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Suitability of Treated Wastewater Produced in Sudan for Irrigation Plants

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Abstract

The aim of this study was to characterize the quality of treated wastewater of Soba treatment plant, in Khartoum state, in term of its potential to be used in irrigation for different plant products, as well as to study the temporal variations of its physicochemical and biological parameters. Sampling of the treated wastewater was performed during Dec. 2014 and November 2015. The parameters indicating the suitability of such wastewater for irrigation were estimated, these include pH, Total Suspended Solids (TSS), Electrical Conductivity (EC), Total Dissolved Solids (TDS), Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Sulphate, Ammonia, Chloride as well as total count, coli from bacteria and parasites. Results showed that, significant variation in values of pH, EC. Chloride, sulphate, BOD, COD was observed throughout the months of year. In spite of variability throughout the year, the values of pH, EC, TDS chlorides and sulphate, in term of their suitability for use in irrigation, fall within the limits set by FAO for irrigation water. Concentration of total coliform and nematodes in treated wastewater, were more than the concentration limit set by WHO, for restricted irrigation, and less than the limit for unrestricted irrigation. The reuse of the treated wastewater in irrigation of non food crops could be carried out without restriction, however, regarding the use of restricted irrigation, it would be necessary to upgrade treatment processes for further reduction in some parameters, providing that, regular testing should be done regularly.

***Key words**: wastewater, reuse, nitrate, sulphate, Biochemical Oxygen Demand*

1. Introduction

During the past several decades, the rapid growth in urbanization due to the continuous migration of people from rural and semi-urban areas to the major cities, in most developing countries around the world, in search of better living standards, has contributed to the generation of great amounts of wastewater and wastes (Lazarova and Bahri, 2005; Asano *et al*., 2007). It is well known that only 15–25% of water diverted to domestic, commercial, and industrial sectors is consumed, while the rest is returned as wastewater (Qadir *et al.,* 2010). Wastewater generated from households and factories usually contains different organic materials whose decomposition can lead to the production of large quantities of malodorous gases. Furthermore, untreated wastewater may contain numerous disease-causing microorganisms that dwell in the human intestinal tract. Wastewater also contains nutrients, which can stimulate excessive growth of aquatic plants and algae, and it may also contain toxic compounds such chemical detergents and pharmaceutical residues (Almeida *et al*, 2014). Due to the growing awareness of the impact of wastewater contamination to environment and human health, wastewater treatment is now receiving greater attention from the international organizations and country governments (Bdour *et al*, 2009). Biological treatment process is usually adopted for many domestic or industrial wastewaters; this method is usually applied following, aerobic digestion and anaerobic digestion as two main technologies that both have a long history (Chan *et al*., 2009). Although many options have been practiced for final disposal of the treated wastewater (Pedrero and Alarcon, 2009 ; Dalahmeh and Baresel ,2014: Baresel *et al.,* 2015), however, many research studies reported that, if wastewater is treated properly, it is then considered as a major component of water resources supply (Zurita and White, 2014; Lu *et al*, 2015), and could be reuse for many purpose such as ground water recharge, toilet flushing, cleaning, industrial reuse , environmental enhancement and crop irrigation (Soller and Nellor, 2011; DEP 2012; and Zurita and White, 2014). In spite of its location in Nile basin as well as the substantial amounts of surface and ground water resources, however, Sudan faces water shortage problems. Storage limitations, the erratic nature and distribution of rainfall, population growth, rising living standards, and accelerated urbanization, all threaten the water supply. This situation drives research to develop additional water resources as well as protect the existing ones. Wastewater could be considered as one of these resources; since about nine millions gallon of domestic sewage water is pumped daily to soba plant treatment (Osman, *et al*., 2007). However, in spite of several researches addressing wastewater, there is limited available information on the extent of wastewater resources that could be potentially exploited in Sudan. The objective of this study was to characterize the quality of treated sewage water of soba plant in term of its potential for irrigation for different plant products, as well as to study the temporal variations of its physicochemical and biological parameters as monitoring programs required for reliable estimates of the water quality.

2. Materials and Methods

2.1. Materials:

The wastewater used in this study was obtained from soba wastewater treatment plant, south Khartoum. This plant was established in 1992 where municipal wastewater is treated with biological stabilization bonds. Three samples of treated wastewater were collected randomly from the outlet canal of the plant. The sampling frequency was monthly. Samples collection lasted from January 2015 to December 2015.

2.2. Methods:

A bench pH meter (WAP–CD 80) was used to measure the pH of wastewater samples as described by Vanukuru *et al* (1998). Electric conductivity was recorded using a calibrated EC meter (Jenway, 4310). Biological oxygen demand (BOD), Chemical oxygen demand (COD), Ammonia and suspended solids (SS) were measured according to the Standard

Methods for the Examination of Water and Wastewater (Clesceri *et al*., 2012). Biological oxygen demand (BOD) of the treated wastewater sample was determined by assimilating and oxidizing the organic matter under aerobic conditions, where a BOD dilution water was prepared by air saturated distilled water by aeration for 1- 2 hrs, two ml of any of $FeCl_3$, $CaCl_2$, $MgSO_4$, and phosphate buffer were added. Sample temperature was brought to 20°C. A volume of the treated wastewater sample was transferred into 1000 ml volumetric flask and completed with BOD dilution water to the mark. The diluted sample was divided equally into three portions each of which was transferred into a BOD bottle. The dissolved oxygen of one bottle was measured immediately and the other two bottles were incubated at 20°C. After five days the dissolved oxygen was measured, The BOD was estimated by difference. The Chemical oxygen demand (COD) was estimated by mixing of ten ml of potassium dichromate solution (1N) and 30 mls of conc. sulphuric acid to specific volume of diluted treated wastewater under high temperature and condensation apparatus, the product was then titrated by ferrous ammonium sulphate solution (0.25N). The amount of COD was estimated as mg/L. Sulphate was estimated by applying the barium chloride precipitation method and using a UV-Vis spectrophotometer (JASCO, V-530) at 420 nm (Harborne,1973). The concentration of chloride ions in treated wastewater under study was determined by using titration methods as described by (Skoog *et al*, 1996), where 3 drops of potassium chromate were added to exact 25 ml of water samples, as indicator. The mixture solution was titrated against standard silver nitrate solution (0.0141N). The concentration of chloride was estimated as mg/L. Estimation of Nitrate was carried out a UV-Vis spectrophotometer (JASCO, V-530) at 420 nm as described by Standard Methods of Examination (Clesceri, *et al*., 2012). The concentrations of Cr, Cd, and Pb were determined by the method described by Walinga *et al*., (1989), using the Atomic Absorption Spectrophotometer (Pye Unicam Model). The total count of bacteria was enumerated using the pour plate method, while the Most Probable Number (MPN) method was used to determine faecal coliforms in treated wastewater ((Clesceri, *et al*., 2012).

3. Results and discussion

It is well known that the quality of treated wastewater is governed by many factors, these factors may be related to human behavior, life style and standards of living, the technical and juridical framework by which people are surrounded as well as method of treatment (Henze and Comeau, 2008). The results illustrated in Figure 1 indicated that the pH values throughout the year ranged between 7.22 – 7.93. The highest value was recorded in April, while the lowest was in November. It is well known that the normal pH range for irrigation water is from 6.5 to 8.4; pH values outside this range are a good warning that the water is abnormal in quality (Clesceri *et al*., 2012). It was reported that the general pH values for normal irrigation should be between 6.00 and 7.00, while values above 7.00 are considered as of increasing hazard (Danko, 1997).

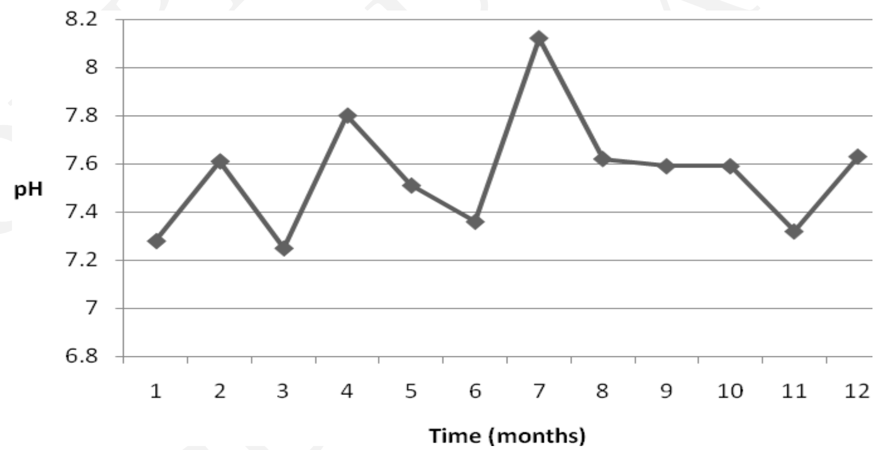

Figure 1: Variations in pH values of the treated wastewater of Soba treatment plant.

Figure 2. Revealed that the EC values throughout the year ranged between 789.3 –111 8.7 μS/cm. The highest value was estimated in October, while the lowest was in May.

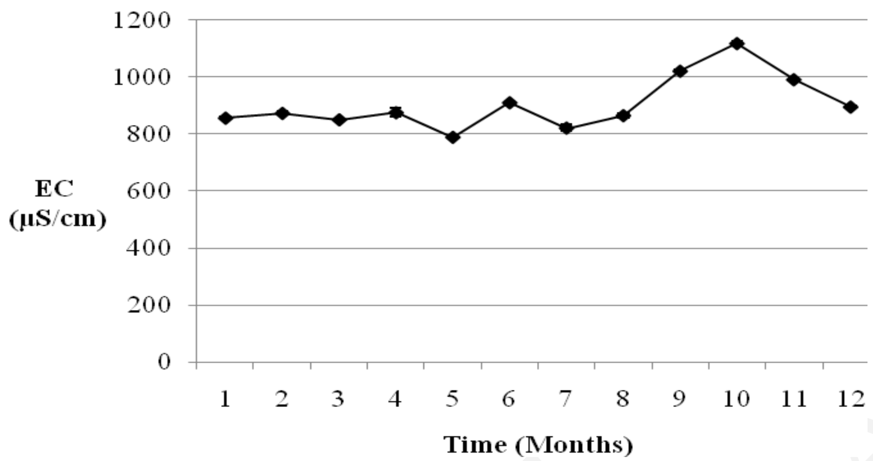

Figure 2: Variations in Electrical Conductivy of the treated wastewater of Soba treatment plant.

Total suspended solids (TSS) values throughout the year ranged between 113.70–146.60. The highest value was recorded in July, while the lowest was in November. Makoni and Ngcobo, (2014) reported that variation in EC and TSS values throughout the year was expected since the conditions of wastewater generation differ from day to day as was highly affected by human activities (Figure 3).

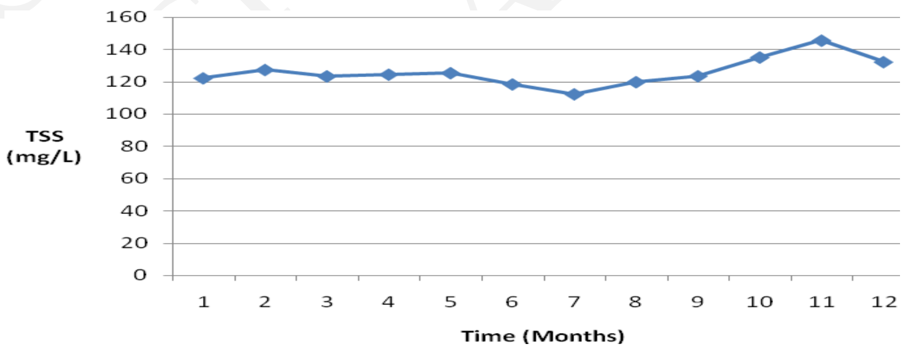

Figure 3: Variations in total suspended solids of the treated wastewater

The BOD values ranged between 79.4 – 107.93 mg/L (Figure 4). The highest value was determined in April while the lowest was recorded in November. It is well known that BOD is an indicator for wastewater treatment efficiency , since it reflect the reduction in organic matter in water (Clesceri *et al*., 2012), although high BOD indicates low quality of treated wastewater, however, it is of no significant as used as water of irrigation. Although in most FAO documents, no standard was adopted for BOD for water of irrigation. However, Salgota *et al*, (2006) reported the values of BOD of wastewater to be used as suitable water for perfect irrigation system should not exceed 20 mg/L, More over in Turkish standards for water irrigation, BOD may range from 0- 100 mg/l, for possible reuse of wastewater for irrigation, and from 100 – 200 mg/L, for conditional reuse, however, values of BOD exceeding 200 mg/l makes wastewater totally unsuitable for any type of irrigation systems known.

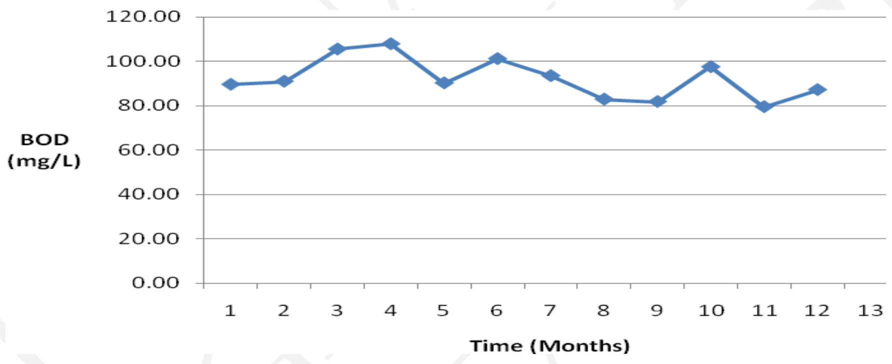

Figure 4: Variations in Biochemical Oxygen Demand of the treated wastewater

Chemical Oxygen Demand (COD) values was ranged between 205.47–328.57 mg/L (Figure 5). The highest value was recorded in November, while the lowest was that of January. It is well known that the purpose of COD detection is to measure the pollution potential of wastewater in term of its organic matter (Furukawa *et al*., 2002). For wastewater that to be used for irrigation, the recommended Value of COD was reported by Salgot *et al*, (2006) as 100 mg/L, however, less value reflected lack of organic matter, while high values may make problems when advanced techniques are used as irrigation system.

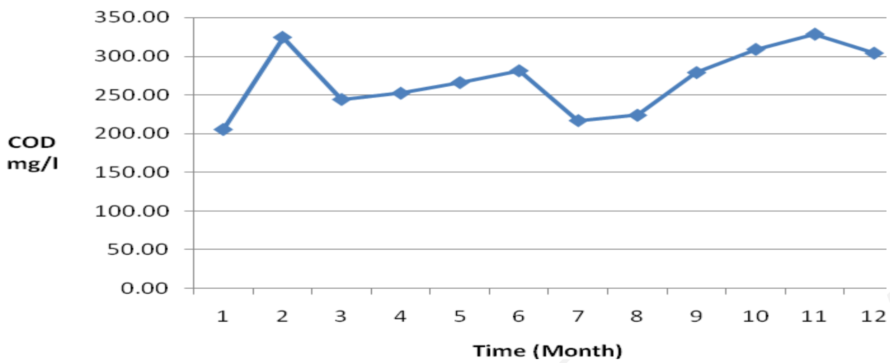

Figure 5: Variations in Chemical oxygen demand of the treated wastewater

Figure 6 Showed that the values of ammonia ranged between 32.37–24.37 mg/L. The highest value was estimated during October, while the lowest was that of July. Variation in ammonia values may be attributed to the fact that although ammonia is initially in wastewater, it is also produced as oxidation result of organic nitrogen. Salgot *et al*, (2006) stated that the values of ammonium-N in wastewater to be used as suitable water for efficient irrigation system should not exceed 20 mg/L.

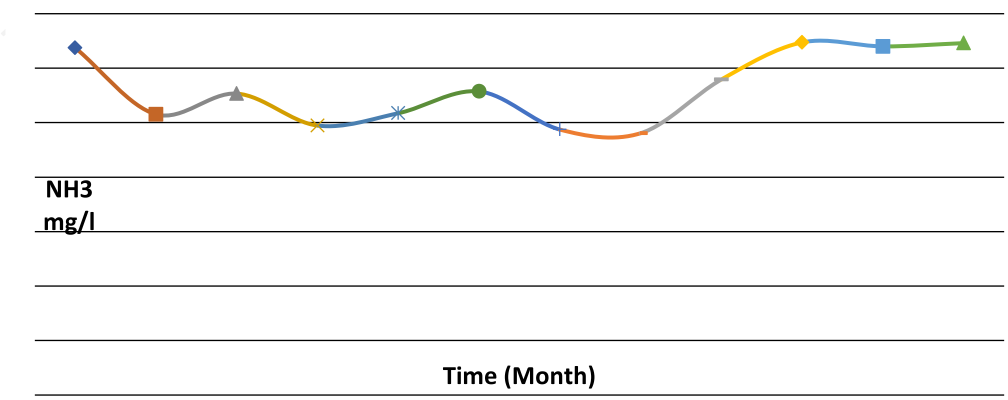

Figure 6:Variations in Ammonia of the treated wastewater of Soba treatment plant

Chloride concentration analysis ranged between 53.53–66.23 mg/L (Figure 7). The peak value was recorded in September, while the lowest was that of November. Chloride concentration determined the suitability of its water for crop irrigation. It was reported that no restriction on use of wastewater for irrigation concerning chloride, if the concentration is less than 140.2 mg/L (FAO, 2003). However Salgot *et al,* (2006) considered 250 mg/L as permissible concentration for Chloride to be in wastewater for used in irrigation. On the other hand, although chloride is considered as among the most toxic substances for water of irrigation, it comes after sodium (Fipps,1998), however, some crops can tolerate chlorides from the concentration 350 ppm up to 1750 ppm (Tanji, 1990).

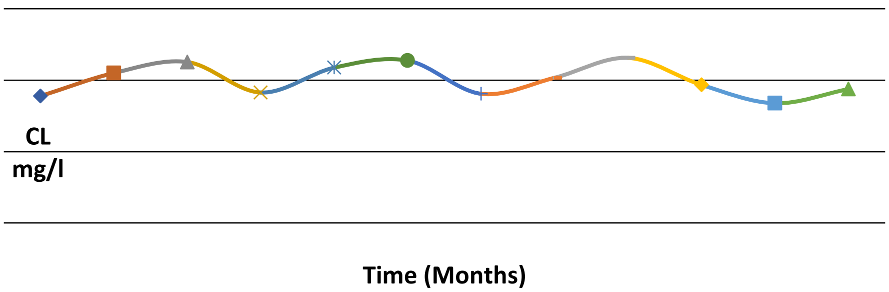

Figure 7: Chloride Concentration of the treated wastewater of Soba treatment plant

Table 1. summarizes the results of total count, total coliform E. coli bacteria, nematode larvae, nematode adult, schistosoma and helminthes in treated wastewater samples taken from three locations of the outlet canal of Soba treatment plant. The results indicate that different locations have the same concentration of total coliform and gave the same positive results regarding E.coli. Also these findings revealed that the effluent from the wastewater plant under study was heavily polluted by microorganisms. As water for irrigation, the concentrations of total coliform in different locations were more than the concentration limits set by WHO for water to be used for unrestricted irrigation (i.e for crops likely to be eaten uncooked) , the WHO guideline limit is that no detectable faecal

coliform bacteria / 100 ml). However, the concentrations of total coliform in different locations were less than that limits for irrigation of fodder crops, the WHO limit was 4200 coliform bacteria per 100) (Blumenthal *et al.*, 2000). The results also indicated that all tested locations were contaminated with nematode larvae, nematode adult, schistosoma and helminthes. For wastewater to be used in irrigation, on basis of WHO guidelines, for restricted irrigation, no more than one viable human intestinal nematode egg per liter, is permissible, however, for unrestricted irrigation, in addition to this criteria, no more than one thousand faecal coliform bacteria is permissible per hundred milliliter as reported by WHO, (WHO, 2005). Blumenthal *et al.*, (1996) suggests that the WHO guidelines for irrigation by wastewater, are used only to protect crop consumers but not necessarily farmers, farm workers and their families, thereby making these guidelines is considered as questionable.

Table 1. Analysis of Bacteria and parasites loads in treated wastewater of Soba treatment plant

Tested microorganism	**Sample locations**		
	Location 1	Location 2	Location 3
Total count Bacteria	$1.2X10^9$	$3.5X10^8$	$2.6X10^7$
Total coliform bacteria	2.400	2.400	2.400
E. Coli bacteria	+ve	+ve	+ve
Nematode larvae	+ve	+ve	+ve
Nematode adult	+ve	+ve	+ve
Schistosoma	+ve	+ve	+ve
Helminthes	+ve	+ve	+ve

4. **Conclusions**

In conclusion it is clear that the treated wastewater can offer a significant opportunity not only to contribute to the solution of water problem but also to the upgrading and protection of the environment. In this study the reuse of the treated wastewater in agricultural irrigation of non food crops could be carried out without restriction, however, regarding other edible plant product, it would be necessary to upgrade treatment processes for further reduction in some parameters.

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