إلى برك لا هوائية واختيارية وهوائية مع تجهيز كل حوض بجهازين لقياس التصرفات، يكون أولهما عند المدخل ويكون الثاني عند المخرج. استكمال الشبكة في المناطق الجديدة وتنفيذ المحطة الجديدة التي من المقترح أن تشمل برك التثبيت مع تركيب هوايات ميكانيكية طافية على سطح البرك الاختيارية لتغطية الخدمة للمنطقة الغربية والشمالية من المدينة إضافة إلى تصميم وتنفيذ محطة جديدة في مصانع الأغذية بالقرف، تشمل مصفاة، مصيدة للزيوت والدهون، ترسيب أولي وثانوي، مرشحين ذات معدل عالي، هضم الحمأة، تجفيف الحمأة إضافة إلى وحدة كلور، لضمان خفض الأكسجين المتص حيويا وإزالة البكتيريا الممرضة لاستخدام المياه المعالجة في الزراعة.

الكلمات الافتتاحية : مدينة تعز، مياه الصرف الصحي البلدية، الأكسجين المتص حيويا، البكتيريا القولونية، محطة المعالجة، كفاءة، بلدي. صناعي.

https://doi.org/10.20428/JST.25.1.1

1. Introduction

The sanitation services in Yemeni cities are badly needed due to its positive affect on the health of the population and due to the pollution reduction of the environment in general, given the already scarce water resources in Yemen. Some of the dry wells in some areas of Yemen, particularly in the cities and rural areas are used to discharge wastewater which threatening the use of aquifers. The seriousness of the sewage water has a negative impact on the water in the water bodies and groundwater basins in the Republic of Yemen, due to the low level of sanitation service and its high concentration in the main cities, despite the efforts exerted over the past decades' to expand this service, and to increase coverage from 26% in 2000 to 52% in 2009 for urban areas of the country [1]. Sanitation services in Yemeni cities have witnessed a remarkable development since the beginning of the 1980s. Most of the provincial capitals and some secondary cities have been equipped with sewerage systems and treatment plants. But the expansion of these services has stopped in the last ten years almost completely because of the political crisis and war. Among the major cities in Yemen, Taiz has witnessed urban growth and expansion of sewerage systems that have extended to most of the city's Neighborhoods has result in an increasing the amount of generated wastewater, which necessitated the establishment of a treatment plant in the surrounding of Taiz City in Al-Buraihy area, using stabilization ponds Lagoons system. The existing Lagoons system at Al-Buraihy would be capable to produce effluent suitable for irrigation purposes. The problem is that the ponds were designed for flows that exceed by far the current wastewater flow to the plant, but is also a result of illegal connection upstream. The current wastewater treatment plant at the Nadfood Factories is in poor condition and the effluent does not meet the standards for irrigation [2] of fodder and vegetables in Saleh Valley of Al-Qurf area. Wastewater is one of the most important water sources used in irrigating agricultural soils in many countries, including Yemen. However, these countries reuse wastewater after treatment, while wastewater in the Republic of Yemen remains pose a major threat to public health, and even increases the environmental risks of irrigated agricultural soils from using this untreated or partially treated wastewater. This is evident in the surrounding of Taiz City, where the salinity of agricultural soil exists [3], and the spread of diseases among farmers who use the wastewater. Animals also suffer from skin/ Dermatologists/ Ringworms and intestinal diseases. The same happened with contamination

of groundwater in Bani Al-Harith area due to insufficient treatment of wastewater in the treatment plant in the Sana'a city. This is the conclusion of the study of many researchers [47-]. Moreover, wastewater is considered an additional water resource for which the country's water resources that can be used to irrigate restricted crops reclaim abandoned or semi-desert lands and recycle in industrial facilities, provided that wastewater is treated to acceptable levels according to local and international standards.

2. Objectives

The objectives of this paper are to evaluate the influent and effluent wastewater of the treatment plant in Al-Buraihy area in the surrounding of Taiz city, as well as the effluent wastewater from the Nadfood factories in the city and the possibility of developing the efficiency of the treatment plants, to ensure the reuse of wastewater for irrigating crops, and to make suggestions and recommendations to maximize the water source of wastewater for agricultural development.

3. The study Area

The study was conducted in the four areas of Al-Qurf, Hidrann Al-Dabab, Al-Hawjalah and Al-Buraihy areas, located within the Central and Al-Hawban areas of the surroundings of Taiz City. The study included sampling of wastewater from influent and effluent used for irrigating crops at these areas. The areas mentioned are shown in Figure. 1. for the sampling areas of wastewater.

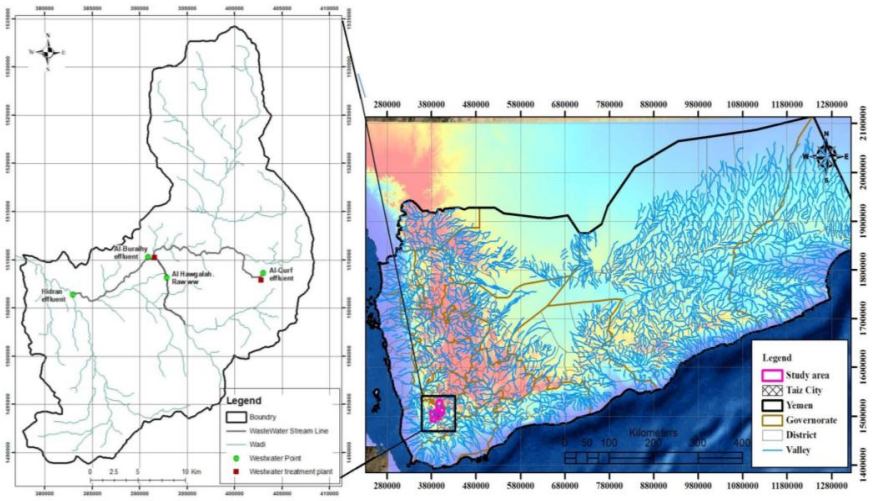

Figure 1: Locations of wastewater treatments sampling points with streamlines in the study area

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4. Methodology

4.1 Field visits to the treatment plant in Al-Buraihy area are made in order to know the mechanism of work and this include visit of the Taiz water supply and sanitation local corporation, in addition to analyze the sewage effluent of the Nadfood industrial plant in the area of Al-Hawban Taiz (Al-Qurf), to the Central Health Laboratory, as well as Agricultural Research Authority in the Taiz city to get preliminary data.

4.2 Investigate the chemical and microbiological properties for the purpose of evaluating wastewater treatment in the study area, increase of treatment the efficiency in order to ensure the reuse of wastewater in a safe and appropriate manner.

4.3 Samples of wastewater collection and preservation:

Four Wastewater samples (Al-Qurf for industrial WWTP, Hidran Al-Dabab for Domestic WWTP mixing point, Al-Hawjalah for Raw Domestic Wastewater network, and Al-Buraihy for Domestic WWTP) were collected from different locations representative of the study area, as shown in Figure 1, and Photos 1, 2, 3, and 4.

Photo 1: Al-Qurf, Effluent industrial WWTP sample location of the study area

Photo 2: Hidran Al-Dabab, Effluent Domestic WWTP mixing point sample location of the study area

Photo 3: Al-Hawjalah, Raw domestic wastewater sample location of the study area

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Photo 4: Al-Buraihy, Effluent domestic WWTP sample location of the study area

4.4 Analytical Techniques of Wastewater Samples

Wastewater analyses were carried out in the Laboratory of Agricultural Research Authority, and at the Central Health laboratory / Taiz governorate. Due to the limitation of the time and security situation in the study area, only four samples were collected.

The field measurements of wastewater samples consist of temperature (oC), pH, and electrical conductivity (EC). The field measurement instruments were calibrated before use by the certain and standard buffer solutions according to standard methods [8].

A pocket pH-meter (370 Meter ELE International) was used in situ to measure pH of Wastewater samples. pH meter was calibrated before using to buffer measurement of pH 4, 6 and 9. The electrical conductivity (EC) of Wastewater samples were measured directly by using the conductivity meter (300 YSI Environmental). The samples in the study areas was analyzed by using Spectrophotometer meter DR/2010. Wastewater temperatures were measured during sampling collection by using graduated thermometers (±5° C).

Total dissolved Solids (TDS) were estimated from the (EC) values of wastewater samples according to the following equation:

$$TDS\ (mg/l) = EC(\mu S/cm) \times 0.65$$

Samples were analyzed for the cations (Ca,++Mg,++ Na+ and K+) and anions (HCO_3-,SO_4-, NO_3-,CO_3-and Cl-).Trace elements (Pb, Zn, and CO) were analyzed by using Atomic Absorption Spectrophotometer (AAS) [8].

4.5 Biological Examination

According to the Standard Methods [8], membrane filtration method was used to determine Total and Fecal Coliform of Wastewater samples. The media (Macc Broth) and water bath used to incubate the Total Coliform at 37° C and Fecal Coliform were incubated at 44° C for 24 hours, whereas BOD was measured by BOD instrument (FOC225E-Refrigerated Incubator Velp Scientific).

4.6 Comparing results of analyses according to local and international standards [9, 10].

4.7 Suggestion of an institutional and social setup, to insure efficiency and effectiveness of wastewater source.

5. Results and Discussion

5.1 Chemical composition of wastewater influent from the wastewater treatment plants

The sewage contains a very small amount of solid in relation to huge amount of water. The liquid content of normal sewage is about 99.9%, and the total amount of solids matter is only 0.1%. The sewage contains organic and inorganic matter. The sewage also contains various gasses. These gasses are obtained either from atmosphere or formed by the decomposition of organic matter present in sewage. In addition, the sewage contains a large number of bacteria and another living micro-organism. They may be classified as pathogenic and non-pathogenic bacteria. The pathogenic bacteria are harmful whereas the non-pathogenic bacteria are harmless [11]. The major part of bacteria in sewage is engaged in carrying out the process of breaking the complex organic compounds into simple and stable compounds, as a result of aerobic and anaerobic decomposition in the treatment plant. The results of the physical, and chemical analyses are shown in Tables 1 and 2.

https://doi.org/10.20428/JST.25.1.1

Table 1: Physical analysis of wastewater samples in the study area

Sample No	Source of the Sample	Sample Area Name	color	pH	EC(μs/ (cm	T° C
1	Influent at Industrial WWTP *	Al-Qurf	Brown-nish	6.5	2500	25
2	Effluent from Industrial WWTP	Al-Qurf	Brown-nish	7.54	2970	20
3	Raw Domestic Wastewater in the Network	Al-Hawjalah	Brown-nish	7.21	6500	13
4	Effluent from Domestic WWTP mixing point	Hidran-Al-Dabab	Colorless	8.02	10450	27
5	Effluent from Domestic WWTP	Al-Buraihy	Green-nish	8.53	6860	22

***Source: (Hayel Saeed Anam and Co., 2007).**

Table 2: Chemical analysis of wastewater samples in the study area. mg/l

Sample NO	Source of the Sample	Sample Area Name	T.D.S	Cotions				Anions					
				Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^-	Cl^-	So_4^{-2}	NO_3^-	CO_3^-	SAR %
1	Effluent from Industrial WWTP	Al-Qurf	1930.5	64	61.2	503.7	47.19	1061.4	504.1	172.8	34.1	12	64
2	Raw Domestic Wastewater in the Network	Al-Hawjalah	4225	272	76.8	715.99	40.17	1732.4	102.95	1008	58.9	ND	54
3	Effluent from Domestic WWTP mixing point	Hidran-Al-Dabab	6792.5	202	330	706.1	7.07	872.3	1849.55	1065.6	55.8	36	44
4	Effluent from Domestic WWTP	Al-Buraihy	4459	216	201.6	299	513.24	1744.6	1072	547.2	40.3	24	21

Tables 1 and 2 show that the quality of the wastewater influent in Al-Hawjalah area is high in its content of total dissolve solids and it is located within the group C4(very high salinity) according to the division of the United States Salinity Laboratory Staff [12], where the electrical conductivity reached 6500 μs/ cm, with the total dissolve solids level was 4225 mg / l. It should be noted that high salinity level is due to the low consumption due to lack of ground water for domestic use in Taiz City, which is up to 30 liters per capita per day [13]. The poverty live by the World Health Organization is at 100 liters / capita/ day [14]. In addition, the quality of ground water used for domestic purposes contain mainly high salinity level as recorded in water wells of up to 8720 mg / l in the area of Al-Hawjalah (Central Region) [15]. In general, this

type of highly saline wastewater is used to irrigate the crops in Al-Hawjalah area before reaching the treatment plant at Al-Buraihy area. As for the wastewater content of positive cations, the predominance of the Sodium element is significant. Calcium and Magnesium constitute no more than 32% of the total Cations. While the wastewater content of negative Inions is highly significant, there is a significant increase in the bicarbonate and sulphates. In contrast chloride is low in comparison to bicarbonate and sulphates with 103 mg / l. Also nitrate concentration was 59 mg / l. With respect to heavy metals, the parameters analysed did not show any significant amounts, except Cobalt, which contained a high level of 7.2 mg / l,as shown at table 3, and exceeded international standards [16]. In the same context it is also evident from table1, that the quality of wastewater influent at the treatment plant in the Nadfood factories in Al-Qurf area is high salinity and located within a group C3 [12], where the degree of electrical conductivity was to 2500 μs / cm. Consequently, the total dissolved solid was to 1800mg/l. It is noting that this level of salinity is due to the fact that the quality of groundwater used for industrial purposes is brought from private wells in Ojelah Valley and Al-Ganad area on the outskirts of Taiz city. This confirms that groundwater used for domestic, industrial and an agricultural purpose in Taiz region is mostly of bad quality of water, so that requires the search for new sources of good quality of water that meets the different uses of the population. In the same context, the efficiency of domestic and industrial wastewater treatment needs to be improved.

5.2 Chemical composition of treated wastewater

Tables 1 and 2 show also that the results of the wastewater samples analyses from the treatment plant in Al-Buraihy and Hidran Al-Dabab(mixing point) and taken from the treatment plant at the Nadfood Factory in Al-Hawban area. The electrical conductivity values were 6860 μs / cm from Effluent Domestic WWTP at Al-Buraihy,10450 μs / cm from Effluent Domestic WWTP mixing point at Hiddran Al-Dabab, and 2970 μs / cm from Effluent Industrial WWTP, at Al-Qurf,. The values and the indicators exceed the values that are allowed by FAO Guide to Water Quality Used for Irrigation, which set the allowable range of $>$ 700 to$<$ 3000μs /cm [17], except for the sample of wastewater taken from the effluent of the treatment plant at the Nadfood factory, which is cope with the value allowed by Yemeni and Saudi standards [9, 18]. This acceptable sample level of salts is explained by the good quality

https://doi.org/10.20428/JST.25.1.1

of the water used in the various factory procedures. While the wastewater effluent of the treatment plant in Al-Buraihy and Hidran Al-Dabab contain high salinity because of the nature and bad quality of the water used by the city's population as originally has high salinity. In contrast, the amount of salts that remains after treatment of wastewater in Al-Buraihy and Hidran Al-Dabab samples did not show a decrease in the amount of salts. On the contrary, it is increased by 5% and 38%, respectively. This explains that the treatment plant for Taiz City is different from other treatment plants in many Yemeni Cities that are affected by increasing organic loading (kg BOD/ day) and hydraulic loading (m3/day). For instance, the Sana'a wastewater treatment plant suffers imbalance between the 74% hydraulic load ratio and the 270% organic load increase. This imbalance has affected the quality of treated wastewater [19]. These problems are due to the lack of adequate quantities of water used in domestic and industrial facilities to the treatment plant based on the design criteria. In addition, some farmers in the upper areas of the treatment plant illegally discharge waste water directly to their farms through the Manholes from the trunk line of the public sewerage system of Taiz city, and thus the amount of waste water reaching at the treatment plant remains limited, which cause increase of the retention time of wastewater in the stabilization ponds than the designs. This is probably caused by the number of household connections and the water consumption per capita which do not meet the earlier expectations [2]. This explains the increase of the total dissolve solids in Al-Buraihy area. In addition to the previous reasons, the wastewater flows for long distance of approximately 10 km to the mixing area (Hidran Al-Dabab), and during the flow of the process, it is subjected to more evaporation. This is leading to an increase in the concentration of total dissolve solids. As for the content of the samples of total dissolve solids, which are a direct reflection of the electrical conductivity, their values were 1930.5,4459, 67925 mg/l, at Al-Qurf, Al-Buraihy and Hidran Al-Dabab respectively. Moreover, increase the total dissolve solids is shown clearly in Table 2, expressing its amount at the influent and effluent of the wastewater treatment plant in Al-Buraihy area (Figure 2).

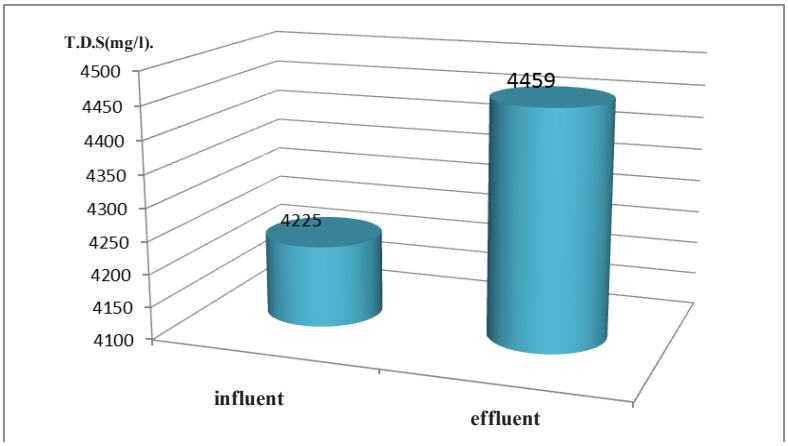

Figure 2: T.D.S (mg/l).comparison between influent and effluent wastewater Al-Buraihy treatment plant

In general, these values are falling within the two groups C3 (high salinity) and C4 (very high salinity) according to the division of [12], and exceed the Yemeni, and Saudi standards, which set the allowable values of 4000, and 2000mg/l respectively [9, 18], except for the sample of Al-Qurf, which is falling under the values allowed by [9, 17, 18]. As for the Cation content, the dominance of sodium content was 706.1, 503.7 mg/l, for Hidran Al-Dabab and Al-Qurf respectively. Calcium and Magnesium constitute 19% and 43%, while in the same samples the content of Calcium and Magnesium elements in Al-Buraihy were 34%.and the sample of sodium constitute 24%. These indicators show that the ratio of adsorption of sodium in the samples of Al-Qurf reached 64% and Hidran Al-Dabab was 44%, they are higher than the sample of Al-Buarihy was21%, as shown at Table 2. As for the wastewater content of the Anions, the dominance bicarbonate element of the chloride in the samples of Al-Qurf and Al-Buraihy were 1061.4 and 1744.6 mg / l respectively, while the dominant chloride element in the Hidran Al-Dabab sample for bicarbonate was recorded at 1849.6 mg / l. The sulphates levels were average in comparison with bicarbonate and chloride, except for the Hidran Al-Dabab sample that is recorded 1065.6 mg / l. This indicates that the high levels in the total of dissolve solids in the Hidran Al-Dabab sample was affected on the Cation and Anion levels in general. The high values of bicarbonate and chloride in the samples restrict the use of wastewater in agriculture [17]. Therefore, it is necessary to monitor these areas, which are irrigated by the wastewater, and adopt the necessary soil treatments, including

https://doi.org/10.20428/JST.25.1.1

the development of treatment efficiency. Therefore, in the current situation, it is necessary to stop using wastewater for irrigation because this case, it will cause soil salinity leading to a gradual reduction of its productivity and affect its long-term production capacity. The concentration of nitrates was high in Hidran Al-Dabab at 55.8 mg / l and decreased relatively in Al-Buraihy and Al-Qurf, recorded 40.3 and 34.1 mg / l, respectively. Since heavy metal elements in water constraint the use of wastewater in industrialized countries. The results of concentration of trace elements shown in Table 3.

Table 3: Concentration of trace elements in an investigated waste water samples in the study area, mg/l

Sample No	Source of the Sample	Sample area Name	Pb (mg/l)	CO (mg/l)	Zn (mg/l)
1	Effluent from Industrial WWTP	Al-Qurf	ND*	7.04	0.05
2	Raw Domestic Wastewater in the Network	Al-Hawjalah	ND*	7.19	0
3	Effluent from Domestic WWTP mixing point	Hidran-Al-Dabab	ND*	3	0
4	Effluent from Domestic WWTP	Al-Buraihy	ND*	2.09	0

.ND*- Not Detected

As the values in Table 3 indicate that the quality and content of wastewater, in an effluent from the Nadfood factories (Al-Qurf) showed a significant and serious increase of Cobalt that element reached at 7.04 mg/l, is exceeding the WHO standards and Yemeni wastewater Guideline In an agriculture [9, 10]. It decreased in the treated sewage used for agriculture in Al-Buraihy and Hidran Al-Dabab (mixing area) to 2.09 and 3 mg / l, respectively, but the amount of Cobalt exceeded the maximum limits allowed by the World Health Organization and Yemeni Guideline (Figure 3 and Table 3).

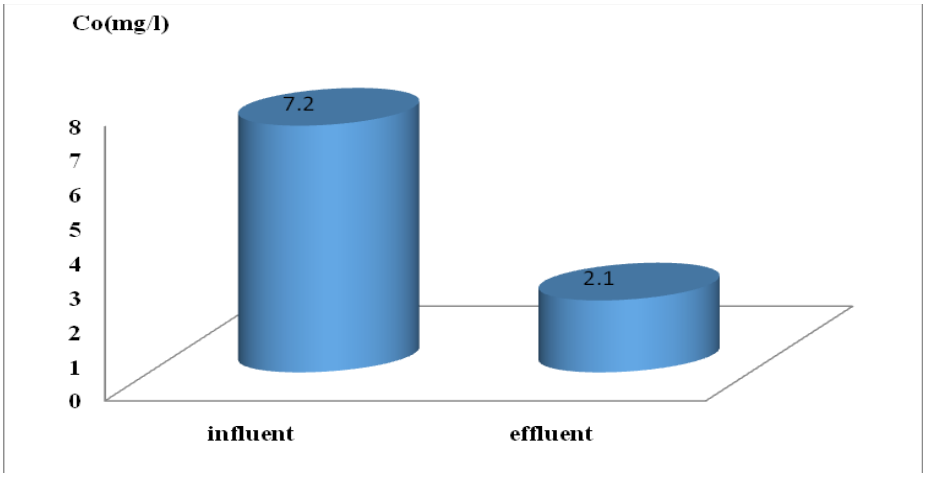

Figure 3: Co (mg/l) – comparison between influent and effluent wastewater Al-Buraihy treatment plant

It is, therefore, necessary to tackle the serious situation of chemical contamination caused by the Cobalt element and its effects by addressing the causes of the infiltration of this element into the wastewater by entering industrial wastewater. The Zinc element was also observed in the wastewater from the Nadfood factories in Al-Qurf and it has a 0.05 mg / l and did not exceed the critical limit, but it does not imply that the wastewater content in the treatment plant of Al-Qurf is good in terms of its Zinc content, Therefore, it showed not be used in irrigation without any controls, because using it will lead to chemical contamination with Cobalt.

5.3 The biological composition of influent and effluent wastewater at the treatment plants

Results of biological and microbiological analyses are shown in Table 4.

Table 4: Biological and microbiological analyses of wastewater samples in the study area

Sample No	Source of the Sample	Sample Area Name	Total coliform coli /100ml	Fecal Coliform coli/100m	BOD5 mg/L
1	Influent at Industrial WWTP	Al-Qurf	-	-	*7791
2	Effluent from Industrial WWTP	Al-Qurf	-	-	457

https://doi.org/10.20428/JST.25.1.1

Table 4: Continued

Sample No	Source of the Sample	Sample Area Name	Total coliform coli /100ml	Fecal Coliform coli/100m	BOD5 mg/L
3	Raw Domestic Wastewater in the Network	Al-Hawjalah	106× 4	105× 3.2	553
4	Effluent from Domestic WWTP mixing point	Hidran-Al-Dabab	106× 1.6	103× 28	38
5	Effluent from Domestic WWTP	Al-Buraihy	106× 1.2	103× 16	135

*** Source: (Hayel Saeed Anam and Co., 2007).**

Table 4 shows that the concentration of biochemical oxygen demand (BOD5) for the influent wastewater at the treatment plant serving Taiz City at Al-Buraihy area was 553 mg / l, Which is used directly in the irrigation of crops in the area of Al-Hawjalah, The concentration of biochemical oxygen demand for effluent wastewater from the treatment plant used for agriculture in Al-Buraihy and Hidran Al-Dabab (mixing area) were 135 and 38 mg / l, respectively (Figure 4).

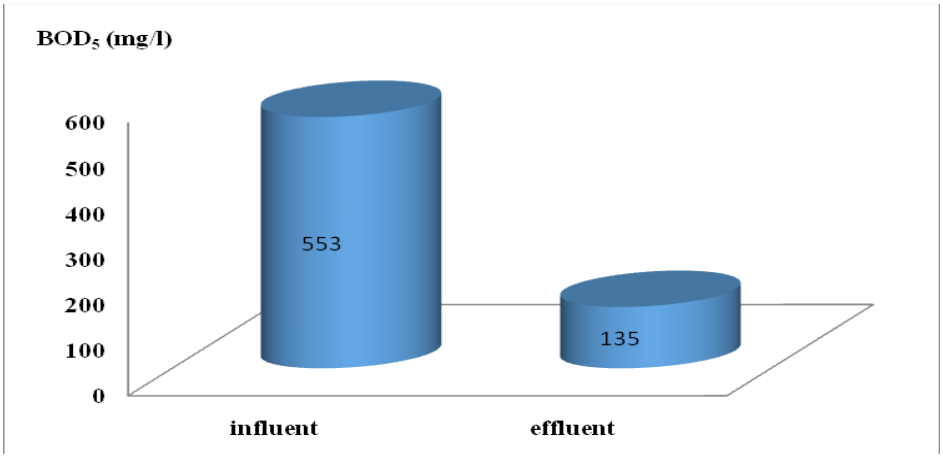

Figure 4: BOD5 (mg/l) – comparison between influent and effluent wastewater at Al-Buraihy treatment plant

This reflects the level of treatment at the stabilization ponds in Al Buraihy area, where the treatment efficiency was 76 % and 93 %, respectively. It is clear that treated wastewater is usable [9, 10]. But according to the Saudi Standard [18], which is more stringent, do not allow the use of treated sewage from Al-Buraihy treatment plant, while the sewage that reaches the Hidran Al-Dabab

at mixing area allows the cultivation of restricted crops because this treated water does not exceed 40 mg / l. In contrast the concentration of biochemical oxygen demand for wastewater from the Al-Qurf Nadfood- plant, which is 457 mg /l (Figure 5).

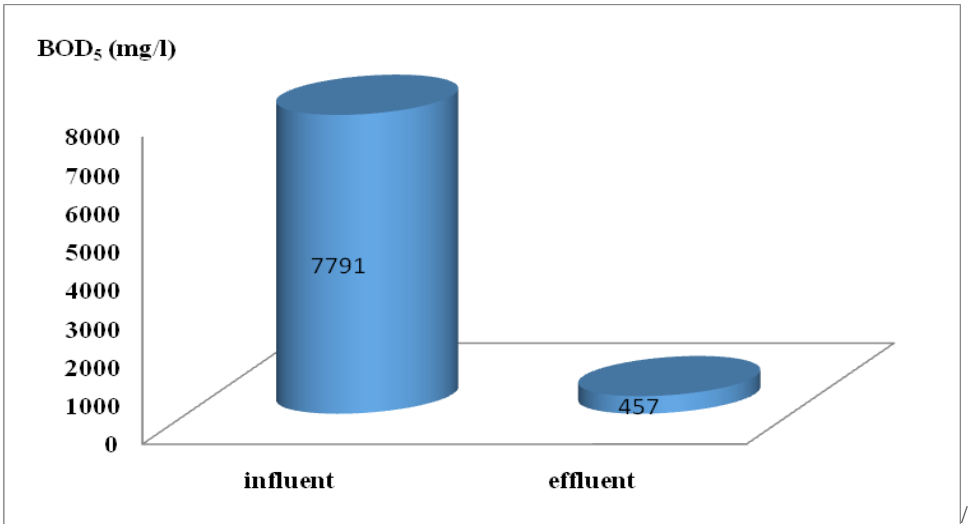

Figure 5: BOD5 (mg/l) – comparison between influent and effluent wastewater at Al-Qurf treatment plant

The wastewater is not usable unless the biochemical oxygen demand is reduced to the acceptable level according to the Yemeni and international standards. Bacteriological results indicate that the total coliform (TC) in the untreated influent wastewater that used for irrigating crops in Al-Hawjalah reached 4×106cells / 100 ml. As for the number of fecal coliform (FC) in the treated wastewater and used to irrigate crops in Al-Buraihy area and Hidran Al-Dabab (mixing area) was 16×103 cells / 100 ml and 28×103 cells / 100 ml, respectively. Although the treatment is improved by reducing the organic loads (kg BOD_5 /day) of the wastewater reaching to the Hidran Al-Dabab (mixing area) from the treatment plant over a path of up to 10 km, this wastewater passes through multiple population activities. For instance, part of the effluent wastewater from the treatment plant in Al-Buraihy area is used to irrigate fodder, in addition to; the most of the residents living on both sides of Al-Buraihy Valley are discharging their sewage into Valley course, which leads to an increase in bacteriological pollution in the mixing area. This makes them susceptible to bacterial contamination. However, the results of the study remain acceptable compared to the number of fecal coliform (FC) existing the treatment plant in Sana'a, which amounted to 41×103 cells/100

https://doi.org/10.20428/JST.25.1.1

ml [7]. This level of indicator for the fecal coliform (FC) indicate that the level of treatment at Al-Buraihy and mixing area of Hidran Al-Dababab is below the required level and exceed the limit for irrigation purposes according to the standards of Yemen and the World Health Organization (WHO), 1000 cells / 100 ml [9, 10].

6. Conclusions

- Farmers are using the raw wastewater before reaching the WWTP which expand to affect soil and crops.
- One of the problems that the existing ponds of the treatment plant in Al-Buraihy area is suffering from the lack of wastewater flows, because part of this untreated water is used by farmers in the area of Al-Hawjalah at upstream line of wastewater.
- The quality of influent wastewater at the treatment plant in Al-Buraihy area has a high of total dissolved solids, which is to lower consumption due to lack of groundwater for domestic use in Taiz city.
- The amount of total dissolve solids in an effluent wastewater from the treatment plant in Al-Buraihy area exceeds the amount of total dissolve solids influent to the treatment plant, which might be due to evaporation.
- Dominance of Sodium element in an untreated and partially treated wastewater samples over the rest of positive Cations, will cause the breakdown in the physical structure of the soil due to the high SAR.
- The increased concentration of Cobalt in treated wastewater exceeds the limit for irrigation purposes, which implies probability its application for irrigation.
- The level of treatment for the effluent at Al-Buraihy Stabilization Ponds for organic loads (kgBOD5/day) reaches 76%, while the effluent wastewater from Al-Buraihy treatment plant, which reach the Hidran Al-Dabab (mixing area) is 93%. This suggests an action of rehabilitation of Al-Buraihy treatment plant to ensure that the amount of biochemical oxygen demand reduced to the acceptable using treated water for agricultural purposes, according national and international standards.
- Indicators of the level of treatment for Biochemical oxygen demand(BOD_5) for the treatment plant in the Nadfood factories, which registered 457 mg / l below the acceptable level because the treated wastewater still exceeds the local and international standards that is used for various agricultural purposes of fodder and vegetables in Saleh Valley in Al-Qurf area.
- The level of bacteriological treatment of the effluent's stabilization ponds in Al-Buraihy area exceeded the permissible limit for irrigation purposes according to the Yemeni standard and the World Health Organization Guide.

7. Recommendations

- Ensure that wastewater reaches the treatment plant directly and does not allow the use of untreated wastewater, for irrigation as it is still not suitable enough.
- Rehabilitation of existing sewerage system and treatment plants in Taiz city, in order to ensure reduction of leakage from the sewerage system, and the division of wastewater stabilization ponds into anaerobic ponds, facultative and aerobic (Maturation) ponds. In addition to, the use of disinfectants such as chlorine to effluent wastewater from the treatment plant, after ensuring the low BOD up to a lowest possible level.
- To provide the pond with two devices/ tools to measure the flows. The first which will be at the entrance and the second at the exist, with the aim of giving indicators of the extent of evaporation and leakage, as well as giving the effect of the mitigation resulting from the rains, and evaluating the pond of performance
- To solve the problem of permanent and regular lack of wastewater flows to the treatment plant in Al-Buraihy area, it requires storing transporting and distributing treated water to the user at the upstream and downstream of wastewater line in Al-Buraihy area.
- Enhancing the collection, treatment and reuse of wastewater through the completion of the sewage network and the new treatment plant by using of stabilization ponds with floating aerators in the facultative ponds at the north of Taiz City.
- To solve the problem of an increasing the amount of biochemical oxygen demand at the treatment plant of Al-Qurf Nadfood factories, it is necessary to implement new treatment plant. The treatment should consist of screening, oil / fat removal, primary and secondary clarifiers, 2 stages high rate trickling filters, sludge digester, sand drying beds, and chlorination, in order to reach hygienic quality required for irrigation purposes and to ensuring the low BOD up to a lowest possible level and more settling S.S.
- Conduct environmental and health awareness campaigns to ensure that the farmers and communities adjacent to the treatment plant are protected from health and the environment hazards.
- Involve the private sector in sanitation services, to encourage more awareness and better understudy of the WWT process.
- Establishment of an association of wastewater users (WUAS) in the upper and lower areas of the valleys surrounding the treatment plant in coordination with the local authorities to ensure continues monitoring the reuse of wastewater after treatment for all the members of the association.

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