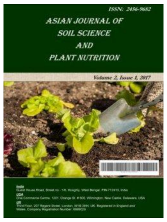

Asian Journal of Soil Science and Plant Nutrition

5(1): 1-15, 2019; Article no.AJSSPN.50635
ISSN: 2456-9682

Manipulation of Chemical Properties in Soil under Wetland Rice through Industrial Effluents

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Authors' contributions

This work was carried out in collaboration among all authors. Author MRI designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author GKMMR managed the analyses of the study. Author MAS managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJSSPN/2019/v5i130054
Editor(s):
(1) Dr. Prabhakar Tamboli, Ph.D, Adjunct Professor and Director International Training Program, Department of Environmental Science and Technology, Patterson Hall, University of Maryland, USA.
Reviewers:
(1) Jimmy Walter Rasche Alvarez, Universidad Nacional de Asunción, Paraguay.
(2) Deepranjan Sarkar, Banaras Hindu University, India.
(3) B. P. Bhaskar, India.
Complete Peer review History: http://www.sdiarticle3.com/review-history/50635

Original Research Article

Received 18 June 2019
Accepted 20 August 2019
Published 31 August 2019

ABSTRACT

A laboratory experiment was conducted in Soil Science Division of Bangladesh Rice Research Institute (BRRI) during 2010-11 aimed to determine the effects of different industrial effluents on some soil chemical properties under long-term industrial wastewater irrigated rice field. Effluents irrigation created some differences in soil pH, electrical conductivity and organic carbon. The pH in all soil depth was higher with wastewater irrigated rice field. Irrigation with wastewater increased in all the effluents irrigated rice fields; the electrical conductivity (EC) was remarkable higher with all soil depth than the control field. In all the rice fields soil (Control + effluents irrigated fields), the organic carbon content (%) started to decrease sharply with the increase in soil depth. Organic carbon content was slightly higher with wastewater irrigated rice soils. Exchangeable cations (Ca, Mg, K and Na), trace elements (Zn, Fe, Mn and Cu) and heavy metals (Pb, Cd, Cr and Ni) were increased through irrigation with wastewater in rice–rice cropping pattern.

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Keywords: Wetland rice; industrial waste; plant nutrients; heavy metals.

1. INTRODUCTION

Growing industrial establishments increased sharply in Bangladesh without proper attention to pollution control. Farmers' of industrial areas are growing crops in their field by using industrial wastewater for many years. The use of different wastewaters (industrial effluents as well as municipal sewage) for irrigation has emerged in the recent past as an important way of the utilization of wastewater taking the advantage of the presence of considerable quantities of nitrogen and phosphorus along with some other essential elements. Another advantage of wastewater irrigation includes an important aspect of pollution removal. The pollutants are partly taken up by the plants and partly transformed in the soil without causing any damage. Nevertheless, the use of wastewaters for agriculture is marred by several constraints due to various problems like soil salinity, the interaction of chemical constituents of the wastes with the uptake of nutrients and changes in soil property and microflora [1]. Darvishil et al. [2] reported that effluents change the soil chemical properties like pH, EC, soil organic matter, primary, secondary nutrient elements including heavy metals. The addition of sewage sludge to a coarse-textured sandy and calcareous soils was reported to have improved the water holding capacity, cation exchange capacity, increase the availability of N, P, K, Cu, Zn, Fe, Mn, Na but with reduced biochemical oxygen demand (BOD) [3]. Lim and P`ng [4] recorded an increase in pH, K, Ca, Mg and organic matter content with the application of palm oil mill effluent. This necessitates a detailed scientific study before any specific waste can be used for irrigation for a particular crop with particular soil and climate. Since crop plants are increasingly being exposed to the effluent discharge in the industrial area, an attempt has been done to study the effects of different industrial effluents on some soil chemical properties.

2. MATERIALS AND METHODS

2.1 History of Soil Sample

Soil samples were collected from Mouchak area of Gazipur district (middle part of Bangladesh; Madhpur tract; AEZ 28) which has a long cropping history under rice–rice systems. The sampling area represents two kinds of farmers' managed rice fields (i) irrigated with underground freshwater (control soil) and (ii) irrigated with effluents water for 8-10 years. The distance between control and effluents irrigated field was 500 meters. The locations of different plots are shown in Fig. 1.

2.2 Soil Sample Collection

The samples were collected through auger from control (rice cultivated with fresh water) and industrial wastewater treated plots in December 2010. Thirty soil samples from ten plots (six from 2 control plots and 24 from 8 effluent water receiving plots) were collected from the depth 0-10 cm, 10-20 cm and 20-30 cm, respectively. The control and effluent irrigated plot soils were denoted by C and I, respectively. The collected samples were composited to make about 1/2 kg and samples were brought in Soil Science Division net house of Bangladesh Rice Research Institute (BRRI), air-dried, crushed and sieved through 2-mm sieve prior to analysis.

2.3 Soil Analytical Methods

Analytical methods that are used for soil samples have been presented in Table 1.

2.4 Statistical Analysis

The obtained data were statistically analyzed following IRRISTAT version 4.3 [9].

3. RESULTS AND DISCUSSION

3.1 Soil pH

The pH of collected soil samples varied from 4.26 to 6.37 at 0-10 cm, from 4.86 to 6.57 at 10-20 and from 4.75 to 6.39 at 20-30 cm soil depth (Fig. 2). The control soil gave a pH of 4.78 at 0-10 cm depth. At 0-10 cm depth, I_1 plot gave 0.98 and I_4 plot gave 0.47 unit's higher pH than that of control plot. At 0-10 cm depth, I_5, I_6 and I_7 plots showed an increase in pH than the control soil by 0.57, 0.42 and 0.53 units, respectively. A remarkable increase in pH was found in the I_2 plot. The I_2 plot showed a pH of 6.37 at 0-10 cm depth. However, the I_3 plot recorded 0.52 and I_8 plot recorded 0.11-unit lower pH as compared to the control plot at 0-10 cm depth.

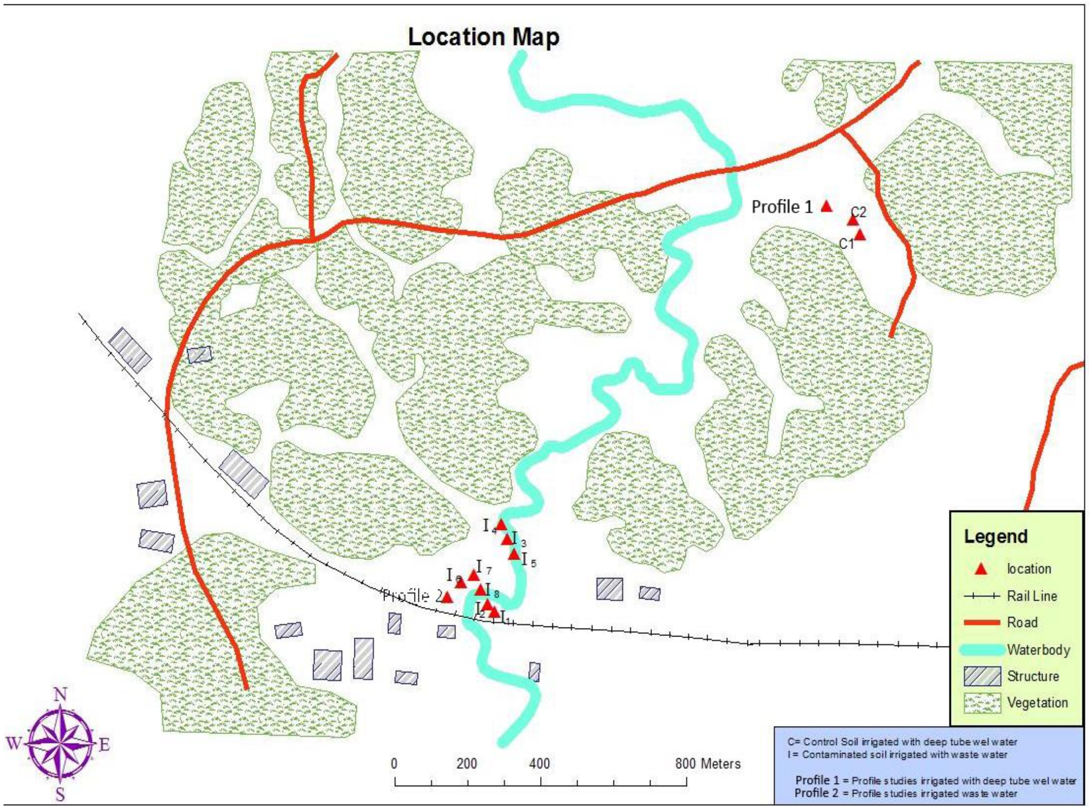

Fig. 1. Locations of soil profiles and different plot soils under study area

Table 1. Analytical methods used for soil analysis

Soil property	Methods
pH (H_2O)	1:2.5 soil-water ratio, using a glass electrode method [5]. Ten g of air-dried soil sample was taken in 50 ml of a beaker and 25 ml of distilled water was added. The suspension was stirred with a glass-rod at regular interval for 30 minutes. A glass electrode pH meter (WPA Linton Cambridge, UK) calibrated with buffer pH 7.0 and 4.0 measured the pH of the soil suspension.
Electrical Conductivity (dS/m)	A portion of 20 gm of air-dried soil sample was taken in a 250 ml of the conical flask and then 100 ml of distilled water was added. It was shaken for 30 minutes and filtered through Whatman # 42 filter paper. Electrical conductivity was measured from the filtered sample using a conductivity meter (YSI Model 32) [5].
Organic Carbon (%)	Walkley and Black wet digestion method Nelson and Sommers [6] was followed to determine organic carbon. The sieved soil was again passed through 0.5 mm sieve to determine organic carbon. One gm soil sample was taken in a 500 ml conical flask, and then 10 ml of 1 N $K_2Cr_2O_7$ solution and 20 ml of conc. H_2SO_4 was added. Flask was then kept for 30 minutes for completion of oxidation. Then 200 ml of distilled water, 10 ml of H_3P0_4 and 2 ml of di-phenyl amine indicator solution were added. The sample was then titrated with 1N $FeSO_4$ solution until the green colour appeared. A blank sample was also taken to calculate the results.
Exchangeable Ca, Mg, K and Na (cmol/kg)	Thomas [7] method was followed to determine exchangeable cations. A portion of ten g of air-dried sieved soil sample was taken in a 125 ml of the conical flask, then 50 ml of extracting solution (1 N CH_3COONH_4, pH 7.0) was added. It was shaken for 10 minutes and filtered through Whatman # 42 filter paper. In the case of exchangeable K and Na direct reading was taken from atomic absorption spectrophotometer at 766.5 nm and 589 nm wavelengths, respectively. For

Soil property	Methods
	Exchangeable Ca was determined by diluting a portion of 2 ml of aliquot with 1 ml of La_2O_3 and 7ml of distilled water into 25 ml test tube and atomic absorption Spectrophotometer reading was taken at 422.7 nm wavelength. For Mg, 1 ml aliquot was diluted in 19 ml of distilled water into 25 ml test tube and atomic absorption Spectrophotometer reading was taken at 285.2 nm wavelength.
Trace elements (Zn, Fe, Mn and Cu) (mg/kg)	Lindsay and Norvell [8] method was followed to determine trace elements. A portion of ten g of air-dried sieved soil sample was taken in a 125 ml of the conical flask, then 20 ml of extracting solution (EDTA-Diethylenetriaminepentraacetic acid) was added. It was shaken for 2 hours and filtered through Whatman # 42 filter paper. Concentrations of Zn, Fe, Mn and Cu were determined by atomic absorption Spectrophotometer with respective wavelength.
Heavy metals (Pb, Cd, Cr and Ni) (mg/kg)	Heavy metals analysis involved digestion of 0.5 g of soil sample with concentrated HNO_3 and $HClO_4$ (5:2) at 120^{0}C following the procedure described by Lindsay and Norvell [8]. Finally, the digest was filtered through Whatman # 42 filter paper and diluted to 50 ml with distilled water prior to analysis. Concentrations of Pb, Cd, Cr and Ni were determined by atomic absorption Spectrophotometer with respective wavelength (AAS; Model: Varian 55B).

At 10-20 cm depth, the control plot gave a pH of 4.86. At 10-20 cm depth, I_1, I_4, I_5, I_6 and I_7 plots showed an increase in pH than the control soil by 1.05, 0.52, 1.0, 0.47 and 0.65 units, respectively. The I_3 and I_8 plots gave equal pH in the soil as that of control soil. A remarkable increase in pH was found in the I_2 plot at 10-20 cm depth. The I_2 plot gave a pH of 6.51 at 10-20 cm depth.

At 20-30 cm depth, the control plot gave a pH of 4.75. At 20-30 cm depth, I_1 plot gave 1.05 and I_4 plot gave 0.45-unit higher pH than that of control. The I_6 plot showed an equal pH to that of the I_4 plot. However, the I_3 and I_8 plots gave the equal pH to that of control plot at 20-30 cm depth. The I_5 and I_7 plots showed an increase in pH than the control soil by 0.31 and 0.61 units, respectively. A remarkable increase in pH was found in the I_2 plot. The I_2 plot had a pH of 6.39 at 20-30 cm depth. In all the fields, the highest soil pH was found at 10-20 cm depth and the lowest was observed in 0-10 cm depth. Effluents irrigated plots showed the highest pH value compared to control indicating that effluents irrigated plots accumulated more Ca and Mg that is responsible to increase in soil pH and decrease in exchangeable acidity. This report was similar to the findings of [10,11].

3.2 Electrical Conductivity (EC)

The EC of tested soil samples ranged from 1.3 to 5.5 dS/m at 0-10 cm, from 1.0 to 4.5 dS/m at 10-20 cm and from 0.8 to 4.0 dS/m at 20-30 cm soil depth (Fig. 3). At 0-10 cm depth, the control plot showed EC of 1.3 dS/m. The I_1 plot gave 4.2 and I_3 plot gave 3.5 folds higher EC than that of control plot. The I_2 plot showed the equal EC to that of I_1 plot. At 0-10 cm depth, I_4, I_5, I_6, I_7 and I_8 plots showed an increase in EC content than the control plot by 3.2, 2.6, 2.7, 3.3 and 3.4 folds, respectively.

At 10-20 cm depth, the control plot gave EC of 1.0 dS/m. The I_1 plot had 4.5 and I_3 plot had 3.7 folds higher EC than that of control plot. The I_2 plot showed the equal EC to that of I_1 plot at 10-20 cm depth. The I_4, I_5, I_6 and I_7 plots showed an increase in EC in soil than the control by 3.9, 3.0, 3.1 and 4.0 folds, respectively. The I_8 plot found a similar EC value to that of I_7 plot.

At 20-30 cm depth, the control plot had EC of 0.8 dS/m. At 20-30 cm depth, I_1 plot had 5.0 folds and I_3 plot had 4.3 folds higher EC compared to control plot. The I_2 plot had a similar EC to that of I_1 plot. At 20-30 cm depth, I_4, I_5, I_6, I_7 and I_8 plots showed an increase in EC content than the control plot by 4.5, 3.2, 3.3, 4.4 and 3.8 folds, respectively. A tremendous increase in EC was found with effluents irrigated plots compared to the control plot may be deposition of salts, especially Na salt and heavy metals from effluents. Similar results were also reported by Begum [12] Saif et al. [13].

3.3 Organic Carbon (OC)

The OC content of tested soil samples varied from 1.13 to 1.28% at 0-10 cm, from 0.86 to 1.02% at 10-20 cm and from 0.71 to 0.88% at 20-30 cm soil depth (Fig. 4). At 0-10 cm depth, the control plot recorded OC content of 1.13%. The I_1 plot gave 4% and I_2 plot gave 2% higher OC than that of control. The I_5 plot showed a similar OC content to that of I_2 plot at 0-10 cm depth. The I_3, I_4 and I_6 plots showed an increase in OC content than the control plot by 5, 3 and 5%, respectively. A considerable increase in OC was found in the I_7 and I_8 plots. The I_7 plot had OC content of 1.28% and that in the I_8 plot was 1.24%.

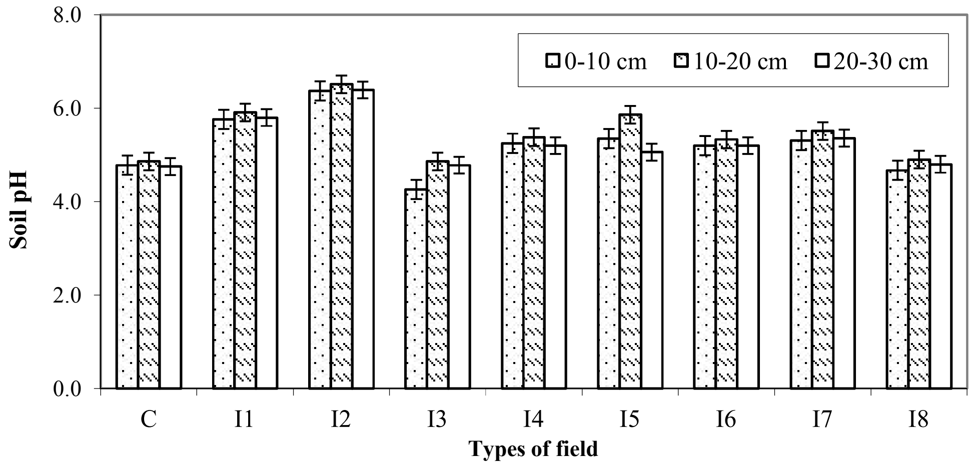

Fig. 2. Distribution of soil pH in effluents and control water irrigated rice soils

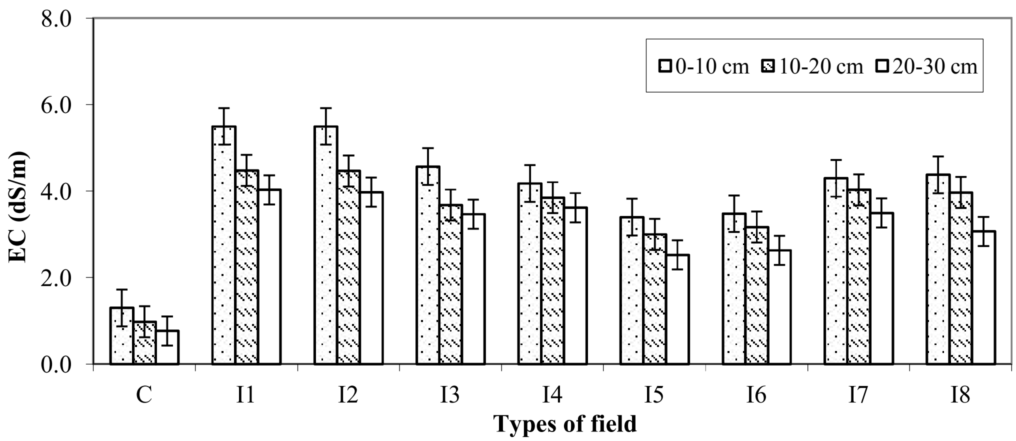

Fig. 3. Distribution of soil EC (dS/m) in effluents and control water irrigated rice soils

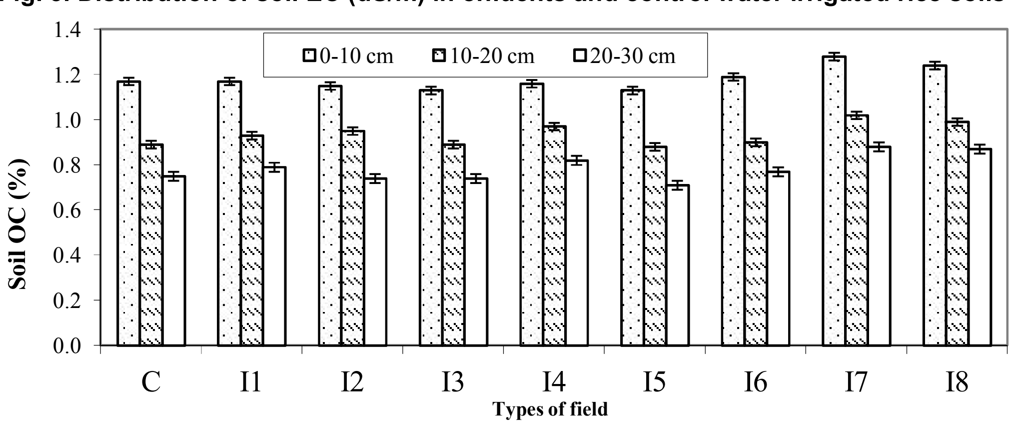

Fig. 4. Distribution of soil OC (%) in effluents and control water irrigated rice soils

At 10-20 cm depth, the control plot gave OC content of 0.86%. The I_1 plot showed 8% and I_2 plot showed 10% higher OC content compared to the control plot. At 10-20 cm depth, I_3, I_4, I_5 and I_6 plots tended to increase in OC content than the control plot by 3, 13, 2 and 5%, respectively. A considerable increase in OC content was found in the I_7 and I_8 plots. The I_7 plot had OC content of 1.02% and that in the I_8 plot was 0.99%

At 20-30 cm depth, the control plot recorded OC content of 0.74%. At 20-30 cm depth, I_1 plot had 7% and I_4 plot had 11% higher OC content than that of control plot. The I_2 and I_3 plots gave similar OC content to that of control plot. The I_5 plot decreased 3% while I_6 plot increased 4% OC content in soil compared to the control plot. A considerable increase in OC content was found in the I_7 and I_8 plots. The I_7 plot had OC content of 0.88% and that in the I_8 plot was 0.87%. In all the fields, the highest OC was found at 0-10 cm soil depth and the lowest was obtained in 20-30 cm depth. The greater concentration of organic carbon content in 0-10 cm soil depth compared to 10-20 and 20-30 cm depth may be due to the accumulation of organic residues left out in former. Sood and Kanwar [14] earlier reported that the organic carbon content decreased with the depth of soils in Himachal Pradesh of India. However, OC content was the highest with effluents irrigated plots than the control plot. It might be due to the high total solid present in the effluent.

3.4 Exchangeable Cations (Ca, Mg, K and Na)

The exchangeable Ca content of collected soil samples varied from 5.62 to 8.08, from 5.04 to 7.84 and from 3.23 to 6.09 cmol/kg at 0-10, 10-20 and 20-30 cm soil depths, respectively (Fig. 5). At 0-10 cm depth, the control plot obtained Ca content of 5.62 cmol/kg. The I_1 plot gave 0. 76 and I_2 plot gave 1.35 units higher Ca content in soil than that of control plot. At 0-10 cm depth, I_3, I_4, I_5, I_6 and I_7 plots showed an increase in Ca content than the control plot by 0.36, 0.24, 1.93 and 1.52 cmol/kg, respectively. The I_7 plot gave the equal Ca content to that of I_5 plot. A considerable increase in Ca content was found in the I_8 plot at 0-10 cm depth. The I_8 plot had a Ca content of 8.08 cmol/kg.

At 10-20 cm depth, the control plot gave Ca content of 5.04 meq/100 g soil. The I_1 plot gave 0. 53 and I_2 plot gave 1.23 units higher Ca content in soil compared to control plot. The I_3, I_4, I_5, I_6 and I_7 plots showed an increase in Ca content than the control plot by 0.23, 0.18, 1.87, 1.58 and 1.81 cmol/kg, respectively. A remarkable increase in Ca content was found in the I_8 at 10-20 cm depth. The I_8 plot obtained a Ca content of 7.84 meq/100 g soil.

At 20-30 cm depth, the Ca content of 3.23 cmol/kg was found in the control plot. The I_1 plot gave 0. 64 and I_2 plot gave 1.05 units higher Ca content compared to control plot. The I_3 plot showed the equal Ca content to that of I_1 plot at 20-30 cm depth. At 20-30 cm depth, the I_4, I_5, I_6 and I_7 plots tended to increase in Ca content than the control plot by 0.29, 1.92, 1.93 and 2.04 cmol/kg, respectively. Like 10-20 cm depth, a considerable increase in Ca content was found in the I_8. The I_8 plot obtained a Ca content of 6.09 cmol/kg. The Ca content was found the higher in effluents irrigated plots as compared to the control plot. It might be due to the higher accumulation of Ca by effluents irrigated plots as because effluents were rich in Ca salt. A similar result was reported by Lim CA and P`ng [4]. They recorded an increase in Ca in soil with the application of palm oil mill effluent. The concentration of Ca was decreased at deeper soil depth. It might be due to leaching related translocation.

The exchangeable Mg content of collected soil samples varied from 0.53 to1.06, from 0.48 to1.0 and from 0.38 to 0.86 cmol/kg at 0-10, 10-20 and 20-30 cm soil depths, respectively (Fig. 6). The control plot gave Mg content of 0.53 cmol/kg soil at 0-10 cm depth. The I_1 and I_2 plots increased Mg content in soil than the control by 0.49 and 0.46 cmol/kg, respectively. The I_3, I_4, I_5, I_6, I_7 and I_8 plots tended to increase in Mg content than the control plot by 0.53, 0.44, 50, 0.43, 0.41 and 0.16 cmol/kg, respectively.

At 10-20 cm depth, the control plot obtained Mg content of 0.48 cmol/kg. The I_1 and I_2 plots increased Mg content in soil than the control by 0.51 and 0.45 cmol/kg, respectively. The I_4 plot gave the equal Mg content to that of I_2 plot at 10-20 cm depth. At 10-20 cm depth, the I_3, I_5, I_6 and I_8 plots showed an increase in Mg content than the control plot by 0.52, 0.50, 0.42 and 0.19 cmol/kg, respectively. The I_7 plot obtained the equal Mg content to that of I_6 plot at 10-20 cm depth.

At 20-30 cm depth, the control plot obtained Mg content of 0.38 cmol/kg. At 20-30 cm depth, I_1 plot gave 0. 38 while I_2 plot gave 0.40 cmol/kg higher Mg content than that of control plot. The I_3, I_4, I_5, I_6, I_7 and I_8 plots showed an increase in Mg content than the control plot by 0.48, 0.35, 0.23, 0.13, 0.22 and 0.14 cmol/kg, respectively. In all the depths, the exchangeable Mg was found the higher in effluents irrigated plots than that of control plot might be due to the higher accumulation of Mg from effluents. A similar result was reported by Lim and P`ng [4]. They recorded an increase in Mg in soil with the application of palm oil mill effluent.

The exchangeable K content of collected soil samples varied from 0.16 to 0.38, from 0.10 to 0.35 and from 0.07 to 0.27 cmol/kg at 0-10, 10-20 and 20-30 cm soil depths, respectively (Fig. 7). The control plot showed Mg content of 0.16 cmol/kg at 0-10 cm depth. The I_1 plot gave 2 and I_2 plot gave 2.4 folds higher K content in soil than that of control plot. The I_3, I_4, I_5 and I_8 plots gave almost the equal K content to that of I_1 plot at 0-10 cm depth. However, at 0-10 cm depth, the I_6 and I_7 plots showed the equal K content to that of I_2 plot.

At 10-20 cm depth, the control plot obtained K content of 0.10 cmol/kg. The I_1 and I_2 plots increased K content in soil than that control plot by 2.1 and 2.9 folds, respectively. At 10-20 cm depth, the I_3, I_4, I_6 and I_8 plots showed an increase in K content than the control plot by 3, 2.8, 3.5 and 2.7 folds, respectively. The I_5 plot obtained the equal K content to that of I_4 plot while I_7 obtained equal K content to that of I_6 plot.

At 20-30 cm depth, the K content 0.07 cmol/kg was found in the control plot. At 20-30 cm depth, I_1 plot gave 2.3 and I_2 plot gave 3.1 folds higher K content compared to control plot. The I_8 plot gave the equal K content to that of I_2 plot at 20-30 cm depth. At 20-30 cm depth, the I_3 and I_4 plots showed an increase in K content than the control plot by 3.3 and 3.0 folds, respectively. A remarkable increase in K content was found in the I_6 and I_7 plots at 20-30 cm depth. The I_6 plot had K content of 3.7 and that in the I_7 plot was 3.9 folds higher than that of control plot. The effluents irrigated plots showed the highest K

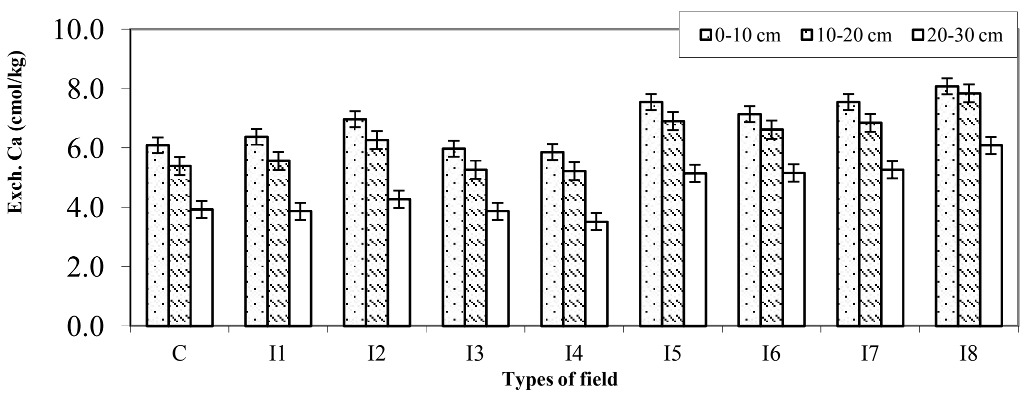

Fig. 5. Distribution of Exch. Ca (cmol/kgl) in effluents and control water irrigated rice soils

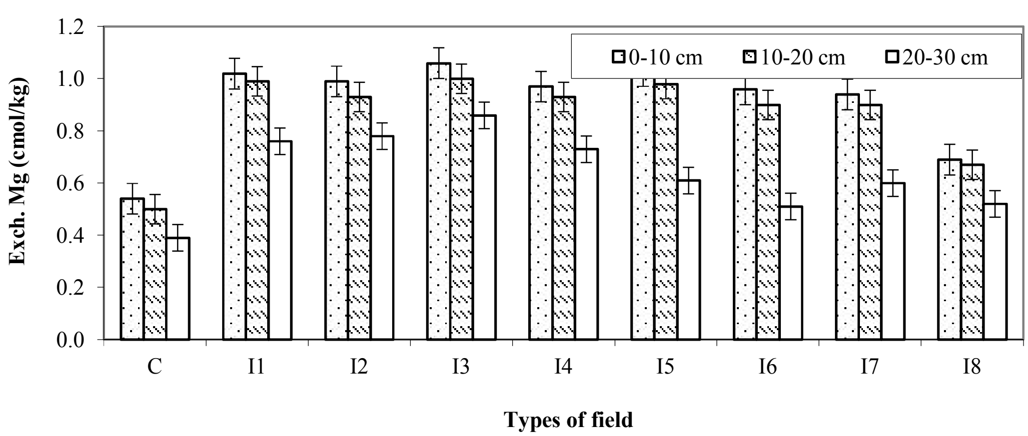

Fig. 6. Distribution of Exch. Mg (cmol/kgl) in effluents and control water irrigated rice soils

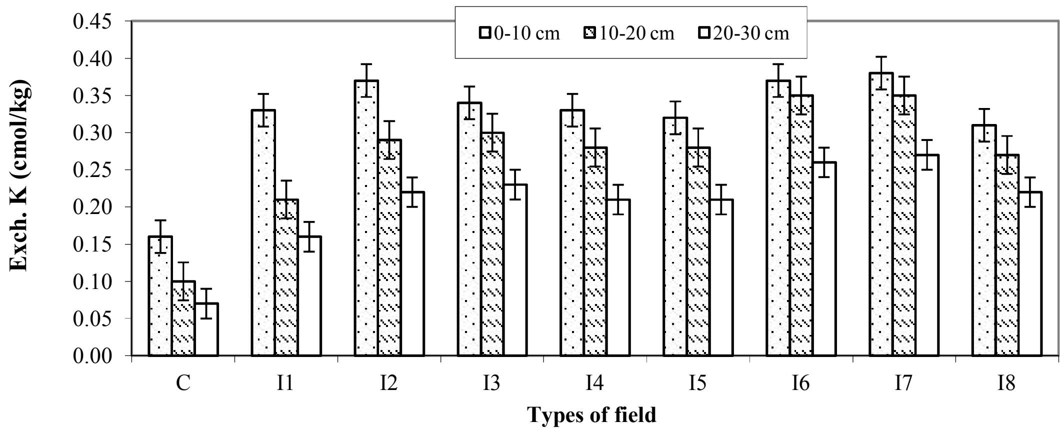

Fig. 7. Distribution of Exch. K (cmol/kgl) in effluents and control water irrigated rice soils

concentration in the whole soil profile than the control plot. It might be due to the higher K salt accumulation from effluents because effluents were rich in K.

The exchangeable Na content of tested soil samples varied from 0.77 to 3.14, from 0.58 to 2.71 and from 0.43 to 2.17 cmol/kg at 0-10, 10-20 and 20-30 cm soil depths, respectively (Fig. 8). The control plot showed Na content of 0.77 cmol/kg at 0-10 cm depth. At 0-10 cm depth, I_1 plot gave 3.5 and I_2 plot gave 3.7 folds higher Na content than that of control plot. The I_3, I_4, I_5 and I_6 plots showed an increase in Na content than the control plot by 3.8, 4.1, 3.3 and 3.1 folds, respectively. The I_7 plot gave the equal Na content to that of I_6 plot while the I_8 gave the equal Na content to that of I_5 plot at 0-10 cm depth.

At 10-20 cm depth, the control plot obtained Na content of 0.58 cmol/kg. The I_1 I_2 plots increased Na content compared to control by 4.1 and 4.2 folds, respectively. The I_3, I_4, I_5 and I_6 plots tended to increase in Na content than the control plot by 4.5, 4.7, 3.9 and 3.6 folds, respectively. The I_7 plot gave the equal Na content in soil to that of I_6 while I_8 plot gave the equal Na content to that of I_5 plot at 10-20 cm depth.

At 20-30 cm depth, the control plot gave Na content of 0.43 cmol/kg. The I_1 and I_2 plot recorded the equal Na content which was 4.6 folds higher than that of the control plot. At 20-30 cm depth, the $I_{5,}$ I_6, I_7 and I_8 plots showed an increase in Na content than the control plot by 4.4, 3.8, 4.2 and 4.3 folds, respectively. A tremendous increase in Na content was found in the I_3 and I_4 plots. The I_3 plot had Na content of 4.8 and that in the I_4 plot was 5.0 folds higher than that of control. The exchangeable Na concentrations were more prominent throughout the soil depths with effluents irrigated plots than the control plot. The exchangeable Na was obtained the highest with effluents irrigated plots compared to the control plot might be due to the accumulation of salt from effluents. A similar result was made by Begum [12].

3.5 Trace Elements (Fe, Zn, Mn and Cu)

Effluents irrigation was affected by the trace elements concentration in soil depths. The Fe content of tested soil samples varied from 53 to 99 mg/kg at 01-10 cm, from 34 to 83 mg/kg at 10-20 cm and from 1 to 47 mg/kg at 20-30 cm soil depth (Fig. 9). At 0-10 cm depth, the control plot gave Fe content of 53 mg/kg. The I_1 plot had 14 and I_2 plot had 23-unit higher Fe content than that of control. The I_3, I_4, I_5 and I_7 plots showed an increase in Fe content than the control plot by 40, 30, 33 and 27 units, respectively. A remarkable increase in Fe content was found in the I_6 and I_8 plots at 0-10 cm depth. In both plots, the Fe content had 46 units higher than the control.

At 10-20 cm depth, the control plot obtained Fe content of 34 mg/kg. The I_1, I_2, I_3, I_4, I_6 and I_7 plots tended to increase in Fe content compared to control plot by 19, 29, 36, 27 and 33 units, respectively. The I_5 plot gave similar Fe content to that of I_3 plot at 10-20 cm depth. A considerable increase in Fe content was found in the I_6 and I_8 plots at 10-20 cm depth. The I_6 plot had Fe content of 125% and that in I_8 plot was 144% higher than that of control.

At 20-30 cm depth, the control plot obtained Fe content of 1 mg/kg. The I_1, I_2, I_3, I_4, I_7 and I_8 plots showed an increase in Fe content than the control plot by 7, 13, 16, 26, 23 and 13 units, respectively. A remarkable increase in Fe content was found in the I_5 and I_6 plots at 20-30 cm depth. The I_5 plot had Fe content of 39 mg/kg and that in I_6 plot was 46 mg/kg than the control. In all the soil depths, the Fe content was obtained the higher with effluents irrigated plots than control. However, in both types of plots, the Fe content was decreased with increasing the soil depth, indicating that the Fe enrichment at the surface.

Industrial effluent irrigation was affected by the zinc status in soil depths. The Zn content of collected soil samples varied from 8 to 47 mg/kg at 0-10 cm, from 2 to 9 mg/kg at 10-20 cm and from 2 to 8 mg/kg at 20-30 cm soil depth (Fig. 10). The control plot had Zn content of 8 mg/kg at 0-10 cm depth. The I_1 plot gave equal Zn content to that of the control plot. The I_2 plot gave 2 and I_4 plot gave 3 folds higher Zn content than that of control plot. The I_3 and I_8 plots obtained the equal Zn content to that of I_2 plot. However, the I_7 plot gave similar Zn content to that of I_4 plot at 0-10 cm depth. A remarkable increase in Zn content was found in the I_5 and I_6 plots at 0-10 cm depth. The I_5 plot had Zn content of 40 mg/kg and that in the I_6 plot was 47 mg/kg than that of control soil.

At 10-20 cm depth, the control plot obtained Zn content of 2 mg/kg. The I_1 and I_2 plots showed an increase in Zn content than the control plot by 3 and 4 folds, respectively. The I_4, I_6 and I_7 plots gave the equal Zn content to that of I_1 plot. However, the I_3 plot obtained the equal Zn content to that of I_2 plot at 10-20 cm depth. The I_5 and I_8 plots obtained 2 folds higher Zn content than that of control plot.

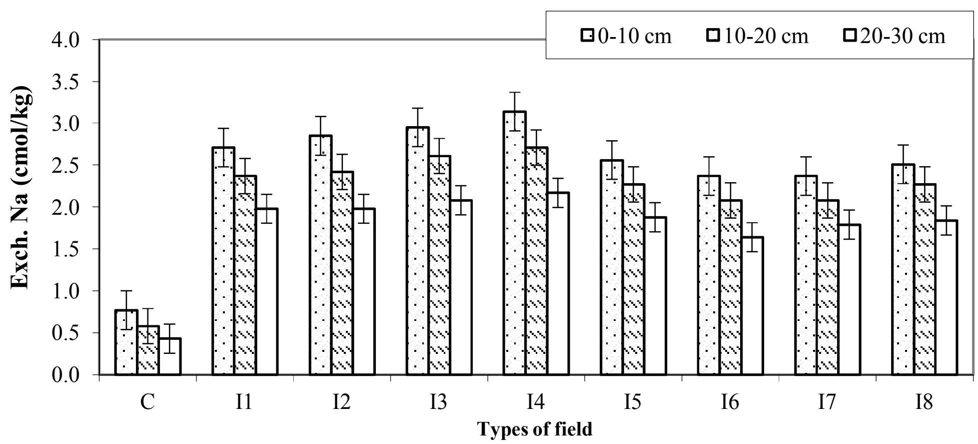

Fig. 8. Distribution of Exch. Na (cmol/kgl) in effluents and control water irrigated rice soils

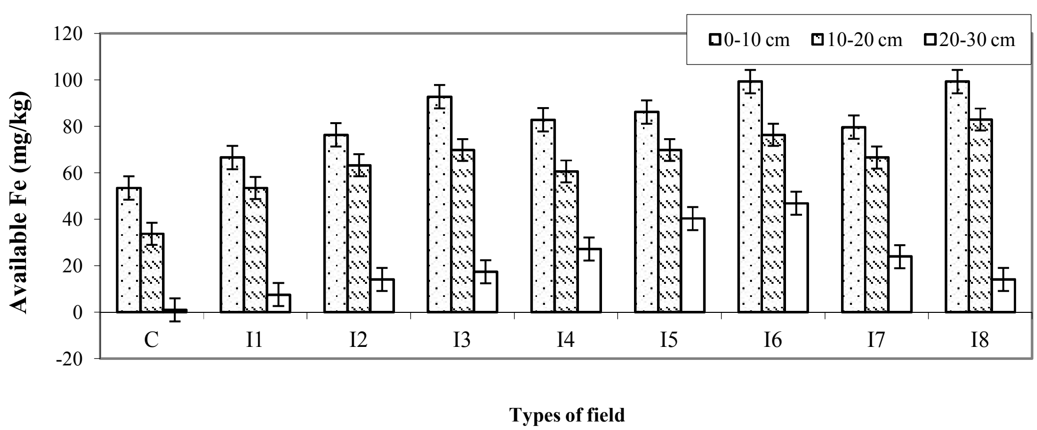

Fig. 9. Distribution of available Fe (mg/kg) in effluents and control water irrigated rice soils

At 20-30 cm depth, the control plot obtained Zn content of 2 mg/kg. The I_1, I_2 and I_5 plots showed an increase in Zn content than the control plot by 3, 4 and 2 folds, respectively. The I_4 and I_7 plots gave similar Zn content to that of I_1 plot while the I_6 and I_8 plots gave similar Zn content to that of I_5 plot at 20-30 cm depth. Zinc concentrations were found to decrease with increasing the soil depths in both effluents irrigated and control field soils, indicating that deposition of Zn at the surface soil.

The Mn content of collected soil samples varied from 47 to 72, from 43 to 66 and from 33 to 51 mg/kg at 0-10, 10-20 and 20-30 cm soil depths, respectively (Fig. 11). The control plot gave Mn content of 72 mg/kg at 0-10 cm depth. The I_1 plot had 11 and I_2 plot had 22 units lower Mn content than that of control plot. The I_7 and I_8 plots gave equal Mn content in soil to that of I_2 plot. The $I_{3,}$ I_4 and I_6 plots tended to decrease in Mn content than the control plot by 19, 15 and 25 units, respectively.

At 10-20 cm depth, the control plot obtained Mn content of 66 mg/kg. The I_1 plot gave 9 and I_2 plot gave 21 units lower Mn content than that of control. The I_6, I_7 and I_8 plots showed the equal Mn content to that of I_2 plot. At 10-20 cm depth, the $I_{3,}$ I_4 and I_5 plots tended to decrease in Mn content than the control plot by 18, 13 and 17 units, respectively.

At 20-30 cm depth, the control plot obtained Mn content of 51 mg/kg. The I_1, I_2, I_3 and I_5 plots decreased in Mn content than the control plot by 16, 19, 15 and 18 units, respectively. The I_6 plot gave the equal Mn content to that of I_1 plot while the I_7 and I_8 plots gave the equal Mn content to that of I_5 plot. In all the soil depths, the Mn content was found the higher with control soil than the effluents irrigated soils indicating that effluents irrigation had no effect on soil Mn. In both the soils, the Mn content was found to decrease with increasing the soil depth, meaning that enrichment of Mn at the surface.

The Cu content of collected soil samples varied from 4 to 9 mg/kg at 0-10 cm, from 3 to 8 mg/kg at 10-20 cm and from 2 to 4 mg/kg at 20-30 cm soil depth (Fig. 12). The Cu content mg/kg was found in the control plot at 0-10 cm depth. The I_1 plot gave 2 and I_2 plot gave 3 units higher Cu content than that of control plot. The I_5 and I_8 plots gave the equal Cu content to that of I_1 plot at 0-10 cm depth. However, at 0-10 cm depth, the I_3 and I_6 plots recorded the similar Cu content to that of I_3 plot. The I_4 and I_7 plots showed an increase in Cu content than the control by 5 and 1 units, respectively.

At 10-20 cm depth, the control plot gave Cu content of 3 mg/kg. The I_1 and I_3 plots had 3 while the I_2 and I_6 plots had 4 units higher Cu content than that of control plot. The I_4, I_5 and I_8 plots showed an increase in Cu content than the control by 5, 2 and 1 units, respectively. The I_7 plot gave the equal Cu content to that of I_5 plot at 10-20 cm depth.

At 20-30 cm depth, the control plot obtained Cu content of 2 mg/kg. The I_1, I_3 and I_8 plots had 2 higher while in I_5 and I_6 plots had 1-unit higher Cu content compared to control plot. The I_2, I_4 and I_7

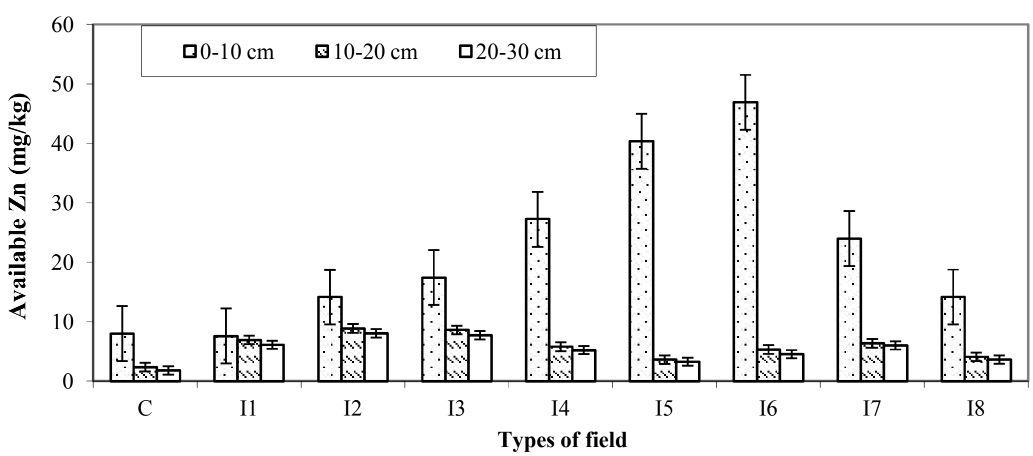

Fig. 10. Distribution of available Zn (mg/kg) in effluents and control water irrigated rice soils

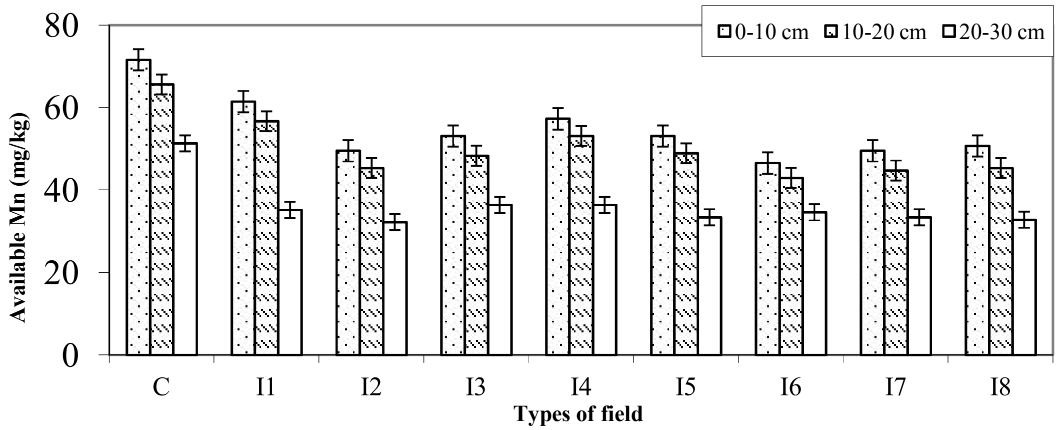

Fig. 11. Distribution of available Mn (mg/kg) in effluents and control water irrigated rice soils

plots showed the equal Cu content to that of control plot. The Cu concentration was found to decrease with increasing the soil depth in both types of soils, indicating that the Cu accumulated at the surface soil.

Trace elements (Fe, Zn, Mn and Cu) were obtained the higher at 0-10 cm soil depth than that of 10-20 cm and 20-30 cm soil depth. The affinity of metals to the organic matter could be responsible for this deposition because of the relatively high organic carbon concentration in the topsoil. Agbenin [15] reported that the trace elements accumulated in the soil surface.

3.6 Heavy Metals (Pb, Cd, Cr and Ni)

The total Pb content of collected soil samples varied from 23 to 27 at 0-10 cm, from 22 to 26 at 10-20 cm and from 19 to 22 mg/kg at 20-30 cm soil depth, respectively (Fig. 13). The control plot gave Pb content of 25 mg/kg at 0-10 cm depth. The I_1 and I_2 plots showed an increase in Pb content than the control plot by 8 and 4%, respectively. The I_3 and I_4 plots gave the equal Pb content to that of I_2 plot while I_5 plot gave the equal Pb content to that of control plot at 0-10 cm depth. The I_6 and I_7 plots gave 4 while I_8 plot gave 8% lower Pb content in soil than that of control plot.

At 10-20 cm depth, the control plot recorded Pb content of 24 mg/kg. The I_1 and I_2 plots showed an increase in Pb content than the control plot by 8 and 4%, respectively. The I_3, I_4 and I_5 plots gave the equal Pb content to that of I_2 plot at 0-10 cm depth. However, the I_7 plot gave equal Pb content to that of the control plot. At 10-20 cm depth, the I_6 and I_8 plots decreased Pb content than the control by 4 and 8%, respectively.

At 20-30 cm depth, the total Pb content 19 mg/kg was found in the control plot. The I_1 and I_2 plots showed an increase in Pb content than the control plot by 16 and 11%, respectively. The I_3, I_4 and I_5 plots gave the equal Pb content to that of I_2 plot while I_7 plot gave similar Pb content to that of I_1 plot. At 20-30 cm depth, the I_6 and I_8 plots had 5% higher Pb content than that of the control plot. In some soil samples, the Pb content was found slightly the higher in effluents irrigated soils than the control soil while in others it was found the lowest that indicates effluents had slight or no effect on Pb content in soil depth. However, the Pb concentration was found the higher at 0-10 cm depth compared to other two depths indicating that the Pb accumulated at the soil surface. Similar result was reported by Abdu et al. [16]. The concentration of Pb in waste water irrigated soil ranged from 44 to 52 mg/kg in industrial areas of Bangladesh [17].

Among the heavy metals, the Cd content was found the lowest in soil. The total Cd content of collected soil samples varied from 0.22 to 0.26 mg/kg at 0-10 cm, from 0.20 to 0.25 mg/kg at 10-20 cm and 0.18 to 0.22 mg/kg at 20-30 cm soil depth (Fig. 14). At 0-10 cm depth, the control plot had Cd content of 0.22 mg/kg. The I_1 and I_2 plots showed an increase in Cd content than the control plot by 9 and 14%, respectively. The I_5 and I_6 plots had the equal Cd content to that of I_2 plot while I_4 and I_7 plots had the equal Cd content to that of I_2 plot. At 0-10 cm depth, the I_3 and I_8

plots gave 18% higher Cd content than the control plot.

At 10-20 cm depth, the control plot obtained Cd content of 0.20 mg/kg. The I_1 plot gave 20% and I_2 plot gave 15% higher Cd content than that of control plot. The I_3 and I_8 plots had the equal Cd content to that of I_1 plot. However, the I_4 and I_7 plots had equal Cd content to that of I_2 plot. The I_5 and I_6 plots showed an increase in Cd content compared to control by 10%.

At 20-30 cm depth, the control plot had Cd content of 0.18 mg/kg. The I_1 and I_3 plots increased Cd content than that of control by 22 and 11%, respectively. The I_2, I_4 and I_8 plots gave the equal Cd content to that of I_1 plot while the I_6 plot gave the equal Cd content to that of I_3 plot. The I_5 and I_7 plots showed an increase in Cd content than the control plot by 17 and 6%, respectively. In all the depth soils, the Cd content was found the higher with effluents irrigated soils compared to control soil might be due to the accumulation of Cd from the effluents.

The total Cr content of collected soil samples varied from 48 to74 mg/kg at 0-10 cm, from 44 to 67 mg/kg at 10-20 cm and from 43 to 61 mg/kg at 20-30 cm soil depth (Fig. 15) which was higher than the values (34-68 mg/kg) reported by Ahmed [17]. At 0-10 cm depth, the Cr content 48 mg/kg was found in the control plot. The I_1 plot had 24 and I_2 plots had 14 unit's higher Cr content than that of control plot. The I_3, I_4, I_5, I_6, I_7 and I_8 plots showed an increase in Cd content than the control plot by 22, 26, 15, 17, 11 and 5 units, respectively.

At 10-20 cm depth, the control plot obtained Cr content of 44 mg/kg. The I_1 plot had 20 and I_2 plot had 11 unit's higher Cr content than that of control plot. The I_3, I_4, I_5, I_7 and I_8 plots increased in Cr content than the control plot by 19, 23, 12,

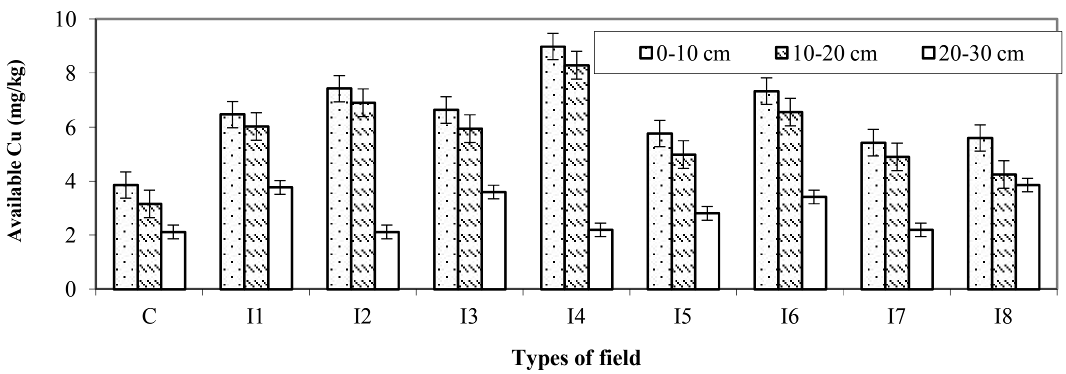

Fig. 12. Distribution of available Cu (mg/kg) in effluents and control water irrigated rice soils

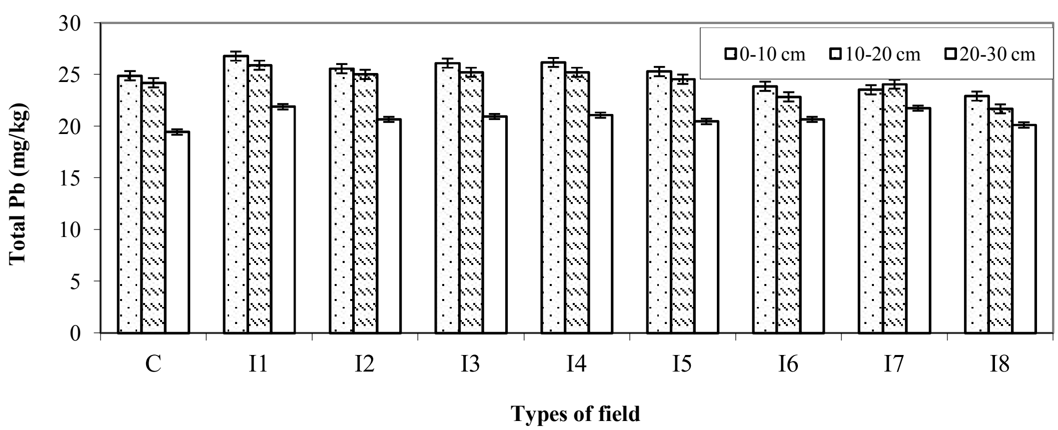

Fig. 13. Distribution of available Pb (mg/kg) in effluents and control water irrigated rice soils

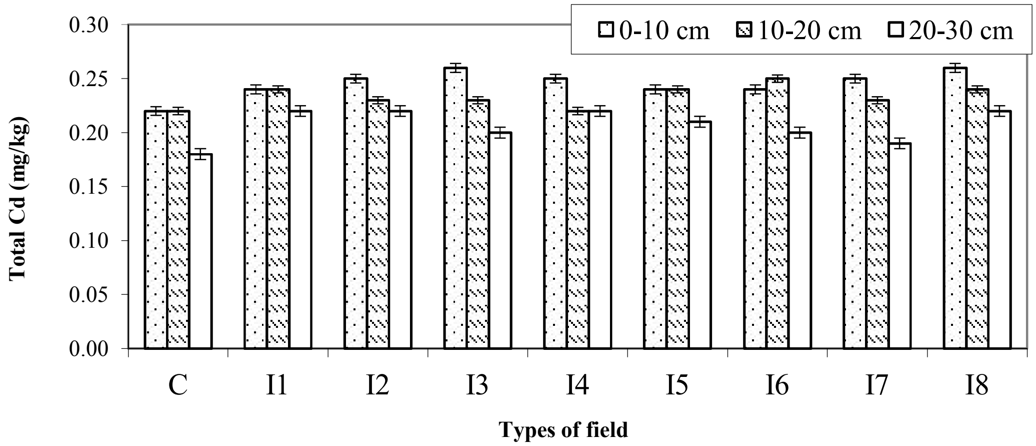

Fig. 14. Distribution of available Cd (mg/kg) in effluents and control water irrigated rice soils

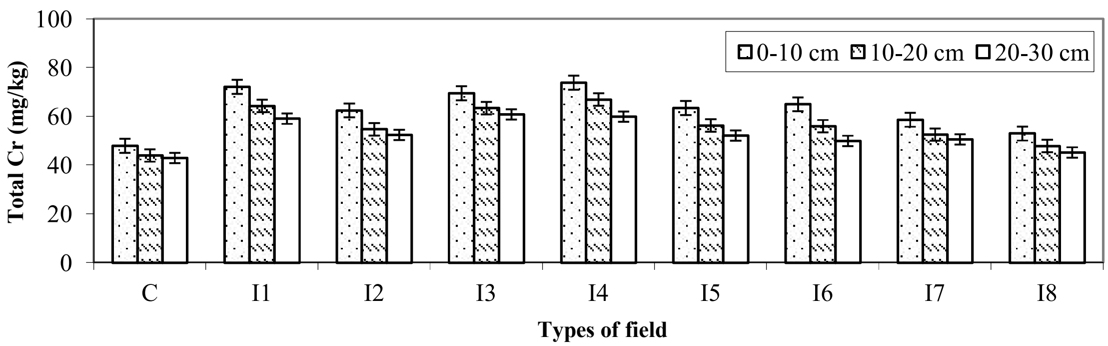

Fig. 15. Distribution of available Cr (mg/kg) in effluents and control water irrigated rice soils

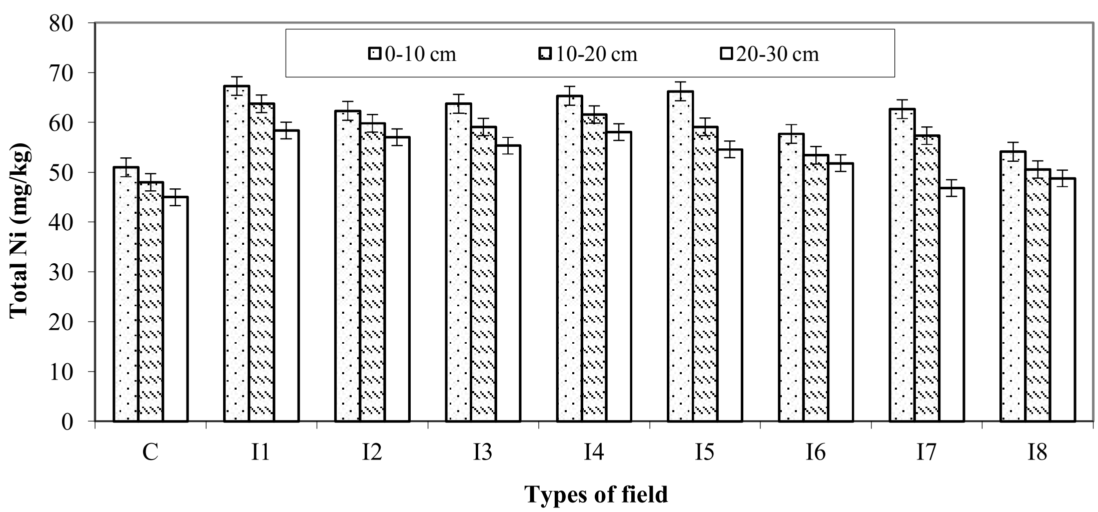

Fig. 16. Distribution of total Ni (mg/kg) in effluents and control water irrigated rice soils.

9 and 4 units, respectively. The I_6 plot gave similar Cr content to that of I_5 plot at 10-20 cm depth.

At 20-30 cm depth, the control plot gave Cr content of 43 mg/kg. The I_1 and I_2 plot increased in Cr than the control by 16 and 9 units, respectively. The I_5 plot gave equal Cr content to that of I_2 plot. At 20-30 cm depth, the I_3, I_4, I_6, I_7 and I_8 plots showed an increase in Cr content than the control plot by 18, 17, 7, 8 and 2 units, respectively. The Cr concentration was obtained the highest at 0-10 cm soil depth as compared to the other two depths indicating that the Cr enrichment at 0-10 cm soil depth. [16] reported that the Cr content decrease with the increasing soil depth in three African cities.

Industrial effluents irrigation affected the Ni status in soil depth. The total Ni content of collected soil samples varied from 51 to 67 mg/kg at 0-10 cm, from 48 to 64 at 10-20 cm and from 45 to 58 mg/kg at 20-30 cm soil depth (Fig. 16). Ahmed and Goni [17] reported that the Ni concentration ranged from 36 to 74 mg/kg in wastewater irrigated soil in industrial areas of Bangladesh. At 0-10 cm depth, the control plot gave total Ni content of 51 mg/kg. The I_1 plot had 16 and I_2 plots had 11 unit's higher Ni content than that of control plot. The I_3, I_4, I_5, I_6, I_7 and I_8 plots showed an increase in Ni content than the control plot by 13, 14, 15, 7, 12 and 3 units, respectively.

At 10-20 cm depth, the control plot obtained total Ni content of 48 mg/kg. The I_1 and I_2 plots increased in Ni concentration than the control by 16 and 12 units, respectively. The I_3, I_4, I_6, I_7 and I_8 plots showed an increase in Ni content than the control plot by 11, 14, 5, 9 and 3 units, respectively. The I_5 plot gave the equal Ni content to that of I_3 plot at 10-20 cm depth.

At 20-30 cm depth, the control plot gave Ni content of 45 mg/kg. The I_1 plot had 13 and I_2 plot had 12 unit's higher Ni content compared to control. The I_3, I_4, I_6, I_7 and I_8 plots tended to increase in Ni content than the control plot by 10, 13, 7, 2 and 4 units, respectively. The I_5 plot obtained the equal Ni content to that of I_3 plot at 20-30 cm depth. The Ni concentration was obtained the highest at 0-10 cm soil depth as compared to the other two depths indicating that the Ni deposition at 0-10 cm soil depth. A similar result was reported by Abdu et al. [16].

4. CONCLUSION

Results of this experiment showed that the soil chemical properties were affected through effluents irrigation. Effluents irrigation created some differences in soil pH, electrical conductivity and organic carbon. Exchangeable cations (Ca, Mg, K and Na), trace elements (Zn, Fe, Mn and Cu) and heavy metals (Pb, Cd, Cr and Ni) were increased in soils with effluents irrigation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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