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Effects of Sole and Combined Physical Filtration Materials on Physicochemical and Microbiological Properties of Waste Waters

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Abstract: Agricultural re-use of waste waters is a feasible alternative for increasing water resources for agriculture. Several methods have been adopted for improving waste water quality for safe re-use in agriculture. However, these methods are complex and difficult to use by local farmers. Hence, a study was conducted to examine the effects of a simple and cost-effective waste water treatment methods on physicochemical and microbial properties of waste waters. The research was conducted in the Department of Crop, Soil and Pest Management, the Federal University of Technology, Akure (FUTA). Waste waters consisted of: fish pond effluent and municipal stream. Materials used for physical filtration of waste waters include: granite, rice husk, charcoal, and pure river sand. Prior to and after treatments, the waste waters were subjected to chemical analysis (pH, electrical conductivity (EC), Nitrate, Cl, P, Ca, and Mg), physical analysis (Total solid, Total dissolved solid and Total suspended solid), and microbiological analysis (Total faecal coliforms, bacteria, yeast and fungi). Results obtained showed that sole and combined applications of physical filtration materials significantly reduced microbial loads in waste waters. Similarly, significant reductions in total solid (TS), total suspended solid (TSS) and total dissolved solid (TDS) were obtained for waters filtered with the filtration materials, both in the single and combined applications. The highest significant pH, EC and chloride were recorded in untreated fishpond effluent (T_1), while fishpond effluent filtered with rice husk (T_5) recorded the highest Significant Ca and Mg. Highest significant Nitrate was recorded in municipal wastewater filtered with rice husk (T_{11}), while highest significant P was obtained at T_5 and T_{11}. Results of this research showed improvement in the quality parameters of waste waters filtered with sole and combined filtration materials.

Keywords: Cucumber, Microbiological Analysis, Municipal Stream

1. Introduction

Continuous rise in global population and industrialization has resulted to increases in the volume of waste generation including waste water yearly [1]. The indiscriminate discharge of waste waters into rivers and lakes without adequate treatment has resulted into contamination of water bodies in many regions of the world [2]. Contamination of water bodies has become a global concern as a result of the growing population of the world which is in boundless need of fresh water [3].

Waste water recycling has become a generally acceptable approach in water management, and this has in great extent reduced the force enforced on available water supply due to population growth [4]. According to Heidarpour *et al.*, the recycling of waste waters for irrigation purpose will considerably reduce the amount of water that is required to be removed from global water sources [5]. Waste waters serve as good source of water and nutrients for crops, therefore, reuse of waste waters serve to maintain soil and crop productivity and protection of the environment [6]. Waste water also contains significant amounts of organic and inorganic nutrients, especially nitrogen (N), phosphorus (P), potassium (K) and micronutrients [7], hence, its reuse can save a lot of fertilizer expenditures when used in agriculture [8].

However, the direct application of untreated waste waters on crop land is associated with a many risks such as Crop yields reduction, crop quality deterioration, contamination of crops with pathogens and intestinal helminthes [9]. Therefore, in order to reduce the health hazards and damage to the natural environment, waste waters must be treated before reuse especially for agricultural irrigation [10]. Waste water reuse in agriculture must comply with re-use standards to minimize environmental and health risks [11].

There are several methods/technologies for treating waste waters for re-use in agriculture. These methods are complex and difficult to use by local farmers. Also, high capital required for the construction of these waste water treatment systems as well as skilled staff needed to operate the systems, which even become more technical each day, are other limiting factors [12]. Hence, the need to provide a simple and cost effective treatment facility for wastewater re-use for agriculture.

2. Materials and Methods

2.1. Experimental Site

The experiment was carried out in the screen house of the Department of Crop, Soil and Pest Management, The Federal University of Technology, Akure.

2.2. Sources of Waste Water

Waste waters used for the experiment consist: (i) Fish pond effluent (FPE) which was collected from a local fish pond, Oda Road, Akure, Ondo State; and (ii) Municipal waste water (MWW) which was collected from a stream situated along FUTA South Gate, Akure, Ondo State.

2.3. Treatment of Waste Waters

Waste water treatment consisted of primary and secondary treatments. In the primary waste water treatment (PWWT), waste waters were allowed to settle in two separate clean basins for 24 hours. Solid and heavy particles, settled at the bottom of the basins, were removed, and the waters were carefully decanted to another separate two basins. Sodium hypochlorite (NaOCl) was applied as disinfectant to the decanted waters before they were subjected to secondary treatments. In the secondary waste water treatment (SWWT), the decanted waters from the PWWT were subjected to physical filtration using filtration materials solely and in combination. The filtration materials were applied in layers in the filtration facility constructed.

Treatments evaluated includes:

T_0=Borehole water (Control)

T_1=Untreated fish pond effluent

T_2=Fish pond effluent filtered with granite

T_3=Fish pond effluent filtered with charcoal

T_4=Fish pond effluent filtered with pure river sand

T_5=Fish pond effluent filtered with rice husk

T_6=Fish pond effluent filtered with combined physical filters

T_7=Untreated municipal waste water

T_8=Municipal waste water filtered with granite

T_9=Municipal waste water filtered with charcoal

T_{10}=Municipal waste water filtered with pure river sand

T_{11}=Municipal waste water filtered with rice husk

T_{12}=Municipal waste water filtered with combined physical filters

Each treatment was replicated four (4) times.

2.4. Analysis of Treated and Untreated Waste Waters

Prior to and after treatments, the waste waters were subjected to chemical, physical, and microbiological analyses. The pH of each water samples was determined using Metro pH meter model E250, and the EC was measured using conductivity meter. Total solids, dissolved solids and suspended solids were determined using the AOAC method of analysis (1984). Chloride ion in water samples was measured titrimentrically using the Mohr's method. Calcium and magnesium ions in water samples were determined using the EDTA titration method. Nitrate concentration in water samples was determined by sodium hydroxide colorimetric method.

Data were subjected to One-way ANOVA and means were separated with Tukey HSD test at 5% level of probability using SPSS 24.0 version.

3. Results and Discussion

The microbial and physicochemical properties of the treated waste waters, when compared to the untreated waste water samples, showed improved water Quality. The results revealed that separate and combined applications of physical filtration materials (granite, charcoal, pure river sand, and rice husk) reduced microbial loads (total faecal colifroms, bacteria, fungi, and yeast) after treatment. Several filtration materials have been adopted for waste water treatment such as sand, peat, wood by-products, biochar, coconut shells, glass bead, and other commercially available filtration materials which considerably reduced microbial loads [13]. Many studies have reported efficient bacteria (4.85–6.8 log10 CFU/100 mL) and protozoa (2 log10 CFU/100 mL) removal through filtration process [14, 15]. Morató *et al.* and Alufasi *et al.* reported that the effectiveness of filtration mainly depends on the characteristics of the pathogen and filtration media, including the type, texture, and size [16, 17]. The total coliforms of the treated waste waters varied between 14.67 to 225.33 MPN/100mL. These results conformed to the acceptable faecal coliform levels of ≤ 1000 MPN/100 mL in waste water for use in agriculture [18]. Bacterial population varied between 53.33 to 160.00 CFU/ml, yeast varied between 25.00 to 256.67 SFU/ml, and fungi varied between 7.00 to 31.00 SFU/ml. Jenkins *et al.* reported an average removal of 1.8 log10 units, that is, 98.5% of fecal coli bacteria from a river water augmented with waste water over 10 weeks in a filter filled with fine sand [19]. However, significant reductions in microbial loads were obtained when the physical filtration materials were used when combined (T_6 and T_{12}). This is in accordance with the result obtained by Huq *et al.* who reported that various types of sari cloth (fine mesh, woven cotton fabric) and nylon mesh used in single or multiple layers removed from water samples the zooplankton and phytoplankton harboring *V. cholera* [20]. The treatments reduced *V. cholerae* concentrations by 95 to 99%. Also Serpieri *et al.* concluded that UV filters reduced microbiological contamination in treated waste water significantly [21].

Table 1. *Microbial loads of treated and untreated waste waters.*

Microbial load				
Water sources	**Total faecal coliforms (MPN/100ml)**	**Bacteria (CFU/ml)**	**Yeast (SFU/ml)**	**Fungi (SFU/ml)**
T_0	0.00^{a}	16.33^{a}	0.00^{a}	0.00^{a}
T_1	1100.00^{g}	1240.00^{e}	990.00^{e}	53.00^{e}
T_2	225.33^{f}	163.33^{d}	115.00^{abc}	15.33^{bc}
T_3	56.00^{bc}	71.33^{bc}	168.67^{bc}	14.67^{abc}
T_4	150.00^{e}	160.00^{d}	201.67^{c}	12.33^{abc}
T_5	97.00^{cd}	66.67^{bc}	25.00^{ab}	15.67^{bc}
T_6	46.67^{ab}	53.33^{b}	27.67^{ab}	12.33^{abc}
T_7	1263.02^{h}	1260.00^{e}	586.67^{d}	101.67^{f}
T_8	143.33^{de}	80.00^{c}	122.67^{abc}	17.00^{bcd}
T_9	145.33^{de}	110.00^{bc}	256.67^{c}	31.00^{d}
T_{10}	225.33^{f}	90.54^{bc}	120.00^{abc}	23.67^{bc}
T_{11}	149.32^{e}	83.33^{c}	33.33^{ab}	20.00^{bcd}
T_{12}	14.67^{ab}	56.67^{b}	32.00^{ab}	7.00^{ab}

Mean with the same letter (s) in superscript on the same column are not significantly different at p=0.05 (Tukey HSD). T_0=Borehole water (Control), T_1=untreated fish pond effluent, T_2=fishpond effluent filtered with granite, T_3=fishpond effluent filtered with charcoal, T_4=fishpond effluent filtered with river sand, T_5=fishpond effluent filtered with rice husk, T_6=fishpond effluent filtered with combined physical filters, T_7=untreated municipal wastewater, T_8=municipal wastewater filtered with granite, T_9=municipal wastewater filtered with charcoal, T_{10}=municipal wastewater filtered with river sand, T_{11}=municipal wastewater filtered with rice husk, T_{12}=municipal wastewater filtered with combined physical filters

Table 2. *Physical properties of treated and untreated waste waters.*

Waste water physical properties			
Water sources	**Total solid (mg/l)**	**Total dissolved solid (mg/l)**	**Total suspended solid (mg/l)**
T_0	16.01^{a}	8.64^{a}	8.17^{a}
T_1	110.81^{d}	37.25^{f}	85.67^{d}
T_2	48.33^{b}	20.66^{bcd}	28.39^{b}
T_3	53.09^{bc}	22.91^{cde}	32.04^{bc}
T_4	49.01^{b}	19.47^{bc}	30.79^{bc}
T_5	49.99^{bc}	20.01^{bc}	30.66^{bc}
T_6	48.72^{bc}	18.79^{b}	28.98^{b}
T_7	141.49^{e}	52.43^{g}	93.97^{e}
T_8	56.11^{bc}	25.43^{e}	35.50^{c}
T_9	58.92^{c}	26.51^{e}	36.24^{c}
T_{10}	54.07^{bc}	23.34^{cde}	34.02^{bc}
T_{11}	54.70^{bc}	24.32^{de}	35.58^{c}
T_{12}	50.84^{bc}	20.48^{bcd}	30.17^{bc}
WHO	-	500.00	-

Mean with the same letter (s) in superscript on the same column are not significantly different at p=0.05 (Tukey HSD). T_0=Borehole water (Control), T_1=untreated fish pond effluent, T_2=fishpond effluent filtered with granite, T_3=fishpond effluent filtered with charcoal, T_4=fishpond effluent filtered with river sand, T_5=fishpond effluent filtered with rice husk, T_6=fishpond effluent filtered with combined physical filters, T_7=untreated municipal wastewater, T_8=municipal wastewater filtered with granite, T_9=municipal wastewater filtered with charcoal, T_{10}=municipal wastewater filtered with river sand, T_{11}=municipal wastewater filtered with rice husk, T_{12}=municipal wastewater filtered with combined physical filters.

The performance of the constructed filtration facility as well as selected physical filtration materials such as granite, charcoal, rice husk and pure river sand were assessed in this study in terms of removal efficiency of Total Solid (TS), Total Suspended Solids (TSS), Total Dissolved Solid (TDS), Electric Conductivity (EC) along with improvement of pH quality of raw waste waters. The pH of the treated waters varied between 6.9 and 7.7 which agrees with the World Health Organization 1989 and Food and Agricultural Organization 1999 standards and guidelines for safe reuse of waste water in agriculture. According to Gao *et al.*, microbial compositions are affected by the pH of solutions or substrate [22]. High TS, TDS, and TSS values were obtained for untreated wastewaters (Table 2). High TS, TDS, and TSS in untreated wastewaters (T_1 and T_7) is due to the existence of colloidal and non-settleable solids including large sand particles, clay and fine silt. In the present study, significant reductions in TS, TDS, and TSS were obtained with the application of physical filtration materials, both in the single and combined applications. The low levels of total solids (TS), total dissolved solids (TDS) and total suspended solids (TSS) in the treated waste waters were similar to earlier reports of Rasool et al. who reported about 87% reduction in TS, 62.8% reduction in TDS, and 99.9% reduction in TSS while using pilot-scale stone media trickling filter [23]. In addition, Khan et al. reported reduction in TDS (66%) and TSS (100%) by integrating stone media trickling filter with sand column filter [24]. The treated wastewater was found to be feasible for agriculture and safe disposal based on the recommended TDS (<1000 mg/L) and TSS (25–80 mg/L) values [25]. Reduced EC and chloride concentration were also recorded in treated waste waters. EC is used to indicate the salinity potential of water by measuring the current carrying capacity due to the presence of free ionized constituents [26, 27]. The permissible limit of EC by FAO is 1400 µS/cm [28]. The EC values of untreated waste waters (T_1 and T_7) were observed as 1321.33 µS/cm and 943.67 µS/cm respectively. In the present study, significant reductions in EC values were found with application of the physical filters, both in the sole and combined applications. Pitchard et al. opined that the reductions in the TSS play a key role in the decline of EC values [29]. Also, Khan et al. found out that fixed biofilm reactor integrated with a sand column filter was effective in reduction of the EC value [24]. The results of this research also showed that chloride concentrations in the treated waste waters is far below the concentration of chlorides (250 mg/liter) for discharge into the receiving environment [30]. Similarly, nitrate, Ca, Mg, and P values obtained for treated waste waters fell within the recommended WHO guidelines of 10 mg/L [25].

Table 3. *Chemical properties of treated and untreated waste waters.*

Chemical Compositions							
Water sources	**pH**	**Ec (µ.S/cm)**	**Cl (mg/l)**	**Ca (ppm)**	**Mg (ppm)**	**N (mg/l)**	**P (ppm)**
T_0	6.71^{a}	240.00^{a}	53.64^{a}	32.25^{def}	19.26^{g}	4.30^{d}	0.65^{a}
T_1	7.81^{g}	1321.33^{h}	46.28^{a}	28.15^{bcd}	16.83^{f}	5.05^{f}	1.49^{bc}
T_2	7.40^{de}	613.67^{f}	216.28^{e}	33.23^{ef}	19.83^{h}	4.54^{de}	1.67^{c}
T_3	7.30^{cd}	328.33^{b}	324.82^{f}	26.12^{bc}	16.99^{f}	4.42^{d}	2.04^{c}
T_4	7.30^{cd}	415.67^{d}	127.81^{b}	26.25^{bc}	15.62^{e}	4.51^{de}	1.67^{c}
T_5	6.90^{ab}	286.67^{ab}	223.65^{e}	28.31^{cd}	12.25^{c}	4.75^{de}	24.54^{g}
T_6	7.05^{bc}	392.00^{cd}	193.69^{cd}	32.29^{def}	19.23^{g}	4.57^{de}	4.80^{d}
T_7	7.44^{def}	949.33^{g}	53.23^{a}	6.52^{a}	3.64^{a}	2.50^{a}	1.82^{c}
T_8	7.70^{fg}	550.00^{e}	177.85^{b}	23.31^{b}	13.83^{c}	3.13^{b}	0.84^{a}
T_9	7.70^{fg}	648.67^{b}	186.32^{c}	40.17^{g}	24.26^{j}	3.62^{c}	0.46^{a}
T_{10}	7.65^{efg}	529.00^{d}	179.83^{c}	28.14^{bcd}	16.83^{f}	3.16^{de}	0.40^{a}
T_{11}	7.40^{de}	331.33^{bc}	213.92^{de}	31.54^{def}	10.85^{b}	3.66^{c}	18.83^{f}
T_{12}	7.20^{cd}	338.33^{bc}	107.27^{b}	34.05^{f}	20.44^{i}	3.41^{bc}	6.60^{e}
WHO	6.5-8.5	1400.00	250.00	75.00	50.00	10.00	200.00

Mean with the same letter (s) in superscript on the same column are not significantly different at p=0.05 (Tukey HSD). T_0=Borehole water (Control), T_1=untreated fish pond effluent, T_2=fishpond effluent filtered with granite, T_3=fishpond effluent filtered with charcoal, T_4=fishpond effluent filtered with river sand, T_5=fishpond effluent filtered with rice husk, T_6=fishpond effluent filtered with combined physical filters, T_7=untreated municipal wastewater, T_8=municipal wastewater filtered with granite, T_9=municipal wastewater filtered with charcoal, T_{10}=municipal wastewater filtered with river sand, T_{11}=municipal wastewater filtered with rice husk, T_{12}=municipal wastewater filtered with combined physical filters

4. Conclusion

Results of this research showed improvement in the quality parameters (physical, chemical and microbial) of waste waters filtered with sole and combined filtration materials (granite, charcoal, rice husk, and river sand). Total solid (TS), total dissolved solid (TDS) and total suspended solid (TSS) were highest in untreated municipal waste water (T_7) while pH and EC were highest in untreated fish pond effluent (T_1). Microbial loads were also higher in both untreated fish pond effluent (T_1) and untreated municipal waste water (T_7). However, Sole use of filtration materials (granite, charcoal, rice husk, and river sand) improved waste water quality (physical, chemical and municipal properties). Waste water quality was further enhanced upon treatment with combined filtration materials. There is need to assess the growth and yield responses of agricultural crops to the treated waste waters.

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