

Long-Term Effect of Industrial Waste Water Irrigation on Soil Chemical Properties

Rafiqul Islam¹, Golam Kibria Muhammad Mustafizur Rahman², Abu Raihan Muhammad Solaiman² and Abu Saleque³

1. Chief Scientific Officer (Current Charge) & Head, Bangladesh Rice Research Institute (BRRI), Rajshahi 6212, Bangladesh

2. Department of Soil Science, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur 1706, Bangladesh

3. Coordinator for Advanced Studies and Research, Bangladesh Rice Research Institute BRRI, Gazipur 1701, Bangladesh

Abstract: A laboratory experiment was conducted in Soil Science Division of BRRI during 2011 aimed to determine the vertical distribution of soil chemical properties under long-term industrial waste water irrigated rice field. Waste water irrigated rice field seemed to create some differences in soil pH profile. The pH_w and pH_{KCl} in all soil depth was higher with waste water irrigated rice field. The surface charge of both the soils was considerably negative. Waste water irrigated rice field developed more negative charges in soils. Irrigation with waste water increased Electrical Conductivity (EC) in rice soils profile. The organic carbon content (%) started to decrease sharply with the increase in soil depth. Organic carbon content was higher with waste water irrigated rice soils. Total nitrogen (%) was high with underground water irrigated rice soils in surface but at deeper, total N was similar in both soils. Olsen P (mg/kg) was higher with underground water irrigated soil at 0-5 cm depth but at 5-100 cm soils profile, it was higher with waste water irrigated rice soils. Micronutrients (Zn, Fe, Cu and Mn) and heavy metals (Pb, Cd, Ni and Cr) in soils were increased significantly through irrigation with waste water in rice-rice cropping pattern.

Key words: Long-term, soil chemical properties, industrial waste, rice.

1. Introduction

The Industrial wastes and effluents have increased sharply in recent years in Bangladesh. Neighboring farmers of industrial areas grow rice in their field by using industrial waste water in many years. Most of the industries in Bangladesh seldom pass the effluent through water treatment plant, as a result, untreated industrial waste water flood the land, most rice fields and surroundings the industries. Application of untreated waste water to irrigated rice fields is raising concern about possible health risks associated with the consumption of rice grain [1]. Albeit industrial waste water contains some plant nutrients that may enhance the growth of crop plants, toxic metals content in them may suppress plant growth severely. Toxic metals in waste water contaminate the soil environment and also change the soil chemical properties like pH, EC, soil

organic matter, primary, secondary nutrient elements including heavy metals [2]. Begum, R. A. [3] expressed her concern about the accumulation of heavy metal in the agricultural soils of Bangladesh. Industrial effluents have been pointed out as the main source of toxic metals both for plant and soils [4, 5]. Among such metals, cadmium and zinc are notoriously mobile and likely to move down through the soil profile to contaminate ground water, even though they are easily intercepted by clay particles in subsurface horizons [6, 7]. Seneviratne, N. M. G. [8] reported that controlled application of rubber effluent on land caused changes in soil properties and improved in soil water retention while Lim, C. A. [9] recorded increase in pH, Ca, Mg and organic matter content with the application of palm oil mill effluent. Valdes, E. observed an increase in soil organic matter by 1% with sugar factory effluent applied to soils in Cuba taking into account the deficiency in the humic matter of the soil. During last decade, the unique agroecological conditions of

Corresponding author: Rafiqul Islam, Ph.D., research field: soil science.

rice soils resulting from their input intensity, intensive rice cover, soil and hydrological characteristics and spatial variability have raised considerable research interest [11-13]. This is especially so considerable in developing countries where treatment of waste waters is limited, thus raising concern about heavy metals contamination of these soils when irrigated with untreated waste water and subsequent accumulation in food chain through plant uptake. In view of the above, this study aimed at determining the vertical distribution of soil chemical properties under waste water irrigated rice field.

2. Materials and Methods

Soil samples were collected from Mouchak area (Madhpur tract, Agro Ecological Zone (AEZ) 28) of Gazipur district (middle part of Bangladesh; lat. 23°58' N, long. 90°23' E, 30 m above mean sea level) which has a long cropping history under rice-rice systems. The average temperature ranges from 8.2 °C in winter to 36.6 °C in summer. The mean annual rainfall is about 2,000 mm. The sampling area represents two kinds of farmers' managed rice fields: (i) irrigated

with underground Fresh Water (FW) and (ii) irrigated with Industrial Waste Water (IWW) for 8-10 years. The distance between FW and IWW irrigated field were 500 meters.

2.1 Soil Collection

Profile sampling in December 2010 was done up to 100 cm depth in a sequence of 0-5 cm, 5-10 cm, 10-15 cm, 15-30 cm, 30-50 cm and 50-100 cm, respectively. The samples were collected with the help of knife from all the side of the pit and the collected samples were composite to make about 1 kg. The collected samples were brought Soil Science Division green house of BRRI, air-dried, crushed and sieved through 2 mm sieve prior to analysis. Soil pH (pH_w , pH_{KCl} and ΔpH), Electrical Conductivity (EC) (dS/m), organic carbon (%), total N (%), Olsen P (mg/kg), exchangeable cations (Ca, Mg, K and Na) (cmol/kg), trace elements (Zn, Fe, Mn and Cu) (mg/kg) and heavy metals (Pb, Cd, Cr and Ni) (mg/kg) were determined from the samples. Details analytical methods that were used for soil analyses have been shown in Table 1.

Table 1 Details analytical methods that were used for soil samples analysis.

Soil property	Method
pH_w	1:2.5 soil water ratio, using glass electrode method [14]. Ten g of air dried soil sample was taken in a 50 mL of 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.
pH (KCl)	The pH_{KCl} was determined by stirring 10 g soil in 25 mL 1.0 M KCl solution in a similar manner of pH (H_2O) determination.
Delta pH (ΔpH)	The difference between the pH in KCl and that in water gave the value of ΔpH , as $\Delta pH = pH_{KCl} - pH(H_2O)$.
Electrical conductivity (dS/m)	A portion of 20 gm of air dried soil sample was taken in a 250 mL of 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 filtered sample using conductivity meter (YSI Model 32, [14]).
Organic carbon (%)	Walkley and Black wet digestion method [15] 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_3PO_4 and 2 mL of di-phenyl amine indicator solution were added. The sample was then titrated with 1 N $FeSO_4$ solution until green color was appeared. A blank sample was also taken to calculate the results.
Total N (%)	Modified Kjeldahl method [16] was followed to determine total N. One gm air-dried and 0.5 mm sieve soil was taken in a Kjeldahl flask, and then digested using 2 g of salt mixture ($K_2SO_4 + CuSO_4$) and 5-7 mL conc. H_2SO_4 until the acid soil mixture turns white. After cooling the digest, 10 mL 4% H_3BO_3 and 2-4 drops of mixed indicator was taken in a 125 mL conical flask and placed under the condenser. Then the whole digest was transferred into distillation flask by washing with distilled water and added 20 mL of 40% NaOH. Absolute 40-50 mL distillate was collected and titrated the distillate against the 0.05 N H_2SO_4 . A blank sample was also taken simultaneously to calculate the results.

Table 1 continued

Soil property	Method
Olsen P (mg/kg)	Olsen method [17] was followed to determine available P. A portion of 2.5 gm of air dried soil sample was taken in a 125 mL of conical flask and then 25 mL of extracting solution (0.5 M NaHCO ₃ , pH 8.5) was added. It was shaken for 30 minutes and filtered through Whatman # 42 filter paper. A portion of 2 mL of aliquot was taken into 25 mL test tube. Exactly 6 mL of distilled water and 2 mL of color reagent was added. The color reagent was prepared following [19]. Finally water was added to make volume up to the mark (10 mL). Reading was through Spectrophotometer at 710 nm wavelength.
Exchangeable Ca, Mg, K and Na (cmol/kg)	Thomas, G. W. [19] method was followed to determine exchangeable cations. A portion of ten gm of air dried sieved soil sample was taken in a 125 mL of conical flask, then 50 mL of extracting solution (1 N CH ₃ COONH ₄ , pH 7.0) was added. It was shaken for 10 minutes and filtered through Whatman # 42 filter paper. In case of exchangeable K and Na direct reading was taken from atomic absorption spectrophotometer at 766.5 nm and 589 nm wavelengths, respectively. For Exchangeable Ca was determined by diluting a portion of 2 mL of aliquot with 1 mL of La ₂ O ₃ and 7 mL 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, W. L. [20] method was followed to determine trace elements. A portion of ten gm of air dried sieved soil sample was taken in a 125 mL of conical flask, then 20 mL of extracting solution (EDTA-Ethylene Diamine Teraacetic 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 °C following the procedure described by Lindsay, W. L. [20]. 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).

3. Results and Discussion

3.1 Soil pH

The control soils showed pH_w less than 5.0 at 0-30 cm depth that was much lower than the IWW soils (Fig. 1). The IWW soil had pH_w of 5.76 compared to 4.60 in FW soil at 0-5 cm depth. At 5-10 cm depth, the IWW soil increased pH_w to 6.60 compared to 4.70 in the FW soil. The difference in pH_w between FW and IWW soils exist throughout the soil profiles. At 15-30 cm depth, IWW soil showed about 1 unit higher pH_w than that of FW soil. At deeper profile, the difference was narrower. The increase in soil pH_w and decrease in exchangeable acidity is attributed to the higher calcium and magnesium ions accumulated in waste water irrigated rice field. This report was similar to findings of Poon, Y. C., [21] and Seneviratne, N. M. G. [8] with palm oil mill and rubber effluent irrigated soils, respectively.

The pH_{KCl} profile was similar with IWW soils but slightly different in FW soils from pH_w profile at deeper soil depth (Fig. 2). Starting from 0-15 cm soil

depth, the pH_{KCl} of FW soils were more or less similar with pH_w but at deeper soil depth, the pH_{KCl} was progressively decreased. The pH_{KCl} of IWW soil was 4.77 compared to 3.90 in FW soil at 0-5 cm depth. At 5-10 cm depth, the IWW soil increased pH_{KCl} to 5.38 compared to 3.94 in FW soil. The difference in pH_{KCl} between control and IWW fields exist throughout the soil profiles. However, the difference was more prominent in surface but at deeper profile the difference was narrower.

The difference in pH_w and pH_{KCl} between FW and IWW rice field in surface soil profile may be attributed to the previous management, but in deeper depth, the difference in soil acidity may be due to difference in soil inherent properties.

3.2 Delta pH (ΔpH)

Delta pH of soil gives a good indication of the charge characteristics of soil colloids. A positive value for ΔpH indicates the net charge associated with the soil colloids was positive, likewise a negative values for ΔpH announces the negative charged colloids in

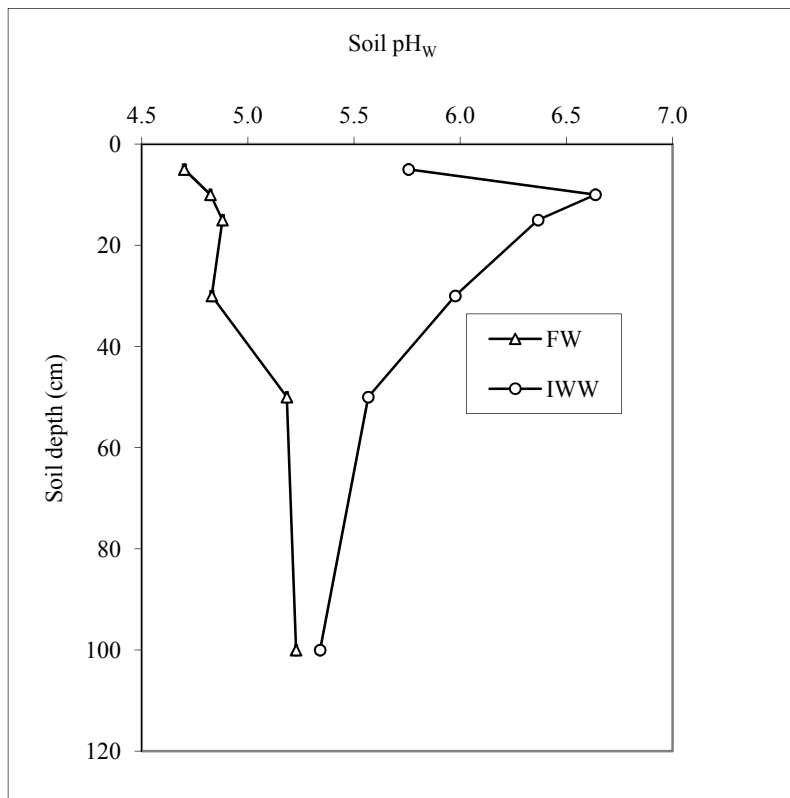


Fig. 1 Distribution of pH_w in soil profiles of industrial effluents contaminated and uncontaminated soils.

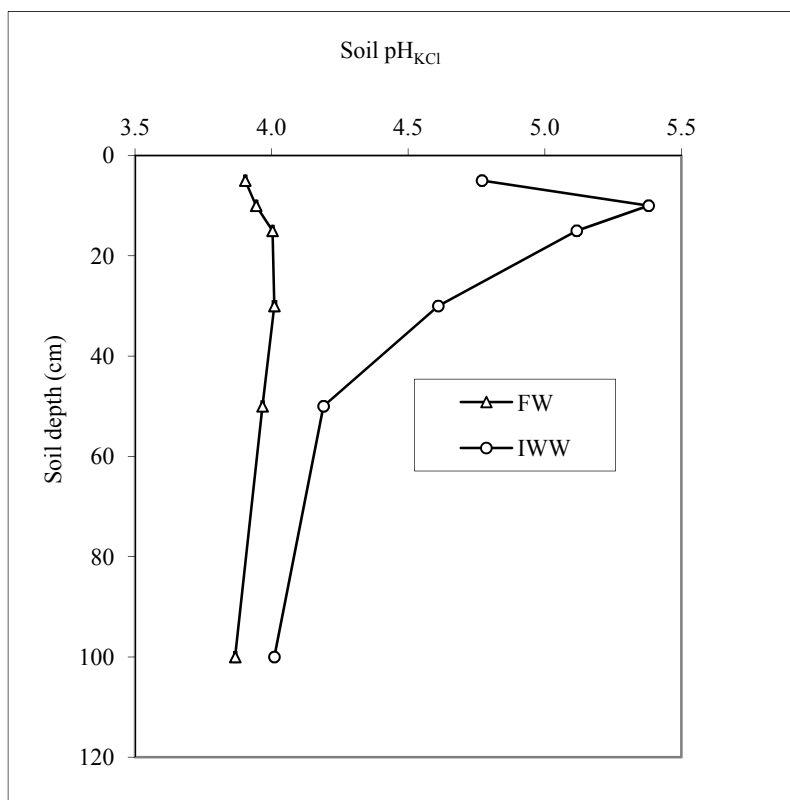


Fig. 2 Distribution of pH_{KCl} in soil profiles of industrial effluents contaminated and uncontaminated soils.

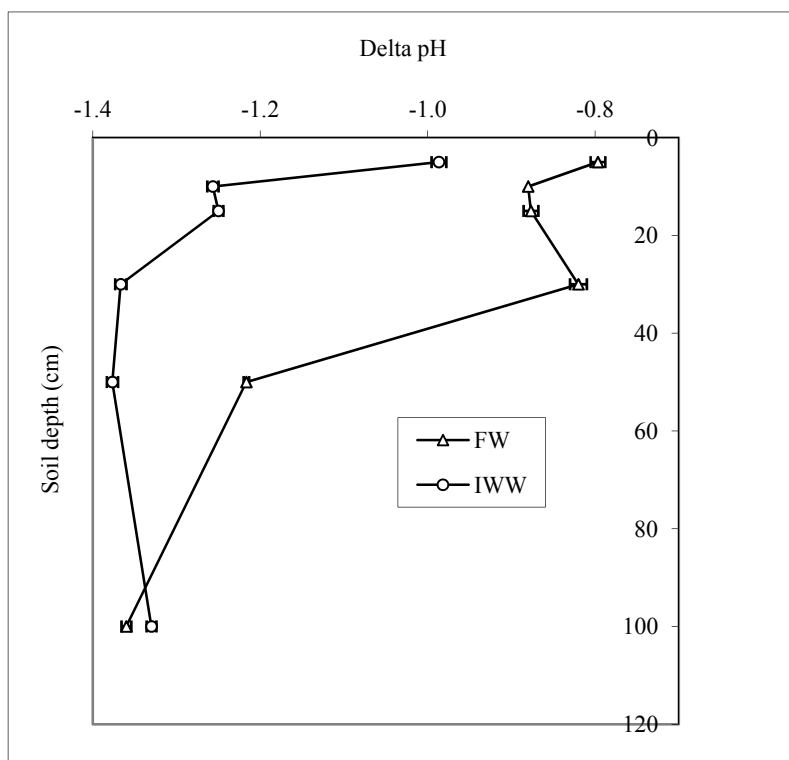


Fig. 3 Distribution of ΔpH in soil profiles of industrial effluents contaminated and uncontaminated soils.

soil. The surface charge of both the soils was considerably negative (Fig. 3). Relatively more negative charges developed with IWW soils than that of FW soils due to adsorption of acidic ions. Industrial waste water irrigated soils developed 0.19 units and 0.37 units more negative charge than that of FW soils at 0-5 cm and 5-10 cm soil depth, respectively. At 10-15 cm depth, both the soils had the similar negative charge to that of 5-10 cm soils. The IWW soils showed an increase in ΔpH than the FW soil by 0.55 units and 0.16 units at 15-30 cm and 30-50 cm depth, respectively. At deeper depth (50-100 cm), IWW and FW soils gave almost the similar ΔpH .

3.3 Electrical Conductivity (EC)

At 0-5 cm soil depth, EC of IWW soil was 6.85 dS/m but in FW soil, it was 1.53 dS/m. At 5-10 cm depth, IWW soil had 5 folds higher EC than that of FW. At 10-15 cm depth soils, it had the similar EC value to that of 5-10 cm depth soils. The IWW soils showed an increase in EC than the FW soils by 1.97 dS/m, 1.23 dS/m and 1.60 dS/m at 15-30 cm, 30-50

cm and 50-100 cm depth, respectively. The EC value was progressively decreased with increasing in soil depth. But above 50 cm soil profile, EC value was slightly increased with IWW soil. The difference in EC between FW and IWW soils exist throughout the soil profiles. The EC difference was more prominent in surface but at deeper profile, the difference was relatively narrower. Throughout the soil profile, a tremendous increase in EC was found with IWW soils than the FW soils, which may be due to enriched IWW soils with different salts specially Na and heavy metals (Fig. 4). These findings are good in agreement with the findings of Begum, R. A. [3] and Saif, M. S. [22].

3.4 Organic Carbon (OC)

The organic carbon content (%) started to decrease sharply with the increase in soil depth (Fig. 5). In all the soil depth, OC content relatively higher with IWW soil than FW soil. The OC content of IWW soil was at 5-10 cm depth, the IWW soil decreased OC content to 1.19% compared to 1.03% in FW soil.

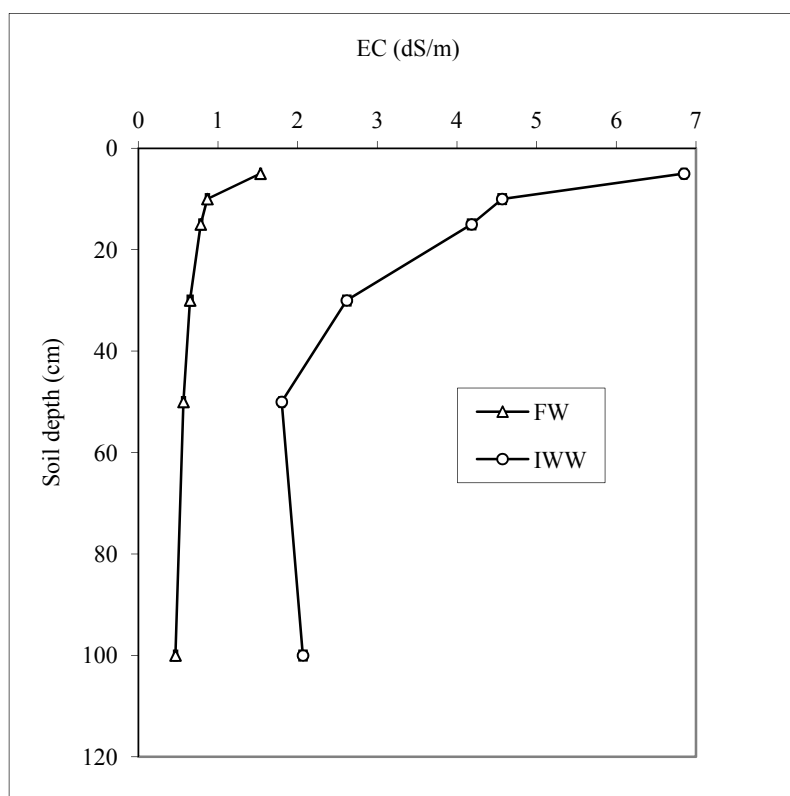


Fig. 4 Distribution of EC in soil profiles of industrial effluents contaminated and uncontaminated soils.

From 15-50 cm soil depths, the OC content in both the soils were more or less similar. At 50-100 cm depth, IWW soil had 0.07% higher OC content than the FW soil. The greater concentration of organic carbon content in surface soil compared to sub-surface soil may be due to accumulation organic residues left out in former. Sood, R. D. [23] earlier reported that the organic carbon content decreased with the depth of soils in Himachalpradesh of India. However, OC content was found higher with IWW soils than the FW soils. The increased OC in IWW soils as a result of high total solid present in the effluent, which may be mineralized while the decrease in C/N ratio may be due to the occurrence of high microorganisms' activities, which assisted in the reduction of the C/N ratio. For 1-3 years, effluents irrigation increased soil total organic carbon [2].

3.5 Total Nitrogen

At 0-10 cm soil profile, total nitrogen (%) was

higher with FW soils than that of IWW soils (Fig. 6). At 0-5 cm depth, FW soil had the total nitrogen of 0.19% as compared to 0.16% in IWW soil. At 5-10 cm depth, FW soil decreased total nitrogen to 0.16% compared to 0.14% in IWW soil. Both in the soil, the total N content found more or less similar at 15-30 cm depth. Industrial waste water irrigated soils gave 0.02% higher and 0.02% lower total N content than that of FW soils at 30-50 cm and 50-100 cm depths, respectively.

3.6 Olsen P

At 0-5 cm soil depth, the level of Olsen P was slightly higher in FW soil compared to IWW soil (Fig. 7). At 0-5 cm soil depth, FW soil gave the Olsen P of 5.77 mg/kg compared to 5.03 mg/kg in IWW soil. Industrial waste irrigated soil gave 0.54 mg/kg higher P content than that of FW soil at 5-10 cm depth while at 10-15 cm depth, it was 0.33 mg/kg lower. At deeper soil profile (30-100 cm depth), the level of Olsen P was found considerably higher in IWW soils than that

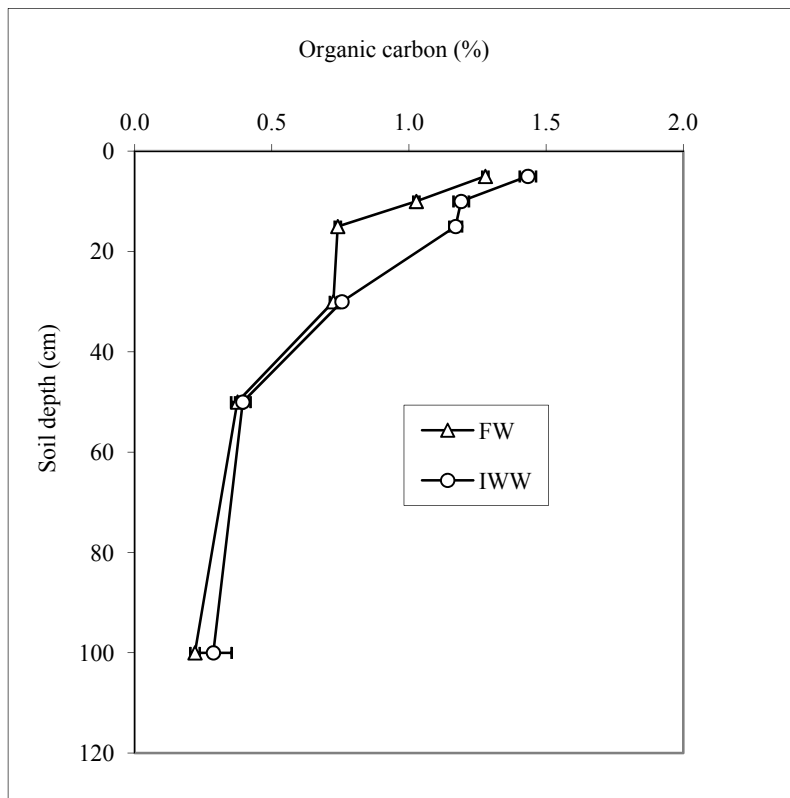


Fig. 5 Distribution of organic carbon (%) in soil profiles of industrial effluents contaminated and uncontaminated soils.

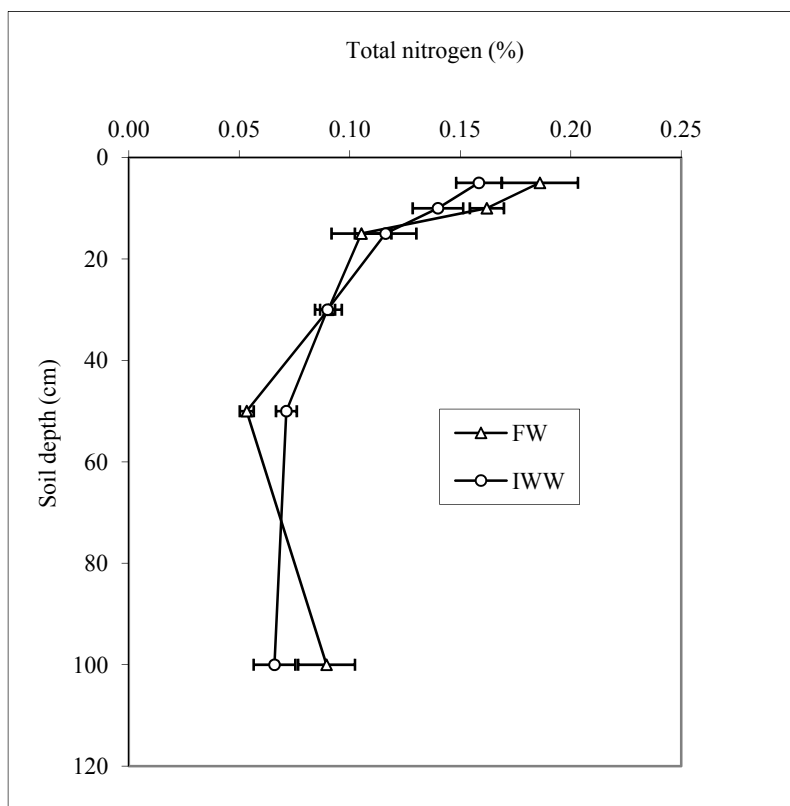


Fig. 6 Distribution of total nitrogen (%) in soil profiles of industrial effluents contaminated and uncontaminated soils.

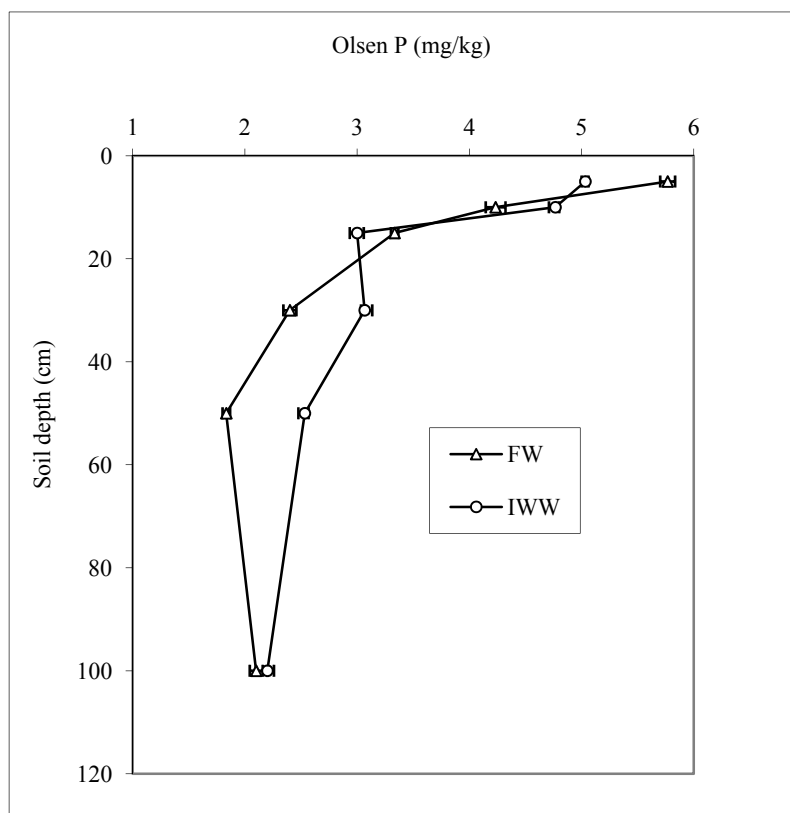


Fig.7 Distribution of Olsen P (mg/kg) in soil profiles of industrial effluents contaminated and uncontaminated soils.

of FW soils. The IWW soils showed an increase in Olsen P than the FW soils by 0.67 mg/kg, 0.70 mg/kg and 0.10 mg/kg at 15-30 cm, 30-50 cm and 50-100 cm depths, respectively. The higher component of P in the soil could be result of fixation attributed to high pH brought about by Ca, Mg and Na in the soil. The decreasing trend of P profile at 0-15 cm depth may be attributed to the influence of rice root uptake. The depletion of Olsen P was more in FW soils than the IWW soils in deeper soil profile due to the lower soil pH value.

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

In all the soil depths, the exchangeable Ca had considerably higher in IWW soils than that of FW soils (Fig. 8). The exchangeable Ca concentration varied from 3.46 cmol/kg to 6.92 cmol/kg in IWW soils but in FW soils, it was ranged from 3.06 cmol/kg to 6.21 cmol/kg. Industrial waste water irrigated soils showed an increase in Ca content than the FW soils by

0.71 cmol/kg, 1.52 cmol/kg, 1.20 cmol/kg, 0.76 cmol/kg and 0.40 cmol/kg at 0-5 cm, 5-10 cm, 10-15 cm, 15-30 cm and 30-50 cm depths, respectively. A tremendous increase in Ca content was found in the IWW soil than that of FW soil at 50-100 cm depth. The IWW soil gave 1.63 units higher Ca content than the FW soil at 50-100 cm depth. From 0-50 cm depth, the concentration of Ca decreased both in the soil but at deeper soil depth, it was increased again. It might be due to leaching related translocation. Lim, C. A. [9] recorded increase in Ca in soil with the application of palm oil mill effluents.

The difference in exchangeable Ca concentration between two soils may be explained by the difference in plant growth, uptake and accumulation.

The exchangeable Mg profile changed in rice soil by the waste water irrigation (Fig. 9). The exchangeable Mg concentration varied from 0.28 cmol/kg to 1.07 cmol/kg in IWW soils, but in FW soils it was ranged between 0.47 cmol/kg and 0.90

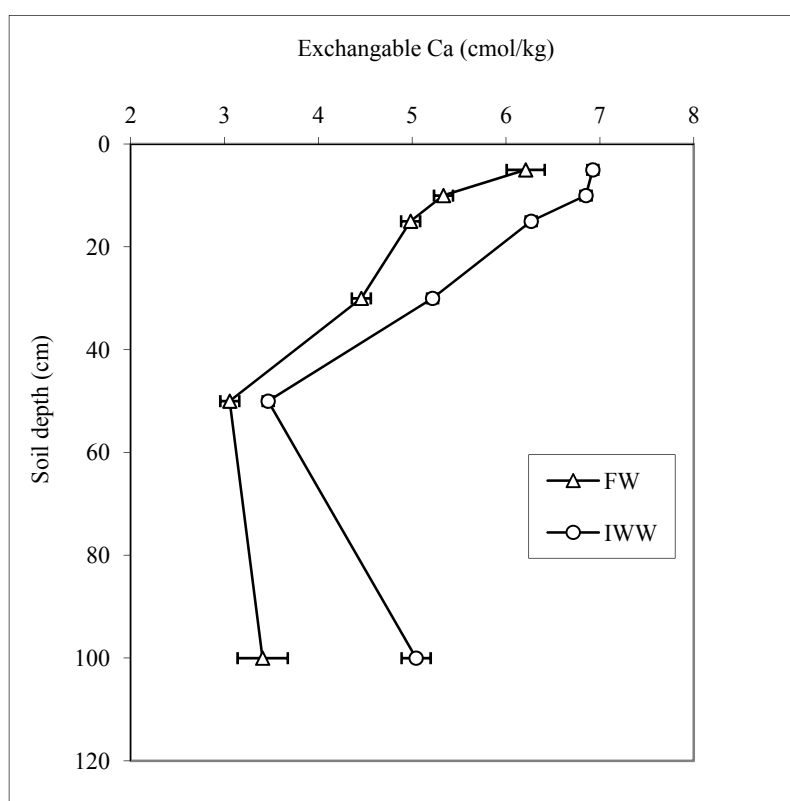


Fig. 8 Distribution of exchangeable Ca (cmol/kg) in soil profiles of industrial effluents contaminated and uncontaminated soils.

cmol/kg. At 0-30 cm soil depth, the exchangeable Mg had the higher in IWW soils than that of FW soils, but at deeper profile it was higher with FW soils. The Mg concentration of IWW soils was progressively decreased with the increased in soil depth. However, in control field, the Mg concentration was found zigzag from 0-30 cm depth, but at deeper depth it was increased progressively. Lim, C. A. [9] recorded increase in Mg in surface soil with the application of palm oil mill effluent. The difference in exchangeable Mg concentration between two soils may be explained by the difference in plant growth, uptake and accumulation.

In all the soil depths, the exchangeable K had remarkably higher in IWW soils than that of FW soils (Fig. 10). The exchangeable K concentration varied from 0.09 cmol/kg to 0.39 cmol/kg in IWW soils but in FW soils, it was ranged between 0.07 cmol/kg to 0.20 cmol/kg. At 0-5 cm depth, IWW soil had about 2 folds higher K content than the FW soil. At 5-10 cm

depth, soil showed the similar exchangeable K content to that of 0-5 cm depth soil. Industrial waste water irrigated soils showed an increase in K content than the FW irrigated soils by 0.05 cmol/kg, 0.06 cmol/kg, 0.02 cmol/kg and 0.01 cmol/kg at 10-15 cm, 15-30 cm, 30-50 cm and 50-100 cm depths, respectively. In both natures of the soils, the exchangeable K content decreased from 0-50 cm depth, but above 50 cm, the K content was increased. Similar result was showed by Haslbach, F. [24]. In his study, he showed the exchangeable K increased in the lower soil horizon. The difference in exchangeable K concentration between two soils may be explained by the difference in plant growth, uptake and accumulation.

The exchangeable Na concentrations were more prominent throughout the soil profiles with IWW soils than that of FW soils (Fig. 11). The exchangeable Na varied from 2.03 cmol/kg to 2.90 cmol/kg in IWW soils, but in FW soils, it was ranged from 0.53 cmol/kg to 1.01 cmol/kg. Industrial waste water irrigated soils

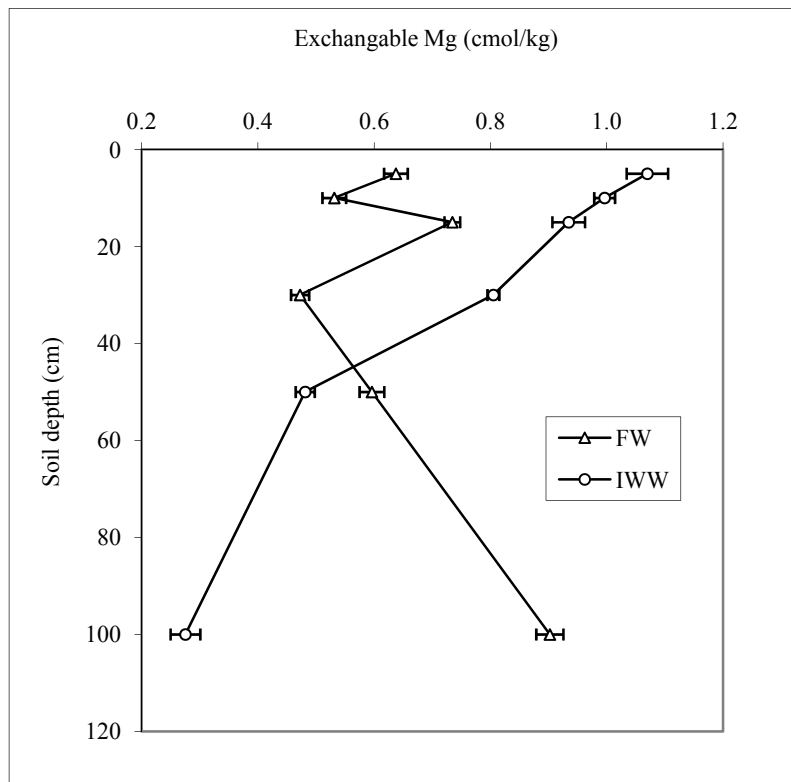


Fig. 9 Distribution of exchangeable Mg (cmol/kg) in soil profiles of industrial effluents contaminated and uncontaminated soils.

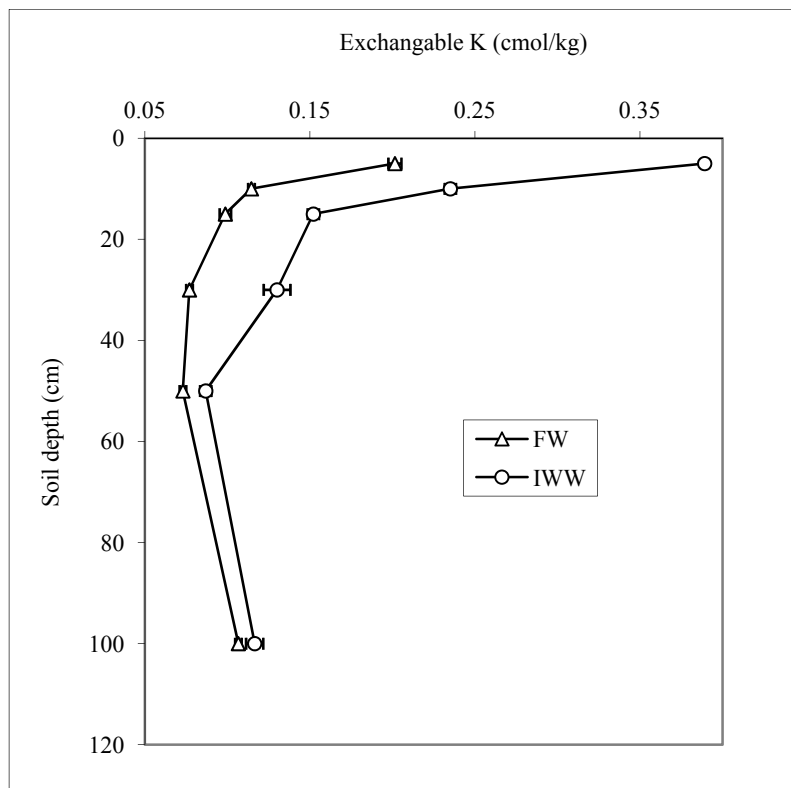


Fig. 10 Distribution of exchangeable K (cmol/kg) in soil profiles of industrial effluents contaminated and uncontaminated soils.

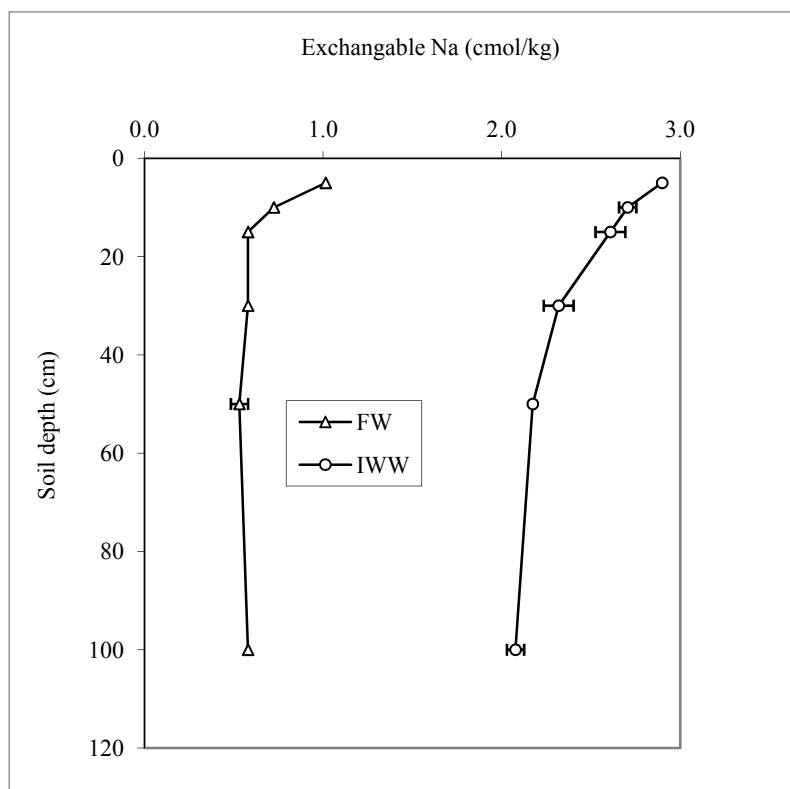


Fig. 11 Distribution of exchangeable Na (cmol/kg) in soil profiles of industrial effluents contaminated and uncontaminated soils.

gave 3 folds and 4 folds higher Na content than that of control soils at 0-5 cm and 5-10 cm depth. At 15-30 cm depth, soil had the similar Na content to that of 5-10 cm depth soil. Industrial waste water irrigated soils showed an increase in Na content than the FW soils by 2.03 cmol/kg, 1.64 cmol/kg and 1.50 cmol/kg at 10-15 cm, 30-50 cm and 50-100 cm depths, respectively. The exchangeable Na found higher with IWW soils than the FW soils may be due to accumulation of salt from waste water. A similar result was reported by Begum, R. A. [3].

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

Industrial waste water irrigation affected the zinc content in soil profile (Fig. 12). Zinc content varied from 0.13 mg/kg to 8.64 mg/kg in IWW soils, but in FW soils it was ranged between 0.24 mg/kg to 3.53 mg/kg. Starting from 0-10 cm depth, a tremendous increase in Zn content was found in IWW soils compared to FW soils. The Zn content had 8.64 mg/kg

and 5.88 mg/kg at 0-5 cm and 5-10 cm depths, respectively. The higher Zn content at 0-10 cm depth may be due to surface deposition from the waste water. At 10-15 cm depth, IWW soil had 0.45 mg/kg higher Zn content than that of FW soil. At 15-30 cm, depth soil showed the similar result to that of 10-15 cm depth soil. In both the soils, the Zn concentration had more or less similar at 30-50 cm depth. At deeper soil depth, Zn concentration had 0.45 mg/kg higher in FW soil than the IWW soil. The maximum tolerable concentration of Zn in soil is 300 mg/kg [25]. Zinc concentration of soil in the vicinities in Bangladesh ranged from 53-477 mg/kg. So, the soil profiles were suitable for crop production with respect to Zn content.

The available Fe profile was changed in rice soil by the IWW irrigation (Fig. 13). At 0-5 cm depth, Fe concentration was 3.28 mg/kg higher with IWW soil than that of FW soil. At 5-10 cm depth, FW soil showed an increase in Fe content than the IWW soil by 3.27 units. But from 15-100 cm soil profile, the Fe

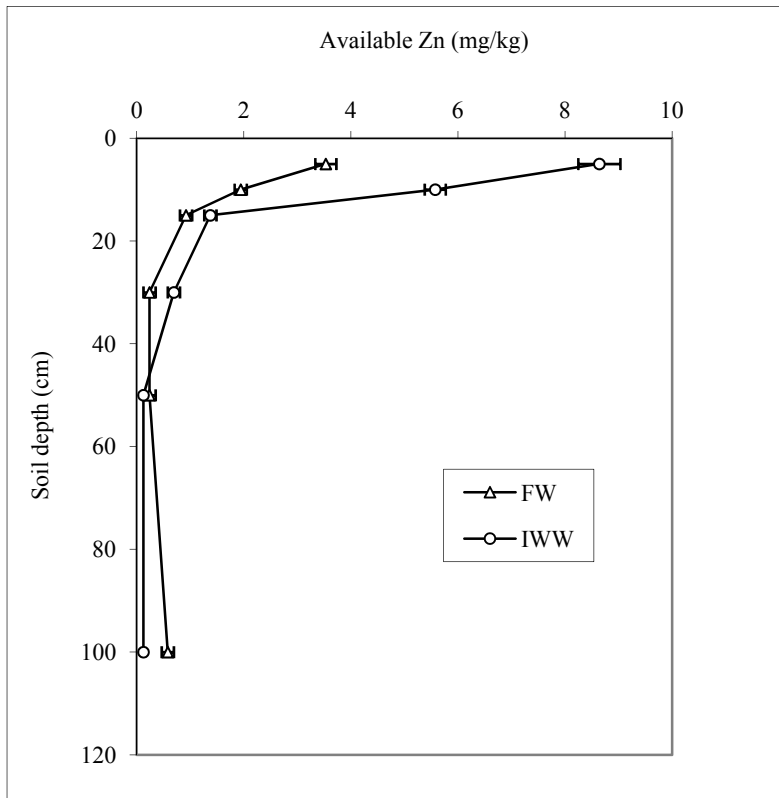


Fig. 12 Distribution of available Zn (mg/kg) in soil profiles of industrial effluents contaminated and uncontaminated soils.

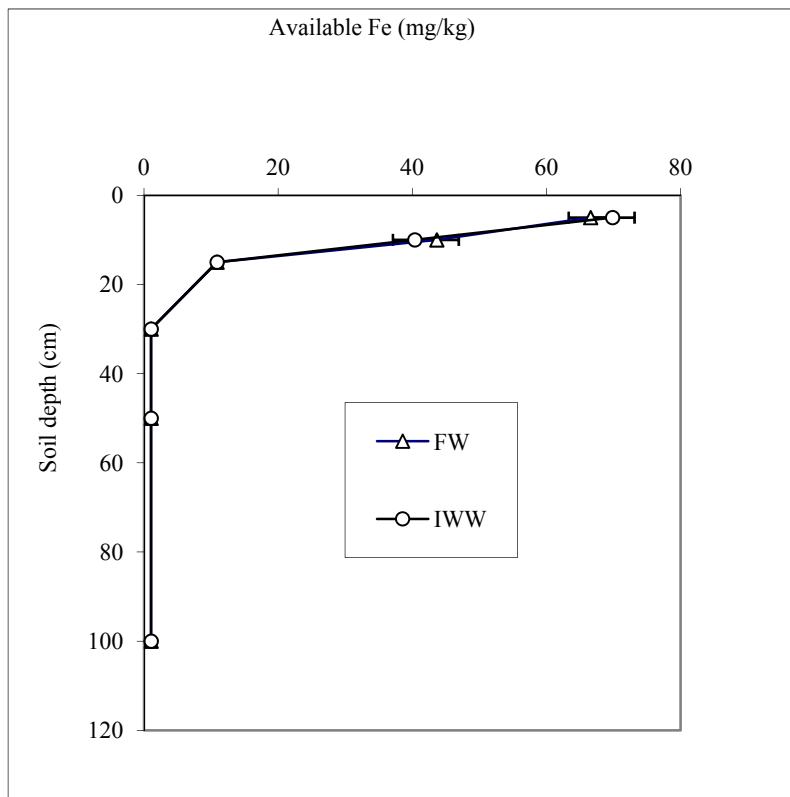


Fig. 13 Distribution of available Fe (mg/kg) in soil profiles of industrial effluents contaminated and uncontaminated soils.

concentration had more or less similar in both the soils. In both the soil profile, the Fe content was decreased with increasing soil depth reflecting Fe enrichment at the surface.

Manganese (Mn) status of different soil depths varied from 20.27 mg/kg to 50.70 mg/kg in IWW soils but, in FW soils, it was ranged from 19.08 mg/kg to 73.97 mg/kg (Fig. 14). Fresh water irrigated soils showed an increase in Mn content than the IWW soils by 25.65 mg/kg, 25.96 mg/kg, 17.27 mg/kg and 8.35 mg/kg at 0-5 cm, 5-10 cm, 10-15 cm and 15-30 cm depths, respectively. At 30-50 cm depth, IWW soil gave 4.77 mg/kg higher, but at 50-100 cm depth, it gave 8.35 mg/kg lower Mn content than the FW soil. In both the soils, the Mn concentration decreased with increasing the soil depth indicating the enrichment of Mn at the surface. Manganese content was found higher with FW soils in most of the soil layer except at 30-50 cm depth than the IWW soils, meaning that waste water had no effect on soil profile with respect to Mn.

Copper status of different soils profile varied from 0.46 mg/kg to 6.91 mg/kg in IWW soils, but in FW soils, it was ranged between 1.59 mg/kg to 4.55 mg/kg (Fig. 15). At 0-10 cm depth, the Cu content had higher while from 10-100 cm depth, it was considerably lower with IWW soils than that of FW soils. In both the soils, the Cu content decreased with increasing the soil depth, reflecting enrichment of Cu at the surface. Copper content was higher with FW soil at deeper soil layer than the IWW soil, meaning metals accumulated at the surface. The maximum tolerable concentration of Cu in soil is 1,000 mg/kg [25]. Copper concentration of soil in the vicinities in Bangladesh ranged from 28 mg/kg to 217 mg/kg.

So, all the soil profiles were suitable for crop production with respect to Cu. Trace elements (Zn, Fe, Mn and Cu) were found higher in surface soils as compared to sub surface soils. Affinity of metals to organic matter could be responsible for this surface enrichment because of the relatively high organic carbon concentration in the top soil [26].

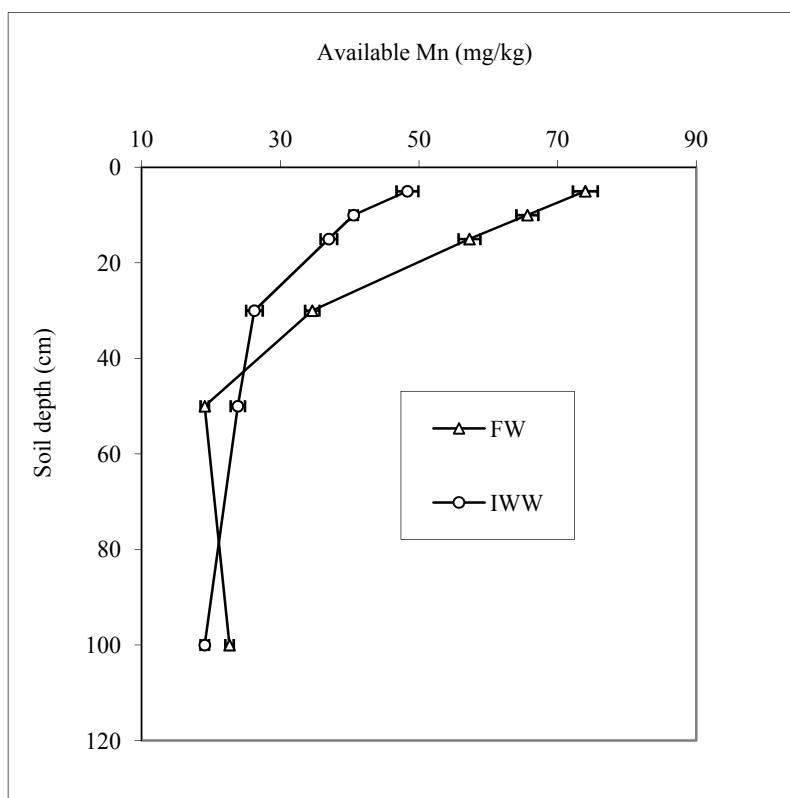


Fig. 14 Distribution of available Mn (mg/kg) in soil profiles of industrial effluents contaminated and uncontaminated soils.

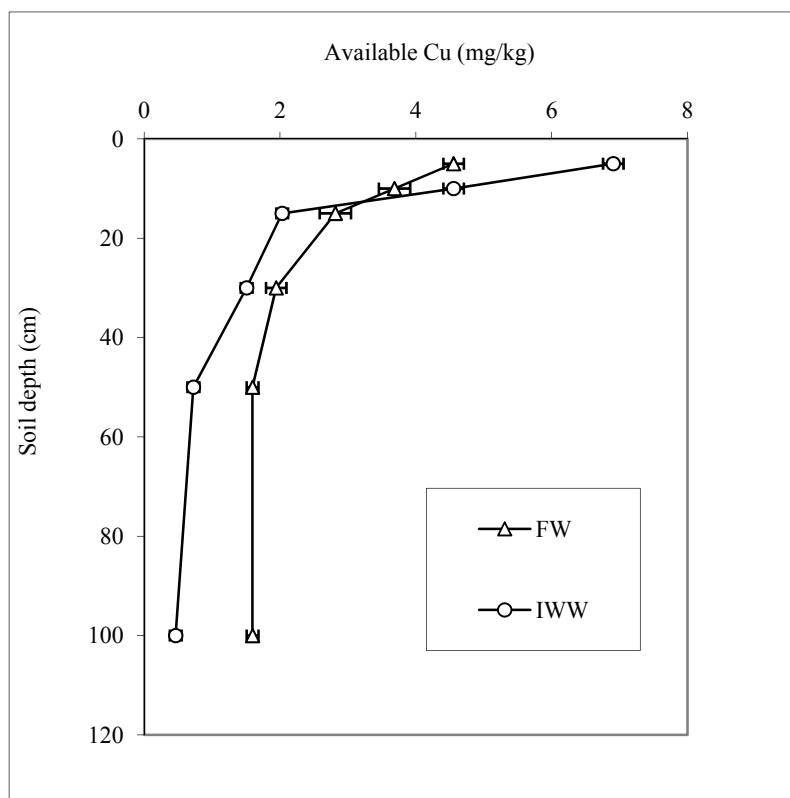


Fig. 15 Distribution of available Cu (mg/kg) in soil profiles of industrial effluents contaminated and uncontaminated soils.

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

Lead (Pb) content in different soil profile varied from 20 mg/kg to 27 mg/kg in FW soils, but in IWW soils, it was varied from 20 mg/kg to 29 mg/kg (Fig. 16). A lead content was found to decrease with the increasing soil depth in both the rice soils, reflecting deposition of Pb at the surface. Similar result was reported by Abdu, N. [1]. Industrial waste water irrigated soils gave 2 units, 1 units and 2 units higher Pb content than that of control soils at 0-5 cm, 5-10 cm and 10-15 cm depths, respectively. But from 15-100 cm depths, the Pb concentrations were more or less similar in both the soils. Affinity of surface enrichment of Pb in waste water treated soils might be due to metals deposition in the surface from the waste water. Ayers, R. S. [25] reported the maximum tolerable concentration of Pb in soil is 100 mg/kg. From this result, it could be concluded that the profile soils were suitable for the cultivation of rice with respect to Pb.

Cadmium (Cd) concentration of soil profiles varied from 0.18 mg/kg to 0.23 mg/kg with FW soils, but in IWW soils, it was ranged between 0.20 mg/kg to 0.25 mg/kg (Fig. 17). In all the soil depths, the Cd content had higher in IWW soils than that of FW soils. Industrial waste water irrigated soils showed an increase in Cd content than the control soil by 0.02 mg/kg, 0.01 mg/kg, 0.01 mg/kg, 0.03 mg/kg, 0.02 mg/kg and 0.02 mg/kg at 0-5 cm, 5-10 cm, 10-15 cm, 15-30 cm, 30-50 cm and 50-100 cm depths, respectively. Enrichment of Cd in IWW soils might be due to metals deposition from the waste water. From 0-50 cm depth, the Cd concentrations decreased in both the rice soils, but above 50 cm depth, the Cd concentrations were increased in both the soils. It might be due to leaching-related translocation. Pendias, A. K. [27] reported that the maximum tolerable concentration of Cd in soil is 5 mg/kg. Therefore, all the profile soils contained Cd beyond tolerable concentration and are suitable for crop production.

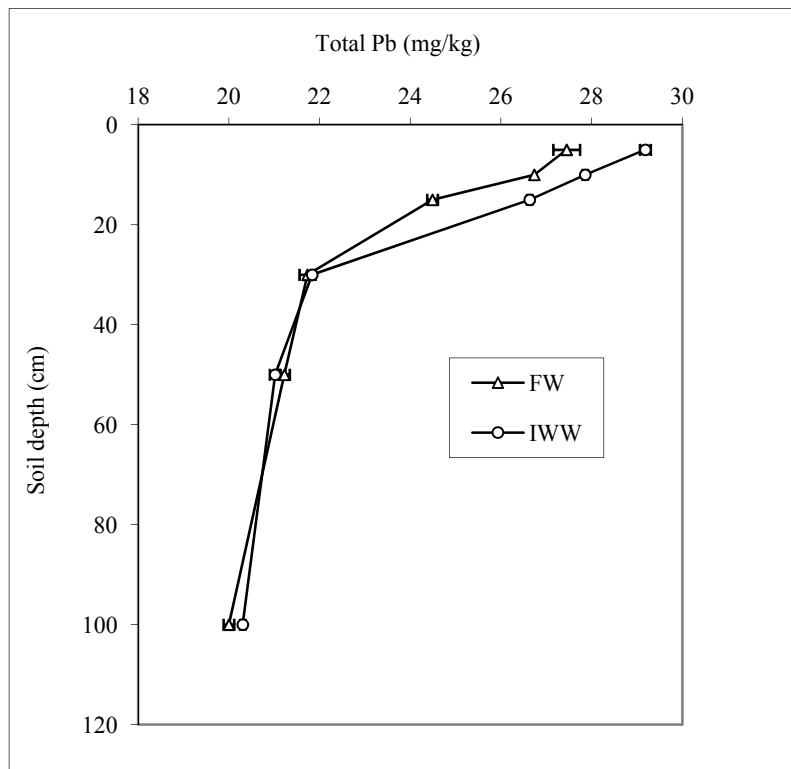


Fig. 16 Distribution of total Pb (mg/kg) in soil profiles of industrial effluents contaminated and uncontaminated soils.

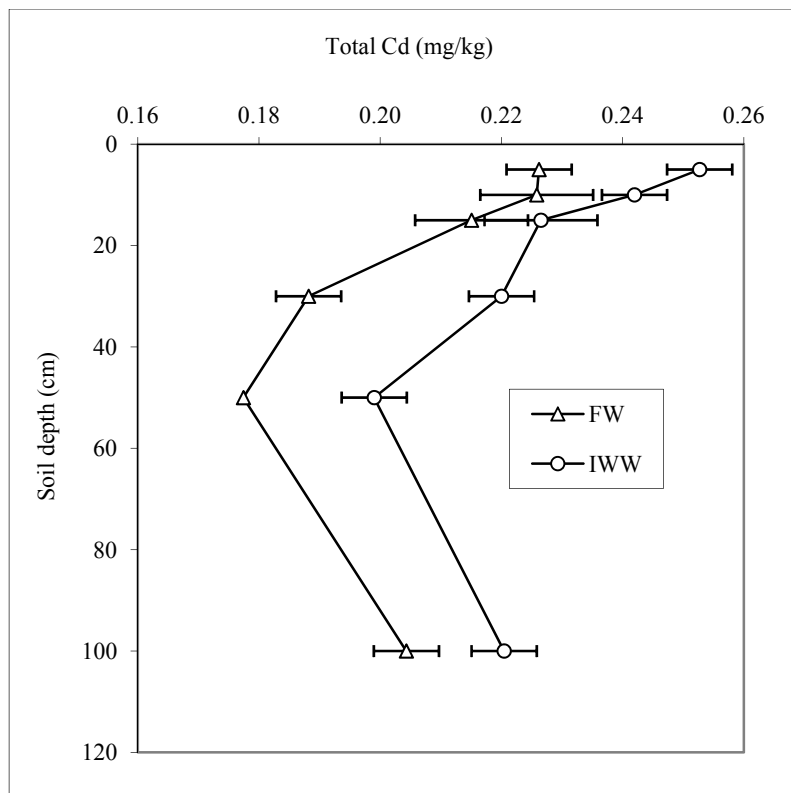


Fig. 17 Distribution of total Cd (mg/kg) in soil profiles of industrial effluents contaminated and uncontaminated soils.

Chromium (Cr) concentration in different soil profiles varied from 44 mg/kg to 66 mg/kg in FW soil, but in IWW soils, it ranged between 42 mg/kg to 74 mg/kg (Fig. 18). The IWW soil gave Cr content of 74 mg/kg as compared to 66 mg/kg in FW soil at 0-5 cm depth. At 5-10 cm depth, IWW soil had 2 units higher of Cr content than that of FW soil. The industrial waste water irrigated soils showed an increase in Cr content than the FW soils by 8 mg/kg and 3 mg/kg at 10-15 cm and 15-30 cm depths, respectively. The FW soils had 7 mg/kg and 2 mg/kg higher Cr content than that of IWW soils at 30-50 cm and 50-100 cm depths, respectively. Both in the soils, the Cr content were found to decrease with the increasing soil depth, reflecting the deposition of Cr at the surface. Similar result was reported by Abdu, N. et al. [1]. Affinity of surface enrichment of Cr might be due to metals deposition in the surface from the waste water. Ayers, R. S. and Westcot, D. W. [25] reported that the

maximum tolerable concentration of Cr in soil is 100 mg/kg. From this result, it could be concluded that the profile soils were suitable for cultivation with respect of Cr.

Nickel (Ni) content in different soil profiles varied from 45 mg/kg to 66 mg/kg in FW soils, but in IWW soils, it was ranged between 48 mg/kg to 72 mg/kg (Fig. 19). The IWW soil had Ni content of 72 mg/kg compared to 66 mg/kg in FW soil at 0-5 cm depth. At 5-10 cm depth, IWW soil had 2 units higher of Ni content than that of FW soil. At 10-15 cm depth, the Ni content had more or less similar in both the soils. The industrial waste water irrigated soil showed an increase in Ni content than the FW soil by 11 mg/kg, 10 mg/kg and 3 mg/kg at 15-30 cm, 30-50 cm and 50-100 cm depths, respectively. Nickel concentrations were found to decrease with profile depth in both the soils, indicating the deposition of Ni at the surface.

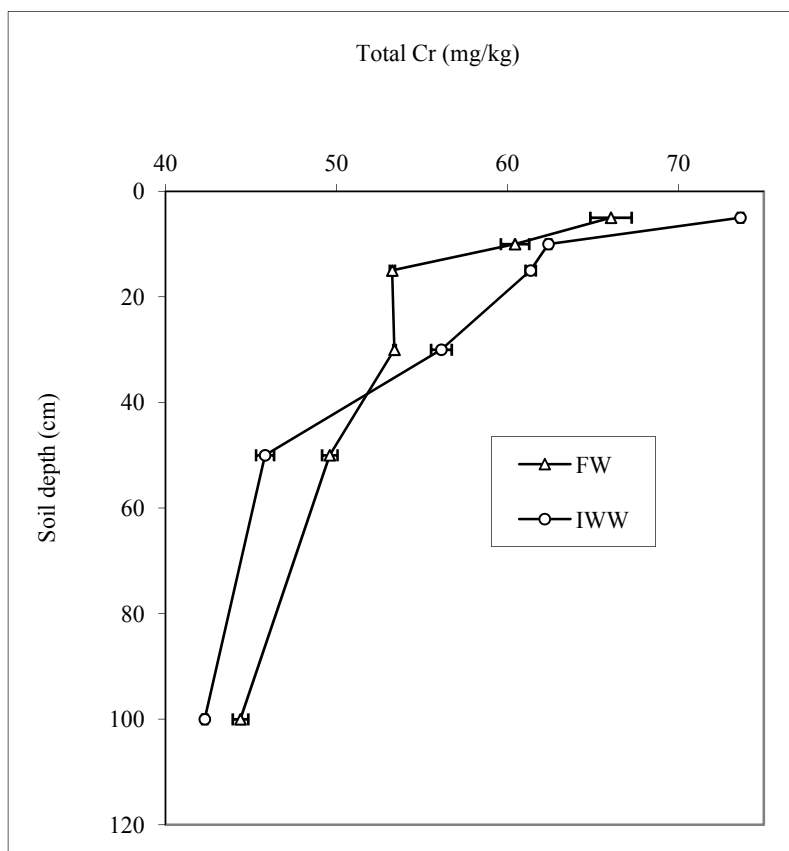


Fig. 18 Distribution of total Cr (mg/kg) in soil profiles of industrial effluents contaminated and uncontaminated soils.

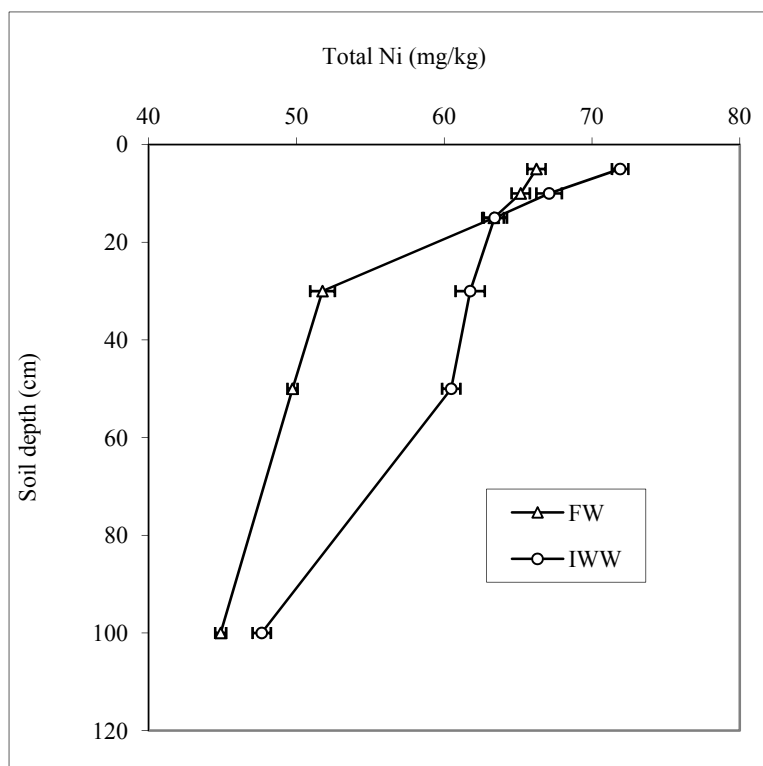


Fig. 19 Distribution of total Ni (mg/kg) in soil profiles of industrial effluents contaminated and uncontaminated soils.

Similar result was reported by Abdu, N. et al. [1]. The maximum tolerable concentration of Ni in soil is 100 mg/kg [27]. All the profile soils contained Ni beyond tolerable concentrations that are suitable for crop production.

4. Conclusions

Results of this experiment showed that the rice soils profile brought a different change in chemical soil properties through long-term industrial waste water irrigation. Industrial waste water irrigated rice field seemed to create some differences in soil pH at different depth. Relatively more negative charges developed in rice soil through waste water irrigation. Irrigation with industrial waste water increased EC in rice soils profile that developed soil salinity in study area of Gazipur district in Bangladesh. Development of soil salinity in inland associated with the industrial waste water application for rice cultivation is one of the unique findings which would be the great threat for declining soil quality as well as rice production.

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