Asian Journal of Advances in Research

5(1): 479-489, 2022

IMPACT OF TREATED AND UNTREATED WASTE WATERS ON SOIL PHYSICOCHEMICAL AND MICROBIAL PROPERTIES

O. AKINBUWA [a,b] *, S. O. AGELE [b] AND A. J. ADEYEMO [b]

[a] Department of Plant Science and Biotechnology, Adekunle Ajasin University, Akungba, Akoko, Nigeria.
[b] Department of Crop, Soil and Pest Management, Federal University of Technology, Akure, Nigeria.

AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Received: 20 December 2021
Accepted: 26 February 2022
Published: 03 March 2022

Original Research Article

ABSTRACT

The quality of water used for the irrigation of agricultural crops has significant effects on soil properties. This experiment was conducted to examine the impact of treated and untreated waste waters on the physicochemical and microbial properties of soil. Waste waters (fish pond effluent and municipal waste water) including water from borehole, were subjected to physical filtration using sole and combination of filtration materials (granite, charcoal, rice husk, and river sand). The treated and untreated waste waters were deployed to irrigate potted cucumber plants arranged in a completely randomized design (CRD). Soil samples were collected for analysis after the experiment. The results obtained showed that soil organic carbon, available P, Ca and N were highest in soil irrigated with fish pond effluent filtered with rice husk (T_5). Organic carbon and CEC were higher for soil irrigated with municipal waste water filtered with charcoal (T_9). Similarly, treated waste waters (T_5 and T_{11}) improved the soil texture. Furthermore, significant differences ($P<0.05$) were observed in soil pH among the treatments. Bacteria, yeast and fungi populations were significantly higher for soil irrigated with untreated fishpond effluent (T_1) and untreated municipal waste water (T_7). Filtered waste waters (fish pond effluent and municipal waste water) using sole and combination of filtration materials improved soil physical and chemical, and also help in reducing pathogenic organisms that could be harmful to other useful microbes in the soil. Therefore, wastewater treated with sole and combined filtration materials has no detrimental effects on soil physical and chemical properties.

Keywords: Municipal wastewater; fish pond; physicochemical; filtration; rice husk.

1. INTRODUCTION

Agricultural reuse of wastewater is an ancient practice which receives renewed concern as a result of the current increase in global population and socio-economic growth, and needs for food security [1]. Also, using waste waters for crop land irrigation is an attractive option for disposal because it could increase soil physical properties and nutrient contents [2]. According to Tymchuk et al. [3], waste water serve as a good source of water and nutrients for crops, therefore, reuse of waste waters serves to maintain soil and crop productivity and protection of the environment.

It has been reported that waste water contains some macro nutrients (nitrogen, phosphorus and potassium) and some micronutrients (iron, manganese and zinc)

**Corresponding author: Email: makindeakinbuwa@gmail.com, olumakinde.akinbuwa@aaua.edu.ng;*

which support crop growth, yield and quality [4]. Nath et al. [5] reported that waste water from different sources does not only supply water but in addition contains substantial amount of organic matter and other plant nutrients that promote crop yield; especially nitrogen (N), phosphorus (P), potassium (K) and micronutrients [6]. Also, the reuse of waste water could save a lot of fertilizer expenditures when used in agriculture [7].

However, application of untreated waste waters to crop plants could result in a number of problems such as pathogenic infection and accumulation of toxic substances both in the soil [8]. Ghafoor et al. [9] reported that incessant and extended application of waste water on agricultural field may result in accumulation and buildup of heavy metals and salinity in the soil which may be toxic to crop plants. Also, according to Rusan et al. [10] long-term irrigation with waste water can lead to 176 % increase in soil EC, 485 % increase in SAR, 0.3 units increase in soil pH, 172 % increase in exchangeable Na and 34 % increase in extractable B concentration. Furthermore, application of waste water to farm lands can encourage soil salinization [11]. Soil salinity causes osmotic stress that hinders the absorption of water and nutrients by plants [12]. Rietz and Haynes [13] reported that salinization as a result of wastewater irrigation reduces soil quality, microbial population and microbial activity in the soil, and also affects the potentially mineralizable N in the soil.

Water quality requirements for irrigation of agricultural soil is a subject of much interest; agricultural water should have potable quality, in physical, chemical and microbiological properties [14]. Wastewater reuse in agriculture is expected to comply with re-use standards to minimize environmental risks [14]. This experiment was designed to examined the impacts of treated and untreated wastewaters on soil physicochemical and microbial properties.

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. longitude 5°06' E, to 5°38'E and between latitude 7°07' N, to 7°37' E).

2.2 Sources of Waste Water

The two sources of waste waters included: (i) Fish pond effluent (FPE) which was obtained from the Federal University of Technology, Akure (FUTA) experimental fish farm; and (ii) Municipal waste water (MWW) which was collected from a stream situated along FUTA South Gate, Akure, Ondo State.

2.3 Treatment and Analysis of Waste Waters

The treatment of the waste waters was carried out in two stages: (i) the primary treatment (PWWT) and; (ii) Secondary treatment (SWWT). 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. 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. Prior to, and after treatments, waste waters were subjected to chemical, physical, and microbiological analyses. The pH of each water sample was determined and the EC measured using a conductivity meter. Total solids (TS), total dissolved solids (TDS) and total suspended solids (TSS) were determined using an accepted method of analysis. Chloride ions in water samples were measured by titration using the Mohr’s method. Calcium and magnesium in water samples were determined using the EDTA titration method. Nitrate concentration was determined by the sodium hydroxide colorimetric method.

2.4 Collection of Soil and Filling of Pot

Top soil used for the experiment was collected under fallow vegetation at the Teaching and Research Farm, The Federal University of Technology, Akure, Ondo State, Nigeria. Perforated pots were filled with 4 kg of the top soil, and were arranged accordingly in a Completely Randomized Design (CRD) in the screen house.

2.5 Application of Treated and Untreated Waste Waters to Potted Plants

Two seeds of cucumber were sown in the perforated pots (8 inches deep, 10 inches wide) filled with 4 kg of top soil. Seedlings of cucumber were allowed to establish for two weeks, after which they were thinned to one seedling per pot. Weeding was also done. About 500 ml of treated and untreated waters were deployed to irrigate the plants three times in a week for 12 weeks. Bore hole water (T_0) served as the control.

Treatments evaluated includes: (i) T_0=Borehole water (Control), (ii) T_1=Untreated fish pond effluent, (iii)

T_2=Fish pond effluent filtered with granite, (iv) T_3=Fish pond effluent filtered with charcoal, (v) T_4=Fish pond effluent filtered with pure river sand, (vi) T_5=Fish pond effluent filtered with rice husk, (vii) T_6=Fish pond effluent filtered with combined physical filters, (viii) T_7=Untreated municipal waste water, (ix) T_8=Municipal waste water filtered with granite, (x) T_9=Municipal waste water filtered with charcoal, (xi) T_{10}=Municipal waste water filtered with pure river sand, (xii) T_{11}=Municipal waste water filtered with rice husk, (xiii) T_{12}=Municipal waste water filtered with combined physical filters. Each treatment was replicated four (4) times.

2.6 Soil Analysis

Soil samples were collected after the experiment for analysis in the laboratory. The soil physicochemical and microbial analysis were carried out at the soil laboratory of the Department of Crop, Soil and Pest Management, Federal University of Technology, Akure, Ondo State, Nigeria. Soil pH was determined using Metro pH meter model E250. Soil particle size was determined with the hydrometer method [15]. Cation exchange capacity (CEC) was determined by the ammonium saturation method method [16]. Organic matter was determined by the wet oxidation method [17]. The K and Na determinations was by flame photometry. The Ca and Mg were determined by versenate or EDTA method. Soil available phosphorus was determined using the Olsen and Mehlich method [18]. Microbial loads in the soil were determined by the standard spread-plate dilution method described by [19].

2.7 Statistical Anaysis

All data collected were subjected to analysis of variance (ANOVA) using MINITAB Version 17 software package, treatment means were separated using Tukey's test at 5 % level of probability.

3. RESULTS AND DISCUSSION

3.1 Microbial and Physicochemical Properties of Treated Waste Waters

There were reductions in microbial population (total fecal coliforms, bacteria, fungi and yeast) recorded in waste waters subjected to single and combined use of physical filters (Table 1). The greatest reductions in microbes were in waste waters filtered with combined physical filters (T_6 and T_{12}). Untreated fish pond effluent (T_1) and untreated municipal waste water (T_7) had values of microbes that were higher than other treatments. Physical and chemical properties of waste waters following physical filtration varied (Table 2). Reductions in total solids (TS), total dissolved solids (TDS), and total suspended solids (TSS) occurred in waste waters filtered with physical filtration materials, alone and combined applications. Both Untreated municipal waste water (T_7) and untreated fishpond effluent (T_1) had the highest values of TS, TDS and TSS in comparison to the treated waste waters. Similar variations in waste waters chemical properties occurred among treatments (Table 3). The highest pH (7.81) was in untreated fishpond effluent (T_1). The T_1 and T_7 had the highest EC values. Fish pond effluent filtered with charcoal (T_3) had highest chloride content; fish pond effluent filtered with river sand (T_4) had the highest Ca and Mg; T_1 had the highest nitrate; fish pond effluent filtered with rice husk (T_5) and municipal waste water filtered with rice husk (T_{11}) had the highest values of P.

3.2 Effects on Soil Physical and Chemical Properties

Soil is a dynamic system of minerals, organic materials, water, air and microorganisms, and direct application of waste waters, either treated or untreated, change its physical, chemical, and biological properties. Many researchers have reported the impacts of waste waters on the physicochemical properties of soil [20-22]. The results of this research show that there were no significant differences among the treatments in terms of soil textural classes (Table 4). Treated waste waters improved soil physical, chemical and microbial properties upon soil application. Soil pH values were observed not significantly different during the study (Table 5). Similar result was reported by Rusan et al. [10] after long-term irrigation of soil with treated waste water. He reported that wastewater irrigation had no significant effect on soil pH regardless of the duration of wastewater irrigation (ten years) or soil depth. However, Angin et al. [23] found that soil pH decreased following long term (fifteen years) wastewater irrigation due to the oxidation of organic compounds. The CEC of soil irrigated with treated waste water increased (Table 6). This may be due to slight increase of the soil organic matters in soil. This finding is consistent with other studies which have reported a correlation between the CEC and organic matter content of soil [24-25].

Table 1. Microbial loads of treated and untreated waste waters

Water source	Total fecal coliforms	Bacteria ($cfu \cdot mL^{-1}$)	Yeast ($sfu \cdot mL^{-1}$)	Fungi ($sfu \cdot mL^{-1}$)
T_0	0.00a[a]	16.33a	0.00a	0.00a
T_1	1100.00g	1240.00e	990.00e	53.00e
T_2	225.33f	163.33d	115.00abc	15.33bc
T_3	56.00bc	71.33bc	168.67bc	14.67abc
T_4	150.00e	160.00d	201.67c	12.33abc
T_5	97.00cd	66.67bc	25.00ab	15.67bc
T_6	46.67ab	53.33b	27.67ab	12.33abc
T_7	1263.02h	1260.00e	586.67d	101.67f
T_8	143.33de	80.00c	122.67abc	17.00bcd
T_9	145.33de	110.00bc	256.67c	31.00d
T_{10}	225.33f	90.54bc	120.00abc	23.67bc
T_{11}	149.32e	83.33c	33.33ab	20.00bcd
T_{12}	14.67ab	56.67b	32.00ab	7.00ab

Values in columns followed by the same letter 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 quality properties of treated and untreated waste waters

	Waste water physical properties		
Water source	**Total solid ($mg{\cdot}L^{-1}$)**	**Total dissolved solids ($mg{\cdot}L^{-1}$)**	**Total suspended solid ($mg{\cdot}L^{-1}$)**
T0	16.01a[a]	8.64a	8.17a
T1	110.81d	37.25f	85.67d
T2	48.33b	20.66bcd	28.39b
T3	53.09bc	22.91cde	32.04bc
T4	49.01b	19.47bc	30.79bc
T5	49.99bc	20.01bc	30.66bc
T6	48.72bc	18.79b	28.98b
T7	141.49e	52.43g	93.97e
T8	56.11bc	25.43e	35.50c
T9	58.92c	26.51e	36.24c
T10	54.07bc	23.34cde	34.02bc
T11	54.70bc	24.32de	35.58c
T12	50.84bc	20.48bcd	30.17bc
WHO	-	500.00	-

Values in columns followed by the same letter 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 waste water filtered with combined physical filters, WHO= World Health Organization

Table 3. Chemical properties of treated and untreated waste water

	Wastewater chemical properties						
Water source	**pH**	**EC ($\mu S \cdot cm^{-1}$)**	**Cl ($mg \cdot L^{-1}$)**	**Ca (ppm)**	**Mg (ppm)**	**N ($mg \cdot L^{-1}$)**	**P (ppm)**
T0	6.71a[a]	240.00a	53.64a	32.25def	19.26g	4.30d	0.65a
T1	7.81g	1321.33h	46.28a	28.15bcd	16.83f	5.05f	1.49bc
T2	7.40de	613.67f	216.28e	33.23ef	19.83h	4.54de	1.67c
T3	7.30cd	328.33b	324.82f	26.12bc	16.99f	4.42d	2.04c
T4	7.30cd	415.67d	127.81b	26.25bc	15.62e	4.51de	1.67c
T5	6.90ab	286.67ab	223.65e	28.31cd	12.25c	4.75de	24.54g
T6	7.05bc	392.00cd	193.69cd	32.29def	19.23g	4.57de	4.80d
T7	7.44def	949.33g	53.23a	6.52a	3.64a	2.50a	1.82c
T8	7.70fg	550.00e	177.85b	23.31b	13.83c	3.13b	0.84a
T9	7.70fg	648.67b	186.32c	40.17g	24.26j	3.62c	0.46a
T10	7.65efg	529.00d	179.83c	28.14bcd	16.83f	3.16de	0.40a
T11	7.40de	331.33bc	213.92de	31.54def	10.85b	3.66c	18.83f
T12	7.20cd	338.33bc	107.27b	34.05f	20.44i	3.41bc	6.60e
WHO	6.5-8.5	1400.00	250.00	75.00	50.00	10.00	200.00

Values in columns followed by the same letter 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, WHO= World Health Organization

Increase in nitrogen was recorded in soil for which treatment fishpond effluent filtered with rice husk (T_5) was applied (Table 5), while soils treated with treatments fishpond effluent filtered with rice husk (T_5) and municipal wastewater filtered with rice husk (T_{11}) recorded significantly higher P available with the values of 35.3 mg/kg and 36.1 mg/kg respectively. Several researchers reported accumulation of N, P and K in the soil with wastewater application and attributed this to the original levels of these nutrients in the wastewater applied [26]. Highest K and Na were recorded in fishpond effluent filtered with granite (T_2) which did not differ significantly from other treatments. Untreated waste water can be a source of excess sodium in the soil as compared to other cations as Ca^{2+}, K^{+}, Mg^{2+} and therefore it must be properly controlled [27]. Significant increase in Ca was recorded in soils irrigated with fishpond effluent filtered with rice husk (T_5) with the value of 4.73 cmol/100g. Insignificant increase in magnesium was observed in treatment municipal wastewater filtered with charcoal (T_9) - Table 5). This results also showed decrease in organic matter content in soil irrigated with untreated waste waters (Table 6). A possible explanation is that more microbial input from untreated waste water influences soil microbiological activity which can induce soil organic matter losses [25]. Soil organic carbon was significantly higher for soil treated fishpond effluent filtered with rice husk.

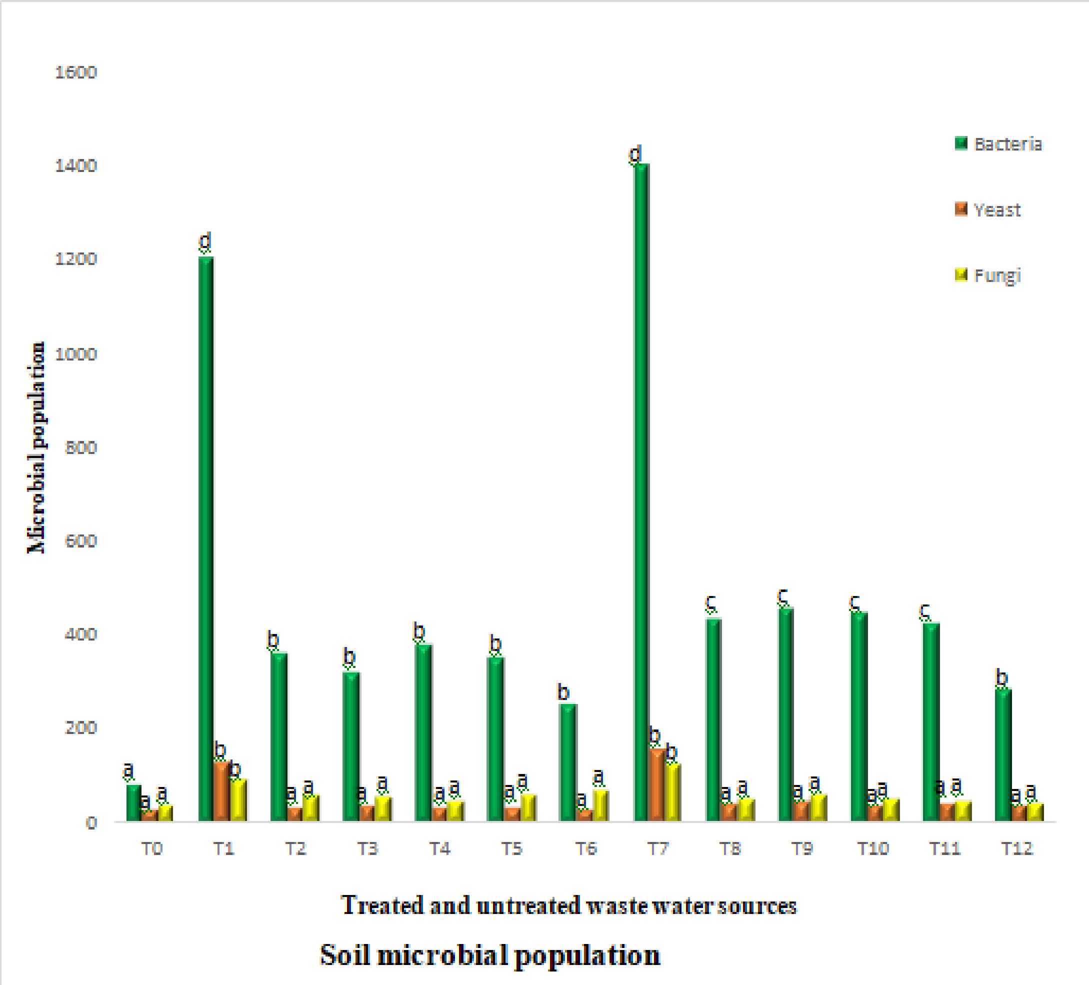

Fig. 1. Microbial properties of soil irrigated with treated and untreated wastewaters

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 4. Physical properties of soil irrigated with treated and untreated wastewaters

	Soil textural classes		
Water source	**Sand %**	**Clay %**	**Silt %**
T_0	56.80^{a}	25.20^{a}	13.00^{a}
T_1	60.80^{b}	25.20^{a}	14.00^{ab}
T_2	60.80^{b}	25.20^{a}	14.00^{ab}
T_3	60.80^{b}	27.20^{ab}	12.00^{a}
T_4	56.80^{a}	27.20^{ab}	16.00^{bc}
T_5	60.80^{b}	25.20^{a}	14.00^{ab}
T_6	58.80^{ab}	27.20^{ab}	14.00^{ab}
T_7	56.80^{a}	27.20^{ab}	16.00^{bc}
T_8	56.80^{a}	25.20^{a}	16.00^{bc}
T_9	58.80^{ab}	27.20^{ab}	14.00^{ab}
T_{10}	58.80^{ab}	23.20^{a}	18.00^{c}
T_{11}	60.80^{b}	23.20^{a}	16.00^{bc}
T_{12}	58.80^{ab}	25.20^{a}	16.00^{bc}

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 5. Chemical properties of soil irrigated with treated and untreated wastewaters

Water source	**pH**	**N %**	**P mg/kg**	**K cmol/100g**	**Na cmol/100g**	**Ca cmol/100g**	**Mg cmol/100g**
T_0	4.40^{abc}	0.50^{a}	23.80^{ab}	0.63^{ab}	0.68^{ab}	3.00^{a}	6.30^{abc}
T_1	5.46^{de}	0.49^{a}	23.36^{ab}	0.46^{a}	0.67^{ab}	2.40^{a}	5.60^{a}
T_2	4.46^{abc}	0.60^{a}	26.80^{ab}	0.76^{b}	0.77^{b}	2.80^{a}	6.00^{ab}
T_3	4.61^{abc}	0.50^{a}	28.86^{cd}	0.61^{ab}	0.54^{ab}	3.10^{a}	6.70^{abc}
T_4	4.34^{abc}	0.56^{a}	26.63^{ab}	0.60^{ab}	0.65^{ab}	2.60^{a}	6.83^{abc}
T_5	4.73^{bc}	0.62^{a}	35.32^{e}	0.64^{ab}	0.62^{ab}	4.73^{b}	6.20^{abc}
T_6	4.62^{abc}	0.50^{a}	23.64^{ab}	0.58^{ab}	0.57^{ab}	3.10^{a}	6.00^{ab}
T_7	5.76^{c}	0.42^{a}	22.24^{a}	0.50^{ab}	0.74^{ab}	2.20^{a}	5.80^{a}
T_8	4.66^{abc}	0.50^{a}	26.06^{bc}	0.56^{ab}	0.62^{ab}	3.0^{a}	6.70^{abc}
T_9	4.89^{cd}	0.50^{a}	31.19^{d}	0.61^{ab}	0.62^{ab}	3.30^{a}	7.80^{c}
T_{10}	4.12^{ab}	0.50^{a}	26.91^{ab}	0.54^{ab}	0.67^{ab}	2.80^{a}	6.30^{abc}
T_{11}	4.62^{abc}	0.60^{a}	36.06^{e}	0.62^{b}	0.67^{ab}	3.53^{a}	6.80^{abc}
T_{12}	4.06^{a}	0.56^{a}	27.61^{ab}	0.63^{ab}	0.57^{ab}	2.90^{abc}	6.00^{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

3.3 Effects on Soil Microbial Properties

Bacteria, yeast and fungi populations were significantly higher for soil irrigated with untreated fishpond effluent (T_1) and untreated municipal waste water (T_7) – Fig. 1. Significantly higher concentration of bacterial, fungi and yeast was observed in soils irrigated with untreated waste waters. This indicates that the microbial characteristics of soil could be affected by the quality of irrigation water and that untreated waste water could be considered as a contamination source of soil. In agreement with other studies, high numbers of bacteria in untreated waste waters could lead to accumulation of the bacteria in soil [28-30].

Table 6. Chemical properties of soil irrigated with treated and untreated wastewaters

Water Source	Organic carbon %	Organic Matter %	CEC cmol/kg
T_0	2.59[ab]	4.46[ab]	12.44[a]
T_1	2.44[a]	4.41[ab]	12.26[a]
T_2	2.64[ab]	4.56[c]	13.82[a]
T_3	2.60[ab]	4.49[c]	13.36[a]
T_4	2.56[ab]	4.46[bc]	12.82[a]
T_5	3.64[c]	5.39[e]	13.98[a]
T_6	2.66[ab]	4.59[c]	12.58[a]
T_7	2.53[ab]	4.44[a]	12.16[a]
T_8	2.63[ab]	4.59[ab]	12.84[a]
T_9	2.60[ab]	4.56[bc]	14.20[a]
T_{10}	2.61[ab]	4.56[ab]	12.64[a]
T_{11}	2.97[b]	5.28[e]	13.23[a]
T_{12}	2.61[ab]	4.58[ab]	12.76[a]

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

Treated waste waters (fish pond effluent and municipal waste water) improved waste water quality parameters (physical, chemical and microbial) which in turn improved the physicochemical and microbial properties of the soil. This study identified simple and efficient waste water treatment procedure using physical filtration materials (granite, charcoal, rice husk, and river sand) either in sole or in combination forms which upon application to the soil has no detrimental effects on the soil physical, chemical and microbial properties. Hence, findings from the study will find applications in efforts to address the increasing need for human and environment concerns associated with waste water re-use in agriculture.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Rosabal A, Morillo González E, Undabeytia López T, Maqueda Porras C, Justo Á, Herencia JF. Long-term impacts of wastewater irrigation on Cuban soils. Soil Science Society of America. 2007;3(1):22–28.
2. Kiziloglu FM, Turan M, Sahin U, Angin I, Anapali O, Okuroglu M. Effects of wastewater irrigation on soil and cabbage-plant (*Brassica olerecea* var. capitate cv. yalova-1) chemical properties. Journal of Plant Nutrition and Soil Science. 2007;170:166–172.
3. Tymchuk I, Shkvirko O, Sakalova H, Malovanyy M, Dabizhuk T, Shevchuk O, Vasylinych T. Wastewater a source of nutrients for crops growth and development. Journal of Ecological Engineering. 2020;21(5):30 - 38
4. Singh PK, Deshbhratar PB, Ramteke DS. Effects of sewage wastewater irrigation on soil properties, crop yield and environment. Agricultural Water Management. 2011;103:100–104.
5. Nath K, Singh D, Shyam S, Sharma YK. Phytotoxic effects of chromium and tannery effluent on growth and metabolism of Phaseolus mungo Roxb. Journal of Environmental Biology. 2009;30:227-234.
6. Ghafoor A, Rauf A, Muzaffar W. Irrigation with Madhuana drains water: Impact on soils and vegetables (spinach and cauliflower) at Faisalabad. Journal of Drainage Recycling. 1995;7:7-12.
7. Ibrahim M, Salmon S. Chemical composition of Faisalabad city sewage effluents: Nitrogen,

phosphorus and potassium contents. Journal of Agricultural Resources. 1992;30:381-390.

8. Amiri SS, Maralian H, Aghabarati A. Heavy metal accumulation in under crown *Olea europaea* L. forest irrigated with waste water. African Journal Biotechnology. 2008;7(21): 3912 – 3916.

9. Ghafoor A, Qadir M, Sadiq M, Murtaza G, Brar MS. Lead, copper, zinc and iron concentrations in soils and vegetables irrigated with city effluent on urban agricultural lands. Journal of the Indian Society of Soil Science. 2004;52(1):114-117.

10. Rusan MJM, Hinnawi S, Rousan L. Long term effect of wastewater irrigation of forage crops on soil and plant quality parameters. Desalination. 2007; 215(1-3): 143-152.

11. FAO. Wastewater characteristics and effluents quality parameters. Food and Agricultural Organization of the United Nations; 2007.

    Available:http://www. fao.org/docrep/to55ie /to55ieo3.html.

    Accessed 06/04/2008

12. Zhao S, Zhang Q, Liu M, Zhou H, Ma C, Wang P. Regulation of Plant Responses to Salt Stress. International Journal of Molecular Sciences. 2021;22(9):4609-4615

13. Rietz DN, Haynes RJ. Effects of irrigation-induced salinity and sodicity on soil microbial activity. Soil Biology and Biochemistry. 2003;35(6):845-854.

14. WHO. Guidelines for the Safe Use of Wastewater. Excreta and Greywater in Agriculture. Volume 2. Wastewater Use in Agriculture; WHO Press: Geneve, Switzerland; 2006.

15. Bouyoucos GJ. Hydrometer method improved for making particle size analyses of soils 1. Agronomy Journal. 1962;54(5):464-465.

16. Jackson ML. Soil chemical analysis; advanced course: Department of Soil Science, University of Wisconsin, Madison, Wisconsin. 1968;894.

17. Walkley A, Black IA. An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. Soil Science. 1934;37(1):29-38.

18. Iatrou M, Papadopoulos A, Papadopoulos F, Dichala O, Psoma P, Bountla A. Determination of soil available phosphorus using the Olsen and Mehlich 3 methods for Greek soils having variable amounts of calcium carbonate. Communications in Soil Science and Plant Analysis. 2014;45(16):2207-2214.

19. Seeley HW Vandemark PJ. Microbes in Action—A Laboratory Manual of Microbiology; 1981.

20. Khodadadi N, Ghorbani S, Kiani S. Effect of Irrigation Water Quality on Some Physical Properties of Soil in Rice Cultivated Land (Oryza Sativa), Journal of Soil and Water Resources Conservation (Scientific-Research). 2015;4:15-28.

21. Abegunrin TP, Awe GO, Idowu DO, Adejumobi MA. Impact of wastewater irrigation on soil physico-chemical properties, growth, and water use pattern of two indigenous vegetables in southwest Nigeria, Catena. 2016;139:167-178.

22. Gharaibeh MA, Ghezzehei TA, Albalasmeh AA, Ma'in ZA. Alteration of physical and chemical characteristi cs of clayey soils by irrigation with treated waste water, Geoderma. 2016;276:33-40.

23. Angin I, Vahap AY, Turan M. Effects of long-Term Wastewater Irrigation on Soil Properties. Journal of Sustainable Agriculture. 2005;26(3):31–42

24. Becerra-Castro C, Lopes AR, Vaz-Moreira I. Silva EF, Manaia CM, Nunes OC. Wastewater reuse in irrigation: A microbiological perspective on implications in soil fertility and human and environmental health. Environment international. 2015;75:117-135.

25. Wu G, Zhu X, Ji H, Chen D. Molecular modeling of interactions between heavy crude oil and the soil organic matter coated quartz surface. Chemosphere. 2015;119:242-249.

26. Kalavrouziotis IK, Koukoulakis H, Robolas P, Papadopoulos A, Pantazis V. Interrelationship of heavy metals and properties of a soil cultivated with Brassica oleracea var Italica (Broccoli), under the effect of Treated Municipal Wastewater' Water, Air and Soil Pollution. 2008;190(1–4):309–321.

27. Quian YL. Recycled wastewater instigates different responses in turfgrass, trees and soils; 2008.

    Available:http://www.tufrgrasstrends.com.

28. Cirelli GL, Consoli S, Licciardello F, Aiello R, Giuffrida F, Leonardi C. Treated municipal wastewater reuse in vegetable production. Agricultural Water Management. 2012;104:163-170.

29. Gatta G, Libutti A, Beneduce L, Gagliardi A, Disciglio G, Lonigro A, Tarantino E. Reuse of treated municipal wastewater for globe artichoke irrigation: Assessment of effects on morpho-quantitative parameters and microbial

safety of yield. Scientia Horticulturae. 2016;213:55-65.

30. Orlofsky E, Bernstein N, Sacks M, Vonshak A, Benami M, Kundu A, Gillor O. Comparable levels of microbial contamination in soil and on tomato crops after drip irrigation with treated wastewater or potable water. Agriculture, Ecosystems & Environment. 2016;215:140-150.