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Impacts of industrial effluents on plant growth and soil properties

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Abstract

Bangladesh Thai Aluminum (BTA) Ltd. produces anodized aluminum sections and profiles. During oxidation of discharged aluminum profile a large amount of chemicals are used, which have subsequently as wastes to the surrounding environment. The agriculture in the area is ultimately has being affected and contaminated with these industrial effluents. Against this background, a pot experiment was conducted with rice and grass grown on normal agricultural and contaminated soils to evaluate the effect of the effluents on soil and plant growth. The contaminated soil exerted significant ($p \leq 0.05$) negative effects on the growth, straw yield and nutrition of rice and grass grown on it. The more reduction (reduction over control, ROC: 55 to 67% for rice and 30 to 68% for grass) of straw dry matter yields of rice at different stages was determined as compared to grass grown on contaminated soil. The contents of N, P and K in the rice plants grown on the contaminated soil were decreased by 28, 32 and 65%, respectively. While increased (increase over normal agricultural soil, i.e. control: IOC) S and Na contents in rice by 55 and 1010% but decreased the S and Na contents in grass by 200 and 114%, respectively. Available N was determined 12 to 22 times higher in normal agricultural soil, while available S content was obtained 3 to 5 times higher in contaminated soil at different time of sampling. Type of crop showed no influence on N, P and S status of the soils.

Key words: industrial effluents, growth and yield, nutrition of rice and grass, soil properties.

Introduction

Industrial wastes are major sources of pollution in all environments and require on-site treatment before discharge into sewage system (Emongor *et al.*, 2005). Soil and environment are under tremendous pressure due to industrial expansion and discharge of effluents. Very few are aware of this discharging, a globally important issue. The third world countries, especially Bangladesh is now in a vulnerable position. Bangladesh has now more than 30,000 industrial units of which about 24,000 are small and cottage industries (Nuruzzaman *et al.*, 1998). Production for all industrial groups has increased by 46 percent since 1981, with some groups such as tannery products, industrial chemicals, pharmaceuticals and garments products increasing by 200 to 4,000 percent over the last ten years (Department of Environment - DOE, 1991). The DOE recently identified 900 large polluting industries, which have no treatment facilities for effluents and wastes. These heavily toxic effluents were discharging directly to adjacent soils and rivers (Khan, 2006). In the production process of these industries, a lot of solid, semi-solid and liquid wastes are generated that may contain substantial amount of toxic organic and inorganic pollutants, and if dumped in the environment without treatment then this may lead to serious environmental consequences. This will also undoubtedly deteriorate soil productivity and adversely affect crop production in the surrounding land. Industrial effluents had remarkable changes in the distribution of ions and their concentrations in wheat and bean plants (Wafaa, 2001). The quality of dissolved minerals in water depends upon the source of water and its path before use (Ahmed *et al.*, 1993). Soil ecosystems throughout the world have been contaminated by various anthropogenic activities resulting in health hazards through food chain (Tu *et al.*, 2000; Dahmani-Mueller *et al.*, 2001; McGrath *et al.*, 2002). Unfortunately, there is little work on this waste material and wastewater in Bangladesh in relation to their use in agriculture or discharge to agricultural land.

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At Kaliakoir of Gazipur district, an industrial unit named Bangladesh Thai Aluminum Ltd. produces anodized aluminum sections and profiles. During oxidization of the aluminum profile a large amount of chemicals are used which is subsequently discharged as wastage from this plant (Das *et al.*, 1996). This waste contaminates the surrounding cultivable land especially during monsoon. Against this background, the objectives of the present study were to evaluate the extent and impacts of the discharging industrial effluents on the growth, yield, nutrition of crops and soil properties.

Materials and Methods

Pot experiments were conducted at the premises of the Department of Soil, Water and Environment, University of Dhaka in order to evaluate the effects of industrial wastes as discharged on normal agricultural soil as well as crop production. Rice and grass were selected as test crops for this study. Contaminated soils near Bangladesh Thai Aluminum (BTA) Ltd. were collected from the village Chandara at upazila (Police station) Kaliakoir of Gazipur district. Five kilograms of air-dried, ground agricultural and contaminated soil samples were filled in each earthen pot as per treatment. Three 30 days old rice plants per hill and four hills per pot were considered for this experiment. Four healthy and uniform grass cuttings were transplanted in each pot. The water content of the soil was maintained at field capacity (38±2% moisture for normal agricultural soil and 45±2% for contaminated soil) through out the growing periods with tap water as required. The tap water was found to contain Ca^{2+}, 1.9; Na^+, 3.0; K^+, 0.2; Mg^{2+}, 2.3; Cl^-, 2.2; SO_4^{2-}, 0.03; HCO_3^-, 1.3 $mmol_cL^{-1}$; had pH and EC values of 6.7 and 0.06 S m^{-1}, respectively.

The original soil samples and soil collected at different growth stages of crops were analyzed for pH (1:2.5; Jackson, 1973). Soil moisture under field conditions was determined by oven drying over-night at 105^0C (Black, 1965). Organic matter content was determined by wet combustion with $K_2Cr_2O_7$ (Nelson and Sommers, 1982). Total nitrogen was determined by micro-Kjeldal method (Jackson, 1973) and the available nitrogen was determined by micro-Kjeldal method using Devardas alloy as suggested by Jackson (1973). Exchangeable Na^+ and K^+ were extracted through 1 M CH_3COONH_4 and determined by flame photometry (Black, 1965). Available P contents were determined by sodium bicarbonate extraction (Olsen *et al.*, 1954).

Plant height, number of tillers per pot and shoot dry matter weights were determined at 30, 60 and 85 days after transplantation. One hill per pot was collected at each sampling time. Shoot dry matters were analyzed for N content by the micro Kjeldal method (Jackson, 1973), P content by spectrometry (Jackson, 1973), S content by turbidometry (Jackson, 1973), Na and K content by flame photometry (Black, 1965) in HNO_3 – $HClO_4$ acid (2:1) digest. The level of least significant difference (LSD) of the treatments was calculated by Duncan's New Multiple Range Test (Zaman *et al.*, 1982).

Results and Discussion

Biomass production of rice

Growth period and environment under which plant is grown are the important factors in the life history of rice plant. It is convenient to regard the life history of rice in terms of three growth stages: vegetative, reproductive and ripening (Yoshida, 1981). The vegetative stage is characterized by tillering and gradual increase in plant height. Plant height and tiller production at different growth stages of rice are important parameters to plan for fertilizing and other cultural practices. Moreover, the present study was made on contaminated soils, where plant life cycle is sometimes irregular and information about growth and yield on the studied polluted soils are almost nil. Against this background, plant height, tiller and straw yield of rice and grass were considered to discuss in this paper.

Plant height

Plant height of rice was found to decrease in the contaminated soils as compared with the normal agricultural soils. The reduction of plant height by different treatments over normal agricultural soil (ROC) ranged between 7 to 19, 25 to 37 and 50 to 65% during 30, 60 and 85 days after transplantation, respectively (Table 1). Hence, the present results are highly significant. The rate of reduction was found to increase with time, which might be due to the adverse effects of contaminants as discharged through the BTA waste materials. This indicates that the factory did not take any pre-treatment measure for the reduction of contaminants of the effluents before discharging from the industry. The contamination by the effluents had no influence on plant height with the distances away from the BTA factory.

ranged from 55 to 59, 60 to 63 and 63 to 67% during 30, 60 and 85 days after transplantation, respectively (Table 1). The extents of reductions

Table 1. The reduction over control (#ROC %) in plant biomass production as influenced by distances (m) from Bangladesh Thai Aluminum (BTA) factory and growth stages of rice grown on contaminated soil in a pot experiment.

Treatment No.	Dist. from BTA (m)	Plant height			Tiller numbers			Straw yield		
		30 d	60 d	85 d	30 d	60 d	85 d	30 d	60 d	85 d
T_1	200	13#	25	50	16	33	50	55	63	65
T_2	400	19	37	58	16	37	64	56	60	64
T_3	600	7	32	65	16	33	45	56	60	63
T_4	800	16	36	-	16	40	74	59	61	67

#About 20% differences between the treatments is statistically significant ($p \leq 0.05$: Zaman *et al*., 1982).

Tiller production

Tiller production of rice was reduced by the contaminated soil and the effects were more pronounced with the advent of plant growth (Table 1). After 60 days of transplantation, the reduction of tiller numbers as compared to normal agricultural soil (ROC) ranged between 33 and 40% (Table 1). After 85 days the ROC was 50 to 74% and these values are highly significant. The rottening of several tillers in contaminated soils were also observed at the later stage of plant growth. The impact of industrial effluents was similar regardless of distances from the BTA factory.

Straw yield

Contaminated soil was exerted significant ($p \leq 0.05$) negative effect on the straw yield at all growth stages of rice (Table 1). The reduction of straw yield over normal agricultural soil (ROC) were increased remarkably with time, which might be due to the prolonged adverse effect of contaminants discharged from the industrial effluents. It is evident that the contamination by waste material did not influence by the distances. The main cause of the higher ROC during 85 days was the gradual increase in growth of rice in agricultural soils as compared with the contaminated soil where it was hindered by the contaminants.

The significant ($p \leq 0.05$) negative effects on the straw dry matter yields of grasses were observed at all three (30, 60 and 85 days) sampling times. The reduction over normal agricultural soil (ROC) ranged in between 30 to 32%, 67 to 68%, and 59 to 61% during 30, 60 and 85 days after transplantation (Table 2). The reduction at 85 days was lower than that at 60 days. The ROC were almost similar in all the treatments regardless of growth stages which demonstrated that the life

Table 2. Comparison of the dry matter yield (g/pot) of grass grown on agricultural (agric.) and contaminated (conta.) soils as influenced by distances from Bangladesh Thai Aluminum (BTA) factory and harvesting time.

Treatment No.	Distance (meter)	30 d after plantation			60 d after plantation			85 d after plantation		
		Agric. soil	Conta. soil	*ROC (%)	Agric. soil	Conta. soil	ROC (%)	Agric. soil	Conta. soil	ROC (%)
T_5	200	1.52a#	1.06b	30	3.34a	1.08b	67	3.69a	1.45b	60
T_6	400	1.50a	1.04b	30	3.33a	1.07b	67	3.60a	1.45b	59
T_7	600	1.55a	1.05b	32	3.38a	1.06b	68	3.75a	1.46b	61
T_8	800	1.52a	1.05b	30	3.35a	1.07b	68	3.72a	1.44b	61
LSD (5%)			0.31			0.67			0.75	

#Means followed by a common letter are not significantly different at 5% ($p \leq 0.05$) level.
*ROC = Reduction over control.

cycle of grass on the contaminated soil is not much hampered with the later periods of time and distances from the factory.

The results obtained from rice production are in line with the findings of Dutta and Boissya (2000) who reported that the Nagaon Paper Mill effluent significantly ($p \leq 0.05$) reduced the yield components of rice as compared with the rice grown in areas beyond the reach of the Paper Mill effluents.

Nutrient contents in plant tissues

The contents of N, P, K, S, and Na in rice plant tissues were obtained maximum during the second harvest at 60 days after transplantation in normal agricultural soil with a few exceptions for sulfur and sodium (Table 3). The contents of N and K in rice plants under contaminated soils decreased but S and Na contents increased during second harvesting and there was no remarkable change in the concentrations of the nutrients at third harvesting, except S and Na (Table 3). The reverse trends of N, P and K and striking increase for the contents of S and Na in grass plants were observed with time. The contents of N, K, S, and Na in grass plant tissues varied significantly ($p \leq 0.05$) and were maximum during the third harvest at 85 days after transplantation in normal agricultural soil, except for Na (Table 3). The concentrations of the N and P quite high in the plant tissues grown on contaminated soil (Table 3). The contents of nutrients in rice and grass plants under contaminated soils were not influenced much, except S and Na, which suggests that the normal life cycle of the plants might be hampered by S and Na in the contaminated soil. The average increments (increase over normal soil, IOC) of S and Na contents in rice were about 55 and 10%, respectively (Table 3). Though these elements showed reverse trends (IOC -200 and –114: Table 3) for grass tissues. These effects were due to the continuous receiving of S and Na from the S and Na rich effluents as discharged from the BTA factory. It was reported that these types of industries are using a large amount of sulfuric acid (Das *et al.*, 1996) and caustic soda for anodizing of aluminum. These results are partially in accordance with the findings of Wafaa (2001) who stated that irrigation with industrial effluents increased Na and decreased K contents in wheat and bean plants. The results also verified the above-mentioned facts as determined by the nutrient status of the contaminated soil. The contents of N, P and K were found to decrease in the rice plants on the contaminated soils and the reduction were 28% for N, 32% for P, and 65% for K (Table 3). The concentration of the nutrients as determined in the rice plants grown on agricultural soil were within the normal range as reported by Donahue *et al.*

Table 3. **Comparison of concentrations (%) of N, P, K, S and Na in plant tissues at different harvesting stages of rice and grass grown on normal agricultural and contaminated soils in a pot experiment**

Parameters/nutrients	Tissue concentrations (%) of rice					Tissue concentrations (%) of grass				
	N	P	K	S	Na	N	P	K	S	Na
Agricultural soil (control)										
1st harvest (30 d)	0.07d#	0.23a	0.21a	0.002e	0.005d	0.50e	0.30a	1.20b	0.02e	0.02b
2nd harvest (60 d)	0.14a	0.25a	0.22a	0.003d	0.002f	0.90c	0.31a	1.50a	0.01f	0.01c
3rd harvest (85 d)	0.11b	0.22a	0.18b	0.004c	0.003e	1.00b	0.32a	1.70a	0.03d	0.01c
Contaminated soil										
1st harvest (30 d)	0.09c	0.15b	0.08c	0.003d	0.023c	0.70d	0.26a	0.40c	0.05c	0.02b
2nd harvest (60 d)	0.07d	0.16b	0.07c	0.005b	0.035b	1.90a	0.26a	0.40c	0.06b	0.02b
3rd harvest (85 d)	0.07d	0.16b	0.06d	0.006a	0.053a	1.10b	0.27a	0.50c	0.07a	0.04a
LSD (5%)	0.02	0.03	0.02	0.001	0.010	0.20	0.08	0.26	0.01	0.01
Increase over control	-28	-32	-65	55	1010	-54	15	70	-200	-114

#Means followed by a common letter are not significantly different at 5% ($p \leq 0.05$) level.

in tissues of grass grown in both the soils were within the normal range, while the contents of K were very low in the grass tissues grown on contaminated soil. The contents of S and N were (1987), though the contents of N, P and K were very low in the rice tissues on the contaminated soil, but the contents of S and Na were quite high in the plants grown on the contaminated soil (Table 3).

Nutrient status of soils

Available N, P, and S contents in the soils are present in Table 4, which reveal that the content of these elements significantly ($p \leq 0.05$) varied with the normal agricultural and contaminated soils and the effects were more pronounced at the earlier stages of plant growth. The availability of N for both the plants grown in normal agricultural soil was 12 to 22 times higher than that of contaminated soil, which might be due to N-fertilization for agricultural purposes. The amount of available P was higher in contaminated soil than the normal agricultural soil. The amount of available S in contaminated soils was 3 to 5 times higher as compared with the normal agricultural soil. The availability of these elements in both the soils decreased with time. The findings are partially agreed with the results of Donahue *et al.* (1987) and Wild (1996). The results (Table 4) indicate that the amounts of N, P and S in the contaminated soils under both rice and grass were similar, which revealed that the type of crop had no significant influence on the status of these nutrient in soils.

Table 4. Comparison of available N, P and S contents (m mol kg^{-1}) in the normal agricultural and contaminated soils at different harvesting times.

Soil and plant types	Available N			Available P			Available S		
	30 d	60 d	85 d	30 d	60 d	85 d	30 d	60 d	85 d
Soil under rice:									
Agricultural soil (control)	3.65a#	3.35a	3.08a	0.11b	0.09b	0.07b	0.32b	0.31b	0.30b
Contaminated soil	0.25b	0.15b	0.15b	0.17a	0.16a	0.16a	1.54a	1.02a	0.88a
LSD (5%)	0.73	0.67	0.62	0.02	0.02	0.01	0.06	0.06	0.06
Increase over control (%)	-93	-95	-95	54	77	128	381	229	193
Soil under grass:									
Agricultural soil (control)	3.45a	3.35a	3.18a	0.13b	0.10b	0.09b	0.31b	0.31b	0.30b
Contaminated soil	0.27b	0.19b	0.19b	0.20a	0.18a	0.17	1.60a	1.57a	1.55a
LSD (5%)	0.69	0.67	0.64	0.03	0.02	0.02	0.06	0.06	0.06
Increase over control (%)	-92	-94	-94	54	80	88	416	406	417

#Means followed by a common letter are not significantly different at 5% ($p \leq 0.05$) level.

Conclusions

The contaminated soil exerted significant ($p \leq 0.05$) negative effects on the growth, yield and nutrition of rice and grass plants grown in it and the reductions were more pronounced in rice. The contents of N, P and K in the rice plants grown on the contaminated soil decreased by 28, 32 and 65%, respectively and increased S and Na contents by 55 and 1010%, but decreased the S and Na contents in grass by 200 and 114%, respectively. Type of crop showed no influence on N, P and S status of the soils. The present investigation suggests that the BTA factory should take much care for the use of chemicals specially sulfuric acid and caustic soda in the production process in order to reduce the contaminants in the discharging effluents. This can be done by setting up a pre-treatment plant for these effluents or by recycling those chemicals into their processing plants.

References

Ahmed, M., M.S.U. Talukder and M.A. Mojid. 1993. Quality of groundwater for irrigation in Muktagacha area. *Journal of the Institute of Engineers, Bangladesh* 21: 91-98.

Black, C.A. (ed). 1965. Methods of soil analysis, Part-1 and 2. American Society of Agronomy Publication, Madison, WI.

Dahmani-Mueller, H., F. Van and M. Balabane. 2001. Metal extraction by Arabidopsis halleri grown on an unpolluted soil amended with various metal-bearing solids: a pot experiment. *Environment Pollution* 114: 77-84.

Das, A.K., M.A. Hossain and S. Hasan. 1996. Recovery and reuse of sulfuric acid of waste electrolyte of anodization plant. *Dhaka University Journal of Science* 44 (2): 147-153.

DOE (Department of Environment). 1991. Report on the environmental quality standards for Bangladesh. Personal communication to Department of Environment, Ministry of Environment, Dhaka 1000, Bangladesh.

Donahue, R.L., R.W. Miller and J.C. Shickluna. 1987. Soils: An introduction to soils and plant growth, 5th Ed. Prentice-Hall of India Private Limited, New Delhi, India,

Dutta, S.K. and C.L. Boissya. 2000. Effects of Nagaon Paper Mill (Jagiroad, Assam) effluent on the yield components of rice (*Oryza sativa* L. Var Mahsuri). *Ecology, Environment and Conservation* 6: 453-457.

Emongor, V., E. Nkegbe, B. Kealotswe, I. Koorapetse, S. Sankwasa and S. Keikanetswe. 2005. Pollution Indicators in Gaborone Industrial Effluent. *Journal of Applied Sciences* 5(1): 147-150.

Jackson, M.L. 1973. Soil chemical analysis. p. 46-183. Prentice Hall of India Pvt. Ltd., New Delhi.

Khan, H.R. 2006. Assessment of SPWAC (Soil-Plant-Water-Air Continuum) Quality within and around Dhaka City. Report submitted to the Director of the Centre for Advanced Studies and Research in Biotechnological Sciences, University of Dhaka, Bangladesh.

McGrath, S.P., F.J. Zhao and E. Lombi. 2002. Phytoremediation of metals, metalloids, and radionuclides. *Advances in Agronomy* 75:1-56.

Nelson, D.W. and L.E. Sommers. 1982. Total carbon, organic carbon and organic matter. p. 539-579. In: Methods of Soil Analysis. Patr-2. (Second Ed.). A. L. Page (ed.), American Society of Agronomy Publication, Madison, WI.

Nuruzzaman, M., A. Islam, S.M. Ullah, M.H. Rashid and M.H. Gerzabek. 1998. Contamination of soil environment by the tannery industries. *Bangladesh Journal of Soil Science* 25: 1-10.

Olsen, S.R., C.V. Cale, F.S. Watanable and L.A. Dean. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate, USDA Circ., p. 939,Washington, DC, USA.

Tu, C., C.R. Zheng and H.M. Chen. 2000. Current status of the soil-plant system in a copper gangue area. *Acta Pedol Sin* (in Chinese) 37: 284-287.

Wafaa, M.S. 2001. The Effect of Industrial Effluents and Vasicular-Arbuscular Mycorrhizae on Nutrient Distribution Concentration of Wheat and Bean Plants. *OnLine Journal of Biological Sciences* 1 (8): 689-693.

Wild, A. 1996. Soils and the Environment: An introduction. Press Syndicate of the University of Cambridge, New York. USA. pp. 199-204.

Yoshida, S. 1981. Fundamentals of rice crops science. IRRI, LosBanos, Philippines. 158p.

Zaman, S.M.H., K. Rahim and M. Holader. 1982. Simple Lesson from Biometry. Publication No. 54, Bangladesh Rice Research Institute, Gazipur, Bangladesh.