بسم الله الرحمن الرحيم

AN- NAJAH NATIONAL UNIVERSITY

FACULTY OF GRADUATE STUDIES

IMPACTS OF IRRIGATION WITH HIGH HEAVY METALS CONCENTRATION ON SOIL AND GROUND WATER

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Submitted In Partial Fulfillment of the Requirements for the Degree of Master of Environmental Science, Faculty of Graduate Studies, at An - Najah National University, Nablus, Palestine.
JUNE 2000

Acknowledgment

I would like to express my deep appreciation and gratitude to my advisors Dr. Mohammed El- Subu and Dr. Marwan Haddad for their guidance and help throughout this work.

I would also like to express my thanks to the committee members Dr. Mustafa Khamis and Dr. Nidal Za'tar for reviewing this work and for their valuable remarks.

I would like to expresses my deepest gratitude and thanks for my mother for her support and encouragement throughout my graduate studies. My thanks extend to my brother Dr. Numan Mizyed for his assistance in presenting and editing the language, graphs and tables.

Special thanks to Al-Quds University and its staff for their assistance in performing some of the chemical analysis needed for this research.

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ABSTRACT

In this study, irrigation with water containing heavy metals (copper, lead and zinc) was simulated for soils from two areas around the city of Nablus; Salim and Deir Sharaf. Plans are already made to apply treated wastewater from Nablus municipality to these two areas. As industrial effluents are usually included in wastewater flow to these areas, there is a risk of soil and groundwater pollution by heavy metals in these areas. Soils from these areas were sampled and analyzed to study their chemical and physical properties. Simulation of irrigation with water containing heavy metals was done using soil columns of 2 meters height.

The results of chemical and physical analysis of these soils showed that the soils are classified as clay loam with good chemical and physical properties. The salinity of these soils was found to be low, the pH was between 7 and 8, the calcium content was high while the sodicity was low. Soils were found to be calcareous soils. These properties make these soils good agricultural soils and suitable for most agricultural crops. The drainage conditions of these soils were found to be good. Their permeability is good due to their good structure resulting from low sodium and high calcium contents.

Simulation of irrigation with water containing heavy metals showed an increase in heavy metals concentrations in soil and in leachate with increasing the addition of heavy metals in irrigation water. Heavy metals concentrations increased with depth and time of application. Although these

soils were classified as clay loam, but their self-purification was highly affected by the formation of cracks due to their expansion and shrinkage resulting from wetting and drying patterns. Therefore, especially near the surface of these soils, water flows through these cracks at high rates without giving the soil enough time to exchange many cations with soil solution.

CHAPTER ONE

INTRODUCTION

1-1: Background:

Water is an essential-vital element for human life and activities including agriculture, industry and recreation. In Palestine the availability of renewable water resources to maintain various human needs is poor and scarcity is accelerating with time. Therefore, alternative water resources development options such as brackish water and the reuse of treated wastewater is gaining much importance at present. The use of these options is expected to be obligatory with time.

Generally, wastewater is a liquid waste which is removed from residential, institutional and commercial establishments. Wastewater includes industrial wastes which might have high concentrations of Pb, Cu and Zn ions (Chang et. al., 1981). Treated wastewater is used in many countries for agricultural irrigation (Avnimelech, 1993) to enhance overall water availability and conserve water resources.

In conventional wastewater treatment, heavy metals are transferred from the liquid to the solid phase through precipitation, adsorption or biological uptake (Wang, 1998). Considerable portions of these metals remain in the treated effluent if special advanced treatment was not conducted. Chemical forms of heavy metals in a soil system would affect their chemical reactivates and their pollution potential in the environment (Schalscha et. al., 1982; Lebourg et.al., 1998).

Long term effects of irrigation with wastewater might include pollution of ground water and soil with heavy metals such as: Pb, Cu and Zn ions (Farid et. al., 1993; and El-Hassanin et. al., 1993). Other impacts of treated wastewater in agriculture include the health impacts of possible contamination of crops by pathogenic bacteria and heavy metals. Reuse of wastewater might result also in contamination of groundwater resources by nitrates and others.

In Palestine, there is no separation between domestic and industrial sources and therefore wastewater collection includes industrial wastes from various origins. As the potential of using wastewater in irrigation is high, long term environmental effects of irrigation with wastewater should be studied including the effects of heavy metals contained in wastewater.

1-2 Nablus Wastewater System:

Wastewater from Nablus flows out in two directions. The first towards the West through Deir Sharaf plain and to Wadi Zeimar. This direction covers about 58% of Nablus Wastewater. The second direction is towards the east through Salim plain to Wadi Fara'a. This direction covers 42% of Nablus wastewater. The Nablus municipality has plans to construct two wastewater treatment plants on both directions (Deir Sharaf and Salim). Treated wastewater from these plants will be reused for irrigation purposes in these two locations. However, the long-term

impacts of such reuse were not simulated to study the self-purification capacities of these soils and their suitability for reuse especially when heavy metals are present in the wastewater. Therefore, this study was conducted to simulate the long term effects of application of treated wastewater on these soils concentrating on heavy metals produced by local industry in Nablus.

1-3: Objectives:

The present work aims at:

1. Conducting a column study to simulate Pb, Cu and Zn ions adsorption and leaching mechanisms in soils from two locations in the West Bank.

2. Recommending soils suitable for wastewater application in irrigation based on simulation results.

CHAPTER TWO

LITERATURE REVIEW

2-1 : Heavy Metals:

There is a rapidly growing awareness of the threat to water resources passed by runoff from highways (highway drainage). The problem has frequently been compared to that caused by sewage effluent (Selim, 1992). Comparisons, however, should be exercised with caution as the chemistry of highway drainage is distinctive and the mode of discharge is very different from sewage effluent (Laxen, 1977).

A comprehensive appraisal is required if proper evaluation of the impact of highway contaminants on water quality is to be made (Giddings, 1973; Lebourg, 1998). The contaminants must be traced from their source to their ultimate introduction into the receiving waters, taking into account physical and chemical interactions that take place in route and the hydrological characteristics of the highway as a sub-catchment. Two principal pathways of pollutant dispersion have to be considered; surface runoff and airborne dispersal. The former introduces contaminants directly into the receiving water, while the latter contributes contaminants indirectly to the receiving water following deposition, and frequently transaction through soil and ground water regimes (Siebe, 1995; Chatoudis, 1998).

For each stage in the transportation network, information is required on: The availability of contaminant, the transport mechanisms, the dilution effects and the physiochemical interaction (Mendoza, 1996; El-Nennah,

1982). Some of the most significant highway contaminants are heavy metal such as copper, zinc and lead.

2-1-1:Copper:

Copper is the 25th most abundant element in the earth crust. Due to its chemical properties, it is one of the few metals to be found naturally in native form. Therefore, it has been known and used by man for thousands of years.

Copper is an essential micro-nutrient for plant growth. Copper deficiencies are most frequently found in organic soils that have been recently brought into production especially production of high value crops which are grown intensively in peat and muck soils.

In soil solutions of pH values below 6.9, the divalent ion Cu^{+2} is the dominant form of this element, above this pH value, $Cu(OH)_2$ is the major form (Sposito, 1989). In addition to soil texture, soil pH, and organic matter content, the availability of copper to plants is influenced by the interaction of copper with other micro nutrients (Temmingho, 1997). Copper deficiencies can be corrected by the application of a wide variety of commercially available fertilizer materials.

Copper is found in surface water generally at concentrations below 20 µg/L. It may be detected in higher values from the consumer's faucet as

a result of corrosion of brass and copper pipes. As an algaecide in surface water, it may vary seasonably in surface supplies. Industrial sources of copper include: smelting and refining, copper wire mills, coal burning industries, electroplating, tanning, engraving photography, insecticides, fungicides and iron and steel producing industries. Presence of copper in ground water is an indication for industrial pollution (Zuane, 1990).

Copper in air can be the product of copper dust, coal burning, and probably tobacco smoke. In food, it is found in organ meats, shellfish, nuts, dried legumes and cocoa (Temminghoff, 1997).

Copper is not a cumulative systemic poison. Doses up to 100mg taken by mouth (adult) cause symptoms of gastroenteritis with nausea. Large doses of copper are harmful to human beings as it causes central nervous system disorder, failure of pigmentation of hair and adverse effects on Fe-metabolism that cause liver damage. Excess copper may also be deposited in the eyes, brain, skin, pancreas and myocardium. It may also causes lung cancer among copper smiths (McAnally, 1997). Its deficiency causes hypochronic and microcytic anemia by defective hemoglobin synthesis.

Plant toxification with copper occurs with high levels of copper from atmospheric fallout or irrigation with polluted water (Zuane, 1990; Townshend, 1995).

2-1-2 : Zinc:

Zinc is used as an alloy with brass, nickel, commercial bronze, soft solder, and aluminum solder (Evangelou, 1998). It is used also in galvanization to prevent corrosion, in preparation of paints, rubber products, cosmetics, pharmaceuticals, floor coverings, plastics, printing inks, soap, storage batteries, textiles, electrical equipment, and other products (Dojlido and Best 1993).

Low solubility in water is reported for carbonates, oxides, and sulfides of zinc, contributing to low zinc concentration in natural waters (Sincero,1996). Many of zinc salts are highly soluble in water; but it is likely that the presence of zinc can be detected only in traces in natural waters. However, in zinc-mining areas, zinc concentrations may reach 50 mg/L in natural water.

Zinc is essential for synthesis of nucleic acids DNA and RNA. It is needed for normal growth and development of mammals and birds and particular types of collagen. It is necessary for some enzymes, enzymatic function, protein, synthesis and carbohydration (Martinez, 1999).

Zinc availability in soils depends on soil pH, adsorption on surfaces of clay, organic matter, carbonates and oxide minerals. The availability of zinc decreases with increasing soil pH as the solubility of zinc reduces by increasing pH. The Zn^{+2} ion is the form absorbed by plants, and diffusion is the main process of transporting this ion to plant root surfaces (Juanico, 1995).

The formation of organic compound facilitates Zn diffusion. As a plant-nutrient, zinc can be supplied from several fertilizer sources directly added to the soil. Tree injections and applications of this element have also been successfully utilized (Hussain, 1991).

The effectiveness of banded applications of zinc in the soil has been increased by the presence of acid forming nitrogen fertilizers and certain acid- forming sulfur compounds (Martinez, 1999).

Pollution with zinc occurs in factories where workers are exposed to zinc fumes or dusts that is known as metal fume fever (Welch et. al., 1987).

2-1-3 : Lead :

Lead is used primarily in storage batteries, cable covering, plumbing ammunition, the manufacture of lead tetraethylead (Giddings, 1973;

Jorgensen, 1970), radiation shields from nuclear reactors and X-ray equipment, the glass industry, and in paints industry.

The magnitude of lead deposition at a particular site depends on many complex variables, including traffic density (Thayer, 1995), driving mode and speed, the site topography and prevailing meteorological conditions.

It has recently been suggested that lead impurities in de-icing salt may contribute lead to highway environment in some localities. Lead dispersed to roadside soils is effectively immobilized in the top 10cm of soil. The concentration of lead in highway runoff can reach levels far in excess of those normally encountered in surface waters.

Lead Related Impacts and Considerations

a . Strategies for lead corrosion control:

Potential sources of lead in drinking water include household plumbing, faucets, fixtures and lead service lines. Uniform corrosion of lead service lines has been shown to be a less significant contributor to lead contamination in drinking water than household plumbing. Galvanic corrosion is common in household plumbing where lead-tin solder has been used to join copper plumbing. When these two metals are in contact with one another, an aggressive galvanic cell is formed. A study

by the American Water Works Service Corporation found galvanic corrosion to be the principal source of lead contamination in drinking water (McAnally, 1997). The use of soft water of slightly acidic pH and the use of lead pipes in service and domestic water lines may provide higher concentrations of lead at the consumers tap, particularly when the water use is minimal in the household.

In most cases, higher lead content is expected at the consumer's tap than at the treatment plant. Higher concentrations of lead are also expected in the early-morning samples, with minimum values in running water and intermediate values in composite samples (McAnally, 1997).

b. Health effects:

Lead is not considered an essential nutritional element and it is a cumulative poison to humans (Laxen, 1977). Its major effects in humans are impairment of hemoglobin and porphyries synthesis (upset metabolism connected with utilization of chemicals) (Zuane, 1990).

Health effects of a toxicological nature include irreversible brain damage (Sincero, 1996) which has been observed by high blood levels. Typical symptoms of advanced lead poisoning are:
Constipation, anemia, gastrointestinal disturbance, tenderness and gradual paralysis in the muscles, specifically arms with possible cases of lethargy and moroseness (Laxen, 1977; Botkin, 1995).

2-2: Wastewater :

Wastewater is defined as a combination of liquid or water carrying wastes removed from residential, commercial and industrial establishments, together with ground water, surface water and storm water. Discharging raw waste to the environment causes pollution problems (Moatogomery, 1988). Therefore, the treatment of wastewater is essential to prevent pollution and protect the environment (Aziz, 1996).

Reuse of wastewater is mandatory in one sense due to the fact that we have a fixed water budget on this plant (Martin, 1991). If raw domestic wastewater is passed into a river and is used for a low quality water use such as navigation, there is hardly any concern (Keller, 1995). However, if the untreated domestic wastewater is pumped directly into water supply reservoir of a downstream city, some eyebrows are raised. The quality required for the subsequent reuse is reached through intermediate treatment (Ditri, 1981; Feachem, 1984).

Several principles are important in designing reuse where domestic consumption may be involved (Balcombe, 1989). Efficient conventional treatment is important. Infiltration through sandy soil back to ground water is most desirable because of water quality enhancement effected in viral and bacterial removed. Also, organics are oxidized (Bolto et al,1987). Practically and to gain approval of the public, the

time period before treated wastewater is subsequently reused should be as long as possible (Purdom, 1980; Bolto, 1987).

Contaminants of domestic wastewater are categorized as: Disease causing microorganisms, essential plant nutrient elements, dissolved minerals and toxic chemicals (heavy metals) and biodegradable organic matter (Hammer, 1996).

Even after the wastewater undergoes the purification processes, the treated effluent is not entirely free of undesirable constituents (Avnimelech, 1993). In terms of a land - oriented wastewater disposal practice, any one category of the above mentioned contaminants may limit the soil's ability to receive such treated wastewater (Martin, 1991). However, since the advent of community wastewater treatment systems, the attention of land disposal of wastewater has invariably been focused on pathogenic organisms (Schulz, 1984).

Wastewater reclamation and reuse is of interest in the Mediterranean region, particularly for irrigation. In Mediterranean environments, uneven distribution of precipitation and runoff requires the construction of costly water storage and higher levels of wastewater treatment (Angelakis et al, 1998).

Regulations on wastewater reclamation and reuse are essential. They help to protect public health, increase water availability, prevent coastal pollution and enhance water resources and nature conservation policies (Abdel-Ghaffar, 1988; Bouwer, 1988).

2-3: Soil:

2-3-1: Soil define:

Soil is the unconsolidated (loose) part of lithosphere with which living organisms interact most directly. The soil formation process ultimately defines three regions: Parent material, fragmented bedrock and region of plant growth (Wild, 1993). The types and sizes of particles in the soil affect its porosity and permeability. The largest and coarsest particles found in soil are sand, silt and clay (Vitkevich, 1963). Sandy soils have larger pores which allow water drains through easily. Sandy soils are characterized by high porosity and high permeability (Jury, 1991; McNeal, 1982). Clay soils have high porosity but low permeability. Some clays tend to soak up, hold water and expand like a sponge instead of allowing water to percolate through (Beaton et al, 1975). Loamy soils have intermediate characteristics as they contain all the three types of soil particles (sand, silt and clay) in percentages that do not allow them the dominant physical characteristics of the three groups (Fitzpatrick, 1986; Neal, 1991).

2-3-2 : Soil Physical Characters:

a. Specific gravity:

The specific gravity of the common soil forming minerals varies from 2.5 gram/cm^3 to more than 5 gram/cm^3. A few minerals, such as quartz and feldspar, might have a specific gravity of more than 5 gram/cm^3. The specific gravity of soil particles which have a low percentage of organic matter varies slightly, and approaches an average of 2.65 gram/cm^3.

b. Apparent Specific Gravity (bulk density):

The apparent specific gravity of a soil is defined as the ratio of the weight of a given volume of dry soil including its air space, to the weight of an equal volume of water. Apparent specific gravity is a dimensionless quantity, being weight of soil per weight of water. Bulk density is the dry mass of a soil divided by its bulk volume. Bulk density has units of mass per unit volume such as gram/cm^3. Apparent specific gravity is a soil property of great importance to irrigation farmer as it is related to the capacity of soils to retain irrigation water. The usual method for determining apparent specific gravity is to obtain a soil sample of known volume. Sometimes pits are dug and blocks of soil are obtained directly. Also, a hole can be bored with an auger and all the soil that has been removed can be dried and weighed. The volume is determined by measuring the average size of the hole or by placing a flexible rubber or plastic tube in the hole and determining the

volume of water required to fill it. The volume of soil could be also determined using sand cone apparatus which utilizes uniform sand to measure the volume of soil pits (Jury, 1991).

c. Infiltration:

Infiltration is a property of soils, of great importance in irrigation, which is defined as the time rate at which water will percolate into soil, or rate of infiltration. The rate is maximum at the beginning of irrigation and reduces with time until it reaches a steady state value which is dependent on soil permeability. Infiltration is influenced by soil properties and initial moisture content. Moisture tension, may be zero near the surface of soil shortly after wetting and may be very high a few centimeters below, thus causing a large downward force pulling the water into the unsaturated soil. Several hours after wetting, these differences in tension may be very small, and gravity then becomes the dominant force causing infiltration (Vitkevich, 1963) to continue at steady rate. Water standing on gravely or coarse sandy soils percolates into the soil rapidly and thus may be lowered several inches an hour. On fine-textured clay soils, water may collect and stand on soil seeming with very little infiltration, for many days. Desirable infiltration rates are between these two extremes. A convenient means of expressing infiltration is in terms of centimeters per hour (Jury and Garrdner, 1991).

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d. Intake:

The rate of infiltration from a furrow into the soil is referred to as the intake rate. This term indicates that infiltration occurs under a particular soil surface configuration. Intake rate is therefore influenced by furrow size and shape, whereas infiltration rate applies to a level surface covered with water. Hence, whenever the configuration of a soil surface influences the rate of water entry, the term intake rate should be used rather than the term infiltration rate to refer to the rate of entry of water into soil (Abdul Rida, 1995).

e. Classes and Availability of Soil Water:

Soil water is classified as hygroscopic, capillary, and gravitational. Hygroscopic water is on the surface of the soil grains and is not capable of significant movement by the action of gravity or capillary forces. Capillary water is that part in excess of the Hygroscopic water, which exists in the pore space of the soil and is retained against the force of gravity in a soil that permits unobstructed drainage (Cairncross, 1993). Gravitational water is that part of water in excess of hygroscopic and capillary water which drains freely by gravity. Soil water may also be classified as unavailable, available and gravitational or superfluous. Gravitational water drains quickly by gravity from the root zone under normal drainage conditions. Unavailable water is held too tightly by strong adhesive forces and is generally not accessible to plant roots.

Available water is the difference between gravitational and unavailable water. Water drains from the soil under the constant pull of gravity. Sandy soil drains rapidly, while clay soils drain very slowly (Markert, 1994). The rate of drainage is most rapid immediately after irrigating and decreases constantly (Mitani, 1998).

f. Field capacity:

When gravitational water has been removed, the moisture content of soil is called field capacity. In practice, field capacity is usually determined 1-3 days after an irrigation depending on the type of soil. Field capacity can be measured by determining moisture content of soil 1-3 days after an irrigation which is sufficiently heavy to insure thorough wetting of the soil to be tested (Tanji, 1989).

g. Electric conductivity:

As a simplified index to the total concentration of dissolved salts in water, its electrical conductivity could be used as a water quality parameter which could be correlated with plant growth (Bohn, 1985). The electric conductivity (EC) measurement is based on the principle that the amount of electrical current transmitted by a salt solution under standardized conditions will increase as the salt concentration of the solution is increased (Jury, 1991).

For solutions in the salt concentration range of concern to irrigated agriculture, the standard unit of EC measurement is mmhos/cm or dS/m. Values for the EC also can be converted to total dissolved salts (TDS) through the approximate relationship (Reeve, 1994):

TDS (mg/ L) = 640 *EC(mmhos/cm)..

2- 3- 3: Soil Chemical Characters:
a. Specific-ion effects:

Specific-ion effects of salinity are two folds. An excess of specific ions may be toxic to various plant physiological processes. Ions contributing appreciably to soil salinity include Cl^-, SO_4^{-2}, HCO_3^-, Na^+, Ca^{+2}, Mg^{+2} ions and occasionally NO_3^- and K^+ ions (Foth, 1990).   Each of these ions can have specific effects.

Different salts may affect plant growth differently. High sodium can cause calcium and magnesium nutritional deficiencies (Bohn, 1985). Additional specific-ion toxicity may occur in soils affected by total salt concentration, Na^+, Cl^-. Boron may be toxic at concentrations only a few fold above the 0.2 to 0.5 mg/L required for normal plant growth (Kiely, 1997).

Certain crops may be sensitive to the presence of moderate to high concentrations of specific ions in the irrigation water or soil solution.

Specific ion analytical data are generally necessary only when toxicity problems are suspected. In arid zone areas, the concentrations of Cl^- and Na^+ ions are highly correlated with irrigation water EC (Bohn, 1995; Baise, 1988).

b.   Cation exchange capacity of soils:

Cations are usually adsorbed on soil surfaces by the negative charge that soils usually have.   The amount of cations that can be adsorbed by a certain weight of soil depends on the negative charge available on the soil.   The negative charge on soil surface allows exchangeable sites for the cations to be adsorbed on the soils and/or exchanged by other cations which exist in the soil solution.   The mechanism of exchange is highly dependent on the available cations on soil surface and in the soil solution.   It also depends on the ionic strength of the cation.   The ionic strength increases by increasing the valence of the cation and by reducing its hydrated radius.   As the ionic strength increases, the energy of adsorption increases and cations will be adsorbed more tightly to soils surfaces. For example the energy of adsorption for calcium cations is higher than for sodium cations.   Therefore, to reclaim sodic soils (soils high in sodium are usually alkaline with low permeability), calcium will be added through irrigation water.   Calcium will be dissolved in soil solution and then calcium cations in solution replace sodium cations from exchangeable sites on soil surfaces allowing soil reclamation (Sposito, 1989).

The amount of negative charge on the soil surface determines soil cation exchange capacity. In general soils have two types of charges. The first type is permanent while the other is pH dependent. Permanent charge results from isomorphous substitution which occurs during the early formation of soil minerals from magma. Isomorphous substitution is the replacement of a cation by another one of equal size (the same coordination number) and smaller size. This usually happens in soil silicates of some clay minerals such as Montmorillonites, micas and vermiculites. Isomorphous substitution in micas occurs during its crystallization from magma where some Al^{+3} substitute for some of the Si^{+4} in the tetrahedrons (under conditions of high pressure and temperature). This results in an excess negative charge. This negative charge is independent of soil pH and is a permanent charge.

The second type of negative charge on soil surfaces occurs from the dissociation of hydrogen from edges of aluminum hydroxyl groups or organic acids depending on soil pH. As soil pH increases, more H^+ dissociate from aluminum hydroxyl and organic acids edges to neutralize the solution resulting in higher negative charge. Therefore, increasing soil pH increases its pH dependent charge (Foth, 1990).

Therefore, cation exchange capacity of soils depends on: type of clay minerals, organic matter content and soil pH. Cation exchange capacity of a soil is the sum of positive charges of the adsorbed cations that a soil can adsorb at a specific pH expressed in cmol/Kg or meq/100gm.

Experimentally, cation exchange capacity could be determined by estimating the sum of cations adsorbed on soil surface through leaching the soil by ammonium acetate and determining these cations in the leachate (Foth, 1990).

c. Soil pH:

Soil pH is important for plant growth, affects cation exchange capacity, affects solubility of many nutrients such as iron (high pH reduces availability of iron) and affects activity of soil organisms. Calcareous soils usually have pH between 7 and 8.3 due to the hydrolysis of carbonates. Alkaline soils usually contain Na_2CO_3 with pH as high as 10 or more (Schaub, 1993). Soil acidity partially results from respiration of roots and other organisms producing carbon dioxides which react with water to form carbonic acid. It also results from mineralization of organic matter forming organic acids, nitrogen and sulfur are oxidized to form nitric and sulfuric acids. Natural or normal precipitation reacts with carbon dioxide of the atmosphere forming carbonic acid increasing the possibility of forming acidic soils.

In general, desert regions are alkaline as a result of low precipitation where there is no leaching of basic cations and the organic activity is low. In humid areas, high precipitation results in more plants and organic activity, more respiration and mineralization and thus acidic soils. Loss of basic cations through leaching results in adsorption of H^+ onto exchange positions of basic cations. Adsorption of H^+ at the edge of silicate clay minerals makes aluminum unstable. Hydrolysis of the released Al^{+3} produces H^+(Foth, 1990).

CHAPTER THREE

METHODOLOGY

3-1: Experimental Program :

The experimental program used in this study was as follows:

1) Different concentrations of Pb, Zn and Cu solutions were applied to a set of columns filled with different soils to simulate long term effects of Pb, Zn and Cu applications to such soils.

2) Rainfall, water applications, evapotranspiration, heavy metals applications to these soils were estimated for 2, 10 and 20 years to determine concentrations of Pb, Zn and Cu ions in leachate at different depths of the soil.

3) Evaluation and comparison of results were conducted to recommend which soil is more suitable for using wastewater in irrigation at the depths.

3 - 2 : Description of Experimental Setup :

The experimental setup consisted of 18 columns made of PVC with 4" in diameter and 2 meters high (Figure 3.1). The volume of soil in each column was estimated at 15.7 liters. Soil samples from the top 100cm-layer soil (light clay) were collected from the two locations (near Nablus city, Salim and Deir Sharaf, see Figure 3.2). The collection of soil was done before the rainy season of 1998/1999. Stones were removed by hand from soil samples and 19 Kg of soil were weighed and placed in each column. This will give a bulk density of 1.3 gm/cm^3 for soil which is within the range of bulk densities for these soils (1.2-1.5 gm/cm^3)

Figure 3.1 Illustration of experimental setup.

Israeli Settlements in the Occupied West Bank, 1996

Figure 3.2 The two locations under consideration in the West Bank.

A plastic container was placed under each column to collect drainage water. To allow leachate (drainage) to flow freely without eroding soil from columns, a layer of gravel and sand was placed in the bottom of each column. A screen (plastic mesh screen) was also placed below the gravel layer at the bottom end of each column.

Water was applied at the top of each column while drainage water was collected from the bottom (using plastic containers) for each column and analyzed to determine the amounts of Pb, Cu and Zn ions in leachate for the different treatments.

For each soil, 3 treatments in addition to the blank were considered. These treatments represent a simulation of irrigation for 2, 10 and 20 years periods. For each treatment, 3 replicates were used. Two other columns for Salim soil and Deir Sharaf soil were used as blank columns (Table 3.1 and Figure 3.1). Rainwater was simulated for these two columns by applying 250 ml of rainwater to each column.

Table 3.2 shows climatic data at the location of the experiment during the simulation period (January to June 1999). Data was obtained from meteorological department in Nablus.

Table 3.1 Type of soil, columns, date of experiment and assumed years
of treatment.

Location of soil	Column number	Designation	Assumed years of treatment	Dates of leachate experiment
Salim	1, 2, 3	T1 S	2	28-12-98 to 23-4-99
Salim	4, 5, 6	T2 S	10	28-12-98 to 8-5-99
Salim	7, 8, 9	T3 S	20	28-12-98 to 19-5-99
D. Sharaf	10,11,12	T1 D	2	28-12-98 to 23-4-99
D. Sharaf	13,14,15	T2 D	10	28-12-98 to 8-5-99
D. Sharaf	16,17,18	T3 D	20	28-12-98 to 19-5-99

Table 3.2 Climatic data at the location of the experiment during
simulation experiment (Meteorological department, Nablus, 1999).

Month[*]	Pan evaporation (mm/day)	Relative humidity (%)
January	2.4	69
February	2.8	64
March	4.2	61
April	5.3	56
May	7.8	49
June	7.5	64

3 -3 : Water and heavy metals applications:

To each column a solution containing known concentrations of Pb^{+2},
Cu^{+2} and Zn^{+2} combined was added. The amount of each metal in the
solution was calculated according to following relation:

Amount of metals (mg) = concentration of element (ppm) * volume of
irrigation water (L).

To estimate the amount of metals added for each treatment, the
following assumptions were used:

1. Average rainfall, evapotranspiration, crop irrigation requirements
    and leaching in Nablus area are shown in Table 3.3.

2. Volume of irrigation water = 1025 mm (m^3 per dunum) assuming
    that mostly fruit trees will be planted in these reuse areas.

3. Volume of leaching water = 403mm (m^3 per dunum) as shown in
    Table 3.3.

4. High of each column =200cm.

5. Diameter of each column = 10cm.

Therefore, the volume of leachate water that will leach the soil in each
column will be 3.17 liters per column per year of simulation while the
volume of irrigation water will be 8.05 liters per column for each year
represented in the simulation.

Table 3.3 Monthly Rainfall, Evapotranspiration, Irrigation needed and leaching in Nablus area (m³/dunum)

Month	Rain[1]	ET[2]	Irrigation	Leaching
Jan.	142	24	0	118
Feb	148	25	0	123
March	93	46	0	47
April	19	116	97	0
May	6	155	149	0
June	0	176	176	0
July	0	182	182	0
August	0	171	171	0
September	0	140	140	0
October	15	119	104	0
November	76	82	6	0
December	148	33	0	115
Total	647	1269	1025	403

[1] : Rainfall data from Ministry of Agriculture for the years from 1978 to 1993.

[2]: ET or actual evapotranspiration from Mizyed, 1996. Optimization of water use for Agriculture in the West Bank. Proceedings for International conference on Water Management, An-Najah National University.

3-3-1 Water application:

In this experiment, 2, 10 and 20 years were selected for simulation to study short term, medium and long term effects of wastewater application. Assuming that annual crop consumptive use for the fruit trees suggested for reuse will be 1025 mm, then the amount of water that will be applied for these three periods will be 2050, 10250 and 20500 mm for 2, 10 and 20 years respectively. Considering the area of each column (10 cm in diameter), then the amount of water that will be applied to each column will be 16.1, 80.5 and 161 liters for 2, 10 and 20 years respectively. Considering

evapotranspiration, these amounts will be lost as crop water requirements, however, these volumes will be utilized to estimate actual amounts of heavy metals that will be applied to each column.

The amounts of water that will be used to leach each column will be depend on the actual leaching that we expect in the field. As was assumed, the annual leaching was 403 mm, then the leaching for each column will be 3.17 liters for each year of simulation. Therefore, the amount of water that will be actually added to each column will be 6.34, 31.7 and 63.4 liters for 2, 10 and 20 years of simulation.

3-3-2 Heavy metal application:

To estimate the amount of heavy metals to be applied to each column, it was assumed that the concentrations of these metals are equal to the maximum limit allowed by FAO (FAO, 1986) for the metals under consideration which are 10, 5 and 10 mg/L for Zn^{+2}, Cu^{+2} and Pb^{+2} respectively. As the annual volume of irrigation water was assumed at 1025 mm or 8.05 Liters per column, then the total amount of heavy metals that will be added will be 80.5, 40.25 and 80.5 mg of Zn^{+2}, Cu^{-2} and Pb^{+2} respectively per year of treatment (table 3.4). Metal solutions were prepared and they were stored in polyethylene bottles. These bottles were treated with 1 M HNO_3 solution and then they were cleaned with de ionized water.

The addition of the solution to each column was at different periods of times. The water was added to each column at different times and at each time 250ml-rain water was added to each column. The addition of water continued for different intervals of times depending on each treatment as follows:

Treatment of 2 years: took the period from 28 of December 1998 to 2 of April 1999 (95 days).

Treatment of 10 years: took the period from 28 of December 1998 to 2 of May 1999 (126 days).

Treatment of 20 years: took the period from 28 of December 1998 to 16 of May 1999 (140 days).

Table 3.4 Water and heavy metal application to columns in experiment.

Description	1 year	2 years	10 years	20 years
Depth of irrigation water (mm)	1025	2050	10250	20500
Depth of leachate water (mm)	403	806	4030	8060
Volume of irrigation water per column (L)	8.05	16.1	80.5	161
Volume of leachate water per column (L)	3.17	6.34	31.7	63.4
Weight of Zinc added to each column (mg)	80.5	161	805	1609
Weight of Copper added to each column (mg)	40.25	80	402	805
Weight of Lead added to each column (mg)	80.5	161	805	1609

3-3-3 : Leachate:

Water leaching from the columns was collected with time on increments of 4 Liters volume.   Each time the leachate volume reached 4 liters

draining from any column, the solution was collected in polyethylene bottles, 10 ml of 1M HNO_3 solution was added to each volume, and the volume was stored for analysis. The total volume of each leachate was measured (Table 3.5).

The leachates of each column were collected and the concentration of each metal ions (Pb, Cu, and Zn) was measured by taking 500ml from each volume of 4 liters. Analysis was done using Atomic Absorption Spectrophotometer VIDEO 11 (Table 3.6).

Table 3.5: Total volume of water added to each column, total volume of water leachate from each column, and total volume of water remained in each column.

Column	Total volume of water added to the column (L)	total volume of water leachate from the column (L)	Total volume of water remained in the column (L)
1 Salim	7.4	1.0	6.4
2 Salim	7.4	1.0	6..4
3 Salim	7.4	1.0	6.4
4 Salim	32.8	23.5	9.3
5 Salim	32.8	23.3	9.4
6 Salim	32.8	21.5	11.3
7 Salim	64.5	52.2	12.3
8 Salim	64.5	53.2	12.3
9 Salim	64.5	52.7	11.3
10 D. Sharaf	7.4	1.5	5.9
11 D. Sharaf	7.4	1.5	5.9
12 D. Sharaf	7.4	1.5	5.9
13 D. Sharaf	32.8	22.8	9.9
14 D. Sharaf	32.8	23	9.8
15 D. Sharaf	32.8	22.3	10.5
16 D. Sharaf	64.5	50.0	14.5
17 D. Sharaf	64.5	52.3	12.2
18 D. Sharaf	64.5	48.7	15.8

Table 3.6 Optimum conditions of atomic absorption spectrophotometer

as recommended by the manufacture company of VIDEO 11.

Element	Lead	Copper	Zinc
Principal line (nm)	217	324.75	213.86
Bandwidth (nm)	1	0.8	0.8
Lamp current (mA)	6	4	7
Voltage (V)	1000	800	800
Fuel	Air/acetylene	Air/acetyle ne	Air/acetylene
Oxidation ratio	5-20	5-20	5-20
Concentrations of standards used for calibration (mg/L)	3, 5, 10, 15, 20	2, 4, 6, 8, 10	2, 4, 6, 8, 10

The concentrations of lead, copper, and zinc ions in each leachate for

each column were measured by first making calibration curve for each

element and using blank of deionized water with HNO_3 solution ,then

using standard concentration for each metals as in :

For lead, 1.598gm of lead nitrate $(Pb(NO_3)_2$ was dissolved in 1 liter

deionized water using 1 liter volumetric flasks to get 1000 mg/L

concentration of lead.   From this solution, standard solutions with

concentrations of 3, 5, 10, 15 and 20 mg per liter were prepared by

dilution.   These solutions were stored in polyethylene bottle after the

bottles were treated with 1M HNO_3 solution. These standard were used

for all calibration curves of lead for all measurements.

The same procedure was repeated to prepare standard solutions of copper and zinc. For copper, 3.8047gm of copper nitrate $(Cu(NO_3)_2. \ 3H_2O \ )$ were used to prepare 1000 mg per liter copper solution. Standard solutions of 2, 4, 6, 8 and 10 mg/liter of copper were prepared by dilution.

For Zinc, 4.55gm of zinc nitrate ($Zn(NO_3)_2$) were used to prepare 1000 mg per liter zinc standard solution. Standard solutions of 2, 4, 6, 8 and 10 mg per liter zinc were prepared by dilution.

After the calibration curves were prepared for the three elements, the concentration of each metal in leachate of each column was measured. The amount of each metal ion in each leachate was then calculated by multiplying the concentration by the volume of leachate of each column.

In addition to the above measurements, the electric conductivity of leachate was measured at different periods by using (Conductivity Meter 4010 instrument).

3-4 : Metals in soil:

Metal concentration in the soil were measured before conducting the experiment. After finishing the experiment, the plastic columns were evacuated from soil and each column was divided into four patches at

10, 67, 133 and 200 cm heights. Each patch was dried and the metal ions were extracted from a given weight of each patch using ammonium acetate (NH_4Ac) and Ethylenendiamine Tetra Acetic Acid (EDTA) solutions. The extracts were then analyzed for Pb, Zn and Cu ions using Atomic Absorption Spectrophotometer VIDEO 11 (FAO, 1980).

3 -5: Soil Laboratory Analysis:

To determine different soil properties, the following tests were conducted for the two soils under consideration:

3-5-1 Soil chemical analysis:
a.Carbonate in soil:

Calcium carbonates in soil were measured by reacting 2 gm of soil with 100 ml. 0.5N HCL. Excess HCL was estimated by back titration with 0.5 N NaOH using phenolphthalein indicator (FAO, 1980).

b. Calcium and magnesium in soil:

Calcium and magnesium in soil extract were determined by titrating the soil water extract with EDTA solution using Erichrome black T indicator (Manual abstract, 1982).

c. Total dissolved salts (TDS).

Total dissolved solids of soil extract was determined by measuring the electrical conductivity of soil extract (FAO, 1980).

Total dissolved solids (mg/L)= 640 * EC

Where EC: electrical conductivity of soil extract in mmho/cm.

d. Chlorides in soil extract:

The concentration of chlorides in soil extract was measured by titrating soil extract against 0.02 N AgNO$_3$ using Potassium chromate (K$_2$Cr O$_4$) as indicator (FAO, 1980).

e. Phosphorus in soils:

Each type of soil was analyzed for phosphorus using sodium bicarbonate solution (0.5 M) and carbon black as an indicator to extract phosphorus from soil. The extract was treated with concentrated sulfuric acid and a solution of ammonium molybdate, antimony potassium tartarate, sulfuric acid and ascorbic acid. The color absorbency at wavelength 720 nm was measured using UV spectrophotometer (Manual abstract, 1982).

f. Potassium and sodium in soil:

Potassium and sodium ions were extracted from soil by 1N ammonium acetate solution. The filtrate was examined by using flame photometer (Manual abstract, 1982).

g. Organic - matter content:

Each type of soil was analyzed for organic matter content by estimating organic carbon through oxidation of carbon under standard conditions using potassium dichromate in sulfuric acid medium. The absorbency was measured using UV spectrometer at wavelength of 460 nm (Laboratory manual, 1992).

h. Soil pH:

For each type of soil, the pH of air-dry soil solution with 0.01 M CaCl$_2$ was measured. The suspension was stirred and the pH was measured using standard pH meter (FAO, 1980).

i. Heavy metals in soil:

Copper, zinc and lead were extracted from each soil using a solution of ammonium acetate and EDTA. The filtered extract was analyzed using atomic absorption spectrometer instrument (FAO, 1980).

3-5-2 Soil Physical Analysis:

a. Soil moisture content:

Moisture content determinations were done by gravimetric method (ASTM, D-2216). Water content in soil samples were estimated by measuring the loss in weight after drying soil samples at 105 °C for 24 hours (Das, 1941).

b. Particle size distribution:

Grain size distribution of each soil was first determined by sieve analysis according to ASTM standard test D-421 (Das, 1941). As the percentage of clay and silt was found to be high in the soils under consideration, particle size distribution was determined using the hydrometer test (ASTM number 152H with Bouyoucos scale in gm/L).

4-1 Chemical and Physical Characteristics of Soil
a. Chemical analysis:

Results of chemical analysis for Salim and Deir Sharaf soils are shown in Table 4.1. For both areas, it is clear that the concentration of total dissolved solids is low for these soils. Therefore, no salinity problems are expected at these soils as the electrical conductivity of saturation extract of these soils is low. No significant difference is observed between the concentration of total dissolved solids for soils at both soils. The low salinity and the low dissolved solids for these soils are a direct result of the climate and the agricultural practices in these areas. Precipitation in these areas is about 600 mm per year which is sufficient to leach soil from any possible salts that could be added by irrigation if it exist. The drainage conditions are also good at both locations and we don't have any shallow water tables in both Salim and Deir Sharaf areas. Also, the addition of salts is low in both areas. Although these soils are considered clay soils, but their sodicity is low, therefore these soils are aggregated in a good soil structure which improves their permeability. Most of the agricultural practices are dependent on rainfed agriculture and no irrigation water is added. Thus, salts added are minimal. In the past, irrigation with untreated wastewater was practiced in both areas. However, agricultural practices then were done in open fields where rainfall is allowed to leach salts added by irrigation. Therefore and due to the high rainfall in both areas no short-term build up of salts was found at both areas.

The above result applies to most cations and anions which could be usually found in soils. The concentration of chlorides, calcium, magnesium, potassium, sodium, nitrate and phosphorous were generally low and below acceptable limits of agricultural soils. This is due to the relatively high rainfall and the low addition of these ions to these soils. Concentration of heavy metals was also found low at both sites indicating that these soils are good, not yet contaminated and thus require a good attention to avoid any future action which might result in soil degradation or pollution.

Table 4.1 Chemical analysis of soils at Salim and Deir Sharaf areas:

Type of analysis.	Salim.	Deir Sharaf.
Electric conductivity for soil extract(mmho/cm)	1.2	1.3
Total dissolved solids for soil extracts (mg/L)	768	832
Soil extract pH	7.29	7.11
Chlorides in soil extract (mg/L)	35	70
Calcium and magnesium in soil extract (meq/L)	11.5	10
Organic matter content (%)	2	12
Phosphorous (ppm)	23	12
Potassium (ppm)	7	9
Sodium (ppm)	57	44
Calcium carbonates CaCO3 (%)	13.75	20
Copper (micro-gram per gram)	4.84	2.52
Zinc (micro-gram per gram)	2.86	1.24
Lead (micro-gram per gram)	2.66	0.94

Table 4.1 shows that both soils contain high percentage of calcium carbonates (13-20%). This is attributed to the fact that most of these soils are calcareous soils as their parent materials are usually originated from rocks rich with calcium carbonates (limestone and dolomite). The high calcium carbonates content indicates a high buffer capacity of these soils. These soils are generally good agricultural soils with pH between 7-8. This pH is suitable for most plants and the nutrient availability of most macro-nutrient is high at this pH. Such soils are usually deficient in some micronutrient such as iron which is usually available in the acidic range of pH. The pH between 7 and 8 indicates that the soils are not alkaline as alkaline soils usually have pH greater than 8.3 due to the high content of sodium carbonates. These soils do not have sodicity problems as their pH is less than 8.3 and their sodium content is low (Foth, 1990). Due to the high calcium carbonates content and the low exchangeable sodium cations on the surfaces of these soils, the aggregate stability of these soils is high. Thus, their permeability is high and therefore, their drainage conditions are also good.

The basic saturation percentage is usually higher than 50% and thus soil pH is higher than 7 (Schwab, 1993). These conditions are also considered as medium weathering conditions, therefore moderately developed clay minerals such as montmorollinites are expected to develop in the plains between the mountains. Montmorollinites are minerals with high cation exchange capacity due to the isomorphous substitution that occurs during

their formation resulting in permanent negative charges (Foth, 1990). These clays are fertile but they expand and shrink by wetting and drying.

b- Soil Physical Analysis :

Sieve analysis for these soils was not sufficient to determine the texture of these soils due to the formation of aggregates. Therefore, hydrometer analysis was utilized to determine the texture of the soil. Table 4.2 shows the results of physical analysis for the soil in Salim and Deir Sharaf.

Table 4.2: Physical analysis of soil:

Type of analysis	Salim	Deir Sharaf
Moisture content (%)	9.4	8.5
Specific gravity (gm/cm^3)	2.6	2.7
Bulk density (gm/cm^3)	1.7	1.8
Silt (%)	43.2	41.6
Clay (%)	37.6	35.6
Sand (%)	19.2	22.8
Soil texture	Clay loam	Clay loam

Table 4.2 shows that soil in both locations contains high percentage clay. Using textural triangle (Wild, 1993), both soils are classified as clay loam soils. The high clay content could be as a result of the topography and climate of these locations. Both locations are located within alluvial plains of wadis with high precipitation. Due to the low erosion in these plains and

the high precipitation, soils will have enough time to allow the formation of clay. These soils are usually heavy but fertile as they hold water and nutrients.

The bulk density was found to be high and this could be as a result of soil compaction and the shrinkage of soils by the end of summer as a result of the long drying months. Specific gravity of soil particles is typical for soils with calcium carbonates parent material.

4-2 Soil Analysis After Simulation Experiment:

Application of heavy metals was carried out during the experimental period for all the columns under consideration to simulate the impacts of heavy metals applications on the soil and the leachate from the soil. The concentrations of metals were analyzed before and after the simulation experiment. Results of analysis are presented for Cu, Zn and Pb in Tables 4.3-4.5 respectively.

Before conducting the experiment, concentrations of heavy metals under consideration were measured for both soils. It was found that the initial concentrations of copper, lead and zinc in Salim soils were higher than those in Deir Sharaf soils (see table 4.10-4.12). This could be as a result of the past use of wastewater in irrigation at these two locations and the different characteristics of wastewater at those locations. The eastern side of Nablus has more industrial waste than the western side. Therefore, the

concentration of heavy metals in the wastewater and consequently in Salim soil is expected to be higher than those for Deir Sharaf soils.

After simulation, soil samples were taken from depths 10, 67, 133 and 200 cm from each column and the samples were analyzed for copper, zinc and lead content (see tables 4.3-4.5). Figures 4.1-4.6 show the changes in the concentrations of the three elements for both soils under consideration.

Table 4.3 Concentration of copper remaining in soil columns at different

depths (ppm):

Volume of extract for each sample 80 ml								
Weight of soil for each sample 20 gm								
For 2 years								
Column	at 200 cm	Dilution	at 133 cm	Dilution	At 67 cm	Dilution	at 10 cm	dilution
	Conc.		Conc.		Conc.		Conc.	
1	4.27	1.00	1.01	1.00	0.79	1.00	0.99	1.00
2	4.37	1.00	0.84	1.00	0.75	1.00	0.91	1.00
3	4.96	1.00	1.21	1.00	0.84	1.00	0.89	1.00
Average	4.53	1.00	1.02	1.00	0.79	1.00	0.93	1.00
10	4.45	1.00	0.52	1.00	0.45	1.00	0.64	1.00
11	4.43	1.00	0.56	1.00	0.55	1.00	0.62	1.00
12	4.54	1.00	0.50	1.00	0.47	1.00	0.65	1.00
Average	4.47	1.00	0.53	1.00	0.49	1.00	0.64	1.00
for 10 years								
4	3.51	5.00	1.05	1.00	0.83	1.00	1.02	1.00
5	3.52	5.00	1.46	1.00	0.81	1.00	0.87	1.00
6	3.41	5.00	1.70	1.00		1.00	1.01	1.00
Average	3.48	5.00	1.40	1.00	0.82	1.00	0.97	1.00
13	3.45	5.00	0.60	1.00	0.51	1.00	0.69	1.00
14	3.51	5.00	1.07	1.00	0.77	1.00	1.04	1.00
15	3.43	5.00	1.12	1.00	0.48	1.00	0.52	1.00
Average	3.46	5.00	0.93	1.00	0.59	1.00	0.75	1.00
for 20 years								
9	3.96	10.00	1.53	1.00	1.21	1.00	1.33	1.00
8	3.86	10.00	1.75	1.00	1.18	1.00	1.25	1.00
7	3.98	10.00	1.13	1.00	0.74	1.00	1.04	1.00
Average	3.93	10.00	1.47	1.00	1.04	1.00	1.21	1.00
18	3.78	10.00	1.45	1.00	0.65	1.00	0.72	1.00
17	3.84	10.00	1.04	1.00	0.81	1.00	0.90	1.00
16	3.87	10.00	0.61	1.00	0.51	1.00	0.66	1.00
Average	3.83	10.00	1.03	1.00	0.66	1.00	0.76	1.00

Table 4.4   Concentration of Zinc remaining in   soil   columns at different

depths (ppm):

Volume of extract for each sample 80 ml							
Weight of soil for each sample 20 gm							
For 2 years							
Number	At 200 cm	Dilution	At 133 cm	Dilution	At 67 cm	Dilution	At 10 cm	Dilution
	Conc.		Conc.		Conc.		Conc.	
1	9.3	1	0.51	1	0.43	1	0.56	1
2	9.5	1	0.37	1	0.35	1	0.48	1
3	9.65	1	0.50	1	0.34	1	0.54	1
Average	9.48	1	0.46	1	0.37	1	0.52	1
10	7.9	1	0.51	1	0.21	1	0.41	1
11	8.15	1	0.28	1	0.17	1	0.13	1
12	9.1	1	0.18	1	0.14	1	0.21	1
Average	8.38	1	0.32	1	0.17	1	0.25	1
for 10 years							
4	9.16	5	0.52	1	0.43	1	0.57	1
5	9.26	5	0.62	1	0.39	1	0.39	1
6	9.4	5	0.67	1	0.43	1	0.59	1
Average	9.27	5	0.60	1	0.42	1	0.52	1
13	8.93	5	0.39	1	0.28	1	0.31	1
14	9.1	5	0.38	1	0.24	1	0.35	1
15	9.12	5	0.41	1	0.25	1	0.21	1
Average	9.05	5	0.39	1	0.26	1	0.29	1
for 20 years							
9	8.81	10	1.5	1	0.54	1	0.48	1
8	8.96	10	1.50	1	0.59	1	0.64	1
7	8.97	10	1.59	1	0.51	1	0.67	1
Average	8.91	10	1.53	1	0.55	1	0.60	1
18	8.71	10	0.61	1	0.37	1	0.44	1
17	8.62	10	0.81	1	0.33	1	0.32	1
16	8.01	10	0.37	1	0.29	1	0.39	1
Average	8.45	10	0.60	1	0.33	1	0.38	1

Table 4.5 Concentration of lead remaining in soil columns at different

depths (ppm):

Volume of extract for each sample 80 ml							
Weight of soil for each sample 20 gm							
For 2 years							
Number	At 200 cm	Dilution	At 133 cm	Dilution	At 67 cm	Dilution	At 10 cm	Dilution
	Conc.		Conc.		Conc.		Conc.	
1	7.99	1.00	0.75	1.00	0.55	1.00	0.59	1.00
2	8.95	1.00	0.72	1.00	0.52	1.00	0.60	1.00
3	8.80	1.00	0.71	1.00	0.51	1.00	0.66	1.00
Average	8.58	1.00	0.73	1.00	0.53	1.00	0.62	1.00
10	8.30	1.00	0.83	1.00	0.42	1.00	0.34	1.00
11	8.60	1.00	0.37	1.00	0.35	1.00	0.24	1.00
12	8.30	1.00	0.23	1.00	0.42	1.00	0.29	1.00
Average	8.40	1.00	0.48	1.00	0.40	1.00	0.29	1.00
For 10 years							
4	8.90	5.00	0.92	1.00	0.87	1.00	0.75	1.00
5	8.95	5.00	0.91	1.00	0.81	1.00	0.67	1.00
6	8.80	5.00	0.95	1.00	0.83	1.00	0.63	1.00
Average	8.88	5.00	0.93	1.00	0.84	1.00	0.68	1.00
13	8.86	5.00	0.52	1.00	0.38	1.00	0.32	1.00
14	8.70	5.00	0.61	1.00	0.53	1.00	0.44	1.00
15	8.80	5.00	0.52	1.00	0.48	1.00	0.24	1.00
Average	8.79	5.00	0.55	1.00	0.46	1.00	0.33	1.00
For 20 years							
9	9.02	10.00	1.90	1.00	0.88	1.00	0.93	1.00
8	9.06	10.00	1.60	1.00	0.78	1.00	0.90	1.00
7	9.01	10.00	2.50	1.00	0.69	1.00	0.86	1.00
Average	9.03	10.00	2.00	1.00	0.78	1.00	0.90	1.00
18	8.09	10.00	0.91	1.00	0.64	1.00	0.49	1.00
17	9.04	10.00	0.73	1.00	0.62	1.00	0.51	1.00
16	9.12	10.00	0.81	1.00	0.42	1.00	0.45	1.00
Average	8.75	10.00	0.82	1.00	0.56	1.00	0.48	1.00

Figure 4.1 Concentrations of copper in micro gram/gram (ppb) versus depth (cm) of the soil remained in the column at different years of treatment (Salim soil).

Figure 4.2 Concentrations of copper in micro gram/gram (ppb) versus depth (cm) of the soil remained in the column at different years of treatment (Deir Sharaf soil).
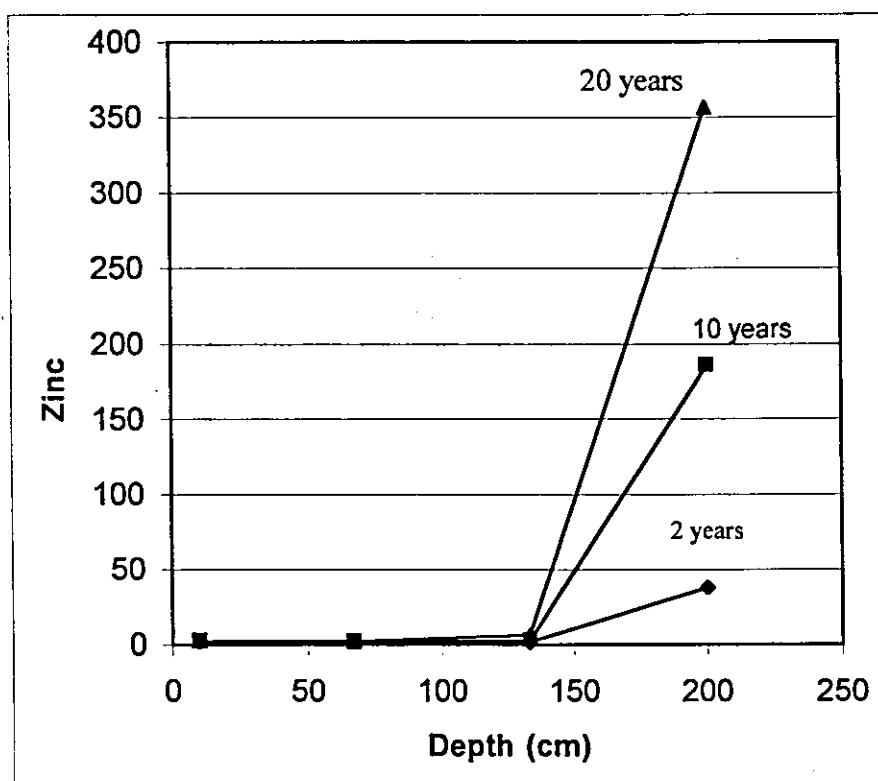
Figure 4.3   Concentrations of Zinc in micro gram/gram (ppb) versus depth (cm) of the soil remained in the column at different years of treatment (Salim soil).
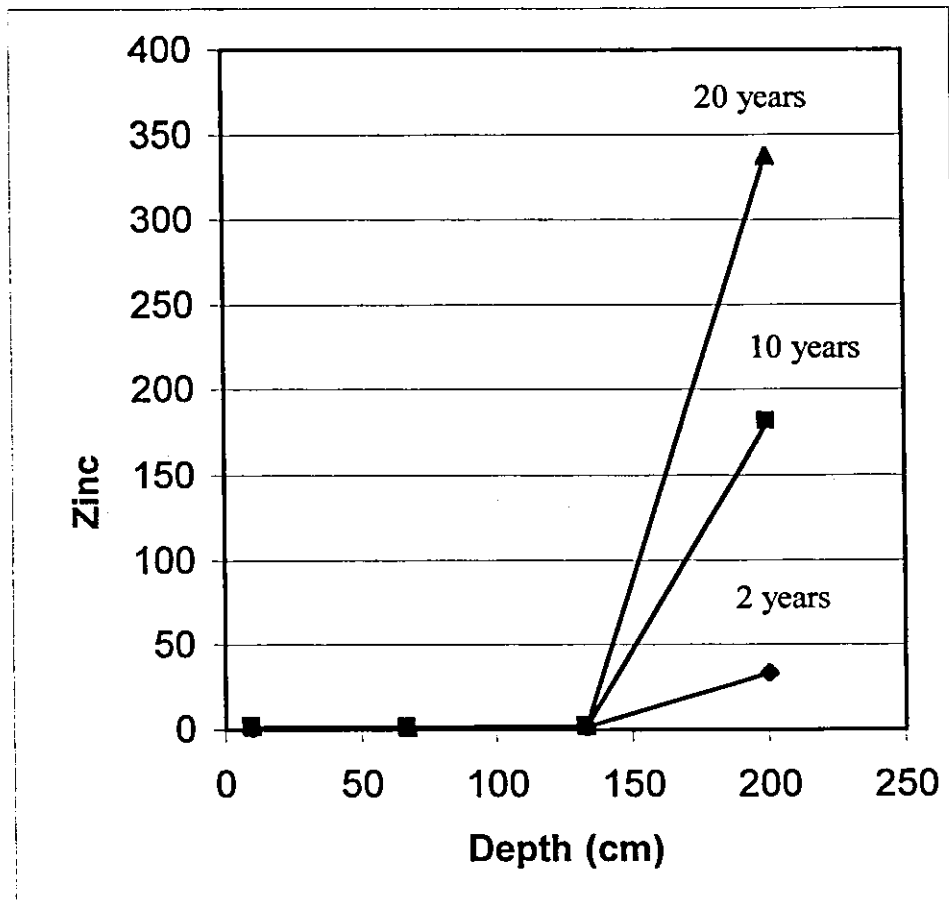
Figure 4.4 Concentrations of zinc in micro gram/gram (ppb) versus depth (cm) of the soil remained in the column at different years of treatment (Deir Sharaf soil).
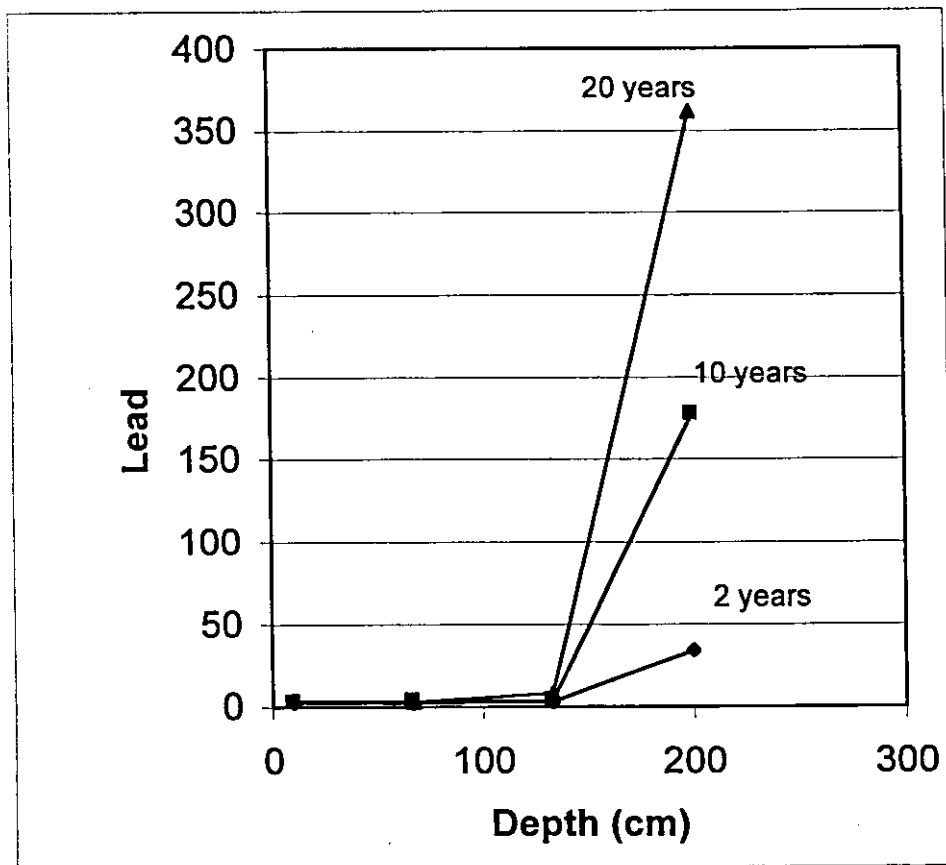
Figure 4.5 Concentrations of lead in micro gram/gram (ppb) versus depth (cm) of the soil remained in the column at different years of treatment (Salim soil).
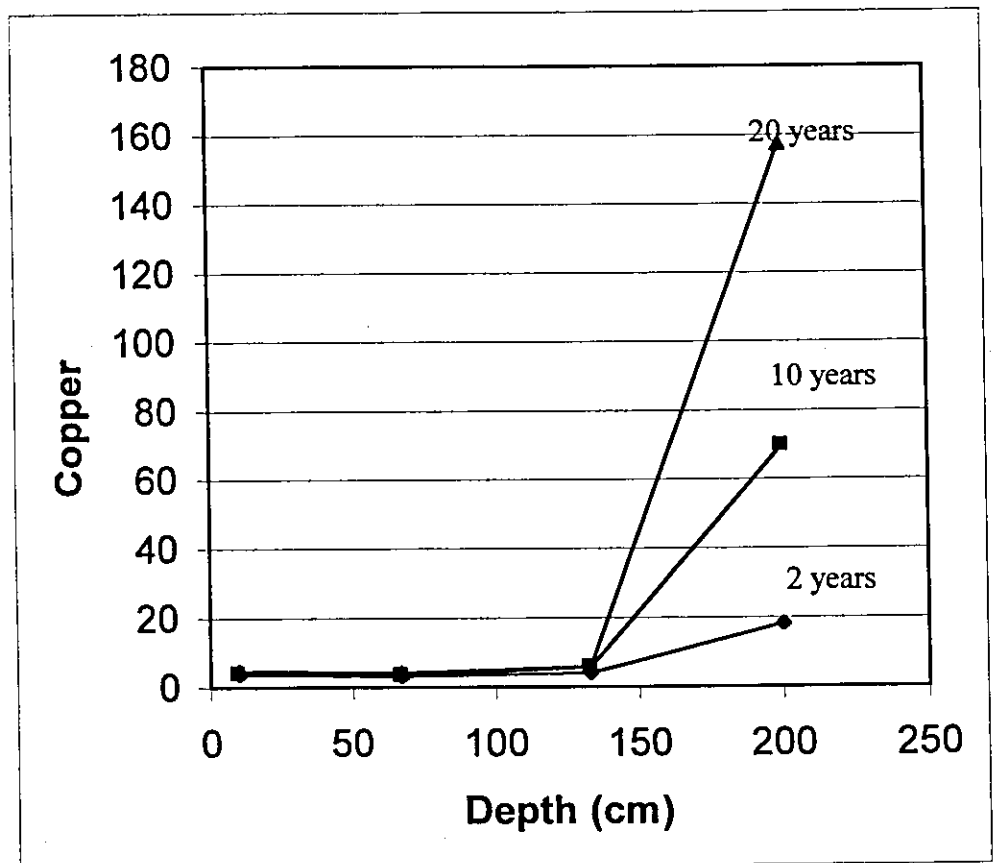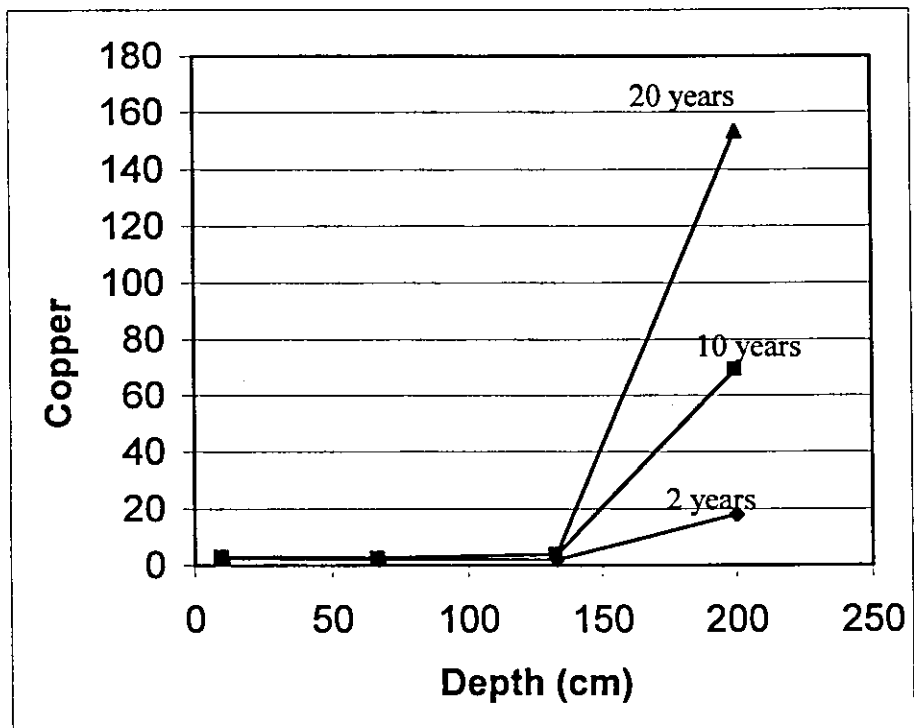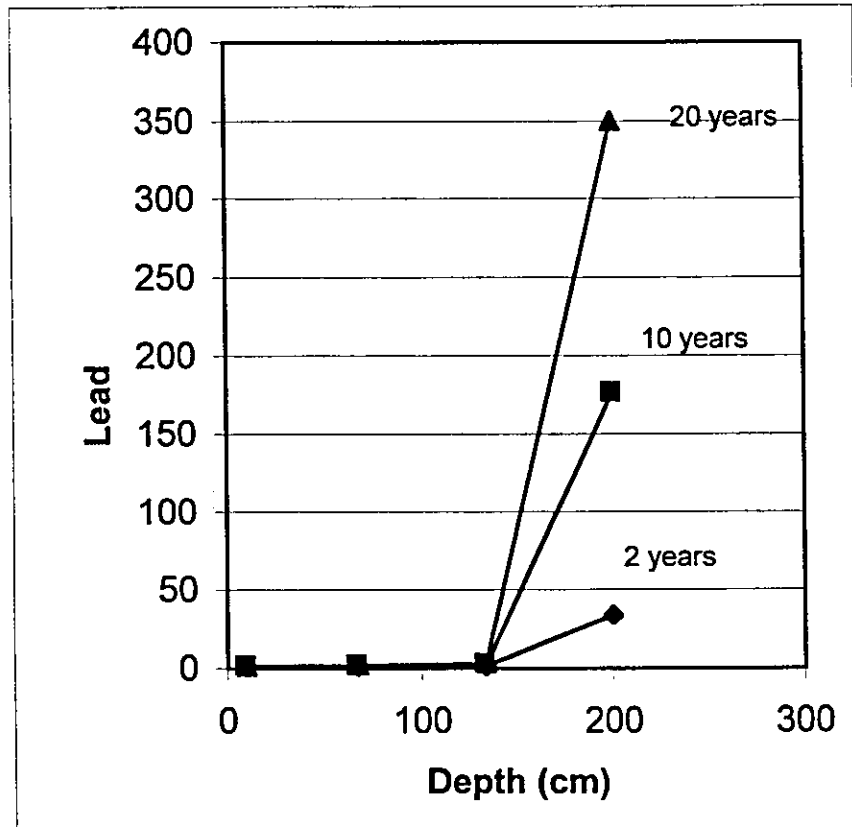
Figure 4.6 Concentrations of lead in micro gram/gram (ppb) versus depth (cm) of the soil remained in the column at different years of treatment (Deir Sharaf soil).

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Figures 4.1 to 4.6 show that the variations of the concentrations of three heavy metals under consideration increase with depth for all treatments. Although the trend is clear of increasing concentration with depth, the concentrations at the bottom depth (200cm) was much higher than the upper depths. This could be attributed to the following:

1) The set up of the experiment where water remained in touch with the bottom soil for longer periods of time which encourage more cation exchange between solution and soil surfaces. Therefore, at the end of the simulation period, the concentrations of heavy metals at the bottom of columns were much higher than the upper depths.

2) The applied concentrations of metals could be low while water was sufficient to leach out added metals.

3) Another concern would be the effect of column walls and diameter which could create the possibility of short circuiting, meaning that the upper sections were not fully used in the simulation.

4) Soil characteristics are very important in simulation. The soil used was clay soil with high expansion and shrinkage properties with wetting and drying conditions. This result in deep cracks and thus the transfer of water could be mostly through these cracks. This transfer will be too fast not allowing metals adsorption and exchange between soil surfaces and soil solution.

The amount of residue of heavy metals was calculated for all columns for the three elements as shown in tables 4.6 to 4.8. These tables show that the residue increased for the three elements with increasing the simulation

period. This indicates the cumulative effects of heavy metals application with irrigation water. Residue calculations indicate that heavy metals remained in the soil are higher for Salim soil than Deir Sharaf soil. However, this could be a result of the higher initial concentrations of heavy metals at this soil.

Although the results show an increase in heavy metals concentrations with depth, the actual increase in the field might be different from the results obtained in the experiment. This could be as a result of different evapotranspiration rates from different soil layers depending on plant physiology and distribution of plant roots.

The total amounts of metals remained in soil were calculated by estimated the average concentration of each element in each soil batch after dividing the soil into three batches. The average concentration of any batch was taken to be the average of the concentrations of soil at the top and bottom of each batch. Soil was assumed to have a uniform density through all columns.

Table 4.9 Electrical conductivity of leachate from the two soils as a function

of time (mmho/cm)

Ten years			
No. of days	Date	Deir Sharaf	Salim
	12/4	1.16	1.17
9	23/4	1.14	1.11
14	28/4	1.08	1.11
19	2/5	1.05	1.10
22	5/5	1.00	1.08
25	8/5	0.99	1.03
20 Years			
	Dates☐	Deir Sharaf	Salim
	12/3	1.28	1.17
22	4/4	1.16	1.15
30	12/4	1.16	1.14
34	16/4	1.08	1.12
41	23/4	1.08	1.07
53	5/5	1.06	1.05
55	7/5	1.04	1.03
58	10/5	1.03	1.02
61	13/5	1.01	1.00
63	15/5	1.00	0.98
64	16/5	1.00	0.98
66	18/5	0.99	0.98
67	19/5	0.98	0.98
2 years			
		Deir Sharaf	Salim
	4/4	1.20	1.18

Both table 4.9 and figure 4.7 show that the electrical conductivity of leachate

started at low values of 1.16-1.28 mmho/cm for both soils at the beginning

of all treatments. This low electrical conductivity is a result of using soils

with low salinity and applying water with nearly zero salinity (rain water).

This rain started leaching the soil, therefore, leachate salinity started at

values equal to the salinity of soil extract. However, as water additions

continued with time, the leaching continued and soil salinity started reducing. Therefore, by the end of the simulation period, salinity of leachate reduced to 0.98 mmho/cm for both soils. The effect of heavy metals on salinity was not significant as the concentrations of these elements is low.

The concentrations of copper, zinc and lead ions in leachate were measured for all columns under consideration. Mass balance of any metal in this simulation requires that the amount of element added plus the amount which was initially in the soil should be equal to the residue in the soil plus the amount of metal in the leachate.

The amount of each metal added was calculated for each treatment as shown in chapter 3. The volume of leachate and the concentration of each metal were measured for each simulation. Mass balance calculations will result in estimating the amount of each metal remained in the soil for both soils as shown in tables 4.10 to 4.12 for copper, zinc and lead respectively.

Table 4.10 to 4.12 show that the initial content of copper, zinc and lead respectively were higher in Salim soils than their concentrations in Deir Sharaf soils. These tables show also that the amount of metals in leachate increased with increasing simulation time. Therefore, there is accumulative effect of adding these elements in irrigation water on these soils. Continual addition of heavy metals in irrigation water resulted in continual leaching of these elements through the soil to the bottom layers. Thus, there is a potential of groundwater contamination as a result of irrigation with water containing high concentrations of heavy metals.

The amount of heavy elements in leachate was also dependent on the simulation period.

Both soils did not exhibit significant difference in the amount of heavy elements removed by their leachate. This could be as a result of their similar physical and chemical characteristics. Therefore, we can conclude that their self purification capacities are similar to each other. The threat on groundwater will be dependent on the hydrogeological characteristics in these two areas.

The blanks of both soils leachate were zero concentration as expected for a non-contaminated soil.

Mass balance calculations were compared to the residual concentration of heavy metals remained in the soil. The residue was found to be different between the amount metal calculated by mass balance and that found experimentally in the soil. It was found from the calculation of metal- ions residue that there was a loss of metal in 2 years treatment was greater than 10 years treatment and 20 years treatments, so this lost of metals could be explained due to several factors among these are :

* Precipitation of metal ions as salts of chloride.

*   Adsorption of heavy metals on the different containers surfaces and columns.

The adsorption of heavy metal depend on the area of surface container, so the container was small as we used for extract solution, the volume of the container was only 100ml for the extract solution and we stored the leachate water in container which its volume was 4 L for all the volume of container which were used to stored and then handling to other container 500ml volume too used in measuring the concentration. So the adsorption in big container have smaller surface area to volume ratios than small containers.

* Adsorption of heavy metals increased as temperature was increased, as the experiment collecting the leachates and measuring concentration and also for the extracted solution soil, the temperature was about 30- 40° C so we added little amount of acid to decrease the adsorption rate.

Table 4.10 Mass balance of copper remained, leachate, applied, initial and residue for different years of treatment

		Mass balance calculations				
		Initial	Applied	Leachate	Residue	Residue
	actual	mg	mg	mg	mg	micro/gm
For 2 years						
Salim	115.14	91.96	80.00	2.21	169.75	8.93
D. Sharaf	90.48	47.88	80.00	3.25	124.64	6.56
For 10						
Salim	288.97	91.96	402.00	38.45	455.51	23.97
D. Sharaf	267.27	47.88	402.00	39.43	410.45	21.60
For 20						
Salim	577.18	91.96	805.00	45.12	845.23	44.49
D. Sharaf	537.57	47.88	805.00	46.61	806.27	42.44

Table 4.11 Mass balance of zinc remained, leachate, applied, initial and residue for different years of treatment

	Total mg	Mass balance calculations				
		Initial mg	Applied mg	Leachate mg	Residue mg	Residue micro/gm
For 2 years						
Salim	147.9	54.37	161	1.01	214.36	11.28
D. Sharaf	121.9	23.55	161	1.41	183.14	9.64
For 10 years						
Salim	619.7	54.37	805	17.07	842.30	44.33
D. Sharaf	593.3	23.55	805	18.12	810.43	42.65
For 20 years						
Salim	1189.2	54.37	1609	66.33	1597.0	84.05
D. Sharaf	1098.2	23.55	1609	82.32	1550.2	81.59

Table 4.12 Mass balance of lead remained, leachate, applied, initial and residue for different years of treatment

Column	Total mg	Mass balance calculations				Residue micro/gm
		Initial mg	Applied mg	Leachate mg	Residue mg	
For 2 years						
Salim	148.2	50.578	161	0.61	210.96	11.10
D. Sharaf	132.2	17.805	161	1.01	177.80	9.36
For 10 years						
Salim	615.9	50.578	805	19.08	836.49	44.03
D. Sharaf	586.4	17.805	805	19.67	805.88	42.41
For 20 years						
Salim	1225.7	50.578	1609	33.18	1623.1	85.42
D. Sharaf	1149.4	17.805	1609	34.26	1592.5	83.82

5-1 CONCLUSIONS:

Based on the results of this study, the following conclusions were reached:

1) Physical and chemical analysis of soils in Deir Sharaf and Salim showed that both soils are of good chemical and physical properties. These properties make them suitable for most agricultural crops.

2) Soils were found to be calcareous with a high percentage of calcium carbonates. Soil pH indicates that most macronutrients will be available in these soils. Deficiency is expected for some micronutrients only such as iron and manganese.

3) The salinity of these soils was found to be low and thus no salinity problems are expected to be found there and even salinity sensitive crops could be also planted there.

4) It was found that heavy metal concentrations in Salim soils before simulation experiment were higher than those in Deir Sharaf soils. This could be as a result of utilizing wastewater with industrial effluents in irrigation there. Addition of water containing heavy elements such as copper, zinc and lead will result in increasing the build up of these elements in the soil and the leachate.

5) Simulation results of continual addition of heavy metals to soil show that the concentration of heavy metals increase with depth and with time in the soil. The leachate will continue carrying these elements below the root zone and thus the possibility of groundwater contamination from irrigation with water containing such elements. Both soils in Deir

Sharaf and Salim were found to have similar chemical and physical properties, thus they had similar response in the simulation experiments. Although, we found the concentrations of heavy metals were found to be higher in Salim soils at the end of simulation for all treatments but this could be attributed to the higher initial content of these elements in that soil.

6) It is found that soil from Deir Sharaf is less conserved with heavy metals than soil from Salim and this is depended on many factors such as:

a) Soil chemical character which means soil from Deir Sharaf has more phosphorus, more organic mater, more total dissolved salts and more electric conductivity than soil from Salim.

b) Soil physical character is different from soil from Salim, the type of each soil according to silt, and clay percentages were different from one another.

7) It is found that the direction and rate of redistribution of metal addition in the soils were affected by: the nature of the metals, the soil properties and the metal loading level.

8) The nature of clay soils in Palestine and their possible high contents of montmorollinites result in soils which have large and deep cracks due to shrinkage and wetting during wetting and drying periods of the year. As a result of forming such cracks, water flows through these cracks at high rates not allowing enough cation exchange between soil surfaces and soil solution. This nature will significantly reduce self-purification capacity of our soils.

5-2 RECOMMENDATIONS:

1. There is a need to put criteria and specifications for concentrations of heavy metals in irrigation water and the period of time that such wastewater could be reused in agriculture.

2. Heavy metals have cumulative effect on soil and groundwater, therefore the concentrations of these elements should be reduced as much as possible.

3. It is recommended that industrial waste should be either separated or treated before added to domestic wastewater. Industries which add heavy metals should separate their wastewater from domestic wastewater and these elements should be extracted before allowing such industries dumping their wastewater in the collection system.

4. It would be recommended to establish industrial centers and separate industries with wastewater containing heavy metals from others to allow safe reuse of wastewater in agriculture.

5. Both areas of Salim and Deir Sharaf have good fertile soils which should be protected from contamination.

6. Continuous monitoring of wastewater, soil and groundwater qualities are essential for any sustainable reuse of wastewater in Palestine.

7. Industries should minimize the use of heavy metals, one recommendation would be to add Tertiarybuty-Methyl-Ether (T.M.E.) instead of tetra ethyl lead to gasoline to prevent antiknock in order to prevent pollution with lead. Also, to use lithium batteries instead of batteries containing lead.

9) Therefore, it is not recommended to continue reusing wastewater in the same soil indefinitely if the wastewater contains heavy elements. The reuse should either be terminated after a certain period of time or such metals should not be allowed in the wastewater collection system.

10) Future research and experimentation of clay soils in Palestine require more attention to the formation of cracks in these soils. Column experiments need special attention to insure the validity of their simulation experiments. Increasing the sizes of such columns could be essential to improve the validity of their results.

11) Additional research will be needed to study the flow through soil cracks and the possibilities of reducing crack formation to improve self-purification capacities of such soils.

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APPENDIX

Table A1: Concentrations of copper in the different soil columns at the end of simulation experiment and the total amount of copper remained in soil:

Column	Residue concentration in soil batches (micro gram/gram)				Total (mg)
	Upper	Middle	Lower	Average	
For 2 years					
1.00	10.56	3.60	3.56	5.91	112.23
2.00	10.42	3.18	3.32	5.64	107.16
3.00	12.34	4.10	3.46	6.63	126.03
Average	11.11	3.63	3.45	6.06	115.14
10.00	9.94	1.94	2.18	4.69	89.05
11.00	9.98	2.22	2.34	4.85	92.09
12.00	10.08	1.94	2.24	4.75	90.31
Average	10.00	2.03	2.25	4.76	90.48
For 10 Years					
4.00	37.20	3.76	3.70	14.89	282.85
5.00	38.12	4.54	3.36	15.34	291.46
6.00	37.50	3.40	2.02	14.31	271.83
Average	37.61	4.45	3.57	15.21	288.97
13.00	35.70	2.22	2.40	13.44	255.36
14.00	37.24	3.68	3.62	14.85	282.09
15.00	36.54	3.20	2.00	13.91	264.35
Average	36.49	3.03	2.67	14.07	267.27
For 20 Years					
9.00	82.26	5.48	5.08	30.94	587.86
8.00	80.70	5.86	4.86	30.47	578.99
7.00	81.86	3.74	3.56	29.72	564.68
average	81.61	5.03	4.50	30.38	577.18
18.00	78.50	4.20	2.74	28.48	541.12
17.00	78.88	3.70	3.42	28.67	544.67
16.00	78.62	2.24	2.34	27.73	526.93
average	78.67	3.38	2.83	28.29	537.57

Table A2: Concentrations of Zinc in the different soil columns at the end of

simulation experiment and the total amount of zinc remained in soil:

Column	Residue concentration in soil batches (micro gram/gram)				Total (mg)
	Upper	Middle	Lower	Average	
For 2 Years					
1	19.62	1.88	1.98	7.83	148.7
2	19.74	1.44	1.66	7.61	144.6
3	20.30	1.68	1.76	7.91	150.3
Average	19.89	1.67	1.80	7.78	147.9
10	16.82	1.44	1.23	6.50	123.5
11	16.86	0.90	0.59	6.12	116.2
12	18.56	0.64	0.70	6.63	126.0
Average	17.41	0.99	0.84	6.42	121.9
For 10 Years					
4	92.64	1.90	2.00	32.18	611.4
5	93.84	2.02	1.56	32.47	617.0
6	95.34	2.20	2.04	33.19	630.7
Average	93.94	2.04	1.87	32.62	619.7
13	90.08	1.34	1.18	30.87	586.5
14	91.76	1.24	1.18	31.39	596.5
15	92.02	1.32	0.92	31.42	597.0
Average	91.29	1.30	1.09	31.23	593.3
For 20 years					
9	179.20	4.08	2.04	61.77	1173.7
8	182.20	4.18	2.46	62.95	1196.0
7	182.58	4.20	2.36	63.05	1197.9
Average	181.33	4.15	2.29	62.59	1189.2
18	175.42	1.96	1.62	59.67	1133.7
17	174.02	2.28	1.30	59.20	1124.8
16	160.94	1.32	1.36	54.54	1036.3
Average	170.13	1.85	1.43	57.80	1098.2

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Table A3: Concentrations of Lead in the different soil columns at the end of simulation experiment and the total amount of lead remained in soil:

Column	Residue concentration in soil batches (micro gram/gram)				Total
	Upper	Middle	Lower	Average	Mg
For 2 years					
1	17.48	2.60	2.28	7.45	141.6
2	19.34	2.48	2.24	8.02	152.4
3	19.02	2.44	2.34	7.93	150.7
Average	18.61	2.51	2.29	7.80	148.2
10	18.26	2.50	1.52	7.43	141.1
11	17.94	1.44	1.18	6.85	130.2
12	17.06	1.30	1.42	6.59	125.3
Average	17.75	1.75	1.37	6.96	132.2
For 10 years					
4	90.84	3.58	3.24	32.55	618.5
5	91.32	3.44	2.96	32.57	618.9
6	89.90	3.56	2.92	32.13	610.4
Average	90.69	3.53	3.04	32.42	615.9
13	89.64	1.80	1.40	30.95	588.0
14	88.22	2.28	1.94	30.81	585.5
15	89.04	2.00	1.44	30.83	585.7
Average	88.97	2.03	1.59	30.86	586.4
For 20 years					
9	184.20	5.56	3.62	64.46	1224.7
8	184.40	4.76	3.36	64.17	1219.3
7	185.20	6.38	3.10	64.89	1233.0
Average	184.60	5.57	3.36	64.51	1225.7
18	163.64	3.10	2.26	56.33	1070.3
17	182.26	2.70	2.26	62.41	1185.7
16	184.02	2.46	1.74	62.74	1192.1
Average	176.64	2.75	2.09	60.49	1149.4

Table A4: Mass balance of copper remained, leachate, applied, initial and residue for different years of treatment

Column		Mass balance calculations				Residue
		Initial	Applied	Leachate	Residue	Residue
Column	actual	mg	mg	mg	mg	micro/gm
For 2 years						
1.00	112.23	91.96	80.00	2.19	169.77	8.94
2.00	107.16	91.96	80.00	2.21	169.75	8.93
3.00	126.03	91.96	80.00	2.22	169.74	8.93
Average	115.14	91.96	80.00	2.21	169.75	8.93
10.00	89.05	47.88	80.00	3.21	124.67	6.56
11.00	92.09	47.88	80.00	3.27	124.61	6.56
12.00	90.31	47.88	80.00	3.26	124.63	6.56
Average	90.48	47.88	80.00	3.25	124.64	6.56
For 10						
4.00	282.85	91.96	402.00	38.82	455.14	23.95
5.00	291.46	91.96	402.00	38.09	455.88	23.99
6.00	271.83	91.96	402.00	38.45	455.51	23.97
Average	288.97	91.96	402.00	38.45	455.51	23.97
13.00	255.36	47.88	402.00	39.26	410.62	21.61
14.00	282.09	47.88	402.00	39.71	410.17	21.59
15.00	264.35	47.88	402.00	39.30	410.58	21.61
Average	267.27	47.88	402.00	39.43	410.45	21.60
For 20						
9.00	587.86	91.96	805.00	48.93	848.03	44.63
8.00	578.99	91.96	805.00	44.75	842.39	44.34
7.00	564.68	91.96	805.00	41.69	845.27	44.49
Average	577.18	91.96	805.00	45.12	845.23	44.49
18.00	541.12	47.88	805.00	44.20	808.68	42.56
17.00	544.67	47.88	805.00	46.36	806.52	42.45
16.00	526.93	47.88	805.00	49.27	803.61	42.30
Average	537.57	47.88	805.00	46.61	806.27	42.44

Table A5: Mass balance of zinc remained, leachate, applied, initial and residue for different years of treatment

Column Number	Total mg	Mass balance calculations				
		Initial mg	Applied mg	Leachate mg	Residue mg	Residue micro/gm
For 2 years						
1	148.7	54.37	161	0.85	214.52	11.29
2	144.6	54.37	161	1.14	214.23	11.28
3	150.3	54.37	161	1.05	214.32	11.28
Average	147.9	54.37	161	1.01	214.36	11.28
10	123.5	23.55	161	1.40	183.16	9.64
11	116.2	23.55	161	1.53	183.02	9.63
12	126.0	23.55	161	1.31	183.25	9.64
Average	121.9	23.55	161	1.41	183.14	9.64
For 10 years						
4	611.4	54.37	805	16.84	842.53	44.34
5	617.0	54.37	805	16.13	843.24	44.38
6	630.7	54.37	805	18.24	841.13	44.27
Average	619.7	54.37	805	17.07	842.30	44.33
13	586.5	23.55	805	17.25	811.30	42.70
14	596.5	23.55	805	19.97	808.58	42.56
15	597.0	23.55	805	17.14	811.41	42.71
Average	593.3	23.55	805	18.12	810.43	42.65
For 20 years						
9	1173.7	54.37	1609	67.42	1596.0	84.00
8	1196.0	54.37	1609	61.67	1601.7	84.30
7	1197.9	54.37	1609	69.89	1593.5	83.87
Average	1189.2	54.37	1609	66.33	1597.0	84.05
18	1133.7	23.55	1609	76.46	1556.1	81.90
17	1124.8	23.55	1609	64.61	1567.9	82.52
16	1036.3	23.55	1609	105.89	1526.7	80.35
Average	1098.2	23.55	1609	82.32	1550.2	81.59

Table A6: Mass balance of lead remained, leachate, applied, initial and residue for different years of treatment

Column Number	Total mg	Mass balance calculations				Residue micro/gm
		Initial Mg	Applied Mg	Leachate Mg	Residue mg	
For 2 years						
1	141.6	50.578	161	0.56	211.02	11.11
2	152.4	50.578	161	0.50	211.08	11.11
3	150.7	50.578	161	0.78	210.80	11.09
Average	148.2	50.578	161	0.61	210.96	11.10
10	141.1	17.805	161	0.99	177.81	9.36
11	130.2	17.805	161	0.99	177.81	9.36
12	125.3	17.805	161	1.04	177.77	9.36
Average	132.2	17.805	161	1.01	177.80	9.36
For 10 years						
4	618.5	50.578	805	19.04	836.54	44.03
5	618.9	50.578	805	19.08	836.50	44.03
6	610.4	50.578	805	19.14	836.44	44.02
Average	615.9	50.578	805	19.08	836.49	44.03
13	588.0	17.805	805	19.61	808.19	42.54
14	585.5	17.805	805	19.10	806.93	42.47
15	585.7	17.805	805	20.29	802.51	42.24
Average	586.4	17.805	805	19.67	805.88	42.41
For 20 years						
9	1224.7	50.578	1609	29.49	1630.1	85.79
8	1219.3	50.578	1609	31.46	1618.1	85.16
7	1233.0	50.578	1609	38.59	1621.0	85.32
Average	1225.7	50.578	1609	33.18	1623.1	85.42
18	1070.3	17.805	1609	33.61	1593.2	83.85
17	1185.7	17.805	1609	25.21	1601.6	84.29
16	1192.1	17.805	1609	43.96	1582.8	83.31
Average	1149.4	17.805	1609	34.26	1592.5	83.82

بسم الله الرحمن الرحيم

ملخص

تقوم بلدية نابلس بأجراء التصاميم والدراسات وذلك لتنفيذ مشاريع لتنقية مياه المجاري
واعادة استخدامها للري في منطقتي دير شرف و سالم. نظرا لاحتواء مياه المجاري على
مخلفات صناعية فأنه توجد خطورة من إمكانية تلوث التربة و المياه الجوفية بالعناصر
الثقيلة. لذا أجريت هذه الدراسة على تربة من هاتين المنطقتين حيث تمت دراسة
خصائص التربة الفيزيائية والكيميائية وكذلك تمت نمذجة الري بمياه محتوية على عناصر
ثقيلة (نحاس، رصاص، خارصين) باستخدام أعمدة ترابية بطول ٢ متر.

بينت نتائج التحاليل الفيزيائية والكيميائية أن هذه الترب طينية ولها خصائص فيزيائية
وكيميائية جيدة حيث أنها منخفضة الملوحة ودرجة حموضتها ٧-٨ وتحتوي على نسب
جيدة من الكالسيوم ونسب منخفضة من الصوديوم ويمكن تصنيفها بترب جيرية. هذه
الترب صالحة لزراعة معظم المحاصيل. كذلك فأن صفات الصرف فيها جيدة ولها نفاذية
معقولة لحسن بنائها نظرا لارتفاع تركيز الكالسيوم وانخفاض تركيز الصوديوم فيها.

بينت اختبارات نمذجة الري بمياه محتوية على عناصر ثقيلة ارتفاع تراكيز العناصر
الثقيلة في التربة ومياه الغسيل كلما ازدادت إضافة العناصر الثقيلة مع الري ومع مرور
الوقت ومع العمق مما يحتم ضرورة التوقف مستقبلا عن الري بمثل تلك المياه مع

ضـرورة المراقبة المستمرة. رغم ارتفاع نسبة الطين في التربة إلا أن قدرتها على تنقية

العناصـر الثقيـلة تأثـرت بتشكل الشقوق نتيجة للتمدد والتقلص بسبب ظروف الرطوبة

والجفـاف خصوصـاً قرب السطح. تشكل الشقوق يؤدي إلى حركة المياه بسرعة مما

يقلل من إمكانية تبادل الأيونات بين التربة ومحلولها وخصوصا عند السطح.