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Soil Pollution in the Agro-Industrial Areas of the Northern Part of Dhaka City

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Abstract: The extent of accumulation of nutrient elements and heavy metals in soils, movement of nutrients and heavy metals in soil-water systems, changes in soil properties due to diurnal and annual flooding with polluted river water, physico-chemical parameters of most nutrient elements and toxic heavy metals in soils and existing crops *viz.-a-viz.* their relationships; possible causes and remediation of soil pollution in north outskirts of Dhaka city, vast areas were investigated where rapid urbanization and heavy industrialization are going on agricultural lands in and around. The crop lands were under alternate wetting and drying due to diurnal and annual flooding. After recession of water, sediments along with nutrients, heavy metals and other elements were deposited on the agricultural lands, which may cause a drastic eco-environmental impact. Overall fertility status of the soils of the study area was low to medium. High Organic Matter, high Cation Exchange Capacity and high clay percentage enriched the nutrient reserve of the soil, although total and water soluble nitrogen, phosphorus, potassium were low, sulfur, iron and zinc concentrations showed a comparatively higher in levels. Presence of heavy metals was identified but except copper, rests of the heavy metals were below the toxic levels. The research work reveals the current status of soil pollution around a polluted river, accumulation and release of heavy metals in soil-water-plant system in a particular agro-industrial zone in a year due to natural flooding.

Keywords: Heavy metal, submerged condition, incubation study, accumulation, concentration.

Introduction

Soil-Water-Plant environment deterioration due to industrial processes is severe in Bangladesh, especially where the industrial and agricultural activities go side by side [1, 2]. Pollutants from anthropogenic sources entering the soil-water-plant environment systems through various matrices are concern for all communities. It is now utmost important to evaluate their effects on soil-water-plant environmental quality of any area at a regular time interval as to minimize and effective control [2, 3, 4].

The industrial effluents and municipal waste water usually contains high amount of heavy metals, such as Chromium, Lead, Copper, Nickel, Zinc, Manganese, Arsenic, Cadmium, Iron, Mercury, along with various degradable and synthetic chemicals [5, 6]. The excessive metals in river water and sediments may pose a toxic affect to plant, animal and even human life [2, 7, 8].

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Tongi agro-industrial area is one of the largest industrial areas in Bangladesh, and consists of different types of large and small industrial units, such as textiles, lead batteries, ceramics, paper and pulp mills, pharmaceuticals, tobacco industries, rubber, paints, detergents, iron and steel and re-rolling mills, etc. [26].

Turag river is the upper tributary of the Buriganga, is located in the north of Dhaka metropolitan city and adjacent to Tongi industrial areas. Industrial and municipal effluents, untreated urban sewage and industrial waste waters from Tongi industrial areas affect Turag river [9]. Turag River at Tongi area is heavily industrialized and densely populated. A large number of local people posses' agricultural lands adjoining industrial zones and use only the river water for irrigation purpose [10,11]. The river banks are flooded daily and seasonally due to tidal effects and left sediments rich in plant nutrients as well as heavy metals [9]. Agricultural lands along the Turag river banks are cropped twice in a year for rice, winter vegetables, pulses and oilseeds. The Turag river supplies huge amount of water for irrigation as it is the cheapest source of water in that area.

Information regarding the accumulation of industrial pollutants in crop land in and around the industrial areas of Bangladesh is scarce. An authentic database is essential to evaluate, monitor and manage quality food crops, healthy peoples and pollution free agriculture. The present studies thus undertaken to evaluate the environmental impact due to industrial processes on the adjoining crop lands and soil-water-plant system of Tongi industrial area on the north outskirts of Dhaka city.

Materials and Methodss

Ten composite samples each from soil and water were collected in pre-monsoon season from different locations (Table 1) of greater Tongi agro-industrial area which is one of the largest industrial areas in Bangladesh, located from $23^{o}53^{'}20^{''}$ N to $23^{o}53^{'}24^{''}$ N and 90º24E to 90º24 18E at north adjacent side of Dhaka.

A major portion of the study area belongs to Belabo series [12] and belongs to general soil type of Non-calcareous Brown Floodplain soil. This soil represents Clayey, Kaolinitic, Hyperthermic, Ultic Ustochrepts of soil family (USDA System) [13]. A vast low lying soil are disturbed and eroded, it may has lost its typical profile morphology [14].

Bulk soil samples were collected from river banks and crop fields (Rice) to a depth of 0 to 15 cm from the surface on the basis of spot sampling following USDA (1975) [13] and water samples were collected from Turag river in pre-monsoon (January) for chemical quality analysis and in post-monsoon (September) seasons for incubation study.

An incubation study was conducted following Jackson (1973) [15] to study the changes in the concentration of Iron, Copper, Cobalt, Lead, Nickel and Zinc due to the submergence upto 07 days in 250 ml conical flasks. Soil samples (10 g) were submerged with deionized water and collected river water. The ratio of soil and water was 1:5. The flasks were then covered with aluminum foil to prevent any gaseous and evaporation loss of waters or other elements. The soil solutions were collected after 7 days of submergence by filtering through Whatman 40 filter paper. These solutions were then analyzed for N, P, K, S and Iron, Copper, Cobalt, Lead, Nickel and Zinc. pH of the solutions were also measured.

Particle size analysis of the soil samples were done by hydrometer method [16] and Textural classes of soil samples were determined by Marshall's Triangular Co-ordinates [13] using values of particle size analysis.

pH of soil and water samples as well as soil extracts was measured by using glass electrode pH meter (SensIon MM 340). For soil pH, the soil:water ratio was 1:2.5 [15]. Soil organic carbon was estimated by Walkley and Black's wet oxidation method [16], converted the values to soil organic matter by the van Bemmlon factor [17]. Cation exchange capacity (CEC) and Electrical Conductivity (EC) of the soils was determined [15].

The soil, plant and water samples were digested in HNO_3- $HClO_4$ acid system for P, K, S and other relavent elemental analysis. Total N and soluble N in samples were determined by micro-Kjeldhal's distillation method [15]. Total P and Fe in HNO_3- $HClO_4$ acid extract and P and Fe in water extract of soils, plants and water samples and soil water extracts were determined by using Spectrophotometer [17]. Total K and K in water extract of soils, plants and water samples and soil water extracts were determined using Flame Photometer [15]. Total S and S in water extract of soils, plants, water samples and soil extracts was determined Turbidimetrically using Spectrophotometer [15].Total Zn, Cu, Ni, Cr and Cu in HNO_3 acid extract of soils, plants, water samples and soil water extracts was estimated using Atomic Absorption Spctrophotometer (Varion AAS 240) [17].

Results and Discussion

Study of Soil Samples

The range of soil pH varies from 5.42 to 6.78 (Table 1). According to SRDI [18] these soils belong to slightly acid soil. The organic matter content of the soils were ranged from 0.31% to 12% with an average of 4.97 % (Table 1), indicating a high range of organic matter [19]. It might be due to heavy organic load in river water, or application of freshly prepared manures in the agricultural land. The cation exchange capacity (CEC) of the soils ranged from 13.65 to 49.22 meq/100g. The average value of CEC for the samples is 25.72 meq/100g (Table 1). All the CEC values are regarded as high to very high [20]. The higher CEC values may due to the high clay and multivalent metals contained in organo-metallic sediments [6, 20]. The carbon-nitrogen ratio (C/N ratio) of the soils is ranges from 2.57 to 182.52. The average value of (C/N ratio) for the samples is 30.0 (Table 1). Most of the (C/N ratio) values are regarded as high to very high as the optimum level of C/N ratio is 10-12 [19].

The total values for Nitrogen (N) in soils ranged from 0.03 to 0.4% with an average value of 0.151%, which indicates a low total Nitrogen status of the soil. Although total N contents in the study area was comparatively low in comparison with other upland's arable soils [21], the agricultural field do not show any indication of industrial pollution as far as the Nitrogen status of the soil is concerned.

The total P contents in soils ranges from 0.008 to 0.10 % with an average value of 0.037 % (Table 2). The total in Bangladesh soils ranged from 0.02 to 0.10% [19] and the values obtained in the present investigation show a wide variation in concentration of soil.

The total K in Bangladesh soils ranges from 0.5 to 2.5% .The total values for K in soils ranges from 0.23 to 0.63% with a mean 0.40 % (Table 2) indicating a medium to low content of total K.

Considering overall N, P, K concentrations in these industrially affected agricultural soils, no excessive deposition of these plant nutrients were observed, this may be due to diurnal flooding, specially intensive seasonal flooding during the monsoon. Excessive deposition of pollutants may not occur at that time.

The average value of total sulfur for the samples is 0.264 % with a range of 0.16 to 0.42%. The total in Bangladesh soils ranges from 0.005 % to 0.10% and the values obtained in the present investigation show very high content of total S [21]. The highest S in the study area was recorded in Ashulia road (Sample 10) with the soil of high clay and organic matter contents (Table 2), intensive rice cultivation area where S is frequently used [8]. The highest average S was also recorded near Ashulia Road (Sample 6 from Kamarpara road), comparatively higher land types, and dense industrial units with high amount of effluents discharge in the study area. Availability of soil S increases with the increase of clay and organic matter content, land type and land flooded with polluted river [8] .

Table 1: *Physical and chemical properties of soil samples under study.*

Soil sample		**Clay (%)**	**Texture**	**C:N Ratio**	**pH**	**Organic Matter (%)**	**CEC (meq/100g)**
Sample No.	Location						
1	Boro Deora, Tongi.	26.96	Clay Loam	182.52	5.73	9.44	49.22
2	Kamarpara road, Ashulia.	22.01	Loam	20.43	6.33	9.86	30.72
3	Boro Deora, Tongi	34.22	Clay Loam	6.28	6.73	1.19	40.91
4	Kamarpara Road, Ashulia.	29.00	Clay Loam	17.93	6.78	3.71	15.49
5	Mudafa, Tongi.	26.94	Loam	17.13	6.47	6.19	23.02
6	Kamarpara Road, Ashulia.	27.09	Clay Loam	17.40	5.42	11.99	19.79
7	Estema field, Tongi.	41.88	Clay Loam	2.57	6.38	0.31	24.42
8	Kamarpara Bridge, Ashulia.	34.23	Clay Loam	5.0	6.74	0.69	24.36
9	Anavola, Ashulia.	26.70	Sandy Clay Loam	27.46	6.35	2.84	13.65
10	Ashulia road, Ashulia.	27.09	Clay Loam	13.19	6.16	3.41	15.59
Average		29.62		30.99	6.309	4.97	25.717
Minimum		22		2.57	5.42	0.31	13.65
Maximum		41.9		182.52	6.78	12	49.22

Table 2: *Chemical composition of soil samples.*

Soil sample		**Nutrient Elements (%)**					**Heavy metals (ppm)**				
Sample No.	Location	N	p	K	S	Fe	Zn	Ni	Cr	Cu	Cd
1	Boro Deora, Tongi.	0.03	0.05	0.47	0.26	0.03	236.81	37.78	18.31	444	0.019
2	Kamarpara road, Ashulia.	0.28	0.03	0.63	0.32	7.91	502.35	80.82	14.16	179.88	0.77
3	Boro Deora, Tongi	0.11	0.05	0.23	0.21	9.49	33.37	13.29	0.25	5.12	0.00
4	Kamarpara Road, Ashulia.	0.12	0.02	0.3	0.16	8.83	39.15	34.17	3.47	26.16	0.006
5	Mudafa, Tongi.	0.21	0.1	0.63	0.21	8.88	68.32	28.66	28.87	10.67	0.011
6	Kamarpara Road, Ashulia.	0.4	0.008	0.5	0.26	4.82	224.61	31.85	108.84	519.73	0.019
7	Estema field, Tongi.	0.07	0.02	0.28	0.35	6.14	345.85	30.07	23.09	554.64	0.020
8	Kamarpara Bridge, Ashulia.	0.08	0.03	0.35	0.22	10.17	22.63	11.11	1.91	1.5	0.201
9	Anavola, Ashulia.	0.06	0.03	0.26	0.23	5.66	30.68	12.56	113.16	12.39	0.00
10	Ashulia road, Ashulia.	0.15	0.03	0.36	0.42	9.15	271.40	21.83	89.12	660.4	0.031
Average		0.15	0.04	0.40	0.26	7.11	177.52	30.21	40.12	241.45	0.11
Minimum		0.03	0.008	0.23	0.16	0.03	22.63	11.11	0.246	1.5	0.00
Maximum		0.4	0.1	0.63	0.42	10.17	502.35	80.82	113.16	660.4	0.77

The total values for Iron (Fe) in soils are ranges from 0.03 to 10.17% with a mean value of Fe for the samples are 7.11 % (Table 2). The total Fe in Bangladesh soils ranges from 0.70 to 5.50% and the values obtained in the present investigation show very high content of total Iron [21] (Table 2). Higher Fe content in the study area is evident and alarming. Dissolved Fe-compounds, which can act as reducing agents, may also deplete oxygen supply [22]. The higher Fe may also result from weathering of Fe rich minerals of the study area [12] and industrial discharge [8].

The total Zn in soils ranges from 22.63 to 502.35 ppm and 177.52 ppm in average (Appendix 1 and Figure 4.10). The total Zn content of most of the soils of Bangladesh ranges from 10 to 300 ppm and the values obtained in the present investigation show a wide range in content of total Zn [19].

The total values for Nickel (Ni), Cadmium (Cd), Copper (Cu), and Chromium (Cr) in the soils are ranges from 11.11 to 80.82 ppm, trace to 0.77 ppm , 1.5 (lower) to 660.4 ppm (higher) and 0.25 to 113.16 ppm, respectively; where the average value for Ni, Cd, Cu and Cr are 30.214, 0.11, 241.45 and 40.12 ppm, respectively (Table 2).

Total Ni content of most arable soils ranges from 1 to 200 ppm [23] and the values obtained in the present investigation show a low to medium range [19] and most of the tested samples do not show any Ni contamination, the Ni concentration are far above the average. Total Cd, Cu and Cr content of Bangladesh soils ranges from 0.01 to 3.0 ppm, 2.0 to 100 ppm and 5 to 1000, respectively. The Cd values obtained in the present investigation are below the permissible limit. Cu content shows trace to very high range beyond the maximum allowable concentration and total Cr shows very low to low range of total Cr in the soil.

Summarizing the results of chemical analysis, the soils can be ranked in low to medium range of soil fertility. Besides, the high organic matter content and high C/N ratio may inhibit proper plant growth; these properties control the supply of nutrients to the plants. These properties also minimize the toxicity of heavy metals or other synthetic chemicals by chelating and complex formation and helps plants to grow and survive in those soils.

Heavy Metal Movement in Soil Solution

Zinc is an important micronutrient for plants and also a pollutant of water bodies. In the present investigation, an irregular variation was observed in Zn dynamics in soil system when submerged with deionized water as well as natural water. More Zn was released to water extracts when the soils were submerged with natural water. Natural flood water or river water contains trace amount of Zn and compared to the natural flood water; river water extracts (rw) contain high Zn than distilled water extracts (dw: Fig. 1). In most soils Zn was released to water (with rw) when in most cases of dw, Zn was bound in soil system (Fig. 1). This incident regards the chemical characteristics of river water which helps to release Zn from soil solids and soil complexes which is absent in deionized water.

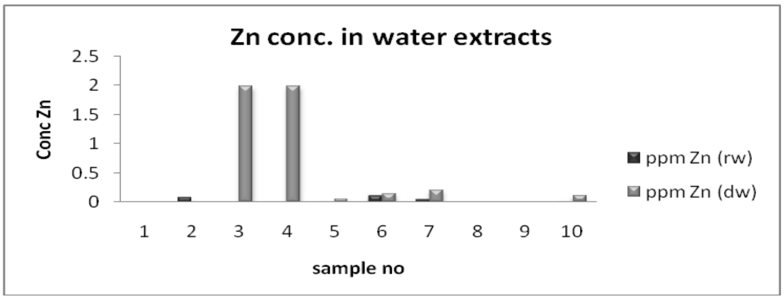

Fig. 1: *Movement of Zinc in soil-water system*

Nickel (Ni) enters in soil system as a counterpart of Iron and replaces Iron from soil solids as well as from soil solution, due to cation exchange reactions and complex formation. A significant variation was observed in soil system when submerged with deionized water as well as natural water. More Ni was released to water extracts when the soils were submerged with natural water. Compared to the natural flood water, rw contained high Ni than dw, the highest difference was seen in sample 9 (Fig. 2). In most soils Ni was released to water when in sample 3 from Boro Deora and 4 (Kamarpara Road) Ni was bound in soil system in both cases (Fig. 2). This indicates that, soluble Ni in the soil solution under sumergence, is more available to the exchange sites of soil root interface, than the soil. Further, as soil is flooded diannally and annually, the excess soluble Ni in the field leached and/or washed out [24, 25].

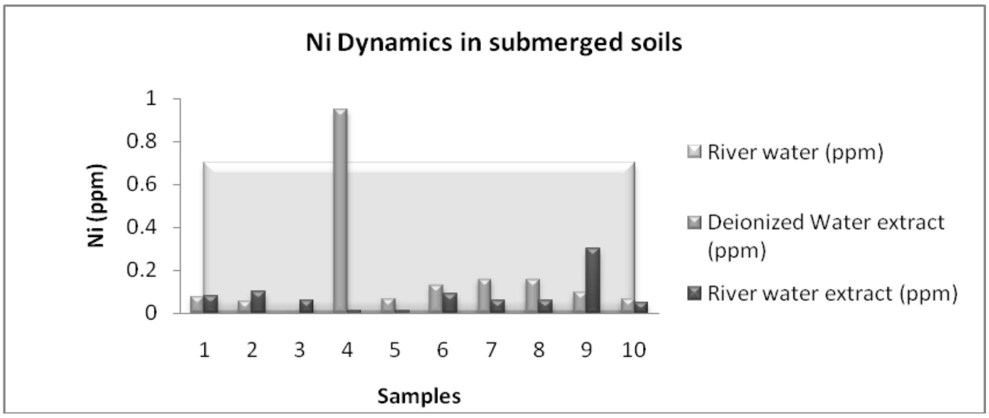

Fig. 2: *Movement of Nickel in soil-water system*

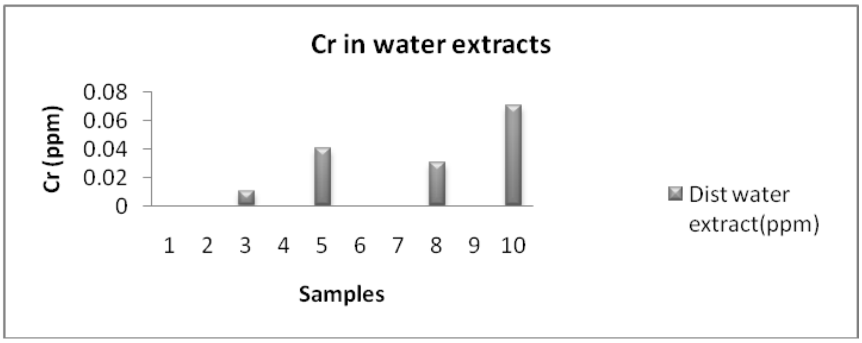

Fig. 3: *Movement of Chromium in soil-water system*

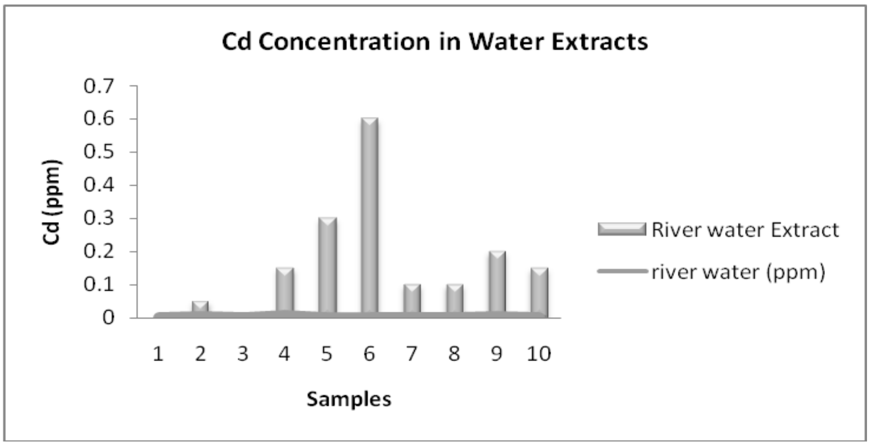

Fig. 4: *Movement of Cadmium in soil-water system*

Chromium (Cr) and Cadmium (Cd) are well known environmental pollutants. This research work revealed that, the Cr and Cd concentration in the soil solution due to submergence were highly irregular. None of the soils had detectable Cr in natural water extracts. Only some dw data had some water soluble Cr (Fig. 3). Highest Cr was found in dw of sample 10 from Ashulia road and lowest detectable value was found in dw of sample 3 from Boro Deora. It is evident that, during diannal and seasonal flooding, the excess soluble Cr in the field leached and/or washed out, may form complex compounds under reduced conditions and participate in ion exchange reactions occur in clay mineral and organic compounds [24, 25].

On the other hand, none of the soils had detectable Cd in deionized water extracts. Only natural water extracts had some water soluble Cd (Fig. 4). Highest Cd was found in dw of sample 6 and lowest detectable value was found in dw of sample 2. No detectable cadmium was found in sample 1 and 3 from different locations of Boro Deora. This may happen due to chemical properties of river water, complexation and ion exchange reactions occur in clay mineral and organic compounds reaction under reduced conditions [24].

Incubation study indicates to a universal truth, 'Nature is the best healer'. In incubation study it was observed that soil blocked nutrients as well as heavy metals of natural flood water. Although, in some cases, it released some nutrients and metals to the water, but the concentrations are still below the toxic levels.

Heavy Metals in Plant Samples

Plant samples collected from the study area show a remarkable response to nutrient elements as well as heavy metals. A significant amount of heavy metals namely Cr, Cu, Cd, and Ni were accumulated, yet to exceed their toxic limits, although concentrations are alarmingly higher (Table 3).

Table 3: *Chemical composition of plant samples*

Plant samples (Numbered according to Location)	Heavy Metals (ppm)				
	Zn	**Ni**	**Cu**	**Cr**	**Cd**
1	116.44	15.23	132.77	22.21	0.81
2	76.92	11.05	79.49	11.02	0.26
3	106.84	31.07	261.79	31.42	0
4	170.83	35.13	561.77	19.258	0.06
5	39.74	6.78	73.87	427.58	0.1
6	29.15	2.04	41.32	13.53	0.02
7	90.82	5.64	123.35	120.86	0.18
8	54.34	7.46	8.2	5.21	0.3
9	20.19	2.32	111.07	24.47	0.04
10	38.42	11.29	314.71	12.84	0.99
Average	74.37	12.80	170.83	68.84	0.27
Minimum	20.19	2.04	8.2	5.21	0
Maximum	170.83	35.13	561.77	427.58	0.99

Conclusion

On the basis of present study, it may be concluded that soil-water-plant systems in the agro-industrial areas of Tongi are contaminated with varying degrees and types of pollutants. Particularly dangerous is the accumulation of the heavy metals in arable soils. Further, the excessive levels of toxic effluents in soil and river water may contaminate groundwater aquifer through the process of leaching, infiltration and percolation in the long run. If this gradual degradation of soil remains unabated without proper and holistic environment friendly approaches, the entire area become environmentally imbalanced /contaminated.

It is hoped that the findings of the present research will be worthy and may be of value to future investigation in this fascinating field of sustainable soil-water-plant environmental research and will ventilate more information regarding possibilities of soil and water pollution in and around the mega industrial complexes.

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