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Effect of Recharging Primary Treated Domestic Wastewater on the Soil Characteristics

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ABSTRACT

A study was carried out to investigate the effects of recharging primary treated domestic wastewater on soil characteristics by special recharge-recovery method developed and practiced in the laboratory working model. Recently, the amounts of wastewater are sharply increasing and the kinds of pollutants are also varied as the world wide industry is being developed incessantly. The subbase soil is brought from Jerashi quarry, northeast of Ramadi and placed in model which is made from plexus glass with dimensions (1.1 m * 1.1 m * 0.6 m). Wastewater characteristics, main soil and soil samples after recharging of wastewater 330L, 420L, 510L, and 600L, for one time every seven days and comparing the means for soil chemical characteristics before and after experiment. Soil reaction (pH), electrical conductivity (EC), organic matter (OM), chloride ions (CL), sulphate content (SO3), gypsum content (GC), total dissolved salt, (TSS), and total dissolved solids (TDS). The soil-aquifer system (SAT) can be used efficiently as a wastewater treatment plant. After recharging wastewater, there were slightly increase of pH and OM in comparison with EC, CL, SO3, GC, TSS, and TDS which might cause problems in the long term if the land was used for construction purposes.

Keywords: Soil Characteristics, SAT System, Subbase Soil, Wastewater

تأثير حقن المياه المنزلية العادمة المعالجة اوليا على خصائص التربة

الخلاصة

أجريت الدراسة للتحري في الآثار المترتبة على حقن المياه العادمة المنزلية المعالجة اوليا على خصائص التربة المعالجة باستخدام طريقة تغذية الاسترداد المتقدمة حيث تم عمل نموذج مختبري حيث انه في الآونة الأخيرة، كميات من مياه الصرف الصحي تتزايد بشكل كبير وتتنوع أيضا أنواع الملوثات كما يجري تطوير هذه الصناعة في جميع أنحاء العالم باستمرار. تم جلب التربة subbase من مقلع الجراشي، شمال شرقي مدينة الرمادي وتم وضعها في النموذج المصنع من الفايبر كلاس ذات الأبعاد 1.1م * 1.1م * 0.6م خصائص المياه المعالجة اوليا والتربة المستخدمة في الموديل تم

فحصها كذلك تم اخذ عينات من التربة الرئيسية بعد إعادة حقن المياه المعالجة اوليا 330L 420L 510L 600L ولمرة واحدة كل سبعة أيام ومقارنة الخصائص الكيميائية للتربة قبل وبعد عملية الحقن وهذه الخصائص هي .تفاعل التربة (pH) التوصيل الكهربائي(EC) والمواد العضوية (OM) أيونات الكلوريد(CL) ، ومحتوى الكبريتات(SO3) sulphate والمحتوى الجبسي(GC) مجموع الاملاح المذابة (TSS) والمواد الصلبة الذائبة(TDS).

من هذه الدراسة يمكن استخدام نظام طبقة التربة والمياه الجوفية (SAT) بكفاءة باعتبارها محطات معالجة المياه العادمة كذلك يمكن ان نلاحظ ان بعد إعادة حقن المياه العادمة، كانت هناك زيادة طفيفة في فحص pH و OM بالمقارنة معEC و CL وSO3 وGC وTSS و TDS وهذا قد يسبب مشاكل على المدى الطويل إذا تم استخدام الأراضي لأغراض البناء.

INTRODUCTION

In ancient times, before any wastewater treatment methods were known, raw domestic wastewater was disposed of by spreading on cropped or uncropped land. This practice, first used in Athens 2000 years ago, became common in Germany and England in the sixteenth century, and is still used in the twentieth century by some large European cities such as Berlin and Paris [1, 2]. Other old techniques of waste disposal used in modern towns, are cesspits or cesspools. These simple disposal techniques were presumably stimulated by the knowledge of the absorptive and purifying capacity of the soil. They should be regarded as old methods of indirect potable reuse of waste water, because certain amounts of waste seeped from cesspools and infiltration fields or leached below irrigated fields, and ultimately reached surface water or groundwater used for drinking water that shown in Figure (1).

In recent years, in areas where groundwater basins have been depleted by over pumping, wastewater effluents are purposely used for groundwater replenishment. Complete treatment (virtually to drinking-water quality) is usually provided prior to recharge either by spreading basins or injection wells. This method of wastewater reuse has been applied in the last few decades in several recharge-reclamation projects in the U. S., particularly in California [3, 4]. In such operations, the wells located in the vicinity of the recharge zone eventually pump a mixture of recharged effluent and native groundwater, which is supplied to all uses, including drinking, see Figure (2).

Because the effluent must be treated to a very high degree prior to recharge, and because of the difficulty of controlling the movement of the recharged effluent in the aquifer, the capacity of the soil to remove pollutants is minimized and its benefits are regarded as incidental.

The special recharge-recovery method developed and practiced successfully in the laboratory working model, presented in this paper. It incorporates the innovative soil-aquifer treatment (SAT) concept, which represents a modern approach to the old method of wastewater reuse. This research also investigated the effect of recharging primary treated domestic wastewater on the soil characteristics for Ramadi city.

DESCRIPTION OF SAT SYSTEM

The name SAT, indicates its main feature: the purification during flow of the effluent through the soil of the unsaturated zone and in the aquifer. The wastewater receives only partial treatment before recharge; the soil-aquifer system is relied on to provide additional treatment by a combination of physical, chemical and biological processes. The partially-treated effluent percolates through the unsaturated soil zone until it reaches the groundwater, and moves radially in the aquifer until it reaches recovery wells that are specially designed to pump the recharged water for supply, see Figure (3). The recharged effluent gradually displaces the native ground water toward the recovery wells. Thus, at the beginning of the operation, the wells pump native groundwater; later, they pump a mixture of native groundwater and increasing amounts of recharged water. In the steady-state phase, the wells pump mostly recharged water from the inner basin where groundwater flow gradients are higher, and small amounts of native groundwater from the outer basin. If the recovery wells are adequately spaced, the recharge and recovery facilities can be operated to confine the recharged effluent within the groundwater sub-basin between the recharge area and the recovery wells. This underground zone is dedicated to the treatment and storage of effluent, and represents only a small percentage of the regional aquifer. The rest of the ground water basin is not affected by the recharge operation and can continue to be used for potable supply [5].

SOIL MATERIALS

The subbase soil is brought from Jerashi quarry, northeast of Ramadi. This type of subbase soil is commonly used as a layer under foundation of building and flexible pavement construction. Grain size analysis is performed on subbase specimen in accordance with (ASTM D 422). The grain size distribution curve is shown in Figure (4) The subbase soil is classified as SP–Poorly Graded Sand with Gravel according to the Unified Soil Classification System (USCS).

The total unit weight, γt was carried out according to (BS 1377-9:1990) and the coefficient of permeability was carried out by used constant permeability testing according to (BS 1377-5:1990). Other physical and chemical properties of the subbase soil used are shown in Table (1).

EXPERIMENTAL PROGRAM

Preparation Model

The model which is made from plexus glass with dimensions (1.1 m * 1.1 m * 0.6 m) and thickness (1cm) were working metal frame to strengthen aspects of model against the earth pressure of the soil and the pore pressure of water which remains in the model. The height of the water with a high side valves distributed on aspects of the model and here was worth (15 cm) from the ground. Model equipped valves in floor to discharge water on demand. These valves were surrounding by filters to avoid clogged because of fine material in the soil as shown in Figure (5).

Soil Preparation

Subbase soil material which is extracted from Jerashi quarry where this region is almost an uninhabited and this is important for our research. The soil with high porous service infiltration of wastewater which easily and is also considered as a medium follicular (Media) for water treatment in multiple ways physically, chemically and biologically.

The subbase soil is placed in model in three stages with total thickness of 30cm and each layer compacted to arrived field unit weight which value 18 kN/m3 as shown in Figure (6).

The model consist of intermediate slot to enter the wastewater (recharging point), has been using a plastic tube of 50 mm diameter with holes, surrounded by a filter of gravel with size less than 2 mm in order to avoid clogging by soft material inland selected. Then, reception of effluent water by valves distributed among the four parts of the model which flowing water in a major pipeline to collect effluent water for the purpose of disposal, and sampling.

Wastewater Discharge

According to the permeability of the soil selected which is (1.61 x 10-3cm / sec), the amount of discharge input model was (0.5 m3/min). For the purpose of installing this discharge, a flow-meter device was used.

Adaptation

After processing model with subbase adaptation started by pumping treated wastewater preliminary sedimentation for a month and a half ago so was pumped 330 liters of wastewater without making any tests. Then, there were processes of pumping of wastewater one time every seven days. The amount of water was 30 liters for each pumping to test the workability of SAT method to treat this kind of wastewater and its effect on the chemical properties of the soil.

LABORATORY DETERMINATIONS

Soil reaction (pH) was determined by pH meter with combine electrode device [6]. The electrical conductivity (EC) and solid matters (TDS) were measured by Portable pH/ ISE conductivity do-meters apparatus [6]. Chloride ion (CL) was measured by Spectro-Photometer DR5000 apparatus [6]. These were measured on 1:5 extract (Soil: Water). Organic matter (OM), gypsum content, SO3 content, and total dissolved salt (TSS) were carried out in accordance the standard methods as shown in Table 1.

Analyses of influent and effluent wastewater were carried out in accordance the Standard Methods (APHA 1998) [7].

STATISTICAL ANALYSIS

Descriptive statistical analysis including mean comparison using Duncan's Multiple Range Test (DMRT) was conducted using SPSS software.

RESULTS AND DISCUSSION

Wastewater characteristics and the performance of the soil-aquifer system as a filter are shown in Table (2), for the following parameters: pH test, temperature, turbidity, electricity, total dissolved salt (TSS), total dissolved solids, biochemical oxygen demand (BOD), and chemical oxygen demand (COD).

Analysis of main soil and soil samples after recharging of wastewater 330L, 420L, 510L, and 600L, for one time every seven days and comparing the means for soil chemical characteristics before and after experiment is shown in Tables (3).

Soil reaction (pH)

After recharging wastewater increased soil pHTable (3) and Figure (7). The reason is likely due to the decomposition of organic matter. Some investigations showed that the soil after recharging wastewater increased soil pH (Rusan et.al. 2007, Rattan et al. 2005) [8, 9]. Most these investigations described the long term impact of wastewater effluents on soil properties while our study was short term.

Electrical conductivity (EC)

Electrical conductivity of soil after recharging wastewater was increased, see Table (3) and Figure (8), because of higher EC of wastewater. This is in line with findings of Rusan et al. (2007) [8], Jahantigh (2008) [10]. The higher concentration of cations such as Na and K in wastewater led to an increase in EC and exchangeable Na and K in soils with wastewater (Khai et al. 2008) [11].

Organic matter (OM)

After recharging wastewater increased OM content of soil, see Table (3) and Figure (9). This is most likely due to the higher OM content of wastewater. This is in line with findings of (Debosz et al. 2002 and Khai et al. 2008) [12, 11].

Chloride ions (CL)

According to Table (3) and Figure (10), it can be seen that the value of CL increase during recharging wastewater. This is in line with findings of Najafi and Nasr (2009) [13]. Increasing the CL of soil after recharging wastewater can be attributed to minerals in the wastewater

Sulphate Content (SO3)

According to Table (3) and Figure (11), the recharging wastewater caused an increase of sulphate content. Increasing the SO3 of soil after recharging wastewater can be attributed to be Sulfate dissolved in wastewater which is normally present in the soil in the form of sodium sulfate (Na_2SO_4), magnesium sulphate ($MgSO_4$), and calcium sulphate ($CaSO_4$).

Gypsum Content (GC)

According to Table (3) and Figure (12), the recharging wastewater caused an increase of gypsum content. Increasing the GC of soil after recharging wastewater can be attributed to be sulfate dissolved in wastewater and the presence of calcium sulfate in the form of gypsum.

Total Dissolved Salt (TSS)

According to Table (3) and Figure (13), soil with wastewater caused an increase of total dissolved salt. Increasing the TSS of soil with wastewater can be attributed to minerals in the wastewater.

Total dissolved solids (TDS)

According to Table (3) and Figure (14), soil with wastewater caused an increase of total dissolved solids. Increasing the TDS of soil with wastewater can be attributed to contain the wastewater relatively high amount of suspended solids, which fluctuates in accordance with the efficiency of the chemical clarification process at the treatment plant.

Statistical Analysis

From Table (3) which represent statistical analysis including mean comparison using Duncan’s Multiple Range Test (DMRT). It can be seen that the values of pH and OM slightly increase during recharging wastewater while the values of other parameters obviously increase.

CONCLUSIONS

The reuse of wastewaters for purposes such as agricultural irrigation can reduces the amount of water that needs to be extracted from environmental water sources. The soil-aquifer system can be used efficiently as a wastewater treatment plant. After recharging wastewater, there were slightly increase of pH and OM in comparison with EC, CL, SO3, GC, TSS, and TDS which might cause problems in the long term if the land was used for construction purposes.

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Table (1) Physical and Chemical Properties of the Sub base used.

Index Property	Index Value	Test Method
Total Unit Weight, γt, kN/m3	18	BS 1377-9:1990
Coefficient of Permeability, k, cm/sec	1.61 x 10-3	BS 1377-5:1990
Total Dissolved Salt (TSS%)	8.59	Earth manual of U.S. [14]
SO3 Content %	3.93	BS 1377-3:1990
Gypsum Content %	8.45	BS 1377-3:1990
Organic Matter (OM %)	2.3	BS 1377-3:1990

Table (2) SAT performance -filtration effect.

Parameters	Units	Wastewater		SAT removal efficiency,** %
		Influent, Before SAT	Effluent, After SAT	
pH Test	-	7.84	7.6	3
T ,Temperature	Co	19.04	18.7	1.8
Tu, Turbidity	NTU	106.8	35.67	67
EC, Electrical Conductivity	µs/cm	2058	2922	42*
TSS, Total Dissolved Salt	mg/L	770	77.6	90
TDS, Total Dissolved Solids	mg/L	1045	1496	43*
BOD, Biochemical Oxygen Demand	mg/L	87.5	24	73
COD, Chemical Oxygen Demand	mg/L	223	53.6	76

*Increase in Electrical Conductivity, EC and Total Dissolved Solids, TDS.
** SAT Removal Efficiency,% = ((Influent Before SAT-Effluent After SAT)/(Influent before SAT) x 100

Table (3) Comparing the means for soil chemical characteristic before and after experiment.

Parameters	Recharge of wastewater				
	Soil without wastewater (Main Soil) (T1)	Soil with 330 L of wastewater (T2)	Soil with 420 L of wastewater (T3)	Soil with 510 L of wastewater (T4)	Soil with 600 L of wastewater (T5)
pH Test	7.02a+	7.05a	7.09a	7.11a	7.29a
Electrical Conductivity, EC(µ.s./cm)	1188a	1426b	1446b	1640c	1953d
Organic Matter, OM %	2.3a	2.33a	2.36a	2.38a	2.40a
Chloride Ion, CL %	0.01a	0.013a	0.07b	0.094c	0.098c
Sulphate Content, SO3 %	3.93a	5.48b	5.57b	6.63c	7.81d
Gypsum Content , GC%	7.29a	11.78b	11.97b	14.25c	16.79d
Total Dissolved Salt, (TSS%)	8.59a	11.36b	12.55c	13.97d	14.5d
Total Dissolved Solids ,TDS %	7.86a	8.21a	8.44a	9.89b	11.50c

$^{+}$ Numbers followed by same letters are not significantly ($P<0.05$) different according to the DMR test.

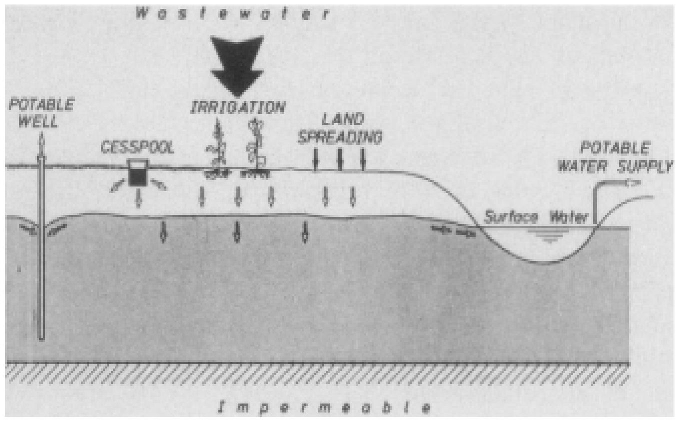

Figure (1) Old method of wastewater reuse via soil-aquifer system[1,2].

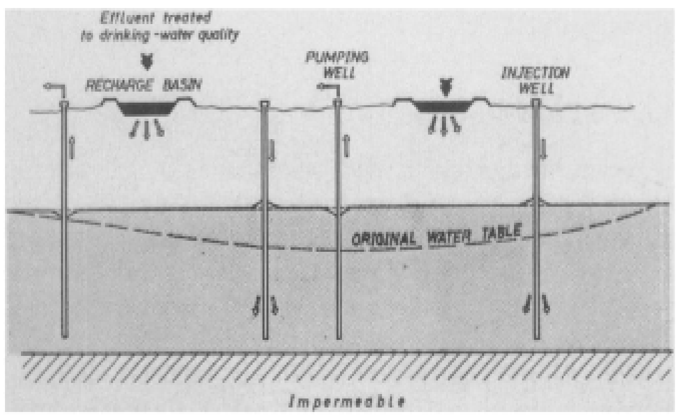

Figure (2) Groundwater recharge with high-quality effluent for aquifer replenishment[3,4].

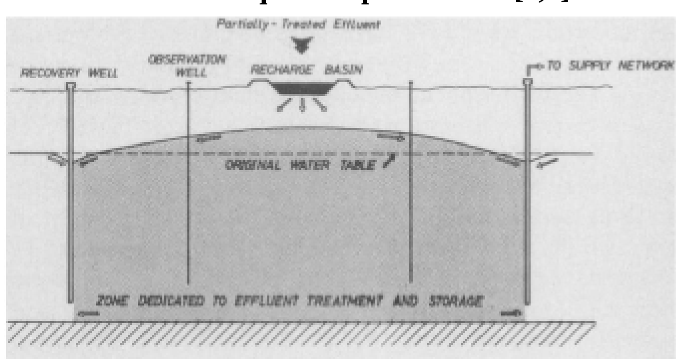

Figure (3) SAT system [5].

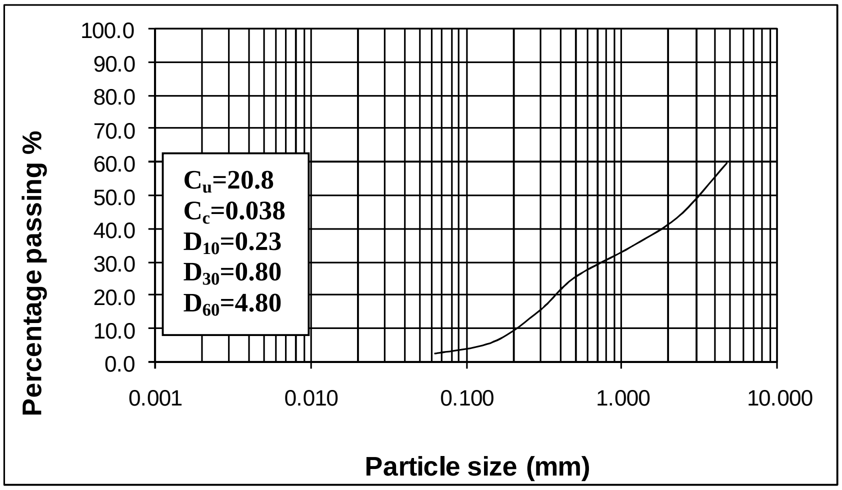

Figure (4) Grain size distribution of the subbase soil used.

Figure (5) Photos represent the frame steel of model and water discharge valves.

Figure (6) Photos represent the soil preparation in model.

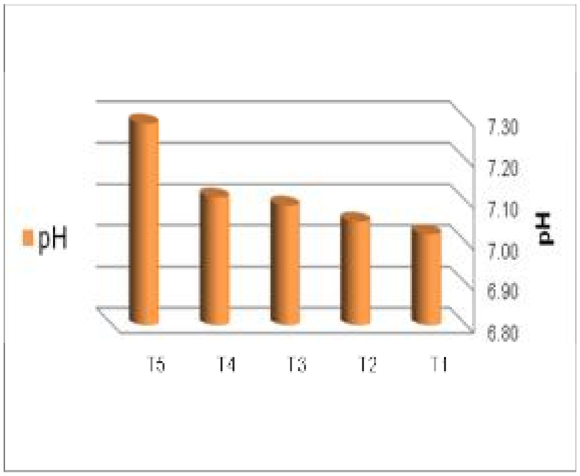

Figure (7) Effect of wastewater on soil pH.

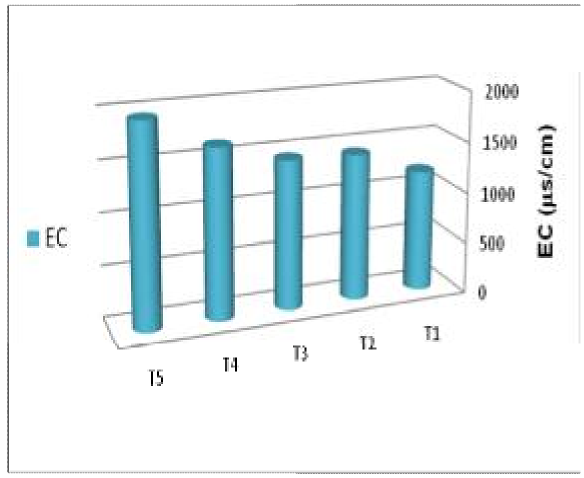

Figure (8) Effect of wastewater on soil EC.

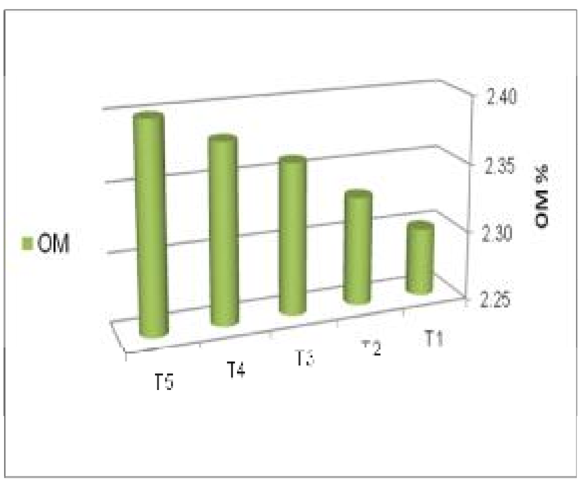

Figure (9) Effect of wastewater on soil OM.

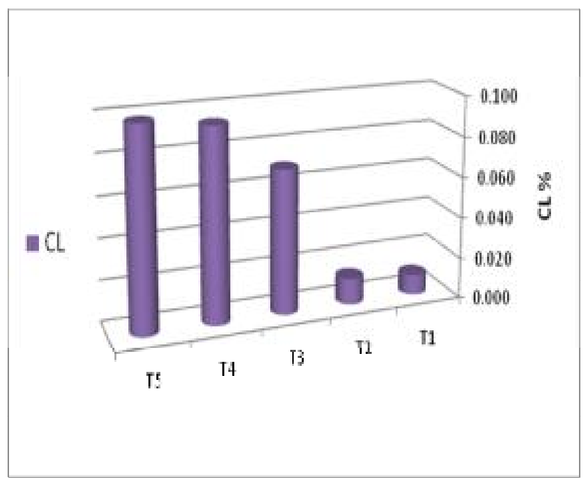

Figure (10) Effect of wastewater on soil CL.

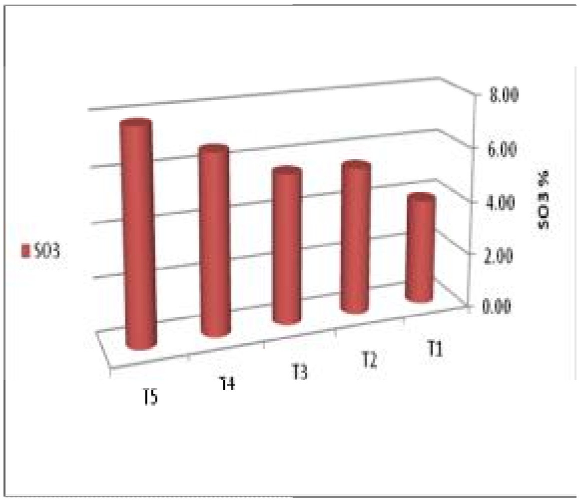

Figure (11) Effect of wastewater on soil SO_3.

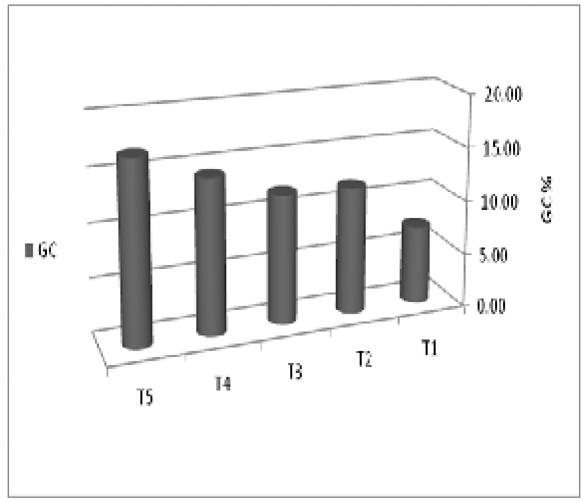

Figure (12) Effect of wastewater on soil GC.

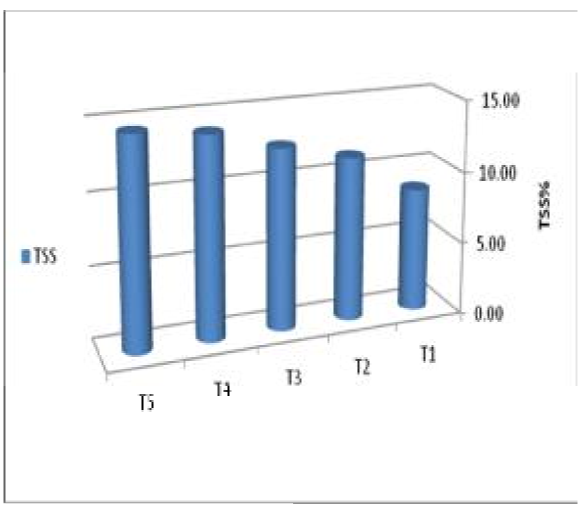

Figure (13) Effect of wastewater on soil TSS.

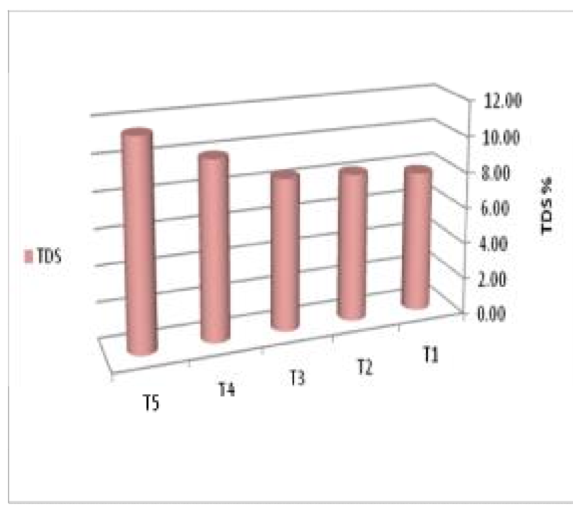

Figure (14) Effect of wastewater on soil TDS.