Investigating municipal wastewater treatment in the sultanate of Oman

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Abstract

Municipal wastewater is the water generated from domestic, commercial, and public sources. This water can be viewed as the only potential water source that will increase as population grows. The importance of wastewater as a potential source of water is apparent in countries that suffer from shortage of water. However, it must be treated properly before reuse and/or disposal due to the need for controlling many parameters such as biochemical oxygen demand (BOD), chemical oxygen demand (COD), solids, heavy metals, anions and microbial content. The aim of this study is to investigate municipal wastewater treatment in the Sultanate of Oman by analyzing wastewater samples collected from different treatment plants in three regions of the country (Muscat, Salalah, and Sohar). Comprehensive analyses including physical, chemical and biological characterization of raw wastewater and final effluents were conducted by collecting samples from major treatment units within the studied treatment plants. Consequently, comprehensive database was established for the raw municipal wastewater quality in the three regions and the performance of the treatment plants over 12 months. The levels of constituents in the final effluents from the treatment plants in the three regions were compared with Omani standards to evaluate their suitability for the current (e.g. landscape irrigation and groundwater recharge) and/or alternative (e.g. cooling and processing water) applications. Better aeration, oxidation, adsorption and disinfection technologies were recommended to improve the quality some of studied treatment plants final effluents.

Keywords: wastewater, Oman, chemical characterization, physical and biological characterization.

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1 Introduction

Wastewaters, generated from domestic, commercial, industrial and agricultural sources, can be viewed as the only potential water source that will increase as the population grows [1]. The quality of wastewaters depends on their source, which can be domestic, commercial, industrial and/or agricultural. Hence, raw wastewater often contains significant concentrations of microorganisms, nutrients, and heavy metals [2]. Therefore, such wastewaters have to be treated to remove/reduce their impurities for safe discharge and/or reuse purposes.

The concept of reusing wastewater is becoming widely accepted and adopted by many countries especially those experiencing water shortages [2, 3]. Reusing treated wastewater effluents can significantly reduce or completely remove the impact of these effluents on receiving environments. Additionally, the reuse of wastewaters may reduce the amount of water that needs to be extracted from environmental water sources. However, due to health and safety concerns, water reuse applications are mostly restricted to non-potable uses such as landscape and agricultural irrigation [4]. Furthermore, the reuse of the wastewater is associated with concerns regarding potential microbial (e.g. Cyanobacteria; microorganisms that can cause severe health problems in livestock and human population, including liver damages, neurological disorders, and liver cancers [5–7]) and chemical (e.g. endocrine disrupting compounds (EDCs); a wide group of environmental pollutants that are able to disrupt synthesis and metabolism of endogenous hormones and hormone receptors [8–10]) contamination of water sources and consequently water supplies.

In Oman, wastewaters collected from domestic and commercial areas are transferred to either wastewater treatment plants (WWTPs) or lagoons via sewer systems (very few) or through tankers from septic tanks (majority). For example, there are collection and treatment systems for about 25% of Muscat municipal population [11]. Wastewaters effluents exiting the WWTPs have been used for landscape irrigation and recharging ground water to resist salt water intrusion in coastal areas.

Recent study on groundwater quality near Muscat area (Barka catchment) indicated elevated concentrations of inorganic constituents, chemical oxygen demand (COD), biochemical oxygen demand (BOD) and bacteria [12]. Another study conducted by [13] showed high levels of lead and chromium in samples taken from private wells in Batina area, which were attributed to uncontrolled industrial discharges. Water quality tests obtained from recharge wells in Salalah indicated the existence of elevated organic and microbial contamination [14].

This study aims at evaluating the current situation of wastewater treatment in Muscat, Sohar and Salalah areas. The study involves extensive wastewater sampling from treatment units. The analysis involves physical, chemical and biological characterization of the collected samples. Results shown in this paper covered six wastewater plants from January 2009 to December 2009.

2 Study area

This paper tries to characterize wastewater treatment in three regions in Oman (Muscat, Salalah and Sohar). Furthermore, the study describes six domestic treatment plants in the studied regions (three in Muscat, two in Salalah, and one in Sohar). Table 1 summarizes the flow rates entering the five plants and the applications of the treated effluents.

The choice of the three regions is basically due to the geographical location, final effluent application, industrial practices and sewer collection in each region. For example, Darsait sewage treatment plant (STP) receives its wastewater (21000 m^3/d) through sewer network while Alansab STP receives its influents (25000 m^3/d) through tankers. Similarly, Salalah STP receives its 22000 m^3/d wastewater through sewer network while Salalah Oxidation Pond receives its 3000 m^3/d wastewater through tankers. Sohar STP receives its raw wastewater (6600 m^3/d) through both sewer network and tankers. Both treated wastewater in Muscat and Sohar are used for landscape irrigation. However, Sohar is undergoing industrial development that worth investigating the quality of treated effluents. On the other hand, treated effluents from Salalah STP are used for groundwater recharge while effluents from the oxidation ponds are discharged to adjacent valley until now.

Table 1: Basic information about the studied wastewater treatment plants.

Treatment Plant	Flowrate, m^3/d	Application of Treated Effluents
Darsait STP	21000	Landscaping
Alansab STP	25000	Landscaping
Rusail STP	300	Landscaping
Sohar STP	6600	Landscaping
Salalah STP	22000	Groundwater recharge
Salalah Oxidation Ponds	3000	Valley discharge

3 Characterization results

3.1 pH and EC

Results obtained for average pH and EC over the study period are shown in Table 2. The average pH values for raw wastewater of the studied treatment plants ranged from 6 to 7.5. The treated effluents pH values for all treatment plants meet the Omani standards range which is 6 to 9. On the other hand, the average EC of the raw sewage ranged from 1000 to 2500 µS/cm. Furthermore, the average EC of the treated effluents for Darsait STP, Alansab STP, Rusail STP, Salalah STP, and Sohar STP are within the Omani Standards 1 (2000 µS/cm while the average EC value obtained for Salalah Oxidation Pond is with Omani Standards 2 (2700 µS/cm).

Table 2: Summary of pH and EC results for the studied treatment plants.

	Darsait STP	Alansab STP	Rusail STP	Salalah STP	Salalah Oxidation Pond	Sohar STP
Raw sewage						
pH	6.70	6.58	6.32	6.87	7.03	6.72
EC (μS/cm)	1121	1518	1073	2153	2785	1552
Final effluent						
pH	7.15	7.26	7.07	7.40	7.46	7.21
EC (μS/cm)	1010	1628	950	1830	2605	1336

3.2 Solids

Table 3 summarizes the results obtained for total suspended solids (TSS) and total dissolved solids (TDS) for the studied treatment plants. Results showed that the average TSS for untreated wastewater ranged from 100 to about 700 mg/L while the average TDS values for raw sewage ranged from 600 to about 1200 mg/L.

The average TSS results of treated effluents showed that effluents from both Sohar STP and Salalah STP are with Omani Standards 1 (15 mg/L) while TSS results of Darsait STP, Alansab STP and Rusail STP effluents are within Omani Standards 2 (30 mg/L). However, the obtained TSS value of effluents from Salalah Oxidation Pond is outside the two Omani standards. On the other hand, final effluent results of TDS from all treatment plants are within Oman Standards 1 and 2 (1500 and 2000 mg/L, respectively).

Table 3: Summary of solid results (in mg/L) for the studied treatment plants.

	Darsait STP	Alansab STP	Rusail STP	Salalah STP	Salalah Oxidation Pond	Sohar STP
TSS						
Raw sewage	225	482	106	407	666	198
Final effluent	17	28	16	11	64	13
TDS						
Raw sewage	602	620	600	1194	1610	893
Final effluent	621	673	594	1099	1490	778

3.3 BOD and COD

Table 4 shows a summary of BOD_5 and COD results for the studied treatment plants. It can be seen that the average BOD_5 for the untreated wastewater of the treatment plants ranged from 176 to 304 mg/L. The average COD results for raw sewage ranged from 320 to 973 mg/L for all treatment plants.

Table 4: Summary of BOD_5 and COD results for the studied treatment plants.

	Darsait STP	Alansab STP	Rusail STP	Salalah STP	Salalah Oxidation Pond	Sohar STP
Raw sewage						
BOD_5 (mg/L)	195	176	187	219	207	304
COD (mg/L)	579	574	407	692	973	320
Final effluent						
BOD_5 (mg/L)	1	1	3	3	6	3
COD (mg/L)	6	28	10	2	-	54

According to the obtained results, effluents from the six plants were will with the Omani Standards in regards with BOD values (15 mg/L (Standards 1) and 20 mg/L (Standards 2)). Similarly, COD values were within the Omani standards for all plants (150 mg/L (Standards 1) and 200 mg/L (Standards 2)).

3.4 Cations

Table 5 illustrates a summary of major cations results for the studied treatment plants. The average values of most of the heavy metals in the final effluents were within the Omani Standards. However, some concern can be raised about the average values of Mo in the final effluents as all plants exceeded Omani Standards 1 for treated wastewater. Furthermore, Alansab STP and Salalah Oxidation Pond violated both Oman Standards 1 and 2.

3.5 Anions

A summary of major anions results for the studied treatment plants is shown in Table 6. The values of most of the anions in the effluents were within the Omani Standards. However, some concern can be raised about the average values of nitrate (NO_3) as they exceeded Omani Standards for treated effluents (50 mg/L). This increase in NO_3 in the final effluent can be related to the oxidation of ammonia in the aeration tank (see next section). Furthermore, all treatment plants except Salalah STP violated Omani Standards for sulphate (SO_4) concentration in the final effluents (40 mg/L). It should be noted that no Omani Standards are set for bromide, nitrates, and nitrite in final effluents.

Table 5: Summary of major cations results (in mg/L) for the studied plants.

	Cu	Zn	Ni	Co	Mo	Pb	Al
Darsait STP							
Raw sewage	0.029	1.697	0.016	0.097	0.014	0.030	0.404
Final effluent	0.015	0.040	0.042	0.020	0.017	0.012	0.173
Alansab STP							
Raw sewage	0.009	0.012	0.007	0.020	0.017	0.082	0.064
Final effluent	0.011	0.020	0.007	0.020	0.063	0.017	0.026
Rusail STP							
Raw sewage	0.016	0.011	0.012	0.201	0.044	0.060	0.065
Final effluent	0.004	0.021	0.011	0.011	0.024	0.027	0.059
Salalah STP							
Raw sewage	0.008	0.022	0.011	0.020	0.033	0.047	0.019
Final effluent	0.008	0.022	0.011	0.013	0.043	0.037	0.007
Salalah OP							
Raw sewage	0.013	0.033	0.014	0.020	0.037	0.043	0.379
Final effluent	0.010	0.005	0.020	0.020	0.068	0.032	0.019
Omani Standards							
1	0.5	5	0.1	0.05	0.01	0.1	5
2	1	5	0.1	0.05	0.05	0.2	5

3.6 Ammonia

Table 7 demonstrates a summary of ammonia results for the studied treatment plants. The average ammonia concentration in raw wastewater ranged from 40 mg/L in Rusail STP to 173 mg/L in Salalah Oxidation Pond.

The average values of ammonia in the final effluents ranged from 0.5 mg/L in Sohar STP to 21.5 mg/L in Salalah Oxidation Pond. This reduction can be explained by the oxidation of initial ammonia concentration to nitrite and nitrate. Furthermore, the average ammonia levels in most of the treated plants except Salalah and Sohar STPs were beyond the Omani Standards for final effluents (5 to 10 mg/L).

3.7 Biological parameters

Microbiological tests for total coliform and E-coli (part of fecal coliform) bacteria (most probable number, MPN) were conducted on final effluents as shown in Table 8. Obtained results revealed that treated effluent from Rusail STP exceeded Omani Standards 1 and 2 (200 and 1000 MPN, respectively for fecal coliform). Furthermore, Alansab STP, Salalah Oxidation Pond and Sohar STP exceeded Omani Standards 1 (200 MPN for fecal coliform). Only Darsait and Salalah STPs final effluents are within both Omani Standards limits.

Table 6: Summary of major anions results (in mg/L) for the studied plants.

	F	Cl	Br	NO_3	PO_4	SO_4	NO_2
Darsait STP							
Raw sewage	0.22	154	2.46	9.67	12.5	42.0	0.32
Final Effluent	0.15	159	0.400	32.6	2.52	55.4	0.45
Alansab STP							
Raw sewage	0.25	188	3.15	7.19	6.81	15.9	0.38
Final Effluent	0.23	287	3.99	65.4	2.99	62.7	0.17
Rusail STP							
Raw sewage	0.38	96.8	1.32	30.7	9.51	34.8	0.06
Final Effluent	0.41	87.5	2.95	25.7	5.61	56.5	0.88
Salalah STP							
Raw sewage	0.14	285	4.21	23.9	13.1	11.1	0.29
Final Effluent	0.17	300	3.44	46.6	4.57	60.8	0.09
Salalah OP							
Raw sewage	0.19	498	6.05	9.56	6.30	17.9	1.00
Final Effluent	0.01	108	24.05	6.88	0.38	12.2	1.14
Sohar STP							
Raw sewage	0.18	182	4.17	26.1	8.22	37.4	0.14
Final Effluent	0.19	259	3.73	65.6	7.28	95.4	0.15
Standards							
1	1	650	NA	50	NA	40	NA
2	2	650	NA	50	NA	40	NA

Table 7: Summary of ammonia results (in mg/L) for the studied plants.

	Darsait STP	Alansab STP	Rusail STP	Salalah STP	Salalah Oxidation Pond	Sohar STP
Raw Sewage	86.3	121	40	122	173	97.5
Final Effluent	11.1	15.3	11.8	3.00	21.5	0.53

Table 8: Summary of microbiology results (in MPN) for the treatment plants.

	Darsait STP	Alansab STP	Rusail STP	Salalah STP	Salalah OP	Sohar STP
Total coliform						
Final Effluent	360	790	10^5	1065	4000	980
E-coli						
Final Effluent	18	700	83000	4	333	774

4. Conclusions

The research work aimed at characterizing domestic wastewater samples obtained from six wastewater treatment plants in three regions in the sultanate of Oman (Muscat, Sohar and Salalah). The sampling process was carried out for 12 months (from January 2009 to December 2009). The analyses were conducted by running the main physical, chemical and microbiology tests. The conducted tests included pH, electrical conductivity (EC), biochemical oxygen demand (BOD), chemical oxygen demand (COD), solids (TSS and TDS), anions, cations, ammonia and microbial content. It was found that most of the treatment plants applied secondary treatment systems (i.e. biological treatment in the form of activated sludge or aerated lagoons). The pH and EC of final effluents were found within regulated limits. Furthermore, the applied biological treatment was good in nutrient removal. The obtained values for BOD_5 and COD were well within Omani Standards. However, the applied treatment systems were not effective in removal of heavy metals as the values of metals in the raw sewage are didn't vary much from the final effluents.

The obtained results indicated that there is a variation in the quality of the treated effluent from time to time (i.e. the final effluents quality parameters were found below the standard values in some visits and higher in other visits). At least two of the six treatment plants had high microbiological contamination in their final effluents. Thus, the disinfection systems in these plants need further investigation, improvements or redesign.

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