SOME HEAVY METALS IN PLANTS IRRIGATED WITH SEWAGE EFFLUENTS

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B.Eng. (Water Resources & Environ. Engineering)

SOME HEAVY METALS IN PLANTS **IRRIGATED WITH** SEWAGE EFFLUENTS

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A Thesis submitted to the Postgraduate School, Ahmadu Bello University, Zaria, in partial fulfillment of the Requirements for the Award of the Degree of Master of Science **M.Sc.)** in Water Resources and Environmental Engineering.

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DEDICATION

This work is dedicated to my late father, Alhaji Muhammadu Song, and my beloved mother, Hajiya Aminatu Tukur.

DECLARATION

I declare that this thesis has been composed by me and that it is a record of my own investigation. It has not been submitted in any previous application for a degree. All sources of information are acknowledged by means of references.

MOHAMMED DAHIRU

11/12/89

July 4, 1989

CERTIFICATION

This thesis entitled, "Some Heavy Metals in Plants Irrigated with Sewage Effluents," by Mohammed Dahiru, meets the regulations governing the award of the degree of Master of Science (Water Resources and Environmental Engineering) of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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ABSTRACT

This study investigates the concentrations of certain metals absorbed by crops when irrigated with sewage effluents. Amaranthus, tomatoes and maize crops were flood-irrigated with A.B.U., Zaria waste stabilization pond effluents for about 4 months at application rate of 80 litres per day per plot of 4m x 2m. Tapwater was used as control irrigation water.

The concentrations of heavy metals including Zn, Mn, Pb, Cd and B in the sewage effluents and the tapwater were determined, in addition to the initial concentrations of these metals in the soil. Also, the cumulative absorption of these metals in the various parts of the experimental crops were determined during the periods of irrigation.

It was found that A.B.U. sewage effluent contained slightly more Zn, Mn, Pb, Cd and B than the tapwater. Although the Pb, Cd and B concentrations absorbed by various tissues of the test crops were more when the crops were irrigated with sewage effluents than with tapwater, the difference was not statistically significant. However, the Mn concentrations absorbed by various parts of the test crops were significantly higher in the tapwater than in sewage effluents irrigated crops.

The results show that different crops absorbed

these metals at different rates and that the absorption of the metals differ from part to part for each crop. Generally the roots of the test crops absorbed the highest concentrations of Zn, Pb, and Cd followed by stem. However, the Mn and B absorption were highest in the leaves than the remaining parts in all the test crops. The maize grains and the tomato fruits contained the lowest concentrations of all the elements investigated.

Although the heavy metal concentrations absorbed by the different parts of the crops increased (except Mn) with increasing sewage application, the concentrations of these metals absorbed during the period of study were within the permissible limits. However, the effect of longer period of. investigation on the absorption of these metals should be investigated.

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NOTATIONS

ART = Amaranthus Roots in tapwater irrigated plots
ARE = Amaranthus Roots in sewage effluent irrigated plots
AST = Amaranthus Stem in tapwater irrigated plots
ASE = Amaranthus Stem in sewage effluent irrigated plots
ALT = Amaranthus Leaves in tapwater irrigated plots
ALE = Amaranthus Leaves in sewage effluent irrigated plots
TRT = Tomatoes Roots in tapwater irrigated plots
TRE = Tomatoes Roots in sewage effluent irrigated plots
TST = Tomatoes Stem in tapwater irrigated plots
TSE = Tomatoes Stem in sewage effluent irrigated plots
TLT = Tomatoes Leaves in tapwater irrigated plots
TLE = Tomatoes Leaves in sewage effluent irrigated plots
TFT = Tomatoes Fruits in tapwater irrigated plots
TFE = Tomatoes Fruits in sewage effluent irrigated plots
MRT = Maize Roots in tapwater irrigated plots
MRE = Maize Roots in sewage effluent irrigated plots
MST = Maize Stem in tapwater irrigated plots
MSE = Maize Stem in sewage effluent irrigated plots
MLT = Maize Leaves in tapwater irrigated plots
MLE = Maize Leaves in sewage effluent irrigated plots
MGT = Maize Grains in tapwater irrigated plots
MGE = Maize Grains in sewage effluent irrigated plots

Zn = Zinc
Mn = Manganese
Pb = Lead
Cd = Cadmium
B = Boron
Mt/ha = Megatonnes per hectre

CHAPTER ONE

INTRODUCTION

1.1 WASTE WATER

Waste water is an inevitable product of population centres, and must therefore be disposed of effectively. Increasing population growth and continuing urbanization and industrial development have generated increasing volumes of municipal and industrial waste waters. In order to protect the public health and to maintain aesthetics, waste water treatment process of increasing sophistication have been developed and are being utilized.

In places where water is scarce such as in arid and semi-arid regions, re-use of municipal and industrial waste waters has become an economically attractive option. Re-use of waste water for irrigation is of particular interest because waste water contains many of the nutrients essential to plant growth. Also re-use of waste water could help to preserve the limited resources of good quality water for drinking, particularly as rapid urban development is now taking place in many regions of the world.

Waste water re-use for irrigation has been practised as far back as 1870 in the United States, England, France, Italy and Germany (Ogunrombi, 1975, Shuval, 1983). At that time, raw or

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partially treated waste waters were mostly used. However, careful considerations must be given to the possible long term effects on soils and plants, particularly the trace elements (heavy metals) that they contain. The trace elements effects are normally manageable if the problems associated with them are understood and allowances made for them. Re-use of effluent for irrigation may also lead to microbial contaminations of soils and plants in the viccinity of irrigation sites. The extent of such contaminations depends on the degree of treatment given to the waste water, the prevailing climatic conditions, types of crops irrigated, and the design of irrigation systems. The potential impacts associated with agricultural re-use of waste water are important economically, environmentally and socially. Hence sound planning during re-use is required in order to reduce the environmental impact associated with sewage irrigation.

1.2.0 OBJECTIVE OF THE STUDY

The sewage at A.B.U., Zaria, main campus originate from Student's hostels sullage, research laboratories and dinning halls, and treated by the waste stabilization ponds situated at the South East of the main campus near the down stream end of the University dam. The pond system serves

a population of about fourteen thousand people. The treated effluent is discharged into nearby Kubanni river through a natural gully, without disinfection. It is estimated that about 1500m^3 are discharged daily into the Kubanni river (Ogunrombi, 1975).

The inhabitants of Jama'a Village not far from A.B.U. main campus make use of the effluents for irrigating their crops. The irrigated crops are sold in the markets. The effluents may contain toxic heavy metals which when applied in large quantities to soils may accumulate and subsequently be taken up by plants.

This study was conducted to determine the concentration of some of the toxic heavy metals in plants as a result of using the waste water effluents for irrigation. The major concern was to determine whether plant absorption of the elements would occur at phytotoxic level or levels harmful to man and animals. Also, since many researches have dealt with the problems of the absorption of heavy metals by plant when treated with sewage sludges, this study will provide useful informations on the absorption of heavy metals by plants when irrigated with sewage effluents.

CHAPTER TWO

LITERATURE REVIEW

2.1.1 SOURCES OF WASTEWATER

The term wastewater is generally applied to the liquid waste collected in sanitary sewers and treated in a municipal wastewater treatment plant. The wasterwater coming from industrial and domestic operations, and from infilteration in flow are the major sources of municipal wastewater. Wastewater from industrial operations includes the spent water from manufacturing or food processing plants, while domestic wastewater is the wastewater consisting of human bodily discharges carried by flushing water; sullage water, and other water-borne material discarded as a result of regular household and human sanitary activities. Inflow is the storm water that enters the sewer systems through man hole and other openings. Wastewater source from infilteration is the ground water that seeps into the sewer through improperly sealed or broken joints or cracks of the pipes. The amount of wastewater from each source vary widely among communities and depend on the number and the type of commercial and industrial development as well as on the age and length of the sewer pipes. (Asano et al, 1985).

2.1.2 CHARACTERISTICS OF WASTEWATER

The physical properties and the chemical and biological constituents of wastewater are important in evaluating the effects of application of effluents on land and crops during irrigation. Also, they are important parameters in the design and operation of collection, treatment, and disposal facilities and in engineering management of environmental quality (Takashi et al, 1985).

(a) Physical Characteristics:

Some important physical characteristics of wastewater include temperature, taste and odour, colour, solids, etc. The solids may be present in suspension and or in solution. They may be organic or inorganic in nature. They also have the tendency to coat the land surface during irrigation (Takashi et al, 1985, Charles and Ronald, 1973).

Temperature is not a great problem in wastewater irrigation. According to Charles and Ronald (1973) the temperature values (50°F - 70°F) for municipal wastewater are not harmful to soil and vegetation. Parizek et al (1967) observed that sewage effluents has been used to

spray on crops in freezing weather to form an insulating ice coatings which protects the crops from cold air. While sewage colour has little effect on crop application, they can be used as an indicator of the composition of the wastewater (Charles and Ronald, 1973). Odours in wastewater are caused by the anaerobic oxidation of organic matter. The by-products of the oxidation such as hydrogen sulphide gas, volatile compounds such as indol, Skatol and mercaptans are the major causes of the obnoxious odours (Charles and Ronald, 1973).

(b) Chemical Characteristics:

The chemical characteristics can be categorised into organic matter, inorganic matter and gases.

The organic matter are principally proteins, carbohydrates and fats. If discharged to the environment, their biological decomposition can lead to the depletion of dissolved oxygen in receiving waters and to the development of septic conditions. Other organic compounds such as phenols, surfactants, and pesticides, are usually present in small quantities, and do not pose serious problems till they reach higher concentrations (Charles and Ronald 1973). Some organic compounds are

toxic in the environment and their presence in wastewater may limit the suitability of the wastewater for irrigation (Asano et al, 1985). Many of the inorganic compounds such as boron, nickel, and zinc provide nutrients for the vegetation at low concentrations (Charles and Ronald, 1973). However, they can be toxic to plants at higher concentrations. The major nutrients essential for plant growth are nitrogen, phosphurus and potassium. Their presence should normally enhance the value of water for irrigation purposes (Takashi et at, 1985). Gases in wastewater (except those associated with odours), are relatively not important in land application. Dissolved oxygen is usually decreased soon after wastewater is applied to land, atmosphieric oxygen is relied on for maintenance of aerobic conditions in soil (Metcalf and Eddy, 1979, Onuoha, 1981, Takashi et al, 1985).

(c) Biological Characteristics:

Wastewater contains micro-organisms that are constantly changing its characteristics, bacteria being the predominant among the micro-organisms. Wastewater may contain pathogenic organisms (bacteria, viruses and parasites) which cause diseases, such as salmonella gastroentritis, typhoid and paratyphoid fevers,

bacillary and amoebic dysentery, cholera and infectious hepatitis (Parizek et al, 1967).

2.1.3 WASTEWATER TREATMENT

Wastewater treatment consists of a combination of physical, chemical and biological processes which are aimed at removing solids, organic matter, pathogens and some nutrients (phosphurus, Nitrogen, heavy metals) from wastewater.

Preliminary treatment includes bar screening, and grit removal by sedimentation. The velocity of the water through the grit chamber is maintained at a sufficiently high rate to prevent settling of most organic solids. In small wastewater treatment plants this step is often excluded (Takashi et al, 1985).

Primary treatment is the removal of settleable organic and inorganic solids by sedimentation. Also the removal of materials that will float (Scum) is achieved by skimming. According to Takashi et al (1985) approximately 25 to 50% of the incoming Bichemical oxygen demand (BOD), 50 to 70% of the total suspended solids, some organic nitrogen and phosphurus, and heavy metals are removed by primary treatment.

Secondary treatment is the removal of

biodegradable dissolved and colloidal matter by means of biological oxidation processes. Some of the conventional biological treatment processes includes:

(1) The activated sludge process.

(2) The trickling filter or biofilter process.

(3) The waste stabilization pond system.

(4) The oxidation ditch and aeration Lagoons. (McKinney, 1962, Charles and Ronald, 1973, Metcalf and Eddy, 1979).

Tertiary treatment is the process of removing wastewater constituents which are not removed by secondary treatment. It is applied where the probability of public exposure to the wastewater or residual constituents is high (Charles and Ronald, 1973).

Physical and Chemical methods for removal of nutrients (nitrogen, and phosphurus), biodegradable and non-biodegradable organics, heavy metals and colloidal suspensions were reviewed by a number of investigators. Shell and Burns (1973), and Hatheway (1973) found that chemical coagulation, carbon adsorption, and filteration could remove 95% of the total organic carbon, Biochemical oxygen Demand (BOD), heavy metals, total phosphates and suspended solids and 78% total nitrogen. Also, they found that the amount of metals removed was closely

related to the change in chemical oxygen demand of the liquid passing through the soil.

Over land flow was shown by Lee et al (1976) in green house model studies to effectively remove heavy metals from applied wastewater at Utica, Mississipi. According to them, over 90% reduction of Zinc, Copper, Nickel and Cadmium was noted from the applied wastewater.

McPherson (1979) reported that the effluent samples from various treatment process (Land filteration, sedimentation and combination of filteration plus sedimentation) at Warribe farm, Australia showed 85% removal of Cadmium, 95% Lead and Zinc by land filteration, and 35% for Cadmium, Lead and Zinc by sedimentation. The combination of filteration and sedimentation removed 85% Cadmium, 95% Lead, and 90% Zinc. He concluded that in general high levels of heavy metal removal obtained by the three processes were 83% ± 12%.

2.2.0 TRACE ELEMENTS IN WASTEWATER

Heavy metals and other trace elements are usually part of soils. If additional quantities are introduced through activities of man, resulting in an altered chemical composition of the environment, natural recycling process are disturbed (Gupta, 1972). The occurrence of

trace elements in wastewater can be traced to the water source and to the activities in the adjacent environment. Industrial wastes from processing and manufacturing of consumer goods are important contributors to high trace metal concentrations in wastewaters (Iskander, 1975). The deterioration of storage and transmission equipment in the community water supply systems and the wear of household plumbing fixtures may also contribute to the presence of trace elements in water. For these reasons small amounts of trace elements are always found in domestic water supplies (Klein et al, 1974). Many wastewater treatment plants have been shown to receive and discharge heavy metals above prudent levels (Mytelka et al, 1973).

Zinc is found in many municipal wastewaters, because its salts are used in producing paints, pigments, cosmetics, dyes and insecticides. However, according to Oliver and Casgrove (1975), the concentrations of zinc in sludge is higher than in the effluent itself. The zinc content in wastewater may vary greatly from one location to the next because of differences in water supplies, the relative contributions of other sources, and the removal mechanisms operating in the waste stream (William et al, 1980). Numerous studies have shown that most

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of the zinc in raw wastewater is in particulate form, capable of being removed by filteration, centrifuging or settling (Chen et al, 1974, Oliver and Casgrove, 1975, Hager and Rizzo, 1973). Most of the metals in industrial wastewater may be in dissolved form, but some are converted to an insoluble forms when they react with municipal sewage (William et al, 1980).

Manganese create serious problems in public water supplies. It imparts objectionable and tenacious stains to laundry and plumbing fixtures. The major source of manganese in water supplies are the insoluble forms found in high concentrations in nearly all soils (McCarty and Sawyer, 1978) and the amount of manganese found in wastewater would therefore depend on the manganese content of the water supplies. The concentration of manganese in agricultural soils is high, and this may be the major source of its presence in wastewater (Horvath and Koshut, 1981). Although manganese in excessive levels are toxic to plants it does not constitute a problem to public health, since its concentration in soil solutions can be corrected or regulated through PH adjustments of soil and soil drainage (Horvath and Koshut, 1981).

The Lead concentrations in municipal sewage varies widely from place to place

(Ewing and Pearson, 1974). It is introduced into waters generally as part of industrial and minning effluents (Patterson, 1968). Many cities with little industrial sources of lead may expect less than 10µg/g of Lead in sewage. Other cities may find 100 to 150µg/g (Ewing and Pearson, 1974), depending on the nature of the collection system and the industrial waste contribution of lead to the municipal system.

Sewage sludge may contain from 0.2 to 0.8% Lead on dry weight basis (Etinger, 1966), and this would be equivalent to 20 to 80 tonnes of Lead per day in the sludge produced in the wastewater treatment plants of the metropolitant sanitary district of Chicago.

Cadmium enters the human environment as a contaminant from minning and metallurgical, chemical and ceramic industries, scrapmetal treatment, electroplating, super-phosphate fertilizers and cadmium containing pesticides (McCarty and Sawyer, 1978). Cadmium has not known essential function in plants or animals, although it is known for its toxic effects to plants and animals (Friberg et al, 1971).

The inclusion of boron in fertilizers as an essential micro nutrients and of borates and perborates in detergents as buffering, softening and bleaching agents has made boron an element

with considerable economic importance in the past few years. Consequently, it is becoming more likely to be a constituent of wastewater effluents. Boron occurs in sewage effluents in increasing amounts because borates have been substituted for phosphates in household detergents.

Bouwer et al (1974) found that boron in the secondary effluents from the city of phoenix, Arizona had risen from 0.4ppm in 1969 to 0.9ppm in 1971. According to them, the average heavy metal contents from each source (from which six samples were taken at biweekly intervals over a 2 months period), showed a concentration of 193µg/g for zinc, 82µg/g for Lead and 7.7µg/g for cadmium.

Mytelka et al (1973) investigated the trace element contents in sewage effluents collected from treatment plants in the interstate sanitation district (New York, New Jersy, and Connecticut). They observed that the range of concentrations of some elements was of less than 0.02-6.4ppm for cadmium; less than 0.02-6.0ppm for lead; less than 0.02-20ppm for zinc and 0.02-0.95ppm for manganese.

Blackslee (1973) studied the total and dissolved trace elements of wastewater effluents from 55 treatment plants in different communities in Michigan. The concentrations of the elements

showed a range of less than 0.005-0.15ppm; less than 0.02-1.3ppm and 0.03-4.7ppm for cadmium, lead and zinc respectively.

Also, data presented by Konrad and Kleinert (1974) for 35 municipal sewage treatment plants in Wisconsin, showed the following ranges for heavy metals in the effluents: Zn, 0.04-1.0ppm; Cd, 0.02-0.04ppm, and Pb, 0.05-0.2ppm.

2.3.0 OCCURENCE OF TRACE ELEMENTS IN PLANTS

Herlin (1979) reported that the majority of researches have dealt with the problems of land application of sludge-borne heavy metals other than that of wastewater. Most of the literature cited in this section deal with the absorption of heavy metals by crops treated with sewage sludges, because of the scarcity of literature on wastewater irrigated plants.

Several investigators such as Chaney (1973), Webber (1972) and Lepper (1972), have expressed concern regarding the introduction of trace elements (heavy metals) into the natural biological systems in conjunction with sludge and effluent application on land. The trace elements may pose harzards to the food chain, since they can readily be transferred from soil, to plants, and finally to animals or humans.

Manganese (Mn), Zinc (Zn), and Boron (B) are

essential elements for plant growth. However, if applied in excessive amounts, they may be phytotoxic. Cadmium (Cd) and Lead (Pb) are both harzards to the food chain, and as they are taken up by plants, their application to land must be controlled.

Lagerwaff (1971) found that the concentrations of Cadmium in radish grown on sludge ammended soils reached 5µg/g dry weight; while according to Chaney and Giordano (1977) the level in spinach grown on sludge ammended soil was 161µg/g. Similarly Jones et al (1975) found that the concentrations of cadmium in corn leaves and corn grains grown on sludge ammended soils were 22.22µg/g and 0.1-1µg3g respectively.

Sidle and Sopper (1976) reported that treated municipal wastewater from Pensylvania University sewage treatment plant was used for irrigation in field areas and forage ecosystem from 1964-1974. They observed that white spruce and wild strawberry foliage from the field showed no increase in cadmium concentration after effluent irrigation. They also observed that irrigated goldenrod contained less cadmium (0.042ppm) than those on the control plots (0.82ppm). They concluded that the observed results were due to greater biomass production as a result of the irrigation.

According to Jones et al (1975), application of high cadmium sludge increases the cadmium content in corn, leaves from 0.5 to 20µg/g. Leafy vegetables such as Lettuce, Spinach, beet greens as well as tobacco contained the highest cadmium levels (Dowdy and Larson, 1975, Chaney and Hornich, 1978).

Dedolph et al (1970) reported that the source of lead found in some plants is the soil and this is absorbed through the roots of the plants. Half of the lead found in Rye grass and radish leaves originated from the soil, according to the report.

Distribution of lead within the plant organism is variable with plant species. Motto et al (1970) observed that the lead occuring in plants was more concentrated in the roots and leaves than in fruits, grains or tubers. Also, the concentrations of lead in the leaves increased as the soil concentrations of the element increased.

Boawn (1971) reported the results obtained when twelve Leafy vegetables on field plots were treated with 356kg zn per acre, and the control (normal water). The results showed that of all the crops grown, only Swiss Orchard and Spinach had tendency to accumulate zinc. The concentrations of zinc in Swiss Orchard and Spinach were 80ppm

and 139ppm respectively in the control plots while in the zinc treated plots (356kg zn per acre), the zinc concentrations in Swiss Orchard and Spinach were 862ppm and 340 ppm respectively.

Lettuce and onions were grown under normal field conditions, in 1 x 1m mini plot, and in pot trials in a glass house respectively, on a soil in Australia. The soil received upto 18 tonnes/ hectre of sludge from melbourne city wastewater treatment plant. Devries and Tiller (1978) analysed for Cd, Cu, Mn, Ni and Zn under the different conditions and concluded that sludge application brought about a sharp increase of the concentrations of the metals in the plant material from the glass house, where as there was little increase in the concentrations of the metals in the field plants.

Sidle et al (1976) irrigated corn with municipal sewage effluents, and control (normal water) at application rate of 7.5cm/week. They analysed for Cu, Zn, Cd, and Pb, and found that the total uptake of these metals by the corn in the control was usually as high or higher than in the sewage effluent treated areas.

Dowdy and Larson (1975) grew vegetable crops on sandy soils treated with sludge from Still water, minnesota at application rate of 450

mega/tonnes hectre. They reported that in the corn area, the concentration of trace elements in the corn leaves were 9ppm for boron, 1.32ppm for cadmium, 77ppm for manganese, 4ppm for lead, and 293ppm for zinc. They trace elements concentrations in the corn grains were 3ppm for boron, 0.05ppm for cadmium, 9ppm for manganese, less than 0.2ppm for lead, and 65ppm for zinc. Similar observations were made by Hinesly et al (1972) when corn was grown on silty loam soil treated with sludge from Chicago at application rate of 70 mega/tonnes hectre. The corn leaf indicated trace element concentrations of 43.6ppm B, 11.6ppm Cd, 116ppm Mn, 6.3ppm Pb, and 212ppm Zn. The corn grain showed 6.6ppm B, 1.03ppm Cd, 18.3ppm Mn, 0.03ppm Pb, and 152ppm Zn.

Kirkham (1975) observed that after growing corn on a silty clay sludge disposal field in Dayton, Ontario and at a sludge application rate of 980 mega/tonnes hectre, the concentrations of some trace elements (Cd, Mn, Pb and Zn) in the roots were 48.7ppm cd, 467ppm Mn, 542ppm Pb, and 1350ppm. In stems, the concentrations were 5ppm cd, 25ppm Mn, less than 5ppm Pb and 320ppm Zn. Corn leaf had concentrations of 13.9ppm Cd, 99ppm Mn, 11ppm Pb and 196ppm Zn. Finally the concentrations in the corn grain were 0.9ppm Cd, 5ppm Mn, less than 5ppm Pb, and 79ppm Zn.

Recently, marecos do Monte et al (1989) presented results obtained during the first two years of irrigation of crops with municipal wastewater from Evora, Portugal, and portable water (control). In the maize plots irrigated with secondary effluents, the chemical composition of the maize grain indicated values of 21.80ppm Zn, 2.10ppm B, and less than 0.05ppm Cd, in 1985; and 20.28ppm Zn, 5.25ppm Mn, 2.50ppm B, and 0.25ppm Cd in 1986. In the control plots the chemical composition of the maize grain were 23.43ppm Zn, 1ppm B, and less than 0.05ppm Cd in 1985, and 21.25ppm Zn, 5.15ppm Mn, 1.97ppm B, and 0.25ppm Cd in 1986. They concluded that generally no adverse effect on the crop composition of the measured elements results from irrigation with secondary effluents.

Page (1974) reported that the concentrations of B, Mn and Zn in spinach leaves grown in fields treated with sludge from Torrington, Connecticut, at an application rate of 176 mega tonnes per hectre were 39, 150 and 815ppm respectively. A similar investigation by Luetting et al (1975) on spinach with a sludge from Chicago, Illinois at application rate of 110 mega tonnes per hectre, showed that the trace elements concentrations in the spinach leaves were 8.27ppm Cd, 31.3ppm Mn, 1.74ppm Pb and 100ppm Zn. From the above

reported results, it can be inferred that the trace elements concentrations in the spinach leaves increased with increase in sludge application rate.

Bradford et 'al (1975) observed that the concentrations of trace elements in tomato leaves grown in sandy soil treated with treatment plant sludges had 85, 4.6, 11 and 90ppm B, Cd, Pb and Zn respectively. Another investigation was reported by Vanloon (1975) on tomatoes grown in silt loam soil, with sludge from Toronto, Canada at an application rate of 30% on dry weight basis, the concentration of Cd, Mn, Pb and Zn in tomato leaves were 3, 100, 3, and 100ppm respectively. He observed further that the tomato fruits had lower concentration of 0.6ppm Cd, 10ppm Mn, 1ppm Pb, and 35ppm Zn.

Similarly, Dowdy and Larson (1975) examined the concentrations of trace elements in tomato fruits. When the tomatoes were grown in a field treated with sludge from Stillwater, Minnesota, at an application rate of 450Mt/ha. They observed that the concentrations of B, Cd, Mn, Pb and Zn in the fruits were 14, 0.33, 10, 0.4 and 31ppm respectively.

2.4.0 FACTORS AFFECTING THE ACCUMULATION OF TRACE ELEMENTS IN PLANTS

Any factor that affects the availability of trace elements in the soil also affects their accumulation in plants. The soil pH affects the availability of trace elements in plants. Increased soil pH commonly reduces the uptake of trace elements (Davies, 1980). According to Chaney (1973) the trace elements are much more available at soil pH of below 6.5-7.0. Zimdahl and John (1974) reported on the influence pH on uptake of Lead by some plant roots treated with Lead nitrate solution at concentration of 10µg/ml. They concluded that the Lead uptake was reduced as the solution approached pH 7.0 in Soya bean and field bean. However, uptake by barley and radish remained nearly constant. Lagerwaff et al (1973) reported a similar effect ofpH for maize except that the suppressive effect of pH on Lead accumulation in the maize plant was relatively minor or absent at higher soil lead concentration.

Organic matter may lower the susceptibility of plants to injury. This action is enhanced by the formation of chelates of trace elements, which protects the roots of the plants from severe injury and stunting (Chaney, 1973).

The reports of Mortvedt and Giordano (1975), and of Cunningham et al (1975) established that trace elements in sludges are taken up less readily than are trace elements added to sludge in the form of inorganic salts or trace elements added directly to soil in the same concentrations as was present in the sludges.

Haghiri (1974) determined the effects of added organic matter on the Cadmium concentrations in Oat shoots and on the exchangeable Cadmium in soil. He observed that neither Cadmium concentrations in Oat shoots nor soil exchangeable Cadmium was significantly affected by the addition of organic matter. He concluded that the retaining power of organic matter for Cadmium was predominantly through its Cation Exchange Capacity property rather than chelating ability.

The Cation Exchange Capacity of soil to some extent affects the uptake of trace elements by plants.

Korte et al (1975) found that the Cation Exchange Capacity is unimportant in predicting the quantity of trace elements leached from soil. However, Singh (1974) determined the effect of Cation Exchange Capacity of soil on the uptake of Cadmium by plants, by adding a constant amount of cadmium at five Cation Exchange Capacity

levels. The cadmium concentrations in Oat shoots was decreased by increasing the Cation Exchange Capacity of the soil.

The species and varieties of plants differ greatly in toxic metal accumulations. Peterson (1977) studied cadmium uptake between crop species and varieties. His experimental results showed that cadmium uptake by several barley varieties cultivated in Sweden, was not significantly different statistically. However, data reported by Council of Agricultural Science and Technology (CAST, 1980) showed the contrary. Also, John and Van Laerhoven (1976) found significantly different levels of Cadmium accumulation in nine varieties of Lettuce grown by sand culture, with Cadmium concentration of the nutrient solution ranging from 0.10 to 50µg/l.

The uptake of metals by plants is also controlled by synergistic and antagonistic interaction with other elements. Mitchell et al (1978) and Bingham et al (1975) studied the interactive effects of Cd, Cu, Ni and Zn on phytotoxicity to lettuce when sludge, spiked with the salts of the metals, was added to the soils. All these metals according to them, may interact both synergistically and antagonistically in affecting the yield of Lettuce. They concluded

that generally the metals interacted synergistically to reduce yield. Root et al (1975) have also reported an interaction between zinc and cadmium in solution culture. As cadmium concentrations of maize leaves and roots increased, that of zinc decreased. In the same experiment, and contrary to the results of John (1976), iron concentration in leaves and roots of Maize plant increased as that of cadmium increased. It was concluded that cadmium reduced the uptake of zinc and that this in turn caused an increase in the uptake of iron. Chaney (1973) observed a lower concentration of zinc in corn leaves at the PH5.5-PH6.6 than at PH6.5-PH7.0. He suggested that this observations was due to the presence of other toxic metals which can interfer with zinc transport.

2.5.0 WATER QUALITY REQUIREMENTS FOR AGRICULTURE

For many years wastewater has been used in different countries for agricultural purposes (Cecil, 1967, WHO, 1973). The quality of such wastewater is important both for the health of workers who come in contact with it and for the particular application for which it is meant.

The major quality consideration regarding the re-used effluents include salinity, sodium

relationships, concentration of boron, and toxic metals. Other quality considerations of importance are organic materials, suspended solids, nutrients and pathogenic organisms.

Hilgard (1906) was among the first to recognise the importance of irrigation water quality and to propose standards based on the composition of the water. Other contributions were made by Doneen (1949), and Food and Agricultural Organisation (FAO, 1985).

Amstrong (1972) reported that sewage effluent from Boliver sewage treatment works at Adelaide, Australia was found to have excessive salinity and high sodium concentrations. This necessitated the planting of only salt tolerent crops in order to determine the suitability of the effluents for irrigation. According to him, the effluent appears to be suitable for the growth of Lucerne plant.

Berrow and Webber (1972) concluded after their studies in the U.K., that zinc, copper, nickel and occasionally chromium were the elements most likely to be present in concentrations toxic to plants when sewage effluent were used for irrigation.

McKee and Wolf (1963) reported the presence of pathogens in sewage effluents, and the

possible health problems to humans and animals associated with them. WHO (1973) has suggested that only a limited health risk would result from unrestricted irrigation of agricultural crops with sewage effluents having a bacterial quality of 100 Coliforms organism/100ml. To obtain this quality the effluent would need to be completely biologically stabilized and chlorinated.

The maximum permissible concentrations of selected trace elements in irrigation waters, and the guidelines for irrigation water quality have been recommended by FAO (1985). Also, the suggested treatment process to meet health criteria for irrigation water has been recommended by WHO (1973).

2.6.0 WASTEWATER RE-USE FOR IRRIGATION OF AGRICULTURAL CROPS

Irrigation seems to be an attractive option for wastewater re-use in developed and developing countries because of the need and desire for self-sufficiency in food. Effluent re-use as irrigation water will provide beneficial nutrients for plant growth. However, the focus in the re-use of the effluent should be on maximising the benefits, and minimising any detrimental effects to the environment and to man.

According to the data collected by Harvey and Cantrell (1965) sewage effluent was successfully used in the production of the major crops of Texas on more than 12,000 acres. Crook (1976) reported that municipal wastewaters in California are re-used for fibre and seed crop irrigation, processed and unprocessed food crop irrigation, and landscape irrigation.

Omran et al (1988) investigated the effect of sewage irrigation on navel orange trees in Egypt. They concluded that the yield increased remarkably with time of sewage application.

Recently Marecos do Monte et al (1989) gave the results of two years of experiment about irrigation of sorghum, maize and sunflower with municipal wastewater effluents and potable water treated with commercial fertilizers. They observed that the crop yield did not differ significantly when the crops were irrigated with municipal wastewater effluents and portable water with fertilizers. They concluded that cost savings on fertilizers will be achieved if the crops were irrigated with municipal wastewater effluents.

Ahmad (1989), in a recent investigation, reported that although the wastewater effluents in Doha, Qatar treatment plant is presently restricted to irrigation of roadside reservation

and side walks; people are generally apprehensive to use it in irrigating public garden and private lawns. He concluded that with adequate planning and surveillance programme, health education of workers and awareness amongst the population, effluent re-use can be practised with minimum risk.

In the past the impetus for wastewater re-use was often the alleviation of water quality problems caused by discharge of wastewater effluents to surface waters or the desire to reduce cost of effluent treatment. Today, in developed countries like the U.S.A., and England where there is large population growth re-use of wastewater is seen as a means of easing the strains on tight water supplies. Other benefits of re-use of wastewater may include improved quality of surface water, landscape improvement, aquifer recharge, industrial cooling, and recreational opportunities.

2.7.0 HEALTH IMPLICATIONS OF SEWAGE EFFLUENT IRRIGATION

Sewage effluents usually contain the complete range of pathogens found in the community producing the sewage (Greenberg and Dean, 1953, Rudolf et al, 1950), together with toxic chemical substances (Shuval, 1962). These constitute a potential health harzard to

those who come in contact with water and the public, especially those living near the irrigation sites. Therefore, re-use of sewage effluents should be given serious thoughts vis-a-vis the public health (Rudolf et al, 1951).

Rigbi et al (1965) observed that various species of pathogens, such as those causing typhoid fever, bacillary dysentery, amoebic dysentery, ascariasis and other protozoan and helminthic diseases were isolated from raw sewage as well as from the effluents of existing biological treatment plants. Other investigation showed that enteric viruses could also be detected.

Shuval (1974) studied an outbreak of cholera in the city of Gaza, observing that, there may be substantial risks associated with the consumption of raw vegetables grown on soils irrigated with sewage. According to him, even crops eaten only after cooking may represent a risk since they may contaminate working surfaces and utensils in the kitchen, which in turn, can lead to contamination of foods in which bacteria multiply.

Also, cases of hookworm and other enteric infections have been reported by India Central Public Health Research Institute (1971), as being more common among workers on sewage farms

than among the farming population in general.

Andre (1987) reported that assessment of risk of infection should be a guiding factor in economic development and protection of public health at the lowest possible cost during wastewater re-utilization. He concluded after epidemiological observation on some communities that, the human pathology associated with agricultural use of raw or partially treated sewage falls among consumers of raw vegetables, insufficiently cooked beef, workers at agricultural facilities, and people living near such agricultural facilities. According to him, ascariasis, taenia, ancylostomiasis, and shigelloses were among the diseases found in the observed communities.

Blumenthal et al (1989) showed the effectiveness of different methods (waste treatment, localised methods of waste application, human exposure) in reducing health risks to agricultural workers and consumers of the crop grown on wastewater irrigated areas. According to them, measures for health protection need not rely on complete removal of pathogens by waste treatment, and suggested that in the future, health risks should be assessed using epidemiologist's concept of attributable risks.

Also, health protection measures should be targetted at specific exposed groups in the populations, within the local context of decision makers, planners and engineers.

2.7.1 TRACE ELEMENTS AND HUMAN HEALTH

As a result of wastewater re-use in irrigation, man and animals are being increasingly subjected to exposure to toxic chemicals including heavy metals. When these chemicals are absorbed in large amounts, severe toxic effects upon the consumers can result unless effective control measures are introduced and maintained.

It has been well established that certain elements such as cadmium, lead, manganese, zinc, and boron present in trace concentrations in human tissues are essential to health, while others have no apparent physiological functions (Harry, 1974). Elements in either category may be extremely toxic at unnaturally high concentrations (Maugh, 1973). Individual responses to given exposure may vary significantly from person to person. So a designation of a tolerable level of exposure is frequently difficult (Maugh, 1973).

Cadmium is toxic to virtually every system in the body whether ingested, injected or inhaled.

According to Underwood (1979) pathological changes have been observed in the kidneys, liver, gastrointestinal tract, heart, testes, pancreas and bones of man and animals affected with chronic cadmium toxicity.

Chronic lead poisoning is characterised by neurological defects, kidney dysfunction and anaemia. Damage to the brain and central nervous system is a marked feature in children, and includes behavioural problems, intellectual impairment and hyper activity (David, 1974).

Manganese toxicity in man arising from excessive intakes in food plants has never been reported, except where industrial contamination occurs (Underwood, 1979). Manganese poisoning is characterised by a severe psychiatic disorder resembling schizophrenia, followed by a permanently crippling neurological disorder (Underwood, 1979).

Zinc is relatively non toxic to mammals. Underwood (1979) observed that man exhibit considerable tolerance to high zinc intakes, the extent of which depends greatly on the nature of the diet with which the zinc interacts in the process of absorption and utilization. According to him, the relatively low toxicity of zinc among the divalent cations, coupled with efficient homoestatic control mechanisms, make

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chronic zinc toxicity from dietry sources an unlikely harzard to man.

Boron in food plants when taken by man is completely absorbed and excreted, largely in urine (Underwood, 1979). However, when taken in high amounts, it can temporarily be retained in the tissues to produce serious toxic effects, such as physiological distress - including disgestive difficulties and toxicity to the central nervous system.

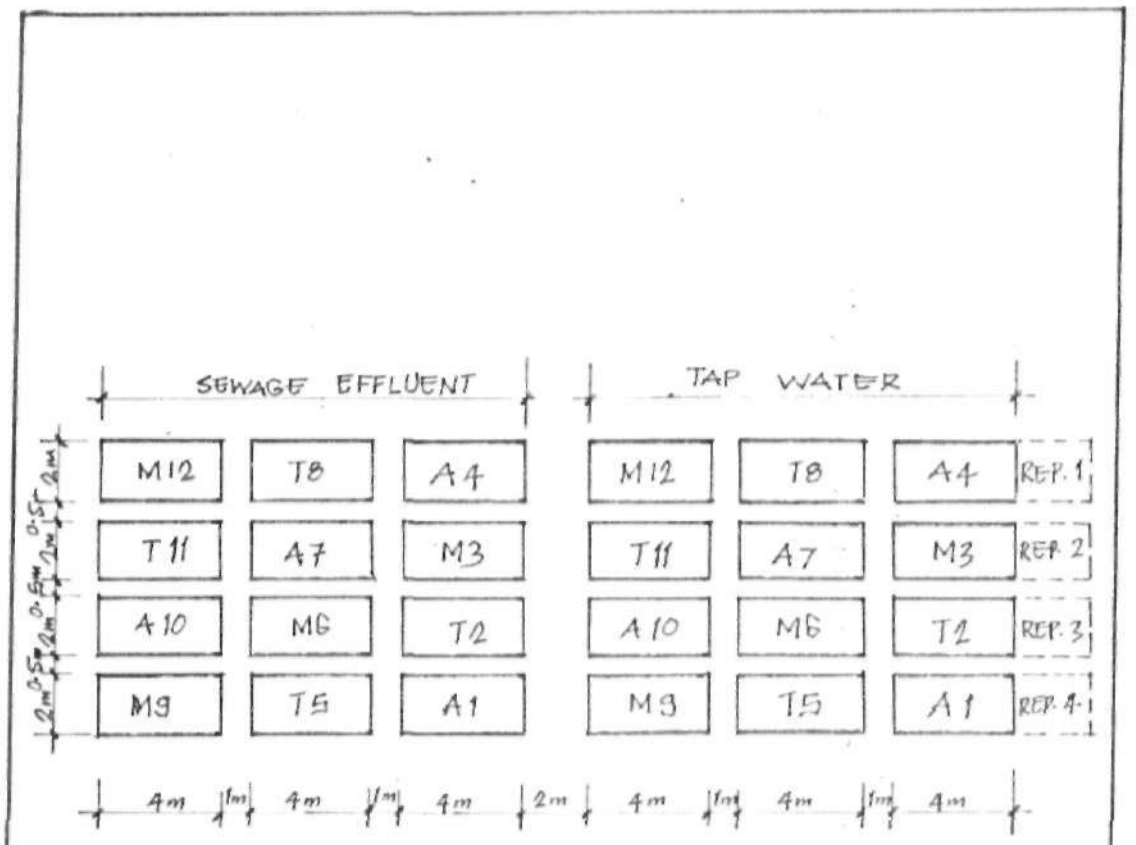
CHAPTER THREE

MATERIALS AND METHOD

3.1 MATERIAL

The experimental farm was located near the waste stabilization pond system at Ahmadu Bello University (A.B.U.) Zaria, Main Campus. It consisted of a 50 x 10m field which was divided into 24 plots of 4 x 2m each in 4 replications in a randomised block designed as shown in fig. 1(a). The three test crops planted on the plots were Amaranthus, Ife plum variety of tomatoes and variety NS 1 maize.

The effluent from the Ahmadu Bello University waste stabilization pond was used for irrigation. While tapwater was used in control experiments. The stabilization pond consists of two facultative ponds and four maturation ponds which can be operated either in series or in parallel (fig. 2). Throughout the period of study, there was little or no effluent from the last maturation pond (MB2) because of low influent flow into the pond system. Therefore, the maturation pond MB2 was used as the source of irrigation water.



SCALE 1:250

KEY

1----12	Nº OF PLOTS
A	AMARANTHUS
M	MAIZE
T	TOMATO

FIG. 1 (a) EXPERIMENTAL FARM LAYOUT.

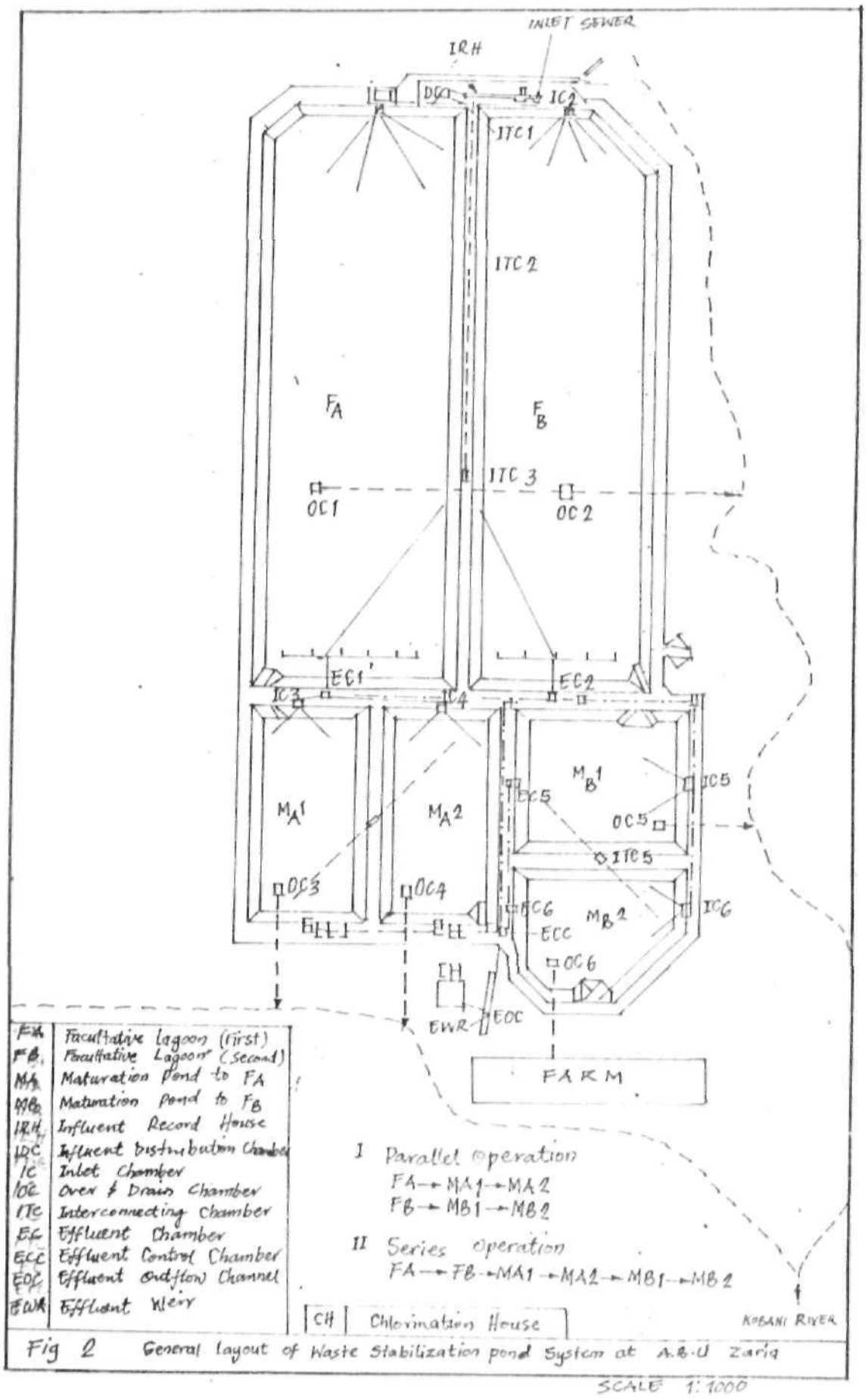


Fig 2 General layout of Waste Stabilization pond System at A.B.U Zaria

3.2 REAGENTS AND PREPARATIONS

3.2.1 BORON DETERMINATION

(a) Buffer Masking Reagent

280g of ammonium acetate, 20g of potassium acetate, 20g of tetra sodium salt EDTA and nitrilotri, acetate acid were all dissolved in 400ml distilled water. 125ml of acetic acid was added slowly and stirred. The solution was gently heated to dissolve the content.

(b) Azomethine-H

0.9g of azomethine-H and 2g of ascobic acid were weighed and dissolved in 100ml of distilled water, and the solution was gently heated on the hot plate (Gallen kamp model) until when the contents dissolved completely.

(c) Working Solution

20ml of azomethine-H were added to 80ml of buffer masking reagent to obtain the working solution.

(d) Boron Stock Solution

100ppm was prepared by dissolving 0.5716g of boric acid in distilled water and the volume was made to one litre.

(e) Boron Standard

Boron standards were prepared by pipetting 1ml, 2ml, 3ml, 4ml and 5ml from boron stock

solution into five different 100ml volumetric flasks and were all diluted to mark with $0.36NH_2SO_4$ to obtain 1ppm B, 2ppm B, 4ppm B and 5ppm B accordingly.

(f) $0.36NH_2SO_4$ (boron plant extracting solution)

This was prepared by diluting 10ml of Conc. H_2SO_4 to one litre with distilled water.

3.2.2 ZINC AND MANGANESE DETERMINATION

(a) Zinc Stock Solution

1g of pure zinc metal was weighed in 100ml beaker. 5ml of distilled water and Conc. Hcl were added, and the mixture was gently heated to warm the contents. The contents were poured in 1000ml flask with 10ml 5NHCl, and diluted to mark. The resulting mixture had a concentration of 1000ppm Zn.

(b) Zinc Standards

Zinc standards were prepared by pipetting 1ml, 1.5ml, and 2ml, from zinc Stock Solution into 3 different 1000ml volumetric flasks and were all diluted to mark with distilled water to obtain 1ppm Zn, 1.5ppm Zn and 2.0ppm Zn respectively.

(c) Manganese Stock Solution

1000ppm of manganese was prepared by weighing 3.603g of $Mncl_2$, $4H_2O$ and dissolving

it with 10ml Hcl and distilled water in 1000ml volumetric flask. The contents were made upto one litre with distilled water.

(d) Manganese Standards

Manganese standards were prepared by pipetting 3ml, 6ml, and 9ml from manganese stock solution into three different 1000ml volumetric flasks and were all diluted to mark with distilled water to obtain 3ppm Mn, 6ppm Mn, and 9ppm Mn respectively.

3.2.3 CADMIUM AND LEAD DETERMINATION

(a) Citrate Solution

420g of citric acid plus 5g of trisodium citrate in 2 litres of distilled water were mixed thoroughly to give the solution.

(b) Bromophenol Blue

0.1g of bromophenol blue was dissolved in 50ml of Ethanol and diluted to 100ml with distilled water to give the reagent.

(c) APDC = Ammonium Pyrollidine dithio carbamate, freshly prepared 0.3% solution and DDDC = Diethyl ammonium diethylthiocarbamate.

(d) MIBK = Methyl Isobutyl Ketone: redistilled commercial grade solvent, saturated with water before use.

(e) Iron Solution

14g of $(NH_4)_2SO_4$. $FeSO_4 6H_2O$ was dissolved in 2 litres of distilled water containing 5ml of Conc. HNO_3. The contents were diluted 40-fold to give a convenient working solution (25µgFe/ml).

(f) Cadmium Stock Solution

100ppm of cadmium was prepared by weighing 0.2031g $CdCl_2.2\frac{1}{2}H_2O$ and poured in 1 litre volumetric flask containing 5ml HNO_3. The contents were made upto mark with distilled water. A single working solution containing 0.1ppm Cd was prepared by dilution, and acidified with 5ml of Conc. HNO_3 to ensure its stability as described by Devries et al (1975).

(g) Lead Stock Solution

100ppm of lead was prepared by weighing 0.958g of $Pb(NO_3)_2$ and poured in 1 litre volumetric flask containing 5ml of HNO_3. The contents were made up to mark with distilled water. A single working solution containing 0.5ppm Pb was prepared by dilution and acidified with 5ml of Conc. HNO_3 to ensure its stability as described by Devries et al (1975).

(h) Preparation of Cadmium and Lead Standards

A series of suitable standards were prepared for Cadmium and Lead in 100ml conical flasks by

pipetting different amount (1 to 5ml) of the working standards for Lead and Cadmium, and 1ml of Conc. perchloric acid and water, and diluted to 20ml. To each flask 10ml of citrate buffer, 4ml of iron solution, and 3 - 4 drops of bromophenol blue were added. The PH of solutions were adjusted to about 3.3 with ammonium solution. All solutions were diluted to about 50ml on flasks, and 4ml of 0.3% APDC and of MIBK were added and the contents shaked for about 10 seconds. Other steps and procedures were followed as described by Devries et al (1975).

The standards for cadmium and Lead in irrigation water analyses were prepared from cadmium and lead stock solutions, but were treated in the same way as the water samples. That is, the metals were concentrated according to the method of Kinrade and Vanloon (1974).

3.2.4 CATION EXCHANGE CAPACITY (C.E.C) DETERMINATION

1N ammonium acetrate (NH_4OAC) at PH7, Ethyl alcohol 99%, 0.25N and 1N ammonium chloride (NH_4cl), ammonium hydroxide (NH_4OH), ammonium oxalate, 0.1N silver nitrate ($Agno_3$), 0.02N sulphuric acid (H_2SO_4), 2% boric acid (HBO_3), 1N sodium hydroxide (NaOH), and bromocresol green - methyl red indicator.

3.2.5 PARTICLE SIZE DISTRIBUTION DETERMINATION

5% sodium metahexaphosphate.

3.3 METHOD

The seeds of maize variety NS 1 and amaranthus were both planted on the field on 15th February, 1988. Ife plum variety of tomato seeds were sown on a nursery bed on the 21st January, 1988, and transplanted to the field on 15th February, 1988. Three seeds were planted; maize with a spacing of 75cm between rows and 40cm between plants within a row. The tomatoes were spaced 60cm x 60cm between rows and plants. Amaranthus were spaced 20cm x 20cm between rows and plants (fig. 1b and 1c).

Thinning was carried out on 29th February, 1988 when the seedlings were well established. Subsequently, the plots were irrigated with the stabilization pond effluents and tapwater which was used as the control. Irrigation of the field was done daily for two weeks with tapwater before planting. Irrigation with both the pond effluent and tapwater commenced on 15th February, 1988 for one week, then every two days for two weeks, and every three days throughout the experimental period. Irrigation was by flooding (80 litres per plot). Irrigation continued until 14th May, 1988 before the final harvest.

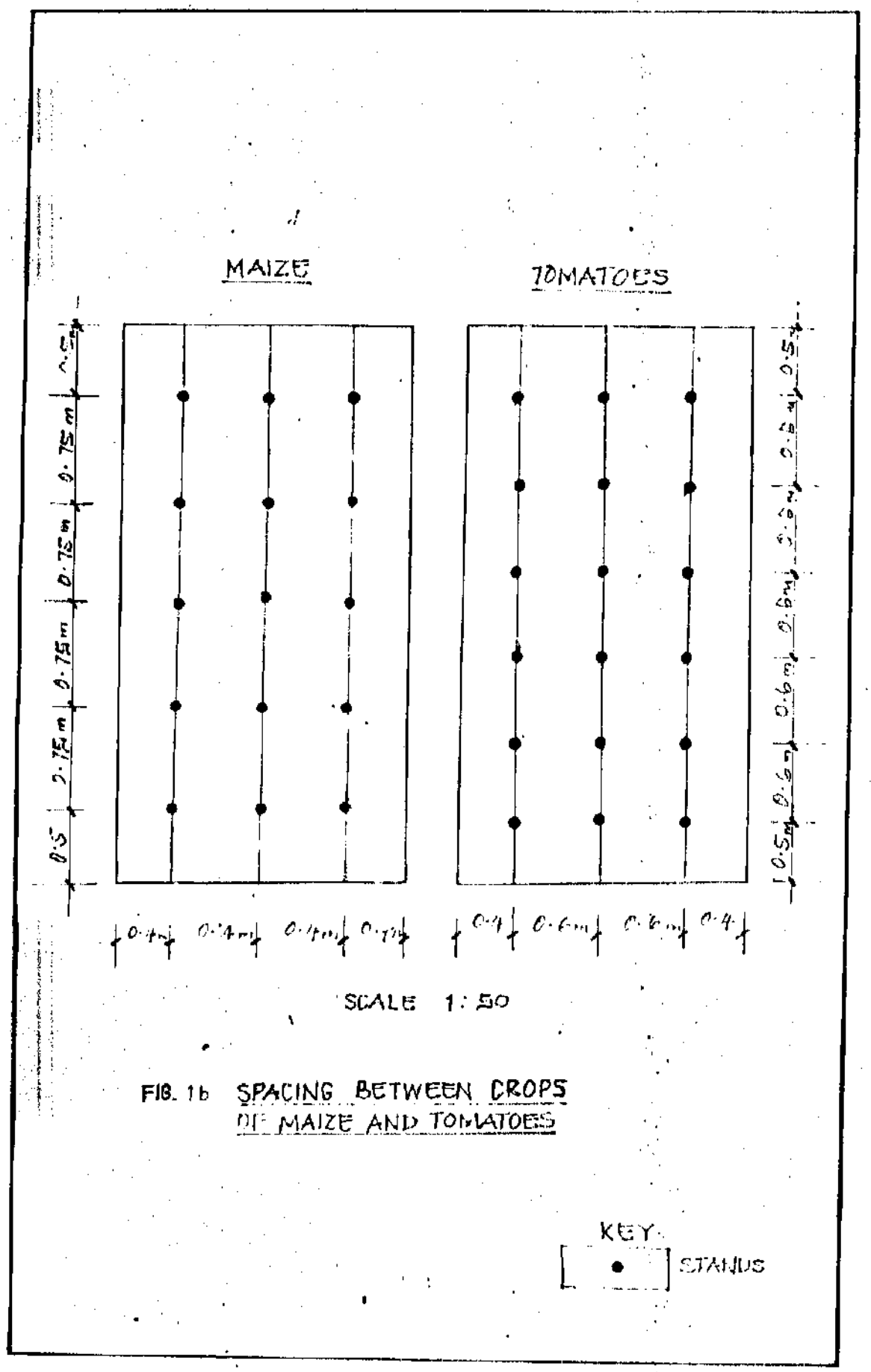
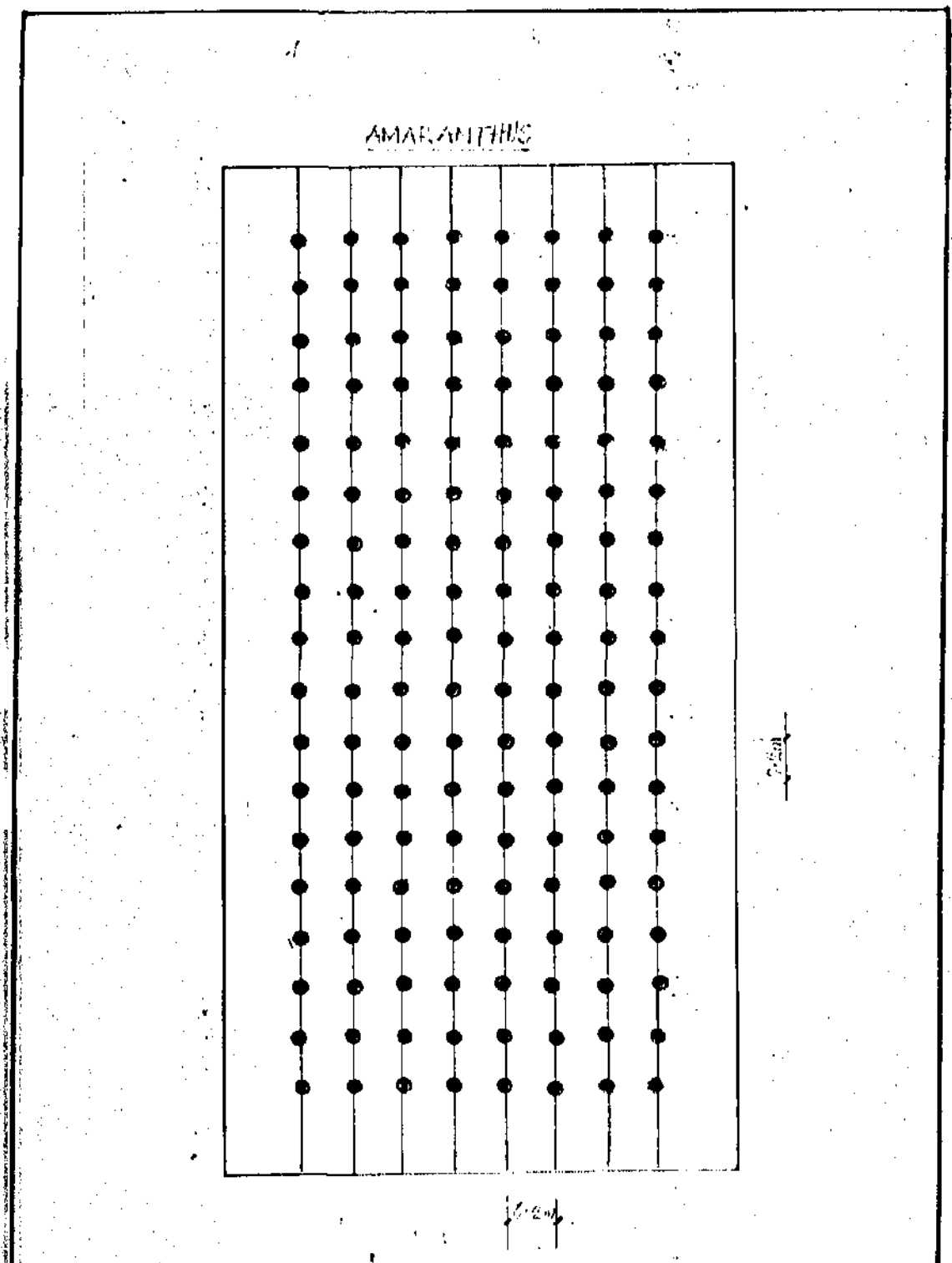


FIG. 1b SPACING BETWEEN CROPS OF MAIZE AND TOMATOES



SCALE 1:25

FIG. 16 SPACING BETWEEN CROPS OF AMARANTHUS

Weeding of the plots was carried out manually. Before irrigation started, the soil samples were analysed for the initial concentrations of the following metals - Zinc, Manganese, Lead, Cadmium and Boron. Also, the sewage effluent and tapwater were analysed at every irrigation for the same parameters.

Plant samples were collected in stages. Maize samples were collected at three locations from each plot during tusseling and flowering, and during final harvest. Tomato samples were collected during flowering and fruiting and when the fruits were ripe, at three locations from each plot. Amaranthus samples were collected during marketable stage, and during seed formation stage.

3.4 ANALYSIS OF SAMPLES

3.4.1 SOIL SAMPLES

(a) "Available" Zn, Mn, Pb, B and Cd determination in soil samples,

Soil samples were collected in -polythene bags at a depth of 0 - 25cm from each plot in the field at three locations and mixed thoroughly prior to the start of irrigation. The samples were dried in the laboratory, and analysed for available zn, Mn, Pb and Cd by double acid extraction method described by wear and Evan (1968)

for Zn, Cox (1968) for Mn, and Cahoon (1974) for Cd and Pb.

During the analysis, 5g of air dried soil was added into a test-tube and 20ml of extractant (0.05N HCl + 0.025N H_2SO_4) double acid was added. The mixture was shaken for 1 hour by mechanical shaker (Griffin model) and allowed to settle. The contents were then filtered with No. 42 filter paper. Zn and Mn in various extracts were determined with Atomic Adsorption spectrophotometer (A.A.S) model 290B, while Cd and Pb in extracts were determined with Perkin elmer model 2280 A.A.S.

(b) Boron contents in soil samples

The boron in soil samples were determined by azo-methine - H method described by Wolf (1971). The samples were analysed by weighing 20g of dried soil samples and added 40ml of Morgan solution. The mixture was shaken by mechanical shaker for 1 hour and filtered after settling. 4ml of the soil extract was pipetted into a photometric tube, and 1ml each of the buffer masking reagent and of azo-methine-H were added in that order. The contents were stirred and allowed to settle for 1 hour the samples were then read on spectrophotomor (spectronic 70) at 430mμ.

(c) Particle Size analysis

50g of oven (Gallen Kamp, OV-420) dry soil was passed through a 2mm sieve and transferred to a plastic beaker. 100ml of sodium hexa-metaphosphate and 100ml of distilled water were added and stirred for 15 minutes with a mechanical shaker (Griffin model). The suspension was transferred to a 1000ml glass cylinder and with hydrometer in the suspension, distilled water was added to mark. Other steps and procedures were followed as described by hydrometer method of International Institute of Tropical Agriculture (I.I.T.A.), (1979). The soils texture was determined using the United State Department of Agriculture (U.S.D.A.) soil classification chart.

(d) Cation Exchange Capacity (C.E.C.) determination of soil samples

The Cation Exchange Capacity of the soil samples was determined by weighing 100g of air dried (2mm sieve) soil into 500ml Erlenmeyer flask, and 40ml of neutral 1 N ammonium acetate (NH_4OAC) added to it. The flask was shaken thoroughly and allowed to stand overnight. The soil was filtered with Whatman No. 42 filter paper using Bucher funnel and leached with neutral 1N NH_4OAC reagent until no chloride occured in the effluent solution.

Other procedures were followed according to ammonium saturation method of Jackson (1958).

(e) PH determination of soil samples

20g of air dried soil samples (passed through 2mm sieve) was weighed into 50ml beaker and 20ml of distilled water was added, and allowed to stand for 30 minutes. The contents were stirred occasionally with a glass rod. The electrode of the PH meter was rinsed with distilled water and wiped thoroughly with cotton wool before each measurements. ThepH meter (Pyellnicam, Model 290MK2) was caliberated with pH_4 buffer solution as described by the manufacturers.

3.4.2 IRRIGATION WATER SAMPLES

Grab samples were collected from the maturation pond (MB2) at three locations and mixed thoroughly during each irrigation. The water samples were collected in nitric acid-washed plastic bottles, acidified in the field with (1:1) HNO_3 to approximately PH of 2.0 and stored in a cold place until they were transported to the laboratory, where they were kept in a refrigerator before analysis.

(a) Determination of total contents of Zn, Mn, Pb and Cd in water samples

The metal concentrations in sewage effluents

were determined in unfiltered aliquots, the suspended material being considered as part of the irrigation system (Banin et al, 1981). 100ml of water samples were digested with 40ml HNO_3 to near dryness as described by United State Environmental Protection Agency (USEPA) guidelines (1979). The metals were then concentrated using ammonium pyrolidin dithio-carbamate (APDC), diethyl-ammonium diethyl-dithio carbamate (DDDC) chelating agents, and then extracted by methyl Isobutyl Ketone (MIBK), according to the method of Kinrade and Vanloon (1974). The Zn and Mn contents in the solution extract were determined using the Atomic Adsorption Spectrophotometer (A.A.S.) Perkin Elmer model 290B and the Cd and Pb were determined using the AAS, perkin Elmer model 2280.

(b) Determination of Boron in Irrigation water samples

The water samples were determined for boron content by azo-methine method described by Wolf (1971). 4ml of water samples was pipetted into a phototube, and 1ml each of the buffer masking reagent and azo-methine reagent were added in that order. The contents were stirred immediately and the boron concentrations were determined after 1 hour using spectrophotometer (spectronic 70) at 430mμ.

3.4.3 PLANT SAMPLES

Amaranthus, Tomatoes and Maize plant samples were collected at 3 locations from each plot (3 stands for amaranthus, 1 stand for tomato and 1 stand for maize, per sample). The plant samples were washed with distilled water containing 0.02% Teepol detergent, re-washed with distilled water to remove soil materials that stuck to the roots, and later kept in an oven at 60°C to dry. The dried samples were then ground with porcelain motar before analysis.

(a) Determination of total contents of Zn, Mn, Pb and Cd in plants samples

The plant materials were analysed for Zn, Mn, Pb and Cd by wet digestion with perchloric, nitric, and sulphuric acids as described by International Institute of Tropical Agriculture (1979).

0.5g of ground plant material was digested in digestion chamber with 25ml of nitric acid, 4ml of perchloric acid, and 2ml of sulphuric acid. Concentrations of Zn, Mn, Pb and Cd were determined by A.A.S model 290B for Zn and Mn and model 2280 for Pb and Cd.

(b) Determination of Boron Content in plant samples

The boron content in plant samples were determined by azo-methine-H method described by Gaines and Mitchell (1979). 1g of plant samples

was muffled for 1 hour at 600°C in a muffle furnance, and allowed to cool. 5 drops of distilled water and 10ml of 0.36NH_2SO_4 were added to the samples. The contents were left to stand for 1 hour, and then filtered with No.2 Whatman filter paper. 4ml of the filterate and 5ml of working solution (2ml of azo-methine-H + 80ml of buffer masking reagent) were mixed and allowed to stand for 1 hour for colour development. The boron concentrations were then determined using spectrophotometer (Spectronic 70) at 420mu wave length.

The soil, water and plant samples readings were all compared with a series of standards prepared at the same time and treated in the same way as the soil extracts, water solutions and plant digested solutions respectively. Digestion blanks were also included with every batch of soil, water and plant samples.

CHAPTER FOUR

RESULTS

The results of the experimental investigations are presented under four sections. These include the metal concentrations in the irrigation waters; the initial concentrations of the metals in the soil; the soil properties such as the Cation Exchange Capacity (C.E.C.), the particle size distribution and PH; and the metal concentrations in experimental plants.

4.1 METAL CONCENTRATIONS IN THE IRRIGATION WATERS

Table 1 shows the concentrations of Heavy metals in the sewage effluents of A.B.U. waste stabilization pond and Tap water. Also presented in the table for comparison are the maximum permissible limits in irrigation waters as recommended by FAO (1985).

Table 1 - The Concentrations of Heavy Metals in Irrigation Waters

METALS	SOURCES				FAO Irrigation Water Standards (mg l)
	Sewage Effluents(mg/l)		Tapwater (mg/l)		
	RANGE	MEAN	RANGE	MEAN	
Zn	0.2-0.4	0.31	-	0.20	2.0
Mn	0.1-0.3	0.21	-	0.10	0.2
Pb	0.10-0.12	0.11	-	0.07	5.0
Cd	0.01-0.03	0.02	-	0.01	0.01
B	0.69-0.85	0.80	-	0.32	3.0

4.2 INITIAL CONCENTRATIONS OF HEAVY METALS IN IRRIGATED SOIL

Table 2 shows the initial concentrations of heavy metals in irrigated soils. The table also shows the PH of the soil.

Table 2 - The Initial Concentrations of Heavy Metals in Irrigated Soils

METAL	Irrigated Soils Prior to Planting	
	RANGE (ppm)	MEAN (ppm)
Zn	2.28 - 3.87	2.79
Mn	30.4 - 42.20	36.29
Pb	0.35 - 0.48	0.43
Cd	0.01 - 0.06	0.03
B	0.64 - 1.00	0.82
PH	6.2 - 6.4	6.3

4.3 SOIL PROPERTIES

Table 3 shows the measured properties of the irrigated soils, including the Cation Exchange Capacity (C.E.C.), the particle size distribution and the textural classification of the soil and the PH.

Table 3 - Soil Properties

SOIL PROPERTIES	REPLICATION			
	1	2	3	4
C.E.C (Meq/100g)	7.5	7.5	7.0	7.0
Particle Size Distribution (%)				
Sand	46	47	61	55
Silt	37	29	33	40
Clay	17	24	6	5
Textural Class	Loamy	Loamy	Sandy loam	Sandy loam
PH	6.4	6.4	6.3	6.3

ARIA, NIGERIA.

4.4 CONCENTRATIONS OF HEAVY METALS IN THE EXPERIMENTAL CROPS

Tables 4, 5 and 6 show the mean concentrations of the metals in the roots, stem and the leaves of the irrigated crops respectively. The tables also show the Least Significant Differences (L.S.D.) at 5% level of signifant among the sewage effluents and tapwater irrigation waters. Figure 3.1 a&b show the mean concentrations of the metals in the edible parts of the crops.

Table 4 - Mean Concentration of Elements in the Roots

CROP	PLANT PARTS	IRRIGATION WATER	FIRST SAMPLING ELEMENTS					SECOND SAMPLING ELEMENTS				
			Zn CONC. IN PPM	Mn CONC. IN PPM	Pb CONC. IN PPM	Cd CONC. IN PPM	B CONC. IN PPM	Zn CONC. IN PPM	Mn CONC. IN PPM	Pb CONC. IN PPM	Cd CONC. IN PPM	B CONC. IN PPM
AMARANTHUS	ROOTS	SEWAGE EFFLUENTS	57.75	31.00	0.16	0.15	32.24	59.50	29.50	0.17	0.16	33.41
		TAP WATER	48.58	57.08	0.14	0.12	24.93	49.91	55.0	0.15	0.13	26.92
		L.S.D (0.05)	4.330	4.694	NS	0.19	6.28	5.32	6.87	NS	0.018	5.37
TOMATOES	ROOTS	SEWAGE EFFLUENTS	54.75	21.58	0.12	0.08	26.26	56.33	27.33	0.13	0.09	27.09
		TAP WATER	40.83	51.66	0.10	0.07	23.58	42.50	48.83	0.11	0.08	24.58
		L.S.D (0.05)	4.330	4.694	NS	NS	NS	5.32	6.87	NS	NS	NS
MAIZE	ROOTS	SEWAGE EFFLUENTS	48.50	38.25	0.06	14.25		49.67	41.83	0.11	0.07	14.53
		TAP WATER	30.50	36.75	0.08	0.05	12.28	31.58	39.75	0.09	0.06	12.61
		L.S.D (0.05)	4.330	4.694	NS	NS	NS	5.32	6.87	NS	NS	NS

NS = Not Significant

Table 5 - Mean Concentration of Elements in the Stem

CROP	PLANT PARTS	IRRIGATION WATER	FIRST SAMPLING					SECOND SAMPLING				
			ELEMENTS					ELEMENTS				
			Zn CONC. IN PPM	Mn CONC. IN PPM	Pb CONC. IN PPM	Cd CONC. IN PPM	B CONC. IN PPM	Zn CONC. IN PPM	Mn CONC. IN PPM	Pb CONC. IN PPM	Cd CONC. IN PPM	B CONC. IN PPM
AMARANTHUS	STEM	SEWAGE EFFLUENTS	43.92	28.58	0.12	0.10	25.20	55.83	26.83	0.13	0.11	26.09
		TAP WATER	38.58	44.83	0.10	0.09	21.89	39.92	43.91	0.11	0.10	24.42
		L.S.D (0.05)	3.26	5.78	NS	NS	6.35	5.28	6.79	NS	NS	NS
TOMATOES	STEM	SEWAGE EFFLUENTS	52.58	23.83	0.09	0.06	22.05	54.08	21.75	0.10	0.07	22.80
		TAP WATER	36.16	42.42	0.08	0.05	20.09	37.58	39.42	0.09	0.06	21.10
		L.S.D (0.05)	3.26	5.78	NS	NS	6.35	5.23	6.79	NS	NS	NS
MAIZE	STEM	SEWAGE EFFLUENTS	46.67	34.33	0,07	0.03	12.17	47.42	36.17	0.08	0.05	12.44
		TAP WATER	27.16	32.50	0.06	0.02	10.38	28.50	34.41	0.07	0.04	10.66
		L.S.D (0.05)	3.26	5.78	NS	NS	6.35	5.28	6.79	NS	NS	NS

NS = Not Significant

Table 6 - Mean Concentration of Elements in the Leaves

CROP	PLANT PARTS	IRRIGATION WATER	FIRST SAMPLING					SECOND SAMPLING				
			ELEMENTS					ELEMENTS				
			Zn CONC. IN PPM	Mn CONC. IN PPM	Pb CONC. IN PPM	Cd CONC. IN PPM	B CONC. IN PPM	Zn CONC. IN PPM	Mn CONC. IN PPM	Pb CONC. IN PPM	Cd CONC. IN PPM	B CONC. IN PPM
AMARANTHUS	LEAVES	SEWAGE EFFLUENTS	51.00	38.00	0.11	0.09	40.91	53.33	36.67	0.12	0.10	41.82
		TAP WATER	34.75	62.75	0.10	0.08	36.22	36.08	60.83	0.11	0.09	37.20
		L.S.D (0.05)	2.69	4.46	NS	NS	2.36	3.79	4.82	NS	NS	2.46
TOMATOES	LEAVES	SEWAGE EFFLUENTS	50.08	31.58	0.07	0.05	30.25	51.33	31.08	0.08	0.06	31.05
		TAP WATER	30.50	52.08	0.06	0.04	28.14	34.42	49.92	0.07	0.05	29.16
		L.S.D (0.05)	2.69	4.46	NS	NS	NS	3.79	4.82	NS	NS	NS
MAIZE	LEAVES	SEWAGE EFFLUENTS	45.08	40.91	0.05	0.03	16.56	46.08	42.83	0.06	0.04	17.00
		TAP WATER	25.17	38.17	0.04	0.02	14.80	29.42	41.00	0.05	0.03	15.04
		L.S.D (0.05)	2.69	4.46	NS	NS	NS	3.79	4.82	NS	NS	NS

NS = Not Significant

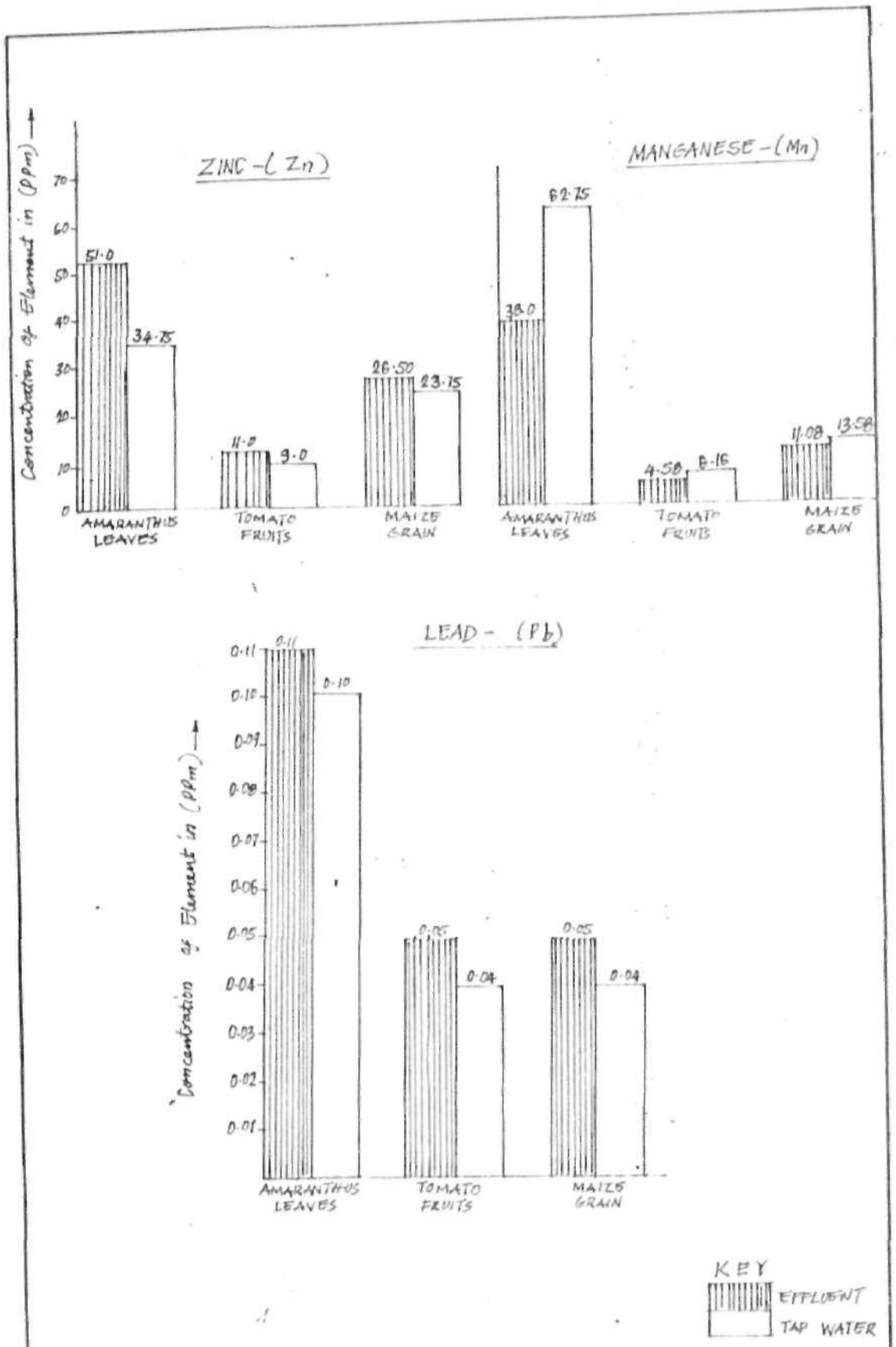
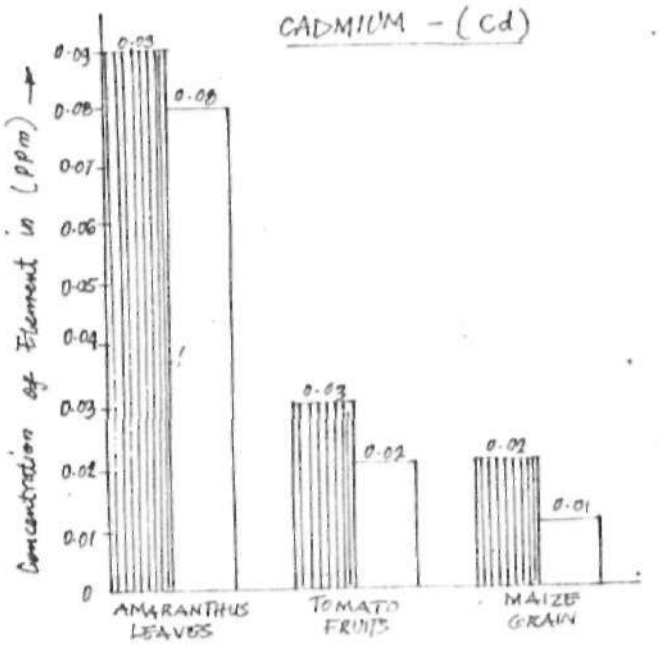


FIG. 3·1 (a) - MEAN CONCENTRATION OF Zn, Mn, and Pb. IN THE EDIBLE PARTS OF THE CROPS.



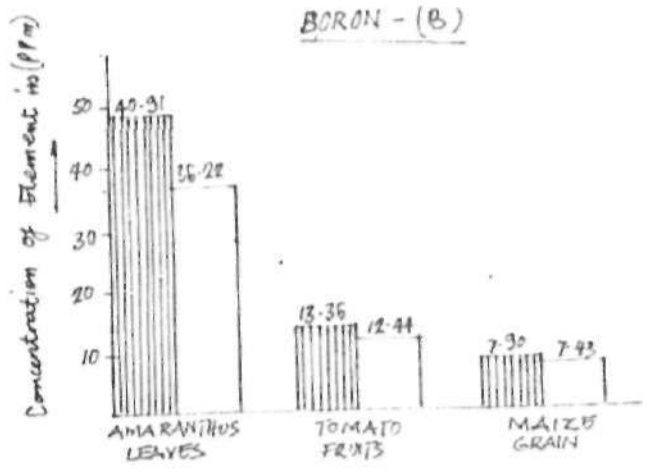




FIG. 3·1(B) - MEAN CONCENTRATION OF Cd and B IN THE EDIBLE PARTS OF THE CROPS.

CHAPTER FIVE

DISCUSSION OF RESULTS

5.1 METAL CONCENTRATIONS IN THE IRRIGATION WATERS

From table 1, the mean concentrations of Zn, Mn, Pb, Cd and B in the Sewage Effluents are 0.31ppm, 0.21, 0.11, 0.02 and 0.80ppm respectively. Also, the mean concentration of these metals in tapwater used for irrigation are 0.20, 0.10, 0.07, 0.01 and 0.32ppm respectively. The maximum permissible limits in irrigation waters recommended by FAO are 2.0, 0.2, 5.0, 0.01 and 3ppm for Zn, Mn, Pb, Cd and B respectively.

These results indicate that the concentrations of the metals in both the sewage effluents and the tapwater are well below the permissible limits and may not be toxic to the crops, animals and man at these concentrations.

5.2 INITIAL CONCENTRATIONS OF METAL IN IRRIGATED SOIL

The uptake by plants of a metal element from soil is a function of the available concentrations of the metal element in the soil and on other properties including the Cation Exchange Capacity (C.E.C), soil textures and the PH of the soil (Leeper, 1978, Chaney, 1973). In the present study (table 2), the initial concentrations of the irrigated soils range from

2.28 - 3.87ppm (mean 2.79ppm) for Zn, 30.4 - 42.20ppm (mean 36.29ppm) for Mn, 0.35 - 0.48ppm (mean 0.43ppm) for Pb, 0.01 - 0.06ppm (mean 0.03ppm) for Cd and 0.64 - 1ppm (Mean 0.82) for B.

From the results, it is observed that the concentrations of the available Zn and Mn in the experimental soil are within the range (0.35 - 3.9ppm for Zn, and 12.8 - 53.9ppm for Mn) suggested by Lombin (1983a, 1983b) for Nigeria's Savannah soils. Also, the range of boron found in the experimental soils are within the reported values by Mahler et al (1985) for agricultural soils (0.3 - 1.5ppm B).

From table 3, despite the close proximity between the plots, the textural class between replications 1 and 2 was different from that between replications 3 and 4. According to the United State Department of Agricultural (USDA) soil classification chart, the soil in replications 1 and 2 was a loamy soil and replication 3 and 4 a sandy loam. Also, the Cation Exchange Capacity (C.E.C) of the experimental soil decreased from 7.5meq/100g soil in replications 1 and 2 to 7.0meq/100g soil in replications 3 and 4. In this tudy (compare table 3 with appendix 15), it appears generally that the concentrations of the metals absorbed from loamy soils

(C.E.C. = 7.5) by the test crops is less than from sandy loam (C.E.C = 7.0). Probably this was *because soils with greater C.E.C. tend to fix* more of the applied metals than soils with lower C.E.C. The fixation of the applied metal in solution may be possible by the adsorption of the metal Cation on the negatively charged colloids of these soils. Haghiri (1974) reported similar observations in which the concentrations of Cadmium absorbed from the experimental soils was reduced when the C.E.C of the soil was increased (from 17.1 to 30.5 meq/100g soil).

Also from table 3, the PH of the experimental soils is slightly acidic and decreased from 6.4 in replications 1 and 2 to 6.3 in replications 3 and 4. In the present study (compare table 3 and appendix 15), the concentrations of the metals absorbed by the test crops from loamy soils with PH = 6.4 appear generally to be less than that from sandy loam soils with PH = 6.3. This may be because the metals in soils with low acidity (PH = 6.4) are held firmly in the soils and are not broken down into free available forms for adsorption by the test crops. MacLean et al (1967) observed that the lead concentrations absorbed by the Oat crop from soils treated with lead chloride ($PbCl_2$)

was reduced by raising the soil PH to a value of low acidity (PH = 6.5).

5.3 HEAVY METALS CONCENTRATIONS IN VARIOUS PARTS OF THE EXPERIMENTAL CROPS

Although the concentrations of Zn, Pb, Cd and B, in sewage effluents, tapwater and the soil are low (tables 1 and 2) the uptake of these metals by the various tissues of the test crops increased with increasing application of the irrigation waters (Tables 4, 5, 6 and figures 3.1(a) & 3.1(b). These observations is expected because the more the availability of these metals in the irrigation waters the more likely the cumulative absorption of the metals by the crops. Similar observations were reported by Sidle et al (1976) when they observed that the concentration of some metals absorbed by Corn during silage increased from 48.20 - 45.5ppm for Zn, 0.173 - 0.267ppm for Cd and from 13.47 - 16.77ppm for Pb with increasing sewage applications.

The behaviour of Mn in sewage effluent was observed to be different from that of other metals studied. The absorption of Mn by the crops (except maize) was observed to decrease with increase in sewage application. This may be due to the antagonistic effect between Mn and other metals in the sewage effluent. Similar observation were made by Leeper (1978)

and by Johnson et al (1974). The uptake of Mn by maize is even more complex. The uptake of this metal by maize would depend on the species and varities of maize concerned (Leeper 1978).

It is observed in this study that although the concentrations of Zn, Pb, Cd and B are slightly more in the sewage effluent than in the tapwater, the concentrations of these metals absorbed by the various tissues of the crops were not significantly different when the crops were irrigated with sewage effluent and tapwater respectively. Similar observation were made by Sidle et al (1976). They observed that the difference between Pb and Cd concentrations absorbed by Corn Silage irrigated with sewage effluent and with normal water at application rate of 3.5cm/week were not statistically significant. Also, Banin et al (1981) observed that the Pb concentrations absorbed by plant irrigated with sewage effluent and with tapwater in Hahoterian was not significant.

The uptake of Mn by the crops do not follow the above trend. The concentrations of Mn absorbed by the crops were observed to be higher with tapwater irrigation than with sewage effluent irrigation. This can probably be explained by the action of micro organisms present in the sewage effluent on Mn. Manganese

may be oxidised by the micro organisms and thereby reduced the amount free available Mn in solution for plant absorption.

It is observed that different crops absorb the heavy metals at different rates. From the results it is observed that amaranthus crop absorbed more Zn, Mn, Pb, Cd and B in its various parts than that of tomatoes and maize crops. Chaney and Hornick (1978) reported similar trend on Cadmium absorption by vegetable crops. They observed that Leafy vegetables such as Spinach, Lettuce, Tobacco and Belt greens absorbed more Cadmium than maize, soya beans and tomatoes crops.

Also, it is observed that the absorption of the metals differ from part to part for each crop. The concentration of Zn, Pb, and Cd absorbed by the roots of the test crops when irrigated with sewage effluents and tapwater were higher than the concentrations of these metals absorbed by the stems and leaves. This was in agreement with the findings of Motto et al (1970) in which they observed that Lead content were generally higher in the roots than in fruits, grains and tubers for a given plant. Also, Jones et al (1973) observed that most plants retain lead almost entirely in the roots.

The concentrations of Zn, Mn, Pb, Cd and absorbed tomato fruits and maize grains were lower than the concentrations of these metals absorbed by the remaining parts (roots, stem and leaves).

However, the highest concentration of Mn and B absorbed by the test crops were observed to be retained in the leaves (compare table 6 with tables 4 and 5). This was in agreement with the findings of Bukavac et al (1957) in which they reported that transport of Mn does occur in plants and that large proportions of it were retained in the leaves.

From the experimental results of the present study, the mean concentrations of Zn, Mn, Pb, Cd and B absorbed by the various tissues of the test crops when irrigated with sewage effluents, generally were within the range (15 - 200ppm for Zn; 15 - 100ppm for Mn; 5 - 30ppm for B; 0.01 - 10ppm for Pb and 0.02 - 0.8ppm for Cd) found in normal plants (Page and Chang, 1985). The absorbed concentration of the heavy metals by the test crops fall below the phytotoxic levels reported by Leeper (1978), Melsted (1973), Lagerwaff (1971), Chapman (1966) and are within the permissible levels in food plants for man and animals as reported by Steubing (1979).

From the above, it would appear that the

concentrations of the metals in various tissues of the experimental crops irrigated with A.B.U. sewage effluents would not ppse any harzard to plants, man and animals.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

Based on the present study, the following Conclusions and Recommendations can be arrived at:-

1. The concentrations of Zn, Mn, Pb, Cd, and B were slightly more in A.B.U sewage effluents than in tapwater.

2. The concentrations of the measured metals (except Mn) in all the test crops tended to increase with increasing sewage application, suggesting that the metals accumulate in the plant parts. Manganese concentrations decreased with increasing sewage application.

3. Since the accumulation of the measured metals gererally tended to increase with amount of sewage applied, continuous monitoring of the absorption of the metals by the test crops over a long period of time is recommended.

4. The concentrations of Pb, Cd and B absorbed by the various parts of the test crops irrigated with sewage effluents and with tapwater were not statistically different. It may appear that the absorption of these metals by the test crops reached saturation

levels. However, the Mn concentrations absorbed by the various parts of the test crops were higher when the crops were irrigated with tapwater than with sewage effluents.

5. The concentrations of the metals absorbed by the crops were not the same for all the crops. Also, the absorption of these metals differ from part to part for each crop

6. Amaranthus absorbed more of the heavy metals in its various parts than tomatoes and maize crops.

7. Generally, the roots of the test crops absorbed the highest concentrations of Zn, Pb and Cd followed by stem. However, the Mn and B absorption were highest in the leaves than the remaining parts in all the crops.

8. The maize grain and the tomato fruits contained the lowest concentrations of all the metals investigated.

9. Zinc, Manganese, Lead, Cadmium and Boron concentrations in all the test crops when irrigated with sewage effluents were well below the phytotoxic levels established by

Leeper (1978), Melsted (1973), Lagerwaff (1971) and by Chapman (1966). Also the concentrations of these metals absorbed by the crops were within the permissible limits reported by Steubing (1979) for food plants for man and animals. Therefore it would appear that A.B.U. waste stabilization pond effluents can be used for irrigation of amaranthus, tomatoes and maize if the bacteriological quality of the effluents proves to be acceptable.

10. The present study is limited to only a few metals and crops. Therefore the study should be extended to cover other toxic metals and other crops.

11. Studies should be conducted to evaluate the fertilizer potential of A.B.U. sewage effluents on the potential yield of same crops.

APPENDIX I

CONCENTRATIONS OF SELECTED METALS IN WASTE WATER SAMPLES

DATE OF SAMPLING	SAMPLE NUMBER	Zn CONCS. IN PPM	Mn CONCS. IN PPM	Pb CONCS. IN PPM	Cd CONCS. IN PPM	B CONCS. IN PPM
15/2/88	1	0.3	0.2	0.11	0.02	0.85
16/2/88	2	0.3	0.2	0.11	0.02	0.85
17/2/88	3	0.3	0.2	0.11	0.02	0.85
18/2/88	4	0.3	0.2	0.11	0.02	0.85
19/2/88	-	-	-	-	-	-
20/2/88	-	-	-	-	-	-
21/2/88	5	0.3	0.2	0.11	0.02	0.85
22/2/88	6	0.3	0.2	0.11	0.02	0.85
24/2/88	7	0.3	0.2	0.11	0.02	0.85
26/2/88	8	0.3	0.2	0.11	0.02	0.85
28/2/88	9	0.3	0.2	0.11	0.02	0.85
1/3/88	10	0.3	0.2	0.11	0.02	0.85
3/3/88	11	0.4	0.3	0.12	0.03	0.79
5/3/88	12	0.4	0.3	0.12	0.03	0.79
7/3/88	13	0.4	0.3	0.12	0.03	0.79
10/3/88	14	0.4	0.3	0.12	0.03	0.79
13/3/88	15	0.4	0.3	0.12	0.03	0.79
16/3/88	16	0.4	0.3	0.12	0.03	0.79
19/3/88	17	0.3	0.2	0.11	0.02	0.80
22/3/88	18	0.3	0.2	0.11	0.02	0.80
25/3/88	19	0.3	0.2	0.11	0.02	0.80
28/3/88	20	0.3	0.2	0.11	0.02	0.80

31/3/88	21	0.3	0.2	0.11	0.02	0.80
6/4/88	-	-	-	-	-	-
9/4/88	-	-	-	-	-	-
12/4/88	22	0.3	0.2	0.11	0.02	0.80
15/4/88	23	0.3	0.2	0.11	0.02	0.80
18/4/88	24	0.3	0.2	0.11	0.02	0.80
21/4/88	25	0.2	0.1	0.10	0.01	0.69
24/4/88	26	0.2	0.1	0.10	0.01	0.69
27/4/88	28	0.2	0.1	0.10	0.01	0.69
30/4/88	29	0.2	0.1	0.10	0.01	0.69
3/5/88	30	0.3	0.2	0.11	0.02	0.79
6/5/88	31	0.3	0.2	0.00	0.02	0.79
9/5/88	32	0.2	0.2	0.11	0.02	0.79
12/5/88	33	0.3	0.2	0.11	0.02	0.79
14/5/88	34	0.3	0.2	0.11	0.02	0.79

CONCENTRATIONS OF SELECTED METALS IN TAPWATER SAMPLES

15/2/88	35	0.2	0.1	0.07	0.01	0.32
16/2/88	36	0.2	0.1	0.07	0.01	0.32
21/2/88	37	0.2	0.1	0.07	0.01	0.32
24/2/88	38	0.2	0.1	0.07	0.01	0.32
28/2/88	39	0.2	0.1	0.07	0.01	0.32
5/3/88	40	0.2	0.1	0.07	0.01	0.32
16/3/88	41	0.2	0.1	0.07	0.01	0.32
25/3/88	42	0.2	0.1	0.07	0.01	0.32
3/4/88	43	0.2	0.1	0.07	0.01	0.32
12/4/88	44	0.2	0.1	0.07	0.01	0.32
24/4/88	45	0.2	0.1	0.07	0.01	0.32

3/5/88	46	0.2	0.1	0.07	0.01	0.32
9/5/88	47	0.2	0.1	0.07	0.01	0.32
14/5/88	48	0.2	0.1	0.07	0.01	0.32

APPENDIX II

THE CONCENTRATIONS OF SELECTED METALS IN SOILS FROM TAPWATER AND EFFLUENT PLOTS PRIOR TO IRRIGATION

SAMPLE NUMBER	Zn CONCS. IN PPM	Mn CONCS. IN PPM	B CONCS. IN PPM	Cd CONCS. IN PPM	Pb CONCS. IN PPM	PH CONCS. IN PPM
1	3.87	42.24	0.94	0.01	0.45	6.2
2	2.87	39.64	0.96	0.02	0.41	6.3
3	2.90	40.01	0.95	0.04	0.48	6.3
4	2.96	42.40	0.88	0.02	0.47	6.3
5	2.98	38.48	0.97	0.03	0.44	6.3
6	3.26	39.24	0.98	0.03	0.45	6.2
7	3.44	40.64	1.00	0.04	0.47	6.2
8	2.69	38.54	1.00	0.05	0.45	6.3
9	2.98	40.36	0.98	0.04	0.46	6.2
10	3.83	41.12	0.07	0.03	0.47	6.2
11	2.72	40.00	0.98	0.04	0.46	6.3
12	3.06	42.12	0.99	0.06	0.47	6.2
13	2.68	37.20	0.70	0.01	0.40	6.3
14	2.28	30.86	0.65	0.02	0.35	6.4
15	2.46	31.00	0.64	0.04	0.43	6.4
16	2.54	32.00	0.65	0.01	0.42	6.3
17	2.36	31.23	0.66	0.02	0.36	6.4
18	2.28	30.54	0.65	0.03	0.39	6.4
19	2.52	31.84	0.67	0.03	0.44	6.3
20	2.48	32.60	0.68	0.04	0.37	6.4
21	2.58	31.26	0.68	0.03	0.40	6.3

22	2.38	30.40	0.69	0.02	0.43	6.4
23	2.54	33.20	0.67	0.03	0.38	6.3
24	2.38	34.01	0.70	0.04	0.42	6.4

APPENDIX III

FIRST STAGE OF SAMPLING

THE CONCENTRATIONS OF SELECTED METALS IN DIFFERENT PARTS OF AMARANTHUS

* TYPE OF PLANT PARTS	Zn CONCS. IN PPM	Mn CONCS. IN PPM	Pb CONCS. IN PPM	Cd CONCS. IN PPM	B CONCS. IN PPM
A^1RT_1	56.0	59.00	0.12	0.10	26.04
A^2RT_1	55.0	60.00	0.12	0.10	25.05
A^3RT_1	55.0	59.00	0.12	0.11	25.28
A^1RE_1	60.0	32.0	0.14	0.13	41.60
A^2RE_1	59.0	34.0	0.14	0.12	40.20
A^3RE_1	59.0	35.0	0.14	0.13	41.60
A^1ST_1	39.0	43.0	0.09	0.07	24.07
A^2ST_1	38.0	44.0	0.09	0.07	23.45
A^3ST_1	39.0	44.0	0.08	0.07	24.08
A^1SE_1	58.0	28.0	0.10	0.09	37.70
A^2SE_1	57.0	28.0	0.10	0.09	36.46
A^3SE_1	58.0	28.0	0.10	0.09	35.25
A^1LT_1	33.0	57.0	0.07	0.06	35.50
A^2LT_1	33.0	56.0	0.07	0.06	36.48
A^3LT_1	34.0	58.0	0.07	0.06	37.47
A^1LE_1	52.0	36.0	0.08	0.07	44.45
A^2LE_1	52.0	37.0	0.08	0.07	42.63
A^3LE_1	51.0	35.0	0.08	0.07	40.64
A^1RT_{10}	50.0	56.0	0.14	0.13	27.60
A^2RT_{10}	49.0	55.0	0.15	0.13	26.94
A^3RT_{10}	49.0	55.0	0.14	0.13	26.67

A^1RE_{10}	57.0	32.0	0.16	0.15	32.84
A^2RE_{10}	56.0	32.0	0.16	0.15	34.50
A^3RE_{10}	55.0	31.0	0.16	0.15	33.65
A^1ST_{10}	40.0	44.0	0.10	0.09	22.36
A^2ST_{10}	41.0	43.0	0.11	0.09	21.84
A^3ST_{10}	40.0	44.0	0.10	0.09	22.21
A^1SE_{10}	55.0	38.0	0.12	0.11	24.20
A^2SE_{10}	54.0	38.0	0.13	0.11	25.40
A^3SE_{10}	54.0	37.0	0.12	0.11	24.69
A^1LT_{10}	32.0	66.0	0.09	0.08	39.37
A^2LT_{10}	31.0	65.0	0.10	0.08	36.07
A^3LT_{10}	31.0	65.0	0.09	0.08	35.60
A^1LE_{10}	50.0	36.0	0.11	0.09	40.00
A^2LE_{10}	50.0	34.0	0.10	0.09	39.40
A^3LE_{10}	50.0	35.0	0.11	0.09	38.94
A^1RT_7	48.0	54.0	0.15	0.14	28.69
A^2RT_7	47.0	55.0	0.14	0.13	29.50
A^3RT_7	48.0	55.0	0.14	0.13	28.83
A^1RE_7	56.0	24.0	0.17	0.16	32.73
A^2RE_7	57.0	26.0	0.18	0.16	32.05
A^3RE_7	58.0	25.0	0.17	0.16	31.86
A^1ST_7	42.0	45.0	0.12	0.11	26.69
A^2ST_7	43.0	46.0	0.13	0.11	27.50
A^3ST_7	42.0	45.0	0.12	0.11	26.80
A^1SE_7	54.0	22.0	0.14	0.12	22.45
A^2SE_7	55.0	20.0	0.13	0.12	23.02
A^3SE_7	56.0	20.0	0.14	0.13	22.06
A^1LT_7	38.0	69.0	0.12	0.10	37.52

A^2LT_7	38.0	69.0	0.12	0.10	35.46
A^3LT_7	37.0	68.0	0.11	0.10	34.84
A^1LE_7	51.0	43.0	0.12	0.11	42.63
A^2LE_7	51.0	44.0	0.13	0.12	43.08
A^3LE_7	52.0	44.0	0.13	0.11	43.24
A^1RT_4	44.0	59.0	0.14	0.13	18.54
A^2RT_4	42.0	58.0	0.15	0.12	17.23
A^3RT_4	43.0	58.0	0.14	0.13	18.86
A^1RE_4	57.0	34.0	0.16	1.14	20.45
A^2RE_4	58.0	33.0	0.16	0.14	21.53
A^3RE_4	58.0	34.0	0.15	0.14	22.46
A^1ST_4	34.0	47.0	0.11	0.10	14.46
A^2ST_4	32.0	46.0	0.11	0.10	15.52
A^3ST_4	33.0	47.0	0.11	0.09	15.32
A^1SE_4	53.0	28.0	0.12	0.11	16.35
A^2SE_4	52.0	28.0	0.13	0.11	17.08
A^3SE_4	53.0	28.0	0.12	0.11	17.80
A^1LT_4	38.0	59.0	0.10	0.09	36.50
A^2LT_4	37.0	60.0	0.11	0.09	35.18
A^3LT_4	38.0	61.0	0.10	0.09	34.74
A^1LE_4	51.0	36.0	0.12	0.10	38.20
A^2LE_4	51.0	37.0	0.11	0.10	39.10
A^3LE_4	51.0	39.0	0.12	0.10	38.60

* ART = Amaranthus Roots in tapwater irrigated plots.
ARE = Amaranthus Roots in sewage effluent irrigated plots.
AST = Amaranthus Stem in tapwater irrigated plots.
ASE = Amaranthus Stem in sewage effluent irrigated plots.
ALT = Amaranthus Leaves in tapwater irrigated plots.
ALE = Amaranthus Leaves in sewage effluent irrigated plots.

Superscripts = Sample Numbers.
Subscripts = Plot Numbers.



Plate 1: First stage of sampling Amaranthus crop Irrigated with Sewage effluents



Plate 2: First stage of sampling Amaranthus crop Irrigated with tapwater

APPENDIX IV

THE CONCENTRATIONS OF SELECTED TOXIC CHEMICALS IN DIFFERENT TISSUE PARTS OF TOMATOES

*TYPE OF PLANT PARTS	Zn CONCS. IN PPM	Mn CONCS. IN PPM	Pb CONCS. IN PPM	Cd CONCS. IN PPM	B CONCS. IN PPM
T^1RT_5	47.0	50.0	0.11	0.07	24.35
T^2RT_5	46.0	51.0	0.10	0.06	23.86
T^3RT_5	46.0	50.0	0.10	0.06	24.04
T^1RE_5	55.0	33.0	0.12	0.08	27.24
T^2RE_5	54.0	33.0	0.11	0.07	26.82
T^3RE_5	54.0	34.0	0.11	0.07	26.90
T^1ST_5	40.0	45.0	0.09	0.06	22.31
T^2ST_5	38.0	44.0	0.08	0.05	21.62
T^3ST_5	37.0	45.0	0.09	0.05	22.23
T^1SE_5	53.0	25.0	0.10	0.06	24.06
T^2SE_5	52.0	25.0	0.10	0.06	23.58
T^3SE_5	53.0	25.0	0.10	0.06	23.86
T^1LT_5	31.0	51.0	0.07	0.04	28.04
T^2LT_5	30.0	51.0	0.07	0.04	27.87
T^3LT_5	30.0	52.0	0.07	0.04	27.93
T^1LE_5	51.0	33.0	0.08	0.05	30.23
T^2LE_5	49.0	33.0	0.08	0.04	30.96
T^3LE_5	50.0	33.0	0.08	0.05	31.02
T^1RT_2	43.0	52.0	0.07	0.04	21.36
T^2RT_2	42.0	53.0	0.08	0.05	20.45
T^3RT_2	52.0	52.0	0.07	0.04	20.93
T^1RE_2	54.0	26.0	0.08	0.06	24.96

T^2RE_2	53.0	26.0	0.09	0.06	25.03
T^3RE_2	54.0	26.0	0.09	0.06	25.08
T^1ST_2	38.0	41.0	0.05	0.03	15.86
T^2ST_2	39.0	41.0	0.05	0.03	15.24
T^3ST_2	38.0	41.0	0.05	0.03	15.58
T^1SE_2	52.0	24.0	0.06	0.04	17.26
T^2SE_2	51.0	25.0	0.06	0.04	16.98
T^3SE_2	52.0	24.0	0.06	0.03	17.05
T^1LT_2	30.0	53.0	0.02	0.01	29.21
T^2LT_2	31.0	54.0	0.02	0.01	28.87
T^3LT_2	31.0	54.0	0.02	0.01	29.06
T^1LE_2	50.0	33.0	0.03	0.02	30.06
T^2LE_2	49.0	33.0	0.03	0.01	30.45
T^3LE_2	49.0	33.0	0.03	0.02	30.82
T^1RT_{11}	40.0	55.0	0.12	0.07	24.35
T^2RT_{11}	41.0	55.0	0.12	0.07	23.86
T^3RT_{11}	38.0	56.0	0.12	0.07	24.04
T^1RE_{11}	56.0	31.0	0.13	0.08	26.24
T^2RE_{11}	55.0	31.0	0.13	0.09	25.74
T^3RE_{11}	56.0	31.0	0.14	0.08	25.06
T^1ST_{11}	35.0	46.0	0.10	0.06	20.41
T^2ST_{11}	35.0	45.0	0.10	0.06	20.00
T^3ST_{11}	35.0	46.0	0.10	0.06	30.60
T^1SE_{11}	54.0	27.0	0.11	0.07	22.62
T^2SE_{11}	53.0	26.0	0.11	0.07	22.47
T^3SE_{11}	54.0	26.0	0.11	0.07	23.00
T^1LT_{11}	32.0	56.0	0.08	0.05	28.65
T^2LT_{11}	31.0	55.0	0.08	0.05	28.90

T^3LT_{11}	32.0	56.0	0.08	0.05	28.05
T^1LE_{11}	52.0	36.0	0.09	0.06	30.23
T^2LE_{11}	51.0	36.0	0.09	0.06	30.07
T^3LE_{11}	51.0	36.0	0.08	0.06	29.89
T^1RT_8	36.0	48.0	0.12	0.09	25.00
T^2RT_8	37.0	49.0	0.11	0.09	25.31
T^3RT_8	36.0	49.0	0.11	0.09	25.50
T^1RE_8	56.0	28.0	0.13	0.10	27.04
T^2RE_8	55.0	28.0	0.13	0.10	27.56
T^3RE_8	55.0	28.0	0.13	0.09	27.82
T^1ST_8	33.0	39.0	0.08	0.05	22.02
T^2ST_8	32.0	38.0	0.09	0.06	22.41
T^3ST_8	34.0	39.0	0.09	0.06	22.86
T^1SE_8	53.0	20.0	0.10	0.07	24.08
T^2SE_8	52.0	20.0	0.10	0.07	24.72
T^3SE_8	52.0	19.0	0.10	0.07	24.94
T^1LT_8	29.0	48.0	0.07	0.04	27.31
T^2LT_8	29.0	48.0	0.07	0.04	27.82
T^3LT_8	30.0	47.0	0.07	0.04	28.00
T^1LE_8	50.0	25.0	0.08	0.05	29.42
T^2LE_8	49.0	24.0	0.08	0.06	29.96
T^3LE_8	50.0	24.0	0.08	0.05	29.98

* TRT = Tomatoes Roots in tapwater irrigated plots.
TRE = Tomatoes Roots in sewage effluent irrigated plots.
TST = Tomatoes Stem in tapwater irrigated plots.
TSE = Tomatoes Stem in sewage effluent irrigated plots.
TLT = Tomatoes Leaves in tapwater irrigated plots.
TLE = Tomatoes Leaves in sewage effluent irrigated plots.

Superscripts = Sample Numbers.
Subscripts = Plot Numbers.



Plate 3: First stage of sampling
Tomatoe crop Irrigated
with Sewage effluents



Plate 4: First stage of sampling
Tomato crop Irrigated
with tapwater

APPENDIX V

THE CONCENTRATIONS OF SELECTED METALS IN DIFFERENT TISSUE PARTS OF MAIZE

*TYPE OF PLANT PARTS	Zn CONCS. IN PPM	Mn CONCS. IN PPM	Pb CONCS. IN PPM	Cd CONCS. IN PPM	B CONCS. IN PPM
M^1RT_9	30.0	36.0	0.09	0.05	13.36
M^2RT_9	29.0	35.0	0.08	0.04	13.28
M^3RT_9	29.0	36.0	0.08	0.04	13.44
M^1RE_9	50.0	38.0	0.10	0.06	15.41
M^2RE_9	49.0	37.0	0.10	0.06	15.30
M^3RE_9	50.0	38.0	0.10	0.06	15.54
M^1ST_9	26.0	32.0	0.07	0.04	11.36
M^2ST_9	27.0	32.0	0.06	0.03	11.45
M^3ST_9	26.0	32.0	0.06	0.03	11.26
M^1SE_9	48.0	34.0	0.08	0.04	13.45
M^2SE_9	47.0	35.0	0.08	0.04	13.52
M^3SE_9	48.0	34.0	0.08	0.04	13.36
M^1LT_9	25.0	38.0	0.05	0.02	16.83
M^2LT_9	24.0	39.0	0.05	0.02	16.74
M^3LT_9	25.0	39.0	0.05	0.02	16.64
M^1LE_9	46.0	43.0	0.06	0.03	18.73
M^2LE_9	45.0	42.0	0.06	0.03	18.56
M^3LE_9	46.0	42.0	0.06	0.02	18.48
M^1RT_6	34.0	36.0	0.05	0.02	10.83
M^2RT_6	33.0	36.0	0.06	0.03	10.64
M^3RT_6	34.0	35.0	0.05	0.02	10.78
M^1RE_6	48.0	36.0	0.06	0.04	12.34

M^2RE_6	47.0	37.0	0.07	0.04	12.72
M^3RE_6	47.0	37.0	0.07	0.04	12.68
M^1ST_6	30.0	31.0	0.03	0.01	9.04
M^2ST_6	29.0	32.0	0.03	0.01	9.06
M^3ST_6	29.0	30.0	0.03	0.01	8.98
M^1SE_6	46.0	33.0	0.04	0.02	11.06
M^2SE_6	46.0	32.0	0.04	0.02	11.15
M^3SE_6	46.0	32.0	0.04	0.02	10.88
M^1LT_6	28.0	37.0	0.02	0.01	12.83
M^2LT_6	28.0	38.0	0.02	0.01	12.98
M^3LT_6	28.0	38.0	0.02	0.01	12.74
M^1LE_6	45.0	41.0	0.03	0.02	14.06
M^2LE_6	44.0	42.0	0.03	0.02	13.96
M^3LE_6	45.0	42.0	0.03	0.02	14.08
M^1RT_3	27.0	34.0	0.10	0.06	10.46
M^2RT_3	28.0	35.0	0.10	0.06	10.76
M^3RT_3	27.0	34.0	0.10	0.06	10.83
M^1RE_3	49.0	36.0	0.11	0.07	12.36
M^2RE_3	49.0	36.0	0.11	0.08	12.44
M^3RE_3	49.0	35.0	0.11	0.07	12.58
M^1ST_3	25.0	32.0	0.09	0.05	8.58
M^2ST_3	25.0	33.0	0.09	0.05	8.64
M^3ST_3	25.0	32.0	0.09	0.05	8.74
M^1SE_3	47.0	34.0	0.10	0.06	10.42
M^2SE_3	46.0	34.0	0.10	0.06	10.45
M^3SE_3	47.0	34.0	0.10	0.06	10.73
M^1LT_3	22.0	38.0	0.05	0.02	13.26
M^2LT_3	23.0	38.0	0.05	0.02	13.40

M^3LT_3	22.0	39.0	0.05	0.02	13.38
M^1LE_3	45.0	40.0	0.06	0.03	15.07
M^2LE_3	46.0	40.0	0.06	0.03	15.15
M^3LE_3	45.0	41.0	0.06	0.03	15.26
M^1RT_{12}	32.0	41.0	0.09	0.07	14.20
M^2RT_{12}	31.0	42.0	0.09	0.07	14.48
M^3RT_{12}	32.0	41.0	0.09	0.07	14.36
M^1RE_{12}	48.0	43.0	0.10	0.08	16.53
M^2RE_{12}	48.0	43.0	0.10	0.08	16.62
M^3RE_{12}	48.0	43.0	0.10	0.08	16.46
M^1ST_{12}	28.0	35.0	0.05	0.02	12.43
M^2ST_{12}	28.0	34.0	0.05	0.02	12.56
M^3ST_{12}	28.0	35.0	0.05	0.02	12.48
M^1SE_{12}	46.0	37.0	0.06	0.03	13.84
M^2SE_{12}	47.0	36.0	0.06	0.03	13.63
M^3SE_{12}	46.0	37.0	0.06	0.03	13.58
M^1LT_{12}	26.0	37.0	0.04	0.01	16.24
M^2LT_{12}	26.0	39.0	0.04	0.01	16.21
M^3LT_{12}	25.0	38.0	0.03	0.01	16.38
M^1LE_{12}	44.0	39.0	0.06	0.02	18.34
M^2LE_{12}	45.0	40.0	0.05	0.02	18.56
M^3LE_{12}	45.0	39.0	0.05	0.02	18.47

* MRT = Maize Roots in tapwater irrigated plots.
MRE = Maize Roots in sewage effluent irrigated plots.
MST = Maize Stem in tapwater irrigated plots.
MSE = Maize Stem in sewage effluent irrigated plots.
MLT = Maize Leaves in tapwater irrigated plots.
MLE = Maize Leaves in sewage effluent irrigated plots.

Superscripts = Sample Numbers.
Subscripts = Plot Numbers.



Plate 5: First stage of sampling
Maize crop Irrigated
with Sewage effluents



Plate 6: First stage of sampling
Maize crop Irrigated
with tapwater

APPENDIX VI

SECOND STAGE OF SAMPLING

THE CONCENTRATIONS OF SELECTED METALS IN DIFFERENT TISSUE PARTS OF AMARANTHUS

* TYPE OF PLANT PARTS	Zn CONCS. IN PPM	Mn CONCS. IN PPM	Pb CONCS IN PPM	Cd CONCS. IN PPM	B CONCS. IN PPM
A^1RT_1	57.0	59.0	0.13	0.11	31.08
A^2RT_1	56.0	58.0	0.13	0.11	29.10
A^3RT_1	56.0	58.0	0.13	0.12	30.05
A^1RE_1	63.0	36.0	0.15	0.14	42.56
A^2RE_1	62.0	34.0	0.15	0.14	41.16
A^3RE_1	62.0	35.0	0.15	0.14	42.60
A^1ST_1	41.0	45.0	0.10	0.08	28.01
A^2ST_1	41.0	42.0	0.09	0.08	28.07
A^3ST_1	41.0	43.0	0.09	0.08	29.20
A^1SE_1	53.0	26.0	0.11	0.09	36.56
A^2SE_1	54.0	25.0	0.11	0.10	37.08
A^3SE_1	54.0	26.0	0.11	0.10	36.84
A^1LT_1	34.0	56.0	0.08	0.07	36.42
A^2LT_1	34.0	55.0	0.08	0.07	37.05
A^3LT_1	35.0	56.0	0.08	0.07	37.87
A^1LE_1	53.0	35.0	0.09	0.08	45.46
A^2LE_1	53.0	36.0	0.09	0.07	43.48
A^3LE_1	52.0	35.0	0.08	0.08	41.67
A^1RT_{10}	51.0	54.0	0.15	0.13	27.64
A^2RT_{10}	50.0	54.0	0.16	0.14	27.62
A^3RT_{10}	50.0	54.0	0.16	0.14	26.78

A^1RE_{10}	58.0	30.0	0.17	0.16	33.67
A^2RE_{10}	58.0	30.0	0.17	0.16	35.47
A^3RE_{10}	57.0	29.0	0.17	0.16	34.48
A^1ST_{10}	42.0	45.0	0.11	0.10	26.43
A^2ST_{10}	42.0	46.0	0.11	0.10	25.96
A^3ST_{10}	41.0	45.0	0.12	0.10	24.98
A^1SE_{10}	54.0	36.0	0.13	0.12	25.30
A^2SE_{10}	54.0	36.0	0.14	0.11	25.88
A^3SE_{10}	54.0	35.0	0.13	0.12	25.69
A^1LT_{10}	33.0	64.0	0.10	0.09	40.06
A^2LT_{10}	32.0	64.0	0.11	0.09	37.76
A^3LT_{10}	33.0	64.0	0.11	0.10	37.06
A^1LE_{10}	52.0	36.0	0.12	0.10	41.10
A^2LE_{10}	51.0	34.0	0.11	0.10	40.53
A^3LE_{10}	52.0	34.0	0.12	0.11	39.97
A^1RT_7	49.0	52.0	0.16	0.15	28.67
A^2RT_7	49.0	52.0	0.15	0.14	27.87
A^3RT_7	49.0	53.0	0.15	0.14	26.96
A^1RE_7	60.0	22.0	0.18	0.16	33.72
A^2RE_7	61.0	23.0	0.19	0.17	33.62
A^3RE_7	60.0	22.0	0.18	0.17	33.74
A^1ST_7	43.0	39.0	0.13	0.12	24.46
A^2ST_7	43.0	40.0	0.13	0.12	23.96
A^3ST_7	43.0	40.0	0.13	0.12	23.06
A^1SE_7	55.0	20.0	0.15	0.13	24.48
A^2SE_7	57.0	19.0	0.15	0.13	24.06
A^3SE_7	57.0	19.0	0.15	0.14	23.82
A^1LT_7	39.0	66.0	0.13	0.11	38.54

A^2LT_7	39.0	66.0	0.13	0.11	36.56
A^3LT_7	38.0	65.0	0.12	0.11	35.87
A^1LE_7	55.0	44.0	0.13	0.12	43.63
A^2LE_7	55.0	44.0	0.14	0.13	44.02
A^3LE_7	55.0	43.0	0.14	0.13	44.14
ART_4	45.00	55.0	0.15	0.14	23.56
ART_4	43.0	55.0	0.16	0.13	22.42
ART_4	44.0	56.0	0.15	0.14	21.74
ARE_4	57.0	31.0	0.17	0.15	24.26
ARE_4	57.0	31.0	0.17	0.15	22.42
ARE_4	56.0	31.0	0.16	0.15	23.24
A^1ST_4	35.0	46.0	0.12	0.11	20.45
A^2ST_4	33.0	48.0	0.12	0.11	19.34
A^3ST_4	34.0	48.0	0.22	0.10	19.05
A^1SE_4	58.0	27.0	0.13	0.11	17.13
A^2SE_4	58.0	26.0	0.14	0.12	18.09
A^3SE_4	59.0	27.0	0.13	0.12	18.20
A^1LT_4	39.0	58.0	0.11	0.10	37.40
A^2LT_4	39.0	58.0	0.12	0.10	36.08
A^3LT_4	38.0	58.0	0.11	0.10	35.78
A^1LE_4	53.0	33.0	0.13	0.11	39.32
A^2LE_4	54.0	34.0	0.12	0.11	39.20
A^3LE_4	55.0	35.0	0.13	0.12	39.40

* ART = Amaranthus Roots in tapwater irrigated plots.
ARE = Amaranthus Roots in sewage effluent irrigated plots.
AST = Amaranthus Stem in tapwater irrigated plots.
ASE = Amaranthus Stem in sewage effluent irrigated plots.
ALT = Amaranthus Leaves in tapwater irrigated plots.
ALE = Amaranthus Leaves in sewage effluent irrigated plots

Superscripts = Sample Numbers.
Subscripts = Plot Numbers.



Plate 7: Second stage of sampling Amaranthus crop Irrigated with Sewage effluents



Plate 8: Second stage of sampling Amaranthus crop Irrigated with tapwater

APPENDIX VII

THE CONCENTRATIONS OF SELECTED METALS IN DIFFERENT TISSUE PARTS OF TOMATOES

* TYPE OF PLANT PARTS	Zn CONCS. IN PPM	Mn CONCS. IN PPM	Pb CONCS. IN PPM	Cd CONCS. IN PPM	B CONCS. IN PPM
T^1RT_5	48.0	49.0	0.12	0.08	25.20
T^2RT_5	47.0	51.0	0.11	0.07	24.76
T^3RT_5	47.0	52.0	0.11	0.07	25.00
T^1RE_5	63.0	32.0	0.013	0.09	28.04
T^2RE_5	64.0	32.0	0.12	0.08	27.78
T^3RE_5	64.0	33.0	0.12	0.08	27.83
T^1ST_5	40.0	43.0	0.10	0.07	23.30
T^2ST_5	41.0	43.0	0.10	0.07	22.44
T^3ST_5	40.0	44.0	0.10	0.06	23.06
T^1SE_5	60.0	24.0	0.11	0.07	25.02
T^2SE_5	60.0	25.0	0.11	0.07	24.50
T^3SE_5	60.0	24.0	0.12	0.07	24.64
T^1LT_5	35.0	50.0	0.08	0.05	29.00
T^2LT_5	36.0	51.0	0.08	0.05	31.06
T^3LT_5	35.0	50.0	0.08	0.05	28.21
T^1LE_5	55.0	32.0	0.09	0.06	31.14
T^2LE_5	53.0	33.0	0.09	0.06	31.82
T^3LE_5	54.0	32.0	0.09	0.05	31.96
T^1FT_5	12.0	7.0	0.06	0.01	12.64
T^2FT_5	11.0	8.0	0.06	0.02	12.53
T^3FT_5	12.0	7.0	0.05	0.02	12.40
T^1FE_5	15.0	5.0	0.07	0.03	13.64

T^2FE_5	14.0	6.9	0.07	0.93	13.48
T^3FE_5	15.0	5.0	0.07	0.03	13.56
T^1RT_2	44.0	52.0	0.08	0.05	22.28
T^2RT_2	43.0	51.0	0.08	0.06	21.84
T^3RT_2	43.0	51.0	0.08	0.05	21.54
T^1RE_2	56.0	24.0	0.09	0.07	25.94
T^2RE_2	57.0	25.0	0.09	0.07	26.05
T^3RE_2	56.0	24.0	0.09	0.07	26.10
T^1ST_2	37.0	40.0	0.06	0.04	16.84
T^2ST_2	37.0	39.0	0.06	0.04	16.32
T^3ST_2	37.0	40.0	0.06	0.04	16.60
T^1SE_2	54.0	23.0	0.07	0.05	17.86
T^2SE_2	55.0	23.0	0.07	0.05	17.24
T^3SE_2	54.0	23.0	0.07	0.04	17.08
T^1LT_2	33.0	53.0	0.03	0.02	29.84
T^2LT_2	34.0	52.0	0.03	0.02	29.45
T^3LT_2	34.0	53.0	0.03	0.02	29.14
T^1LE_2	52.0	33.0	0.04	0.02	31.02
T^2LE_2	53.0	32.0	0.04	0.03	31.34
T^3LE_2	52.0	32.0	0.03	0.02	31.76
T^1FT_2	10.0	8.0	0.02	0.01	11.56
T^2FT_2	9.0	6.0	0.02	0.01	11.47
T^3FT_2	10.0	6.0	0.02	0.01	11.86
T^1FE_2	11.0	6.0	0.03	0.02	12.42
T^2FE_2	11.0	4.0	0.03	0.02	12.67
T^3FE_2	11.0	5.0	0.03	0.02	12.72
T^1RT_{11}	41.0	54.0	0.13	0.08	25.24
T^2RT_{11}	42.0	54.0	0.13	0.08	25.02

T^3RT_{11}	40.0	54.0	0.13	0.08	25.14
T^1RE_{11}	54.0	30.0	0.14	0.09	27.24
T^2RE_{11}	55.0	31.0	0.13	0.10	27.06
T^3RE_{11}	53.0	30.0	0.15	0.09	26.94
T^1ST_{11}	38.0	44.0	0.11	0.07	21.41
T^2ST_{11}	38.0	44.0	0.11	0.07	21.06
T^3ST_{11}	37.0	43.0	0.11	0.07	21.60
T^1SE_{11}	52.0	26.0	0.12	0.08	23.45
T^2SE_{11}	53.0	36.0	0.13	0.08	23.26
T^3SE_{11}	53.0	25.0	0.12	0.08	23.94
T^1LT_{11}	35.0	54.0	0.09	0.06	29.12
T^2LT_{11}	34.0	54.0	0.08	0.06	29.54
T^3LT_{11}	35.0	54.0	0.09	0.06	29.02
T^1LE_{11}	50.0	35.0	0.10	0.07	31.05
T^2LE_{11}	50.0	35.0	0.10	0.06	31.00
T^3LE_{11}	50.0	36.0	0.09	0.07	30.94
T^1FT_{11}	8.0	6.0	0.05	0.04	13.21
T^2FT_{11}	8.0	7.0	0.06	0.04	13.05
T^3FT_{11}	8.0	6.0	0.05	0.04	13.26
T^1FE_{11}	10.0	5.0	0.06	0.05	14.23
T^2FE_{11}	9.0	5.0	0.06	0.04	13.98
T^3FE_{11}	10.0	5.0	0.05	0.05	14.07
T^1RT_8	38.0	41.0	0.13	0.09	26.02
T^2RT_8	39.0	40.0	0.12	0.10	26.35
T^3RT_8	38.0	41.0	0.12	0.10	26.56
T^1RE_8	51.0	22.0	0.14	0.11	28.02
T^2RE_8	52.0	23.0	0.13	0.11	28.43
T^3RE_8	51.0	22.0	0.14	0.09	28.78

T^1ST_8	35.0	31.0	0.09	0.06	23.24
T^2ST_8	36.0	31.0	0.09	0.07	23.43
T^3ST_8	35.0	31.0	0.10	0.06	23.88
T^1SE_8	49.0	14.0	0.11	0.08	25.68
T^2SE_8	50.0	14.0	0.11	0.08	25.82
T^3SE_8	49.0	14.0	0.11	0.07	25.12
T^1LT_8	34.0	43.0	0.08	0.05	28.32
T^2LT_8	34.0	43.0	0.08	0.05	28.74
T^3LT_8	34.0	42.0	0.08	0.05	28.45
T^1LE_8	49.0	25.0	0.09	0.06	30.04
T^2LE_8	49.0	24.0	0.09	0.06	30.26
T^3LE_8	49.0	24.0	0.09	0.05	30.31
T^1FT_8	7.0	5.0	0.04	0.01	12.10
T^2FT_8	7.0	6.0	0.04	0.02	12.84
T^3FT_8	6.0	5.0	0.04	0.01	12.44
T^1FE_8	9.0	3.0	0.05	0.02	13.52
T^2FE_8	8.0	3.0	0.04	0.02	13.07
T^3FE_8	9.0	3.0	0.05	0.02	12.98

* TRT = Tomatoes Roots in tapwater irrigated plots.
TRE = Tomatoes Roots in sewage effluent irrigated plots.
TST = Tomatoes Stem in tapwater irrigated plots.
TSE = Tomatoes Stem in sewage effluent irrigated plots.
TLT = Tomatoes Leaves in tapwater irrigated plots.
TLE = Tomatoes Leaves in sewage effluent irrigated plots.
TFT = Tomatoes Fruits in tapwater irrigated plots.
TFE = Tomatoes Fruits in sewage effluent irrigated plots.

Superscripts = Sample Numbers.
Subscripts = Plot Numbers.



Plate 9: Second stage of sampling
Tomato crop Irrigated
with Sewage effluents



Plate 10: Second stage of sampling
Tomato crop Irrigated
with tapwater

APPENDIX VIII

THE CONCENTRATIONS OF SELECTED METAL IN DIFFERENT TISSUE PARTS OF MAIZE

*TYPE OF PLANT PARTS	Zn CONCS. IN PPM	Mn CONCS. IN PPM	Pb CONCS. IN PPM	Cd CONCS. IN PPM	B CONCS. IN PPM
M^1RT_9	31.0	36.0	0.10	0.06	13.86
M^2RT_9	30.0	36.0	0.09	0.06	13.75
M^3RT_9	30.0	37.0	0.09	0.05	13.94
M^1RE_9	51.0	39.0	0.11	0.07	15.84
M^2RE_9	50.0	39.0	0.11	0.07	15.98
M^3RE_9	50.0	38.0	0.10	0.07	15.86
M^1ST_9	27.0	33.0	0.08	0.05	11.56
M^2ST_9	28.0	33.0	0.07	0.04	11.86
M^3ST_9	28.0	33.0	0.07	0.05	11.67
M^1SE_9	48.0	35.0	0.09	0.06	13.65
M^2SE_9	47.0	34.0	0.09	0.06	13.94
M^3SE_9	48.0	35.0	0.09	0.05	13.74
M^1LT_9	29.0	39.0	0.06	0.04	16.97
M^2LT_9	30.0	39.0	0.06	0.04	16.85
M^3LT_9	30.0	39.0	0.06	0.04	16.73
M^1LE_9	45.0	43.0	0.07	0.05	19.04
M^2LE_9	45.0	43.0	0.07	0.05	19.86
M^3LE_9	46.0	44.0	0.07	0.05	19.74
M^1GT_9	25.0	15.0	0.04	0.02	8.05
M^2GT_9	24.0	14.0	0.04	0.02	8.04
M^3GT_9	25.01	15.0	0.04	0.02	8.02
M^1GE_9	27.0	10.0	0.05	0.03	8.46

M^2GE_9	26.0	11.0	0.05	0.03	8.34
M^3GE_9	27.0	10.0	0.05	0.03	8.28
M^1RT_6	35.0	38.0	0.06	0.03	11.0
M^2RT_6	36.0	37.0	0.06	0.04	10.95
M^3RT_6	35.0	38.0	0.06	0.04	10.97
M^1RE_6	55.0	40.0	0.07	0.05	12.56
M^2RE_6	55.0	40.0	0.07	0.05	12.84
M^3RE_6	55.0	40.0	0.07	0.05	12.75
M^1ST_6	30.0	36.0	0.03	0.02	9.36
M^2ST_6	30.0	36.0	0.04	0.01	9.48
M^3ST_6	30.0	37.0	0.04	0.02	9.05
M^1SE_6	51.0	38.0	0.05	0.03	11.45
M^2SE_6	50.0	37.0	0.04	0.02	11.64
M^3SE_6	50.0	38.0	0.05	0.03	10.96
M^1LT_6	32.0	44.0	0.03	0.02	12.98
M^2LT_6	31.0	44.0	0.03	0.02	13.01
M^3LT_6	30.0	44.0	0.03	0.02	12.89
M^1LE_6	48.0	45.0	0.04	0.03	14.45
M^2LE_6	48.0	44.0	0.04	0.03	14.02
M^3LE_6	47.0	45.0	0.04	0.03	14.54
M^1GT_6	27.0	16.0	0.02	0.01	6.04
M^2GT_6	26.0	16.0	0.02	0.01	6.00
M^3GT_6	27.0	16.0	0.02	0.01	6.06
M^1GE_6	29.0	14.0	0.03	0.02	6.56
M^2GE_6	29.0	14.0	0.03	0.01	6.42
M^3GE_6	29.0	14.0	0.02	0.02	6.68
M^1RT_3	28.0	42.0	0.10	0.07	10.65
M^2RT_3	29.0	42.0	0.10	0.07	10.96

M^3RT_3	28.0	12.0	0.10	0.07	10.98
M^1RE_3	42.0	44.0	0.12	0.08	12.54
M^2RE_3	41.0	44.0	0.12	0.08	12.68
M^3RE_3	42.0	44.0	0.12	0.08	12.79
M^1ST_3	26.0	33.0	0.10	0.06	8.69
M^2ST_3	27.0	33.0	0.10	0.06	8.76
M^3ST_3	26.0	34.0	0.10	0.06	8.85
M^1SE_3	41.0	35.0	0.11	0.07	10.63
M^2SE_3	40.0	35.0	0.10	0.07	10.74
M^3SE_3	41.0	35.0	0.11	0.07	10.95
M^1LT_3	26.0	40.0	0.06	0.03	13.46
M^2LT_3	27.0	40.0	0.06	0.02	13.62
M^3LT_3	26.0	41.0	0.06	0.03	13.59
M^1LE_3	42.0	41.0	0.07	0.03	15.27
M^2LE_3	42.0	42.0	0.06	0.04	15.36
M^3LE_3	41.0	41.0	0.07	0.04	15.44
M^1GT_3	18.0	13.0	0.05	0.01	07.00
M^2GT_3	19.0	13.0	0.04	0.01	06.94
M^3GT_3	20.0	14.0	0.05	0.01	07.01
M^1GE_3	21.0	11.0	0.06	0.02	07.54
M^2GE_3	21.0	11.0	0.05	0.02	07.14
M^3GE_3	21.0	12.0	0.06	0.02	07.63
M^1RT_{12}	33.0	42.0	0.10	0.07	14.62
M^2RT_{12}	31.0	43.0	0.09	0.08	14.89
M^3RT_{12}	33.0	44.0	0.09	0.08	14.75
M^1RE_{12}	53.0	45.0	0.11	0.09	16.84
M^2RE_{12}	53.0	46.0	0.11	0.09	16.96
M^3RE_{12}	52.0	45.0	0.11	0.09	16.78

M^1ST_{12}	30.0	35.0	0.05	0.03	12.84
M^2ST_{12}	30.0	35.0	0.06	0.02	12.98
M^3ST_{12}	30.0	35.0	0.06	0.03	12.86
M^1SE_{12}	51.0	38.0	0.07	0.04	13.98
M^2SE_{12}	51.0	37.0	0.06	0.04	13.84
M^3SE_{12}	51.0	37.0	0.07	0.04	13.78
M^1LT_{12}	30.0	42.0	0.05	0.02	16.75
M^2LT_{12}	30.0	42.0	0.05	0.02	16.73
M^3LT_{12}	30.0	41.0	0.05	0.02	16.90
M^1LE_{12}	51.0	41.0	0.07	0.03	18.65
M^2LE_{12}	50.0	43.0	0.06	0.03	18.93
M^3LE_{12}	51.0	42.0	0.06	0.03	18.78
M^1GT_{12}	26.0	10.0	0.03	0.01	09.02
M^2GT_{12}	25.0	10.0	0.03	0.01	08.96
M^3GT_{12}	26.0	11.0	0.03	0.01	08.98
M^1GE_{12}	29.0	09.0	0.04	0.02	09.54
M^2GE_{12}	30.0	08.0	0.03	0.02	09.08
M^3GE_{12}	29.0	09.0	0.04	0.01	09.10

* MRT = Maize Roots in tapwater irrigated plots.
MRE = Maize Roots in sewage effluent irrigated plots.
MST = Maize Stem in tapwater irrigated plots.
MSE = Maize Stem in sewage effluent irrigated plots.
MLT = Maize Leaves in tapwater irrigated plots.
MLE = Maize Leaves in sewage irrigated plots.
MGT = Maize Grains in tapwater irrigated plots.
MGE = Maize Grains in sewage effluent irrigated plots.

Superscripts = Sample Numbers.
Subscripts = Plt Numbers.

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Plate 11: Second stage of sampling
Maize crop Irrigated
with Sewage effluents



Plate 12: Second stage of sampling
Maize crop Irrigated
with tapwater

APPENDIX IX

MEAN CONCENTRATIONS OF ELEMENTS IN VARIOUS PARTS OF CROPS

TYPE OF CROP PARTS	TYPE OF CROP	FIRST SAMPLING					SECOND SAMPLING				
		E L E M E N T S					E L E M E N T S				
		Zn CONC. IN PPM	Mn CONC. IN PPM	Pb CONC. IN PPM	Cd CONC. IN PPM	B CONC. IN PPM	Zn CONC. IN PPM	Mn CONC. IN PPM	Pb CONC. IN PPM	Cd CONC. IN PPM	B CONC. IN PPM
ROOTS	AMARANTHUS	53.17	44.04	0.15	0.13	29.58	54.58	42.25	0.16	0.14	30.19
	TOMATOES	47.79	40.62	0.11	0.07	24.92	48.41	38.08	0.12	0.08	25.84
	MAIZE	39.50	37.50	0.09	0.06	13.27	40.62	40.79	0.10	0.07	13.57
	LSD(0.05)	3.06	3.32	0.012	0.013	4.43	3.77	4.87	0.01	0.01	3.80
STEM	AMARANTHUS	46.75	36.71	0.11	0.10	23.55	47.87	35.37	0.12	0.11	25.26
	TOMATOES	44.37	33.12	0.09	0.06	21.07	45.83	35.29	0.10	0.07	21.95
	MAIZE	36.92	33.42	0.06	0.03	11.28	37.96	30.58	0.07	0.05	11.55
	LSD(0.05)	2.30	NS	0.01	0.01	4.49	3.78	NS	0.01	0.01	4.05
LEAVES	AMARANTHUS	42.87	50.37	0.01	0.09	38.56	44.71	48.75	0.11	0.10	39.51
	TOMATOES	40.29	41.83	0.07	0.04	29.20	42.87	41.92	0.08	0.05	30.10
	LSC(0.05)	1.90	3.15	0.02	0.01	1.67	2.68	3.40	0.02	0.01	1.74

APPENDIX X

TYPICAL CONCENTRATIONS OF ELEMENTS IN PLANT PARTS

ELEMENT	CONCENTRATION IN NORMAL PLANT PARTS
	RANGE (PPM)
Zn	15 - 200
Mn	15 - 100
Pb	0.01 - 10
Cd	0.02 - 0.8
B	5 - 30

SOURCE: Page and Chang (1985)

APPENDIX XI

INDICATOR VALUES FOR LEAD, CADMIUM, ZINC AND FLUORINE IN FOOD PLANTS FOR MAN AND ANIMALS

COMPONENT	CONCENTRATION IN PPM DRY WT	OBJECT	REMARKS
Lead	10	Grazing animals	Tolerance limit in the food
"	5	Man	Recommended Indicator Values for limitation of contents in food
Cadmium	5 (50)	Grazing animals	Tolerance limit
"	1.	Man	Recommended Indicator Values for limitation of contents in food
Zinc	250	Grazing animals	Tolerance limit
"	600	Man	Upper limitation of daily absorption
Fluorine	30	Grazing animals	Tolerance limit
"	200	Man	Tolerance limit for daily oral absorption

SOURCE: L. Steubing: Monitoring serial inorganic pollutants by plant indicator systems, - Monitoring Environmental materials and Specimen Banking, Edited by N.P. Luepke 1979 MARTINUS NIJHOFF Publishers - Pages 538 - 554.

APPENDIX XII

RECOMMENDED MAXIMUM CONCENTRATIONS ON SELECTED TRACE ELEMENTS IN IRRIGATION WATER

ELEMENTS	RECOMMENDED MAXIMUM CONCENTRATION*	R E M A R K S
Cd	0.01mg/l	Toxic to beans, beats and turmps at concentrations as low as 0.1mg/l in nutrient solutions. Conservative limits recommended due to its potential for accumulation in plants and soils to concentrations that may be harmful to humans.
Mn	0.2mg/l	Toxic to a number of crops at a few tenths to a few mg/l, but usually only in acid soils
Pb	5.0mg/l	Can inhibit plant cell growth at very high concentrations.
Zn	2.0mg/l	Toxic to many plants at widely varying concentrations; reduced toxicity at PH 76.0 and in fined texured or organic soils.

*The maximum concentrations is based on water application rate which is consistent with good irrigation practices (10,000m^3/ha/yr). If the water application rate greatly exceeds this, the maximum concentrations should be adjusted downwards accordingly. No adjustment should be made for application rates less than 10,000m^3/ha/yr. The values given are for water used on a continuous basis at one site.

SOURCE: FAO (1985)

APPENDIX XIII

GUIDELINES FOR INTERPRETATIONS OF WATER QUALITY FOR IRRIGATION

POTENTIAL IRRIGATION PROBLEM	UNITS	DEGREE OF RESTRICTION ON USE		
		NONE	SLIGHT MODERATE	SEVERE
Salinity				
Electrical conductivity (ECW)	ds/m	0.7	0. - 3.0	3.0
Total Dissolved Solids (T.D.S)	mg/l	450	450 - 2000	2000
Infilteration				
Evaluate Using ECW and Sodium Adsorption Ratio (S.A.R).				
S.A.R = 0-3&ECW		0.7	0.7 - 0.2	0.2
= 3-6&ECW		1.2	1.2 - 0.3	0.3
= 6-12&ECW		1.9	1.9 - 0.3	0.5
= 12-20&ECW		2.9	2.9 - 1.3	1.3
= 20-40&ECW		5.9	5.0 - 2.9	2.9
Specific Iron Toxicity				
Sodium (Na)				
Surface Irrigation	SAR	3	3 - 9	9
Sprinkler Irrigation	Me/l	3	3	
Chloride (Cl)				
Surface Irrigation	Me/l	4	4 - 10	
Sprinkler Irrigation	Me/l	3	3	
Boron (B)	Mg/l	0.7	0.7 - 3.0	3.0
Miscellaneous Effects				
Nitrogen (NO_3/N)	Mg/l	5.0	5 - 30	30
Bicarbonate (HCO_3) (Over head Sprinkler only)	Me/l	1.5	1.5 - 8.5	8.5
PH			Normal Range 6.5 - 8.4	

SOURCE: FAO (1985)

APPENDIX XIV

SUGGESTED TREATMENT PROCESSES TO MOST HEALTH CRITERIA FOR WASTE WATER RE-USE FOR IRRIGATIONS PURPOSES

Health Criteria	A	B	B
Primary Treatment	Essential	Essential	Essential
Secondary Treatment		Essential	Essential
Sand Filteration or Equivalent polishing methods		Sometimes Required	Sometimes Required
Disinfection		Sometimes Required	Essential

SOURCE: WHO, 1973

A Freedom from gross solids; significant removal of parasite eggs.

B As A, plus not more than 100 coliform organisms/ 100ml in 80% of samples; and no chemicals that lead to undesirable residues in crops.

APPENDIX XV

VIEW DATA

CASE	TISU	CROP	TRT	REP	ZN	MN	PB	CD	B
1	1	1	1	1	55.33	59.33	0.12	0.10	25.46
2	1	1	2	1	59.33	33.67	0.14	0.13	41.60
3	1	1	1	2	49.33	55.33	0.14	0.13	27.07
4	1	1	2	2	56.00	31.67	0.16	0.15	33.66
5	1	1	1	3	46.67	55.33	0.14	0.13	28.98
6	1	1	2	3	57.00	25.00	0.17	0.16	32.21
7	1	1	1	4	43.00	58.33	0.14	0.13	18.21
8	1	1	2	4	58.67	33.67	0.16	0.14	21.48
9	2	1	1	1	38.67	43.67	0.09	0.07	23.36
10	2	1	2	1	57.67	28.00	0.10	0.09	36.46
11	2	1	1	2	40.33	43.67	0.10	0.09	22.14
12	2	1	2	2	54.33	37.67	0.12	0.11	24.76
13	2	1	1	3	42.33	45.33	0.12	0.11	26.97
14	2	1	2	3	55.00	20.67	0.14	0.12	22.52
15	2	1	1	4	33.00	46.67	0.11	0.10	15.10
16	2	1	2	4	52.67	28.00	0.12	0.11	17.08
17	3	1	1	1	33.33	57.00	0.07	0.06	36.48
18	3	1	2	1	51.67	36.00	0.08	0.07	42.57
19	3	1	1	2	31.33	65.33	0.09	0.08	37.01
20	3	1	2	2	50.00	35.00	0.11	0.09	39.45
21	3	1	1	3	36.67	68.67	0.12	0.10	35.94
22	3	1	2	3	51.33	43.67	0.13	0.11	42.98
23	3	1	1	4	37.67	60.00	0.10	0.09	35.45
24	3	1	2	4	51.00	37.33	0.12	0.10	38.63

25	1	2	1	1	46.00	50.33	0.10	0.06	24.08
26	1	2	2	1	54.33	33.33	0.11	0.07	26.87
27	1	2	1	2	42.33	32.33	0.07	0.04	20.91
28	1	2	2	2	53.67	26.00	0.09	0.06	25.02
29	1	2	1	3	38.67	55.33	0.12	0.07	24.08
30	1	2	2	3	55.67	31.00	0.13	0.08	25.68
31	1	2	1	4	36.33	48.67	0.11	0.09	25.27
32	1	2	2	4	55.33	28.00	0.13	0.10	27.47
33	2	2	1	1	38.33	44.33	0.09	0.05	22.05
34	2	2	2	1	52.67	25.00	0.10	0.06	23.83
35	2	2	1	2	38.33	41.00	0.05	0.03	15.56
36	2	2	2	2	51.67	24.33	0.06	0.04	17.10
37	2	2	1	3	35.00	45.67	0.10	0.06	20.33
38	2	2	2	3	53.67	26.33	0.11	0.07	22.70
39	2	2	1	4	33.00	38.67	0.09	0.06	22.43
40	2	2	2	4	52.33	19.67	0.10	0.07	24.58
41	3	2	1	1	30.33	51.33	0.07	0.04	27.47
42	3	2	2	1	50.00	33.00	0.08	0.05	30.74
43	3	2	1	2	30.67	53.67	0.02	0.01	28.85
44	3	2	2	2	49.33	33.00	0.03	0.02	30.44
45	3	2	1	3	31.67	55.67	0.08	0.05	28.53
46	3	2	2	3	51.33	36.00	0.09	0.06	30.06
47	3	2	1	4	29.33	47.67	0.07	0.04	27.71
48	3	2	2	4	49.67	24.33	0.08	0.05	29.77
49	1	3	2	1	29.33	35.67	0.08	0.04	13.36
50	1	3	2	1	49.67	37.67	0.10	0.06	15.42
51	1	3	1	2	33.67	35.67	0.05	0.02	10.75
52	1	3	2	2	47.33	36.67	0.07	0.04	12.58

53	1	3	1	3	27.33	34.33	0.10	0.06	10.68
54	1	3	2	3	49.00	35.67	0.11	0.07	12.46
55	1	3	1	4	31.67	41.33	0.09	0.07	14.35
56	1	3	2	4	48.00	43.00	0.10	0.08	16.54
57	2	3	1	1	26.33	32.00	0.06	0.03	11.36
58	2	3	2	1	47.67	34.33	0.08	0.04	13.44
59	2	3	1	2	29.33	31.00	0.03	0.01	9.03
60	2	3	2	2	46.00	32.33	0.04	0.02	11.03
61	2	3	1	3	25.00	32.33	0.09	0.05	8.65
62	2	3	2	3	46.67	34.00	0.10	0.06	10.53
63	2	3	1	4	28.00	34.67	0.05	0.02	12.49
64	2	3	2	4	46.33	36.67	0.06	0.03	13.68
65	3	3	1	1	24.67	38.67	0.05	0.02	16.73
66	3	3	2	1	45.67	42.33	0.06	0.03	18.59
67	3	3	1	2	28.00	37.67	0.02	0.01	12.85
68	3	3	2	2	44.67	41.67	0.03	0.02	14.03
69	3	3	1	3	22.33	38.33	0.05	0.02	13.35
70	3	3	2	3	45.33	40.33	0.06	0.03	15.16
71	3	3	1	4	25.67	38.00	0.04	0.01	16.28
72	3	3	2	4	44.67	39.33	0.05	0.02	18.46
73	1	1	1	1	56.33	58.33	0.13	0.11	30.08
74	1	1	2	1	62.33	35.00	0.15	0.14	42.11
75	1	1	1	2	50.33	54.00	0.16	0.14	27.38
76	1	1	2	2	57.67	29.67	0.17	0.16	34.54
77	1	1	1	3	49.00	52.33	0.15	0.14	27.83
78	1	1	2	3	60.33	22.33	0.18	0.17	33.69
79	1	1	1	4	44.00	55.33	0.15	0.14	22.57
80	1	1	2	4	56.67	31.00	0.17	0.15	23.31

81	2	1	1	1	41.00	43.33	0.09	0.08	28.44
82	2	1	2	1	54.67	25.67	0.11	0.10	25.79
83	2	1	1	2	41.67	45.33	0.11	0.10	25.79
84	2	1	2	2	54.00	35.67	0.13	0.12	25.62
85	2	1	1	3	43.00	39.67	0.13	0.12	23.83
86	2	1	2	3	56.33	19.33	0.15	0.13	24.12
87	2	1	1	4	34.00	47.33	0.12	0.11	19.61
88	2	1	2	4	58.33	26.67	0.13	0.12	17.81
89	3	1	1	1	34.33	55.67	0.08	0.07	37.11
90	3	1	2	1	52.67	35.33	0.09	0.08	43.53
91	3	1	1	2	32.67	64.00	0.11	0.09	38.29
92	3	1	2	2	51.67	33.67	0.12	0.10	40.53
93	3	1	1	3	38.67	65.67	0.13	0.11	36.99
94	3	1	2	3	55.00	43.67	0.14	0.13	43.93
95	3	1	1	4	38.67	58.00	0.11	0.10	36.42
96	3	1	2	4	54.00	34.00	0.13	0.11	39.31
97	1	2	1	1	47.33	49.67	0.11	0.07	24.99
98	1	2	2	1	63.67	32.33	0.12	0.08	27.88
99	1	2	1	2	43.33	51.00	0.08	0.05	21.89
100	1	2	2	2	56.33	24.33	0.09	0.07	26.03
101	1	2	1	3	41.00	54.00	0.13	0.08	25.13
102	1	2	2	3	54.00	30.00	0.14	0.09	27.06
103	1	2	1	4	38.33	40.67	0.12	0.10	26.31
104	1	2	2	4	51.33	22.33	0.14	0.11	27.41
105	2	2	1	1	40.33	43.33	0.10	0.07	22.93
106	2	2	2	1	60.00	24.33	0.11	0.07	24.71
107	2	2	1	2	37.00	39.67	0.06	0.04	16.59
108	2	2	2	2	54.33	23.00	0.07	0.05	17.39
109	2	2	1	3	37.67	43.67	0.11	0.07	21.36

110	2	2	2	3	52.67	25.67	0.12	0.08	23.55
111	2	2	1	4	35.33	31.00	0.09	0.06	23.53
112	2	2	2	4	49.33	14.00	0.11	0.08	25.54
113	3	2	1	1	35.33	50.33	0.08	0.05	29.42
114	3	2	2	1	54.00	32.33	0.09	0.06	31.64
115	3	2	1	2	33.67	52.67	0.03	0.02	29.48
116	3	2	2	2	52.33	32.33	0.04	0.02	31.37
117	3	2	1	3	34.67	54.00	0.09	0.06	29.23
118	3	2	2	3	50.00	35.33	0.10	0.07	31.00
119	3	2	1	4	34.00	42.67	0.08	0.05	28.50
120	3	2	2	4	49.00	24.33	0.09	0.06	30.20
121	4	2	1	1	11.67	7.33	0.06	0.02	12.52
122	4	2	2	1	14.67	5.33	0.07	0.03	13.56
123	4	2	1	2	9.67	5.67	0.02	0.01	11.63
124	4	2	2	2	11.00	5.00	0.03	0.02	12.60
125	4	2	1	3	8.00	6.33	0.05	0.04	13.17
126	4	2	2	3	9.67	5.00	0.06	0.05	14.09
127	4	2	1	4	6.67	5.33	0.04	0.01	12.46
128	4	2	2	4	8.67	3.00	0.05	0.02	13.19
129	1	3	1	1	30.33	36.33	0.09	0.06	13.85
130	1	3	2	1	50.33	38.33	0.11	0.07	15.89
131	1	3	1	2	35.33	37.67	0.06	0.04	10.97
132	1	3	2	2	55.00	40.00	0.07	0.05	12.72
133	1	3	1	3	28.33	42.00	0.10	0.07	10.86
134	1	3	2	3	41.67	44.00	0.12	0.08	12.67
135	1	3	1	4	32.33	43.00	0.09	0.08	14.75
136	1	3	2	4	51.67	45.00	0.11	0.09	16.86
137	2	3	1	1	27.67	33.00	0.07	0.05	11.70

138	2	3	2	1	47.67	34.67	0.09	0.06	13.88
139	2	3	1	2	30.00	36.33	0.04	0.02	9.30
140	2	3	2	2	50.33	37.67	0.05	0.03	11.35
141	2	3	1	3	26.33	33.33	0.10	0.06	8.77
142	2	3	2	3	40.67	35.00	0.11	0.07	10.77
143	2	2	1	4	30.00	35.00	0.06	0.03	12.89
144	2	3	2	4	51.00	37.33	0.07	0.04	13.87
145	3	3	1	1	29.67	39.00	0.06	0.04	16.85
146	3	3	2	1	45.33	43.33	0.07	0.05	19.55
147	3	3	1	2	31.67	44.00	0.03	0.02	12.96
148	3	3	2	2	47.67	44.67	0.04	0.03	14.34
149	3	3	1	3	26.33	40.33	0.06	0.03	13.56
150	3	3	2	3	41.67	41.33	0.07	0.04	15.36
151	3	3	1	4	30.60	40.67	0.05	0.02	16.79
152	3	3	2	4	49.67	42.00	0.06	0.03	18.77
153	5	3	1	1	24.67	14.67	0.04	0.02	8.04
154	5	3	2	1	26.67	10.33	0.05	0.03	8.36
155	5	3	1	2	26.67	16.00	0.02	0.01	6.03
156	5	3	2	2	29.00	14.00	0.03	0.02	6.55
157	5	3	1	3	19.00	13.33	0.05	0.01	6.98
158	5	3	2	3	21.00	11.33	0.06	0.02	7.44
159	5	3	1	4	24.67	10.33	0.03	0.01	8.65
160	5	3	2	4	29.33	8.67	0.04	0.02	9.24

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