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Enhancement of Wasted Backwash Water Using Basic Sand Filtration System

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Abstract
During the last stage of treatment in the drinking water treatment plants, backwashing the sand filter effluent consumes roughly 15 to 20% of the treated drinking water. This backwashing water (BWW) is finally discharged as useless wastewater. The present study subjected BWW to a soil infiltration system as an aquifer treatment. The infiltration depths of the renovated water were studied by collecting samples at different depths from the in-filtered water. The results showed that the employed sandy soil in the present study efficiently renovated BWW. The depth should be 300 cm or deeper for an efficient renovation process. The characteristics of the in-filtered water, depth, and the type of soil employed represent important factors in terms of water renovation. It was recommended; then; to employ the suggested renovation system for treatment of the discharged BWW. The effectiveness and affordability of the sand infiltration system as a technique for BWW treatment have been demonstrated. It was; then; recommended that the BWW should not be discharged as wasted water, but should be considered as additional source to be treated along with the Canal water as an additional water resource. It was; then; recommended to treat the BWW; accordingly; instead of discharging to any water ways. Consequently; we should avoid the discharge of BWW to waterways as wastewater.
Keywords: Drinking; treatment plants; filter; valorization; vadose zone; filter depth.

1. Introduction

Due to limited water resources in many countries, including Egypt, it is important to consider the huge amount of wasted water as a valuable additional source of water if adequately treated. Such a source of water, if treated, can be reused for other purposes, such as irrigation [1]. In water treatment plants, conventional water treatment steps consist of flocculation followed by sedimentation [2]. The treated water is further sand-filtered, followed by chlorination [3]. The normal practice of conventional drinking water treatment plants is to clean their sand filters to remove the suspensions and precipitants by backwashing. This backwashing process consumes a large quantity of cleaned water ranging between 15 to 20% of their already clean and well-treated drinking water. Such backwashing water is discharged into the environment or the close by waterway as wasted water, causing environmental problems. Thus, it is recommended to treat this water for recycling and reusing. Furthermore, recycling this water has several advantages, including saving such amount of wasted water, and decreasing the amount of contaminants while providing an additional water source that can be used for irrigation [3]. It has been proved that such backwashing water could be treated and recycled using sand filter systems [4].

However, the soil infiltration technology is frequently used to treat wastewater at the tertiary level [5]. In subsurface infiltration, treated wastewater is infiltrated through the soil's aerated unsaturated zone [6]. During the infiltration system, the wastewater is treated through several processes, including adsorption to suspended solids removal, and microbial biodegradation. It has been reported that subsurface wastewater infiltration systems have high efficiency in pollutant removal [7-9]. Land filtration is an appropriate treatment of wastewater as a cost-effective and high treatment performance [10]. Contaminant removal during infiltration is attributed to the combination of physical, chemical, and biological factors. Other factors influence the quality of the in-filtered water including the type of soil, the retention time, the flow rate, and the depth of the soil.

The advantages of the infiltration system are the efficiency, low cost, and simplicity while improving the quality of water for future use. Therefore, the soil of the infiltration system provides a natural medium for water

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purification processes [11]. This is due to the fact that the soil aquifer treatment (SAT) system permits the partially treated in-filtered wastewater to gradually seep through the aquifer, significantly improving the quality of the recharged wastewater [12-15]. During the recharge of wastewater, the pollutants including heavy metals, organics, pathogens, and other hazardous compounds could be consumed and/or efficiently removed [16-18]. The unsaturated zone acts as the medium in which biological and physico-chemical reactions occur [19-20].

A minimum in-filtration recommended depth is 3 m is recommended to safeguard the groundwater of the underlying aquifer's quality [21]. Some researchers showed the vital role of the thin upper layer of the soil in the removal process in SAT [22-25]. It was reported that most microbiological activity; in such an infiltration system; occurs in the SAT topsoil layer due to the conditions in which oxygen supply, water, and nutrients are available. In addition, the biodegradation process is certainly an essential part of the SAT system, where it decomposes the organic compounds in the wastewater by the native microorganisms in the soil [26-28].

The present study concerns the treatment of a sand filter washing water through local sand infiltration in a real case study. Accordingly, EL-Taqaddum Village in North-West Sinai is home to the EL-Taqaddum drinking water treatment plant (DWTP). Ismailia City is almost 65 kilometers away from the settlement. An expansion of the Ismailia Canal serves as the freshwater source for this DWTP. The amount of this water supply is very limited. Usually, the drinking water treatment plant receives water for only six days every 12 days. The other following six days, water is used for agricultural land irrigation. Due to these restricted water resources, the people in EL-Taqaddum Village used to store their drinking water in tanks to cover their needs during the following days.

Chemical and biological pollutants are naturally dilute due to the soil's vadose (unsaturated) physico-chemical features. Soil can have detrimental chemical, physical, and microbiological characteristics and can be calcareous or alkaline in many arid environments. The physical and chemical makeup and size of the soil grains affect how well the infiltration system works. For example, clay soil shows a good chemical collecting ionic strength. For ionic strengths between 1 and 50 mM, nanoparticle retention increased with ionic strength. The pH affects nanoparticle agglomeration, leading to their entrapment in soil pores. The pH value is the most important parameter in the study of water quality and chemistry [29].

The aim of the present study is the renovation of the backwashing wastewater in the drinking water treatment plant. This wasted water is the backwashing water of the sand filters, where it; is usually; discharged as useless wastewater. The present study shows a simple, low-cost, and effective process is employed for recycling and renovation of such wasted water as an additional source of treated water. Therefore, the purpose is to consider the in-filtered water as a source of domestic one in case the physico-chemical and biological characteristics would meet the local permissible standard.

2. Materials and Methods

2.1. Site description

The present case study deals with the outlet of the sand filter of the drinking water treatment plant (DWTP), located in Sinai. Several locations in Sinai receive treated drinking water from this DWTP. These areas included some small villages and towns. The DWTP employs the conventional treatment process to purify the water. This process includes receiving the raw fresh water (originally from Nile River), chemical coagulation using alum, sedimentation, sand filtration, followed by chlorination as the last step. The treated water is finally pumped directly to the distribution piping system. The final treated drinking water should cope with the Egyptian regulations [30] in terms of the physico-chemical and bacteriological characteristics.

The sand filtration is usually backwashed three times a day as a routine system. The amount of such water estimated around 15 to 20% of the total final produced drinking water by such DWTP. The final destination of this backwashing water is the discharge as wasted water to the nearby canal.

2.2. Infiltration system

An infiltration site was selected according to different considerations including nearby the DWTP, sandy soil, and the ability to pump the in-filtered water up. The sand contents were determined using sieve analysis procedure [31]. Fine silt and clay particles passing from the 0.075 mm sieve were assessed and their contents were evaluated using hydrometer tests [32]. Meanwhile, the physical and chemical characteristics' as well as the bacteriological examination of the backwashing water were also determined frequently according to APHA [33]. In addition, samples of the filtered water at different soil depths were taken out to determine the physical, chemical, and bacteriological characteristics.

The present study was conducted to introduce an innovative treatment system as a sand filter for the purpose of handling the backwashing water for the first time in treatment of the Sand Filter Back Washing Water (SFBWW). The purpose is to obtain the final treated fresh water. Efficiency of the treatment system is evaluated to obtain additional freshwater resource that could be considered as additional raw fresh water. This study was implemented and carried out practically in one of the drinking water treatment plants in Egypt using real samples.

2.3. Soil sampling area

The backwashing water was allowed to be in-filtered by flooding through a sandy soil basin into a groundwater aquifer near the DWTP site. The in-filtration site consisted of infiltration basin of sandy, clay, and silt ranging from 1 to 10 m in depth.

The water samples were collected from variable depth namely: 0, 30, 60, 100, 150, 200, 250, and 300 cm. The water samples were collected from the infiltration site after the end of flooding period. Water sampling was conducted by using the backhoe (i.e., the type of excavation digger equipment) consisting of digging bucket by the end of two-arms. Before collecting the soil samples, it was cleaned to remove any potential smearing.

2.4. Water sampling procedure

The in-filtered as the sand-filtered water and the infiltrated water were sampled frequently. The later samples were collected at different depths namely: 30, 60, 100, 150, 200, 250, and 300 cm. Meanwhile, periodical samples of the raw canal water, and the treated drinking water were collected and subjected to the physico-chemical, and biological examination according to APHA, 2021 [33]. The physico-chemical analysis characteristics of the collected water samples include electrical conductivity (EC), Total Dissolved Solids (TDS), total suspended solids (TSS), total hardness (T. Hard.), aluminum (Al), turbidity (Turb.), nitrites (NO_2), nitrates (NO_3), sulfates (SO_4), chlorides (Cl), sodium (Na), calcium (Ca), magnesium (Mg), and potassium (K). The obtained results were correlated to the local-Egyptian permissible limits.

2.5. Bacteriological sampling procedures:

One liter of each sample was collected in sterile, labeled bottles. The bottles were transferred on ice box to the laboratory. Each sample was well combined prior to inoculation by repeatedly inverting the bottle. The bottle mouth was flamed after removing the cap.

2.6. Bacteriological analyses:

Escherichia coli (*E. coli*) counts were enumerated in MacConkey broth medium. For the presumptive test, 11 tubes dilution series were prepared as follows: One bottle containing 50 ml of double strength broth was inoculated with 50 ml of water sample, five tubes each containing 10 ml of double strength broth were inoculated with 10 ml of water sample and five tubes each containing 5 ml of single-strength broth were inoculated with 1 ml of water sample. Five tubes each holding 10 ml of double strength broth were inoculated with 10 ml of water sample; five tubes each holding 5 ml of single strength broth were inoculated with 1 ml of water sample; and the remaining five tubes, each holding 5 ml of broth, were inoculated with 0.1 ml of water sample. This was the procedure used to prepare the other fifteen tubes for the dilution series. Broth produced with twice as much broth powder as usual is referred to as double strength broth. Single-strength broth contains the normal amount of broth powder as instructed by the manufacturer. Media and tubes were sterilized by autoclaving. The MacConkey broth tubes were incubated at 37°C, and gas production was monitored. The MPN index was then used to determine the presumed coliform populations. Sub-cultures from positive tubes were cultured for 24 to 48 hours at 45.5°C to ensure confirmation. The MacConkey broth tubes were observed for both acid and gas production. The number of positive tubes was used to calculate the most probable number (MPN) of fecal coliform bacteria in 100 ml or 105 ml of a water sample using the MPN index table [31]. Acid production in positive tubes was shown by a change in the color of the MacConkey broth from purple to yellow and gas production by the collection of the bubbles in the Durham tube. MacConkey broth ingredients comprises: 20 g/L peptone, 5 g/L lactose, 5 g/L Na Cl, 5 g/L sodium taurocholate, 0.01 g/L bromocresole purple, pH 7.2.

3. Results and Discussion

3.1. Physico-chemical characteristics of the studied water

The physico-chemical characteristics of the BWW are given in Table (1). The turbidity ranged from 8.9 to 15 NTU at an average of 13.5 NTU. The TSS ranged from 89.2 to 107.3 mg/l with an average of 99.3 mg/l. The TDS ranged from 257 to 357 at an average of 331 mg/l. The average values of chlorides, and sulfates, are 52.1 and 57.8 mg/l respectively. In addition, the values of Na, K, and Ca are 21.4, 3.0, and 53.3 mg/l, successively. This BWW is turbid, high level of TSS, and TDS, and contains reasonable amounts of Na, K, and Ca.

Table 1: Physico-chemical characteristics of the sand filter backwashing water as the inlet to the sand infiltration system

Parameters	Unit	Backwashing water samples					
		1	2	3	4	5	Mean± S.D.
pH		7.2	7.3	7.4	7.3	7.29	7.198 ± 0.04
TDS	mg/l	290	340	348	254	357	331 ± 31.0
EC	µmhos	528	479	521	443	523	512 ± 43.2
Turbidity	NTU	15	13	8.9	14	14.7	13.25 ± 3.1
TSS	mg/l	107.1	99.9	101.3	89.6	99.2	99.3 ± 6.6
T. Hard.	mg/l $CaCO_3$	150.8	150.6	147	152	154	150.08 ± 3.0
Alkalinity	mg/l	157	159	160	163	162	161.6 ± 3.4
Chlorides	mg/l	50	52	54	49	57.5	52.1 ± 4.7
Sulfates	mg/l	52	51	52	55	57	51.8 ± 2.3
Nitrates	mg/l	0.10	0.11	0.12	0.11	0.10	0.11 ± 0.01
Nitrites	mg/l	Nil	Nil	Nil	Nil	Nil	Nil
Al	mg/l	0.20	0.21	0.22	0.25	0.22	0.22 ± 0.02
Sodium	mg/l	22.1	19.9	21.7	19.7	22.8	21.4 ± 1.8
Potassium	mg/l	3.1	2.8	2.9	3.1	3.0	3.01 ± 0.1
Calcium	mg/l	52.3	56.2	55.9	51.5	57.2	53.3 ± 2.5
Cells or eggs of nematode	Count/L	Nil	Nil	Nil	Nil	Nil	Nil
Sludge	%	5.3	4.8	5.1	4.4	5.1	5.0 ± 0.7

3.2. Soil Infiltration System

Table 2 shows the soil infiltration system's distribution. The soil texture indicated that it is mainly sandy ranging between 67.1 to 73.6%. The silt and clay texture ranged from 13.3 to 17.7% and from 12.2 to 17.1% respectively (Table 2).

Table 2: Characteristics of the soil samples collected from the infiltration site

Soil depth (cm)	Sand (%)	Silt (%)	Clay (%)
0-30	67.1	17.7	15.2
30-60	73.6	14.2	12.2
60-100	69.6	13.3	17.1
100-150	70.1	14.0	15.9
150-200	69.7	14.6	15.7
200-250	68.7	15.7	15.6
250-300	68.1	16.0	15.9

3.3. Physico-chemical characteristics of the in-filtered water

The characteristics of the in-filtered water at different depths are given in Table 3. It is evident that the removal rate rises with increasing depth. At 300 cm depth, the quality of water was highly improved. At this depth, the removal rates of the turbidity, EC, TDS, TSS, sulfates, and nitrates reached 84.0, 54.9, 56.6, 15.3, 52.5, and 100 % respectively. Meanwhile, a notable decrease was also achieved in the removal rates of Na, Ca, Mg, and K. Figure (1) presents the removal rates of the different parameters concerning the depths. On the other hand, both bacterial counts as total count and *Escherichia coli* counts deceased by depth (Table 4). The removal reached 100% at 300cm depth.

Table 3: Physico-chemical characteristics of the in-filtered water at different depth

Soil Depth (cm)	pH	Turb. (NTU)	E.C. µmhos	TDS mg/l	TSS mg/l	NO_2 mg/l	NO_3 mg/l	SO_4 mg/l	Cl mg/l	Na mg/l	Ca mg/l	Mg mg/l	K mg/l
Raw water	7.20	13.25	512	331.2	99.3	BDL	0.11	51.8	52.1	21.4	53.2	3.2	3.01
0-30	7.19	11.9	510	331.2	97.2	BDL	0.10	52.0	51.9	20.9	52.8	3.1	3.0
30-60	7.21	9.8	507	308.4	81.5	BDL	-	39.9	50.2	19.8	51.9	2.9	2.9
60-100	7.33	7.5	495	283.4	78.6	BDL	-	30.5	49.5	17.5	49.7	2.9	2.9
100-150	7.34	5.9	443	212.7	73.1	BDL	-	24.7	48.3	18.1	50.1	3.0	3.0
150-200	7.34	3.8	429	182.3	59.9	BDL	BDL	25.9	44.5	18.0	49.2	2.9	2.8
200-250	7.35	2.7	434	161.8	45.8	BDL	BDL	25.2	41.2	18.0	49.1	2.85	2.9
250-300	7.31	1.9	431	149.3	42.2	BDL	BDL	24.7	40.5	17.9	49.0	2.87	2.7
300-350	7.30	1.7	425	144.2	39.1	BDL	BDL	22.9	38.9	16.8	49.1	2.77	2.6

BDL = below detection limits

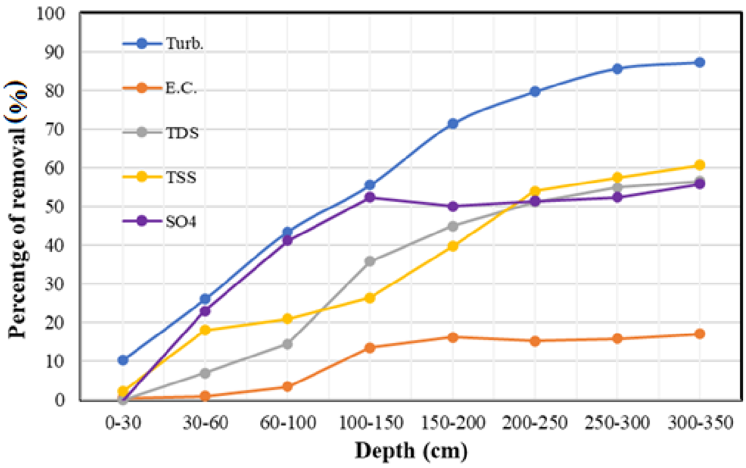

Fig. 1. Removals percentage of Turb., EC, TDS, TSS, and SO_4 at different successive depths of the infiltration system.

Table 4: Total Bacterial counts and the *Escherichia coli* count at three successive depths

Site of collection (Depth, cm)	*E. coli* count (MPN/100 ml)	% of reduction
Intake (0 cm)	8400	
60	790	90.6
250	68	99.2
300	zero	100
350	zero	100

3.4. Correlation between the characteristics of the in-filtered water and other waters:

Correlation between the physical, chemical, and biological characteristics of the in-filtered water at 300cm depth (Table 3) and the raw canal water on one hand (Table 5) and the treated drinking water on the other hand (Table 5) indicated that the in-filtered water at 300cm is within the same level of the Canal water in terms of Turbidity, E.C., TDS, TSS, nitrites, nitrates, sulfates chlorides, as well as the metals including Na, K, Ca, and Mg. However, the quality of the in-filtered water at that depth is not the same as that of the drinking water that has been treated. Therefore, the in-filtered water can be used as additional raw water to the "Drinking Water Treatment Plant" instead of discharging it as wastewater.

Table 5: Physico-chemical, and biological characteristics of the raw canal water and the treated drinking water

Parameters	Unit	Raw Canal Water				Drinking water			
		1	2	3	Mean	1	2	3	Mean
pH		7.7	7.8	7.8	7.76	7.3	7.4	7.3	7.33
TDS	mg/l	348	234	342	310	340	262	325	309
EC	µmhos	527	390	531	496	522	436	520	492.6
Turbidity	NTU	6.7	12.9	9.5	9.7	0.64	0.88	0.69	0.74
TSS	mg/l	68.9	87.3	72.7	73.8	zero	zero	zero	zero
T. Hard.	mg/l as $CaCO_3$	144	141	149	144.6	146	150	155	150.3
Alkalinity	mg/l	160	129	155	148	149	130	144	141
Chlorides	mg/l	58.3	51.1	53.5	54.3	66.3	50.5	61.8	59.5
Sulfates	mg/l	44	39	48	43.6	52.5	50	55	52.5
Nitrates	mg/l	0.11	0.12	0.07	0.20	0.13	0.08	0.14	0.11
Nitrites	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Al	mg/l	0.16	0.11	0.13	0.13	0.23	0.15	0.18	0.18
Sodium	mg/l	21.9	20	23.5	21.8	25.1	20.1	28	24.4
Potassium	mg/l	3.0	2.6	2.8	2.86	2.9	3.3	2.8	3.0
Calcium	mg/l	47.5	44.0	45.9	45.8	52.5	50.5	55	52.7
Number of cells or eggs of Nematode	Count/L	----	----	----	----	Nil	Nil	Nil	Nil
E.Coli count	MPN/100mL	----	----	----	----	Nil	Nil	Nil	Nil
Sludge %	%	----	----	----	----	----	----	----	----

4. Conclusions and Recommendations

The present study presents a very low-cost renovated system employing an environmentally friendly, simple, and cost-effective method for the treatment of wasted water namely: back-washing water from the sand filter of the drinking water treatment plant. The obtained treated water proved to be well treated at 300cm depth. However, deeper samples improved to achieve considerable improvement.

From soil column and field studies, it was concluded that biological degradation coupled with mechanical filtration are responsible for the removal of the polluted parameters including the suspended solids in the top few centimeters of the soil layer where a surface-clogging layer is formed. However, the primary pollution removal mechanism includes adsorption to soil grains and/or soil organic matter as well as biodegradation under oxic and anoxic redox conditions. Adhesion of certain charged particles to sand, clay, and/or organic media can also be an additional obstacle.

It is recommended to employ the studied system for the treatment of the wasted backwashing water that consumed between 15 -20% of the plant-treated water. It is also recommended that the present treated water can be reused either as raw fresh water along with the raw Canal water, and/or for irrigating the green area around the DWTP.

5. Conflicts of interest

There are no conflicts to declare.

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