A Study of Changes in the Chemical Properties of Soil due to Irrigation by Polluted River Water (Army Canal in Baghdad) for a Long Period

Shaimaa Taleb Kadhum & Ayat Hussain*

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Abstract

Soil is an essential natural resource for support of human life, but with time, its degradation has been constantly increasing due to the deposition of pollutants.

The aim of this research is to study the changes of the chemical properties of the soil which has been irrigated for a long period with polluted river water, and the effect of each property on the other properties.

The study was on the agricultural soil besides Army canal in Baghdad city which is irrigated by the canal water. This canal ends at Al-Rustamia wastewater treatment plant. Samples of soil which is irrigated and not irrigated with canal water were taken. The samples were analyzed to find the chemical properties such as heavy metals(Pb,Zn,Ni,Cr,Cd) and other parameters of soil (SO_4 ,Cl,TSS,pH,OM).

Samples were taken from points far from the canal (non irrigated soil), the other samples have decreasing distances from the canal bank and the last one is just at the river margin (irrigated soil) to find out the differences in chemical properties.

The relation between soil concentrations of heavy metals and the other parameters in the chemical properties of the soil was studied the following results were found: A positive corelation between SO_4 and OM, TSS and EC was found, also Zn and Pb with SO_4, Zn and Pb with OM.

Also, a comparison was done between the properties of irrigated soil and the properties of non irrigated soil. Results show that Pb and Ni increased out of the allowable limits, Ec and TSS increment has also been found especially in the non irrigated soil.

Keywords: Chemical properties of soil, polluted river water, irrigation, Army canal

دراسة التغيرات الحاصلة في الخواص الكيميائية للتربة نتيجة الري بمياه النهر الملوثة (قناة الجيش في بغداد) لفترة طويلة

الخلاصة

التربة هي مصدر اساسي لاسناد حياة النسان, لكن بمرور الوقت, يتزايد تاكل وانحدار مستوى التربة بصورةثابتة نتيجة الترسب في الملوثات.

الهدف من هذا البحث هو دراسة التغيرات التي تحصل في الخواص الكيميائية للتربة المروية ولفترات طويلة بمياه النهر الملوثة, وتاثير كل خاصية على الخواص الاخرى للتربة.

تم اجراء الدراسة على التربة الزراعية المحاذية لقناة الجيش في مدينة بغداد والمروية بمياه القناة. هذه القناة تنتهي عند محطة الرستمية لمعالجة مياه الصرف الصحي. تم اخذ عينات من التربة المرويه وغير المروية بمياه القناة. تم تحليل عينات التربة لايجاد الخواص الكيميائية مثل تراكيز

* Building and Construction Department, University of Technology/Baghdad

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University of Technology-Iraq, Baghdad, Iraq/2412-0758

المعـادن الثقيلـة (رصـاص, زنـك, نيكـل, كـروم, كـادميوم) والمتغيـرات الاخـرى للتربـة (الكبريتـات, كلورايد, المواد العالقة الكلية,الرقم الهيدروجيني, والمواد العضوية).
اخذت نماذج من التربة من نقاط بعيدة عن القناة (تربة غير مروية), واخـذت نمـاذج اخـرى علـى ابعاد مختلفة اقترابا من حافة القناة وكان النموذج الاخير قريب جدا من حافة القنـاة (تربـة مرويـة), لايجاد الاختلافات في الخواص الكيميائية للتربة.
تم دراسـة العلاقـة بين تراكيز المعـادن الثقيلـة فـي التربـة وبين المتغيرات والخـواص الكيميائيـة الاخرى للتربة وكانت النتائج كمايلي : وجود علاقة طردية بين الكبريتات والمواد العضـوية, المـواد العالقـة الكليـة, والتوصـيلية الكهربائيـة وكذلك بـين الزنـك والرصـاص مـع الكبيرتـات, كـذلك الزنـك والرصاص والمواد العضوية.
كـذلك تـم اجـراء مقارنـة بـين خصـائص التربـة المرويـة وغيـر المرويـة. اظهـرت النتـائج بـان تراكيز الرصاص والنيكل تتعدى الحدود المسموحة, كذلك زيادة التوصيلية الكهربائية والمواد العالقة الكلية خصوصا في التربة غير المروية.

Introduction

Soil _ defined as a dynamic, ever _ changing natural body composed of inorganic and organic solid particles with properties which result from the interactive effects of climate (atmosphere) and biological activity (biosphere) on the unconsolidated remnants of rock [1]. The soil supports the plants that provide us with food, fiber, and forest products [2].

Agriculture serves as the foundation on which many countries build their economics. For Iraq, agriculture has traditionally been the second largest employer, after oil sector [3]. The cultivated area in Iraq is (16%) of the total area [4].

Under irrigation, soil and water compatibility is very important. If they are not compatible, the applied irrigation water could have an adverse effect on the chemical and physical properties of the soil. Determining the suitability of land for irrigation requires a through evaluation of the soil properties, the topography of the land within the field and the quality of water to be used for irrigation [5].Irrigation, even with water of high quality, often represents a large increase in the amount of water which would pass through a soil profile under natural conditions and has the capacity to accelerate mineral weathering, to transport and leach soluble and colloidal material [6].

When we talk about the effects of irrigation by river water on the chemical properties of the soil, we have to mention the most important of these properties:

Heavy metals, such as zinc, cadmium, copper, lead, nickel, and chromium are present in all soils but are usually found at low concentrations. The background concentration of metals in virgin soil depends primarily on the bedrock type from which the soil parent material was derived [7]. Enhanced concentrations are found in soils from naturally mineralized areas, but more commonly arise where heavy metals have became dispersed as a result of human activity. These include mining manufacturing, and waste disposal as well as some agricultural activities such as the use of phosphate fertiliesers and metal _ containing pesticides [8]. This has significant implications for human health and the ability of ecosystems to function properly [9].

Salinity is the accumulation of salts (often dominated by sodium chloride) in soil and water to levels that impact on human and natural assets (e.g. plants, animals, aquatic, ecosystems, water supplies, agriculture and infrastructure) [10].

High soil salinity may result from the application of saline irrigation water, insufficient rainfall and irrigation to leach excess salts, poor drainage, up ward movement of leached salt from perched water tables, and / or salt water intrusion [11], [12].

Water salinity is usually measured as TDS (Total Dissolved Solid) or EC (Electrical Conductivity) [13].

Classification of saline soils by saturated paste method is shown in table (1). [11].

Soil pH refers to the level of acidity in a soil. The pH is a measure of the number of hydrogen (H^+) ions that are in the soil [14].

The pH of a soil /sediment is critically important in terms of the preservation of various natural materials and artifacts (e.g. bone, mollusca and many metals rapidly decompose in acidic conditions), and also effects the retention of phosphate. It is important therefore to have some knowledge of the pH soils [15].

If the pH of the soil is extreme either alkaline or acid, the plant will die. Soil microorganisms, insects, and other animals present in the rhizosphere are equally sensitive to pH [16].

Alkaline soils have pH 7.5-8.5

Acidic soils have pH 4-6.5

Soils with pH values outside these ranges are usually toxic to most plants.

(SOM) is the organic matter component of soil. It can be divided into three general pools: Living biomass of microorganisms, fresh and partially decomposed residues, and humus: The well – decomposed organic matter and highly stable organic material [17], [18].

Organic matter is widely regarded as a vital component of a healthy soil [19].

Beneficial impacts of soil organic matter on soil properties [12]:

1. Physical: stabilizes soil structure, improves water holding characteristics, lowers bulk density, dark color may alter thermal properties.
2. Chemical: higher cations exchange capacity, acts as pH buffer, ties up metals, interacts with xenobiotics.
3. Biological: supplies energy and body – building constituents for soil organisms, increases microbial populations and their activities, source and sink for nutrients, ecosystem resilience, affects soil enzymes.

Characteristics of Wastewater Flow

Though the actual composition of wastewater may differ from community to community, all municipal wastewater contains the following broad groupings of constituents: [20]

1) Organic Matter.
2) Nutrients (nitrogen, phosphorus, potassium).
3) Inorganic Matter (dissolved minerals).
4) Toxic Chemicals.

5) Pathogens.

Table (2) represents an overview of some wastewater parameters and there possible impacts.

Fieldwork and Sampling

Two surface soil Samples were taken from points far from the canal B_1 and B_2 (non irrigated soil) as shown in figure (1), three samples were taken from point across the cultivated area near Army canal which was irrigated from the canal water have decreasing distance from the canal bank and the last one is just at the river margin points (1,2,3) respectively (irrigated soil) to find out the differences in chemical properties.

The samples were analyzed to find out the chemical properties such as heavy metals(Pb,Zn,Ni,Cr,Cd) which was tested at the Central Organization for Standardization and Quality Control by using the atomic absorption apparatus, and other parameters of soil (SO_4, Cl, SS, pH, OM) which was tested at the University of Technology/Chemical Engineering Department by using titration methods [21], [22].

Sample of the Army canal water used for the irrigation was also analyzed.

The data were analyzed by using statistical programs; comparisons between soil parameters have been done. Data also compared with data obtained by other researches, the Ministry of Environment (2007) [23], and the University of Technology (2009) [24], to find the variation of soil parameters along the period (2007-2010).

Figure (1) represents Army Canal and sampling position

Results

1) Relation between Soil Properties

Data obtained appears relations between some of soil parameters. Figure (2) shows incessant relationship between SO_4 and OM. This was expected due to the various chemical compounds that may relate with SO_4 causing the increase in the OM ratio. Also the expected relationship found between TSS and EC, the increasing of the cations, anions leads to increase the EC, Figure (3).

Figure (4) represents relation of EC with pH as it is clear from the figure that
EC increased in the acidic range between (6.4-6.8).

Figure (5) represents TSS relation with pH. TSS decreased with pH increasing within the pH range (6.4-7.2), which means that soil salts decomposed in the acidic range.

2) Relation between Metal Concentrations and Soil Properties:

Concentration of Pb and Zn increased with increasing of sulfate concentration, this means that there is chemical reaction with sulfate which affected on the concentration of Pb and Zn, while concentration of Ni and Cr decreased with the increasing of sulfate concentration. Cd concentration still almost in the same range of concentration, figure (6).

Figure (7) represents relation of the trace metals with OM. In this figure organic matter significantly related with concentrations of Zn, Pb, Cd, while concentration of Ni and Cr decreased with the increasing of OM. This finding was attributed to the strong absorption of transition metals by soil organic matter. This is in agreement with results obtained by Ma L.Q. [25] which showed significant correlation with trace metals concentration except for Be, Cr, Mn, and Ni. The significant correlation was also found between certain metal concentration and organic carbon contents in Dutch topsoils [26] and agricultural soils of north western Alberta [27], [28].

Sahib, results appears that Pb concentrations accumulate at top layers of soil and decrease with depth. The organic content has been considered as most efficient adsorbent of Pb on soil solids [29].

3) **Relation among Trace Metals**

Significant correlation was found between Zn and Pb , figure (8) and Ni and Cr figure (9), while negative correlation was found with other metals. As referred by Kabata and Dean [30], [31].This correlation may occur because they have similar ionic radii and this result is consistent with published data by Ma, L.Q. [25] for 40 Florida surface soils. In the annual progress report (1998) [32] for 15 trace metal, Ni correlated with Cr which may suggest possible anthropogenic impact on Ni concentration in soils. Correlation between concentrations of Ni and Cr has been reported, however, for surface soils of California and Minnesota [33], correlation between concentrations of Ni and Cr was also reported by Prych [34] in Washington soils. They suggested that Cr and Ni were associated mostly with mineral phase in the soils. Most relations between elements were controlled mainly by natural factors. The high correlation among trace metals suggest that similar chemical and physical factors control element associations in parent material and during soil forming processes [35].

Figure (10) shows the negative relation of Pb with Cd and Cr, Pb displayed significant correlation with most metals, excluding Ni,Cr and Cd.

This probably because Pb have much larger ionic radii than Cd,Cr and Ni [30], [31].

Finally, the negative relation appeared between Cr and Cd (figure 11).

4) Comparison between Irrigated and non Irrigated Soils:

As it was referred previously that samples have been taken from surface soils near Army canal. In figure (12), point B represents the soil near the street bank (non irrigated soil) it appears that Pb concentrations decreased when we go to the direction of the canal this is because of the exhausted gases from cars. Ec and TSS decreased towards the canal direction because of washing which happens to the surface soil that is irrigated with water from the canal.

Figure (13) compares between the irrigated and non irrigated soils, concentrations of (Cl, SO_4, TSS, Ec, Zn and Pb) decreased when soil is irrigated this is because the dilution and sediments which happens when the soil is irrigated. The increment found for other elements may come from the pesticides used in the irrigated soil of the field.

An increment in heavy metals concentrations was noticed by [36] especially when using the organic fertilizer in the garden beet crop, pH-value of the soil dropped from 7.6 to 6.93 due to degradation of the organic matter in the sludge may contribute to the decrease in pH because of the acidic nature of several of the decomposition products.

5)Standards and Limitations :

Comparisons for the data have been made with studies which happened for the same soil at the Ministry of Environment (2007) and a study by [24].

Figure (14) illustrates heavy metals concentration for the irrigated water during the period (2007-2010) and compared with WHO standards. Zn concentration increased gradually from (2007-2010), Ni concentration exceeded which is regulated by WHO. This exceeding appears in the study which has been made by [24].

Pb concentration shows a little increment for the non irrigated soil. Cd and Cr stay almost on the same range during (2007-2010) and did not exceed the WHO regulations.

Table (4) represents a summary for the obtained data for the irrigated soil

6) Chemical Analysis for the Canal water:

Table (5) shows the chemical analysis of Army canal water, untreated water used in the irrigation of the nearby soils.

This data could be compared with data in table (6) which represents the chemical composition of the two water sources in Sadat area. Comparing data appears the variation between characteristics of the treated and untreated water used in the irrigation of the soil in Iraq. An increasing in the concentrations of Cl and TDS have been noticed they were more than FAO guidelines limits. This increasing in the concentration of the parameters was expected because most of the industries and other services in the country disposes there effluent without good treatment, this may transported to the irrigated soil. Although the concentration of some parameters were lower than the allowable limit, the continuous irrigation with untreated water may leads to change the characteristics of the soil in the future.

Conclusions

According to the results, the conclusions can be summarized in the following items:

1. A Positive increasing relationship was found between sulfate and organic matter, also between TSS and EC. This is expected because of the decomposition of sulfate components and organic matter which come from the fertilized used in soil. This also effects on salts concentration in soil which leads to increase EC concentration. EC concentration decreased when soil is irrigated continuously because of the dilution which happened to the salts of soil.
2. TSS, EC increase found in the acidic range of pH. EC value reached to 5190 µs/cm when pH

ranged (6.5-7) and decreased to 640 when pH was (7-7.2).

3. The positive increase was found in Zn and Pb concentration with sulfate, while the negative increase was found in Ni and Cr concentration with sulfate. Cd concentration did not effected by sulfate.
4. Zn and Pb concentration increased with the increasing of organic matter, while Ni and Cr decreased with organic matter increscent.
5. A Positive relationship was found between Zn and Pb,Ni and Cr, Pb and Cd ,while the negative relationship found between Zn and Ni, Zn and Cr , Ni and Pb, Pb and Cr , Cd and Cr.
6. TSS and Ec values decreased towards the canal (from the non irrigated soil to the irrigated soil) because of the dilution which may happen to the salts found in soil by the irrigation water.
7. Pb concentration increased at the boundary of the road because of cars exhausted gases and decreased towards the canal away from the road. This increscent near by the road reached to (253) ppm which exceeded the allowable limits for non polluted soil by WHO (100) ppm.
8. Zn and Cd concentrations in the non irrigated soil were larger than there concentration in the irrigated soil.
9. Ni and Cr concentrations increased in the irrigated soil. This may be because the decomposition of the fertilize and pesticides which is used for the soil.
10. Comparing results obtained for the irrigated soil with WHO limits appears that Ni concentration exceeded the allowable limits for the last two years.

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Table (1) Classification of saline soils by saturated paste method [11]

Salinity Class	EC(ds/m) (saturated paste method)	TDS(ppm)
Low	2.0 to 4.0	1300 to 2500
Medium	4.0 to 12.0	2500 to 7500
high	>12.0	>7500

Table (2) Pollutants and Contaminants in Wastewater and their Potential through Agricultural use [20]

Pollutant/ Constituent	**Parameter**	**Impacts**
Stable organics	Phenols, pesticides, chlorinated hydrocarbons	-persist in the environment for long periods - toxic to environment - may make wastewater unsuitable for irrigation
Dissolved inorganic substances	TDS, EC, Na, Ca, Mg, Cl, and B	-cause salinity and associated adverse impacts -phytotoxicity - affect permeability and soil structure
Heavy metals	Cd, Pb, Ni, Zn, As, Hg, etc	-bio accumulate in aquatic organisms (fish and planktons) - accumulate in irrigated soils and the environment - toxic to plants and animals - systemic uptake by plants - subsequent ingestion by humans or animals - possible health impacts - may make wastewater unsuitable for irrigation
Hydrogen ion concentrations	pH	-especially of concern in industrial wastewater concentrations - possible adverse impact on plant growth due to acidity or alkalinity - impact sometimes beneficial on soil flora and fauna

Table (3) USDA Salinity Laboratory's classification of saline irrigation water based on salinity level, potential injury to plants, and management necessary for satisfactory utilization. [11]

Salinity class	Electrical conductivity (dS/m)	Total dissolved salts (ppm)	Potential injury and necessary management for use as irrigation water
Low	<0.25	<150	Low salinity hazard; generally not a problem; Additional management is not needed.
Medium	0.25 - 0.75	150 - 500	Damage to salt sensitive plants may occur. Occasional flushing with low salinity water may be necessary.
High	0.75 - 2.25	500 - 1500	Damage to plants with low tolerance to salinity will likely occur. Plant growth and quality will be improved with excess irrigation for leaching, and/or periodic use of low salinity water and good drainage provided.
Very High	>2.25	>1500	Damage to plants with high tolerance to salinity may occur. Successful use as an irrigation source requires salt tolerant plants, good soil drainage, excess irrigation for leaching, and/or periodic utilization of low salinity water.

Table (4), Summary Descriptive Statistics for the Irrigated Soil

Descriptive Statistics

	N	Range	Minimum	Maximum	Mean		Std.	Variance
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
Cl	3	67.355	74.445	141.800	8.07833	1.88477	.905539	436.830
SO4	3	19.750	200.860	220.610	3.75467	6.45164	.174560	124.871
OM	3	.500	3.700	4.200	3.93333	.14530	.251661	.063
TSS	3	120.000	90.000	210.000	6.66667	7.11843	.291005	133.333
pH	3	.700	6.500	7.200	6.93333	.21858	.378594	.143
EC	3	730.000	640.000	370.000	816.667	0.27430	403.436	1969633
Zn	3	8.300	57.500	65.800	2.63333	2.58994	.485904	20.123
Ni	3	16.300	101.400	117.700	9.20000	4.71840	.172515	66.790
Pb	3	7.300	13.500	20.800	6.16667	2.32546	.027820	16.223
Cd	3	.008	.085	.093	.08800	.00252	.004359	.000
Cr	3	14.100	30.020	44.120	8.14667	4.21031	.292471	53.180

Table (5) Army Canal Wastewater Chemical Analysis

Parameter	Concentration
Cl^{-2}	314 (mg/l)
SO_4	529 (mg/l)
TDS	1020 (mg/l)
Ec	2040 (µs/cm)
pH	6.5
Zn	0.047 (mg/l)
Ni	0
Pb	0
Cd	0
Cr	0

Table (6) some chemical composition of the two water sources used in the irrigation in Sadat area [37]

Parameter	FAO guidelines	Well water	Treated water
pH	6.5-8.4	7.28	7.12
EC $dS.m^{-1}$	<3	1.1	4.04
TDS	<450	15	212
Cl^{--}	<140	181	903
Zn	2.0	0.06	0.72
Ni	0.2	n.d	0.27
Cd	0.01	n.d	0.06
Pb	5.0	n.d	1.28

n.d.= not detected

Figure (1) represents Army Canal and sampling position

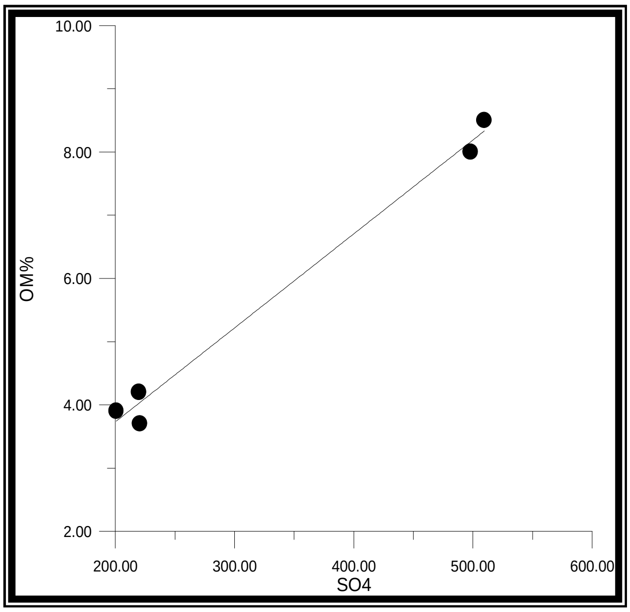

Figure (2) SO_4 and OM Relationship

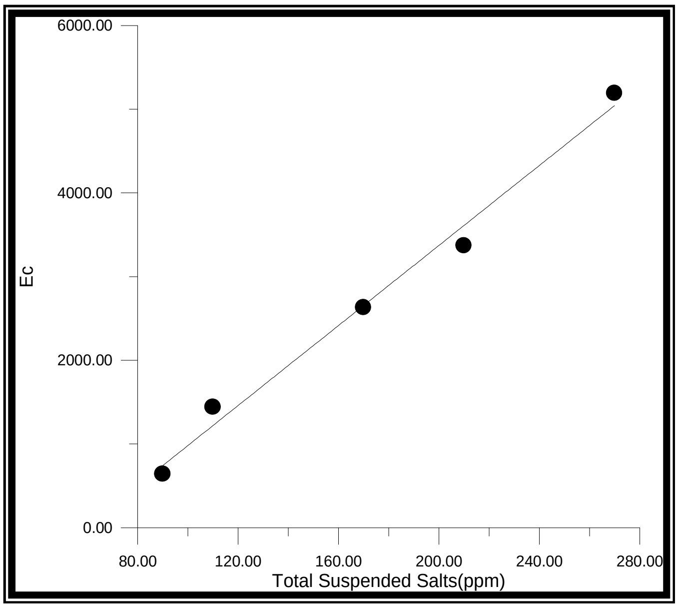

Figure (3) TSS and EC Relationship

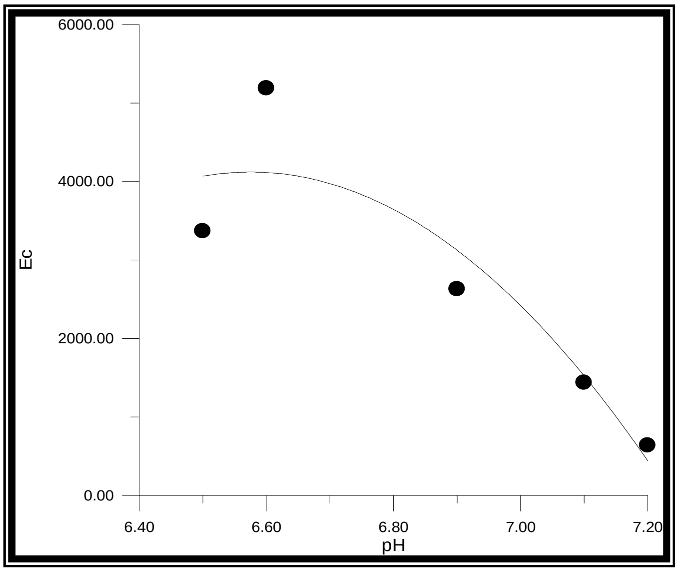

Figure (4) pH and EC Relationship

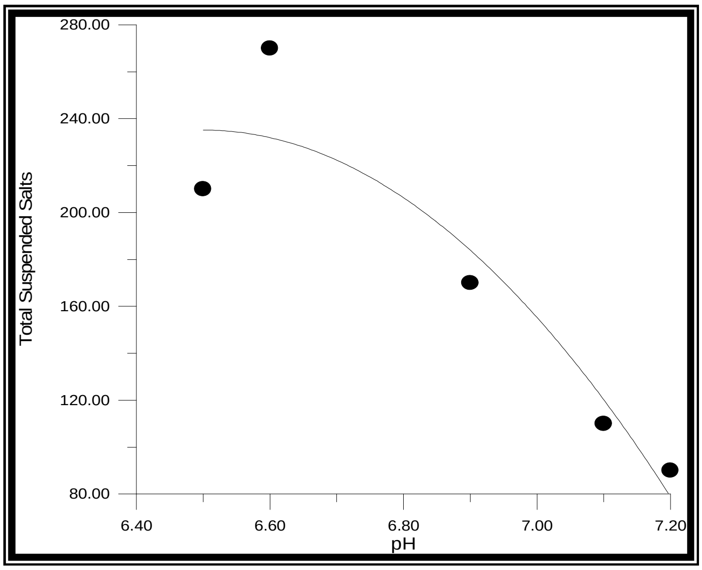

Figure (5) pH and TSS Relationship

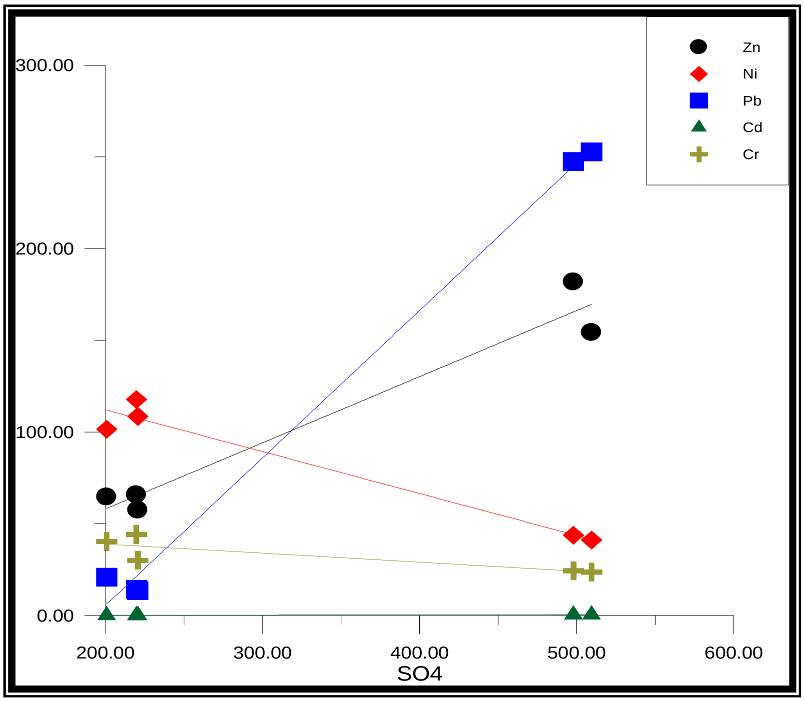

Figure (6) Relation of Sulfate with Heavy Metals

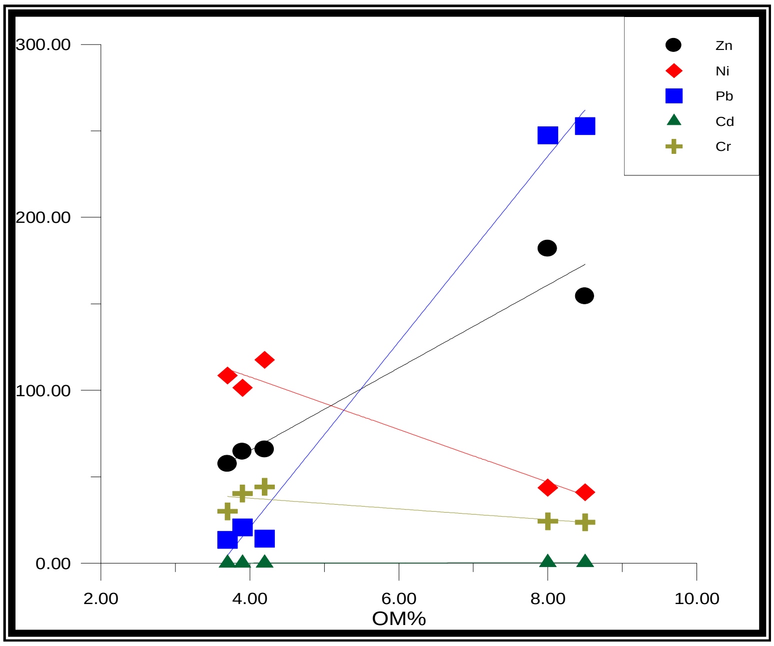

Figure (7) Relation of OM% with Heavy Metals

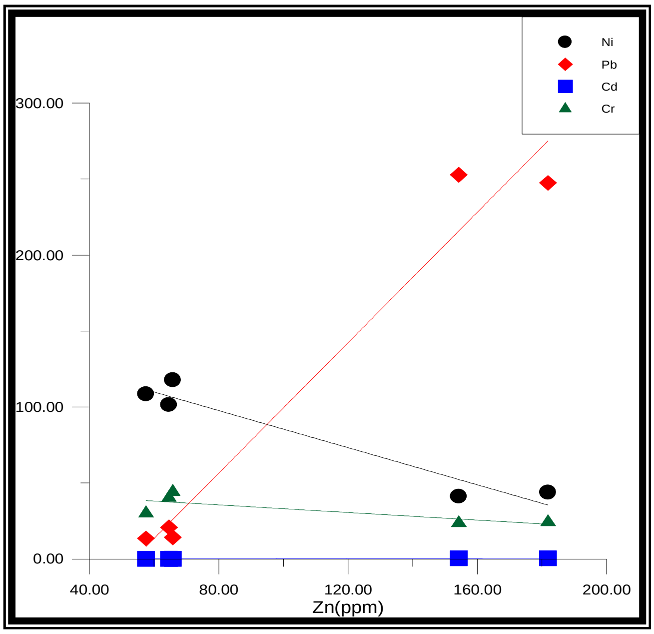

Figure (8) Relation of Zn with Heavy Metals

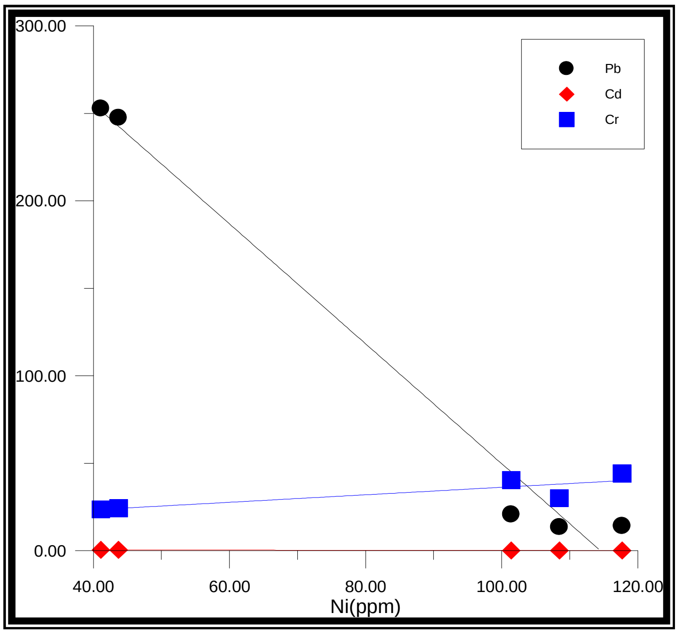

Figure (9) Relation of Ni with Heavy Metals

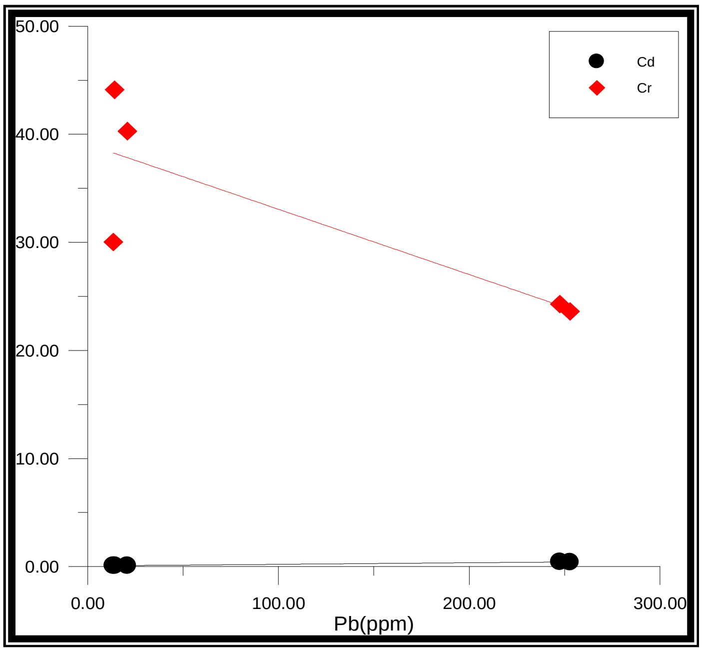

Figure (10) Relation of Pb with Heavy Metals

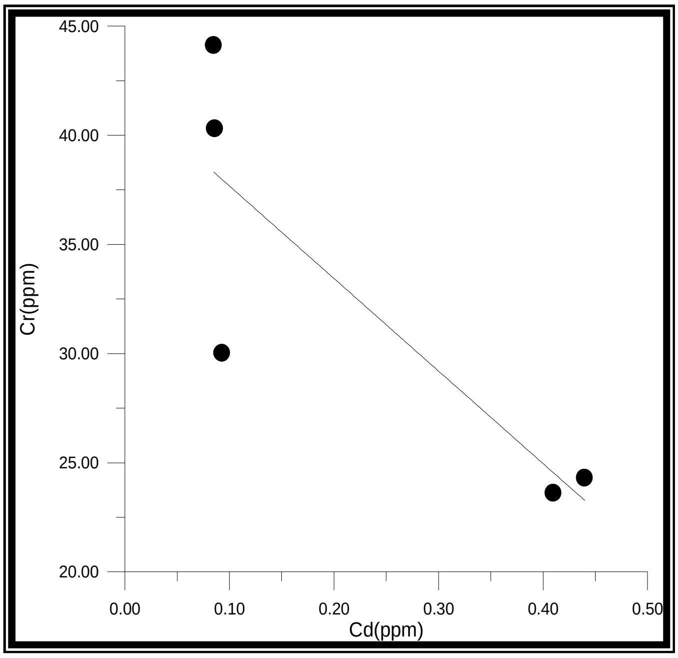

Figure (11) Relation of Cd with Cr

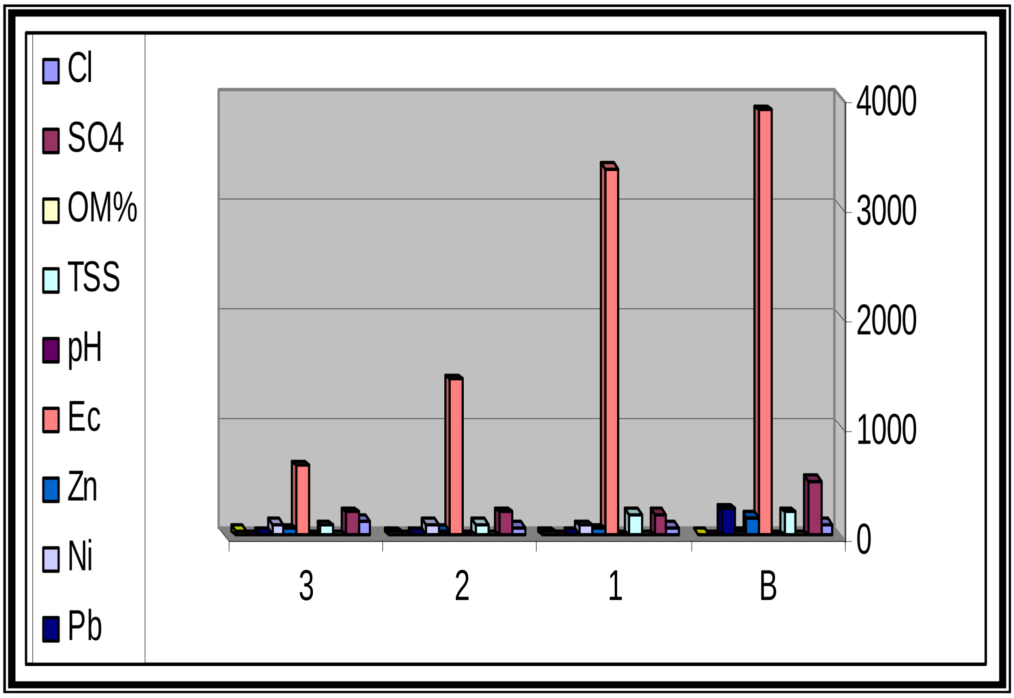

Figure (12) Soil Parameters at Sampling Positions

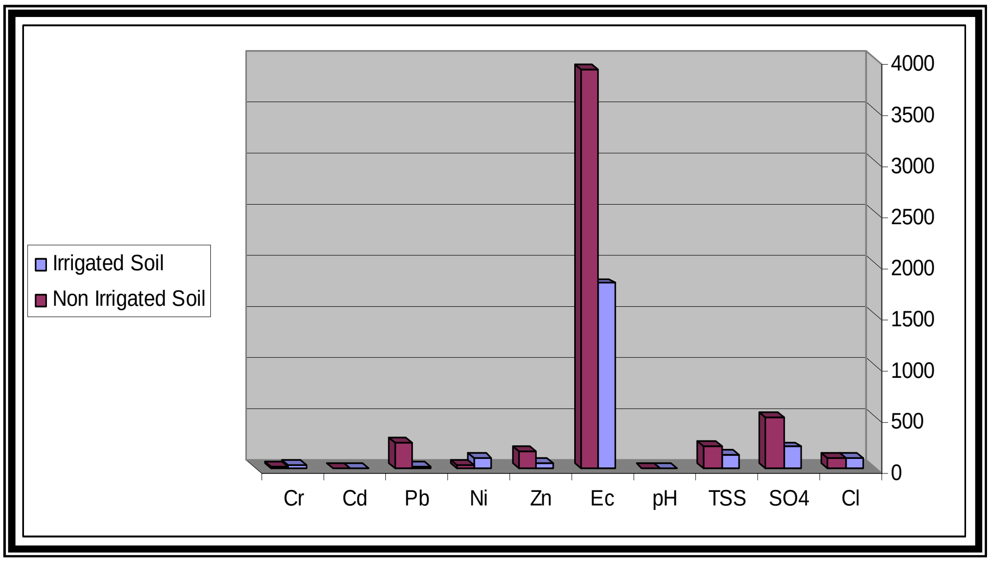

Figure (13) Comparisons between Irrigated and Non Irrigated Soil

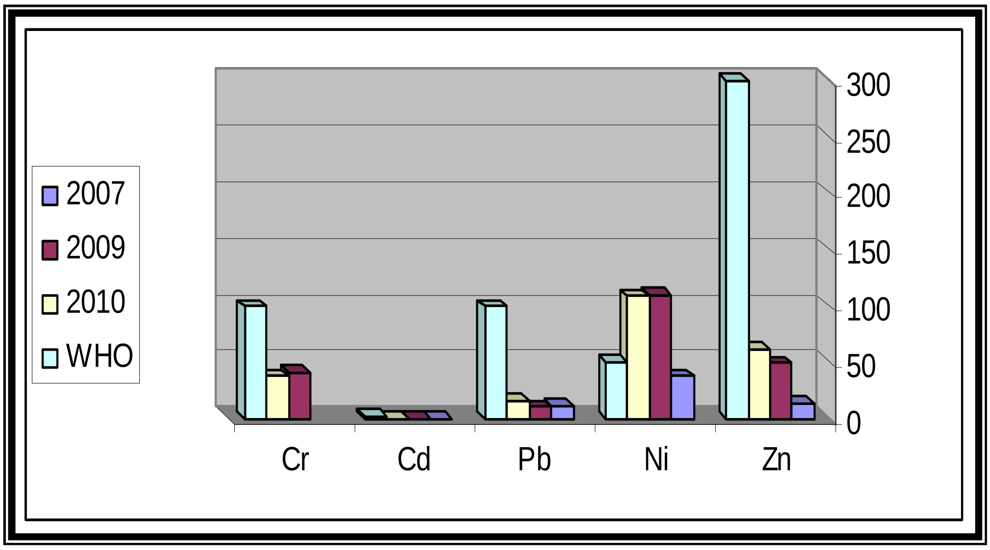

Figure (14) Comparisons with previous studies and WHO standards