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IMPACT OF INDUSTRIAL EFFLUENTS ON SPATIAL DISTRIBUTION OF SOIL CHEMICAL PROPERTIES IN GAZIPUR

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Abstract

Rapid industrialization contributes to the rising economic growth rate in Bangladesh. Gazipur district is one of the largest industrial zones in Bangladesh. Every day a huge amount of untreated industrial effluents is produced and delivered to the nearby crop field or water body. These effluents might have influenced the major chemical properties of soils. Hence, the present study was conducted to assess the impact of untreated industrial effluents on soil chemical properties expressed through a spatial distribution pattern map of the industrial zone of Gazipur district. A total of one hundred and four agricultural soil samples were collected with grid basis from different unions of the industrial areas of Sreepur and Gazipur Sadar upazilas. In Sreepur upazila, the mean values of soil pH, organic carbon (OC), N, P, S, K, Ca and Mg were 4.85, 0.81%, 0.11%, 6.08 ppm, 26.5 ppm, 0.13 meq/100g soil, 0.53 meq/100g soil and 0.19 meq/100g soil, respectively in uncontaminated soil, while the mean values of soil pH, OC, N, P, S, K, Ca and Mg were 5.15, 1.96%, 0.23%, 14.2 ppm, 187.61 ppm, 0.15 meq/100g soil, 0.64 meq/100g soil and 0.2 meq/100g soil, respectively due to industrial contamination. In both the upazilas, soil pH was strongly to slightly acidic while soil organic carbon was low to medium and N content was low. A weak spatial variation was detected for soil pH and N in these industrial areas indicating less influence on both the parameters by the effluents. Similarly, the contents of K, Ca and Mg were low in most of the areas of these two upazilas and a very little or no spatial variation was observed. On the other hand, OC and P contents were low to medium whereas S content was high in most of the study areas.

Keywords: Industrial effluents, soil chemical properties, spatial distribution and spatial variation.

Introduction

Soil is one of the Earth's vital resources, serving as a medium of plant growth and development. The availability of essential nutrients and optimum condition of other soil chemical properties affect crop growth, yield and quality directly. At the same time, deficiency of major elements, excess of trace elements and heavy metals may cause soil pollution (Jenny, 1941; Zwolak *et al.,* 2019). Rapid industrialization, emissions from automobiles, agricultural inputs, improper disposal of waste, *etc.*, are the major causes of soil contamination with heavy metals (Sharma *et al.,* 2023).The comprehensive understanding of spatial and temporal

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variability, physicochemical parameters and their effects on the environment is becoming an essential task in soil and environment. Soil properties vary spatially and strong fluctuations are recorded even in short distances (Trangmar *et al*., 1985; Warrick *et al*., 1986). Soil physicochemical properties deteriorate to the change in land use, especially from agriculture and forest. The Gazipur district is one of the major industrially developed areas of Bangladesh, where effluents are directly discharged to the environment without treatment. Discharge of untreated effluents to the environment is of great concern for the sustainable use of the resources (Eruola *et al*., 2011). Untreated industrial influent pollutes surface water and soil and ultimately it creates negative impacts on crops, insect pests, and animal and human lives (Hossain *et al*., 2010). The toxicity of industrial effluent varies considerably among different industries (Rautaray *et al*., 2007). Textile effluent is the most polluting among all industrial sectors, considering the volume and composition of effluents, in both developed and developing countries (Vanndevivera *et al*., 1998; Roy *et al*., 2010). Water consumption in textile and composite industries is very high (Roy *et al*., 2010). The effluent is contaminated with different chemicals and toxic components and also harbours a number of harmful pathogens that may cause many diseases for humans and other living beings (Molla *et al*., 2004). Considering the above-mentioned scenarios, a research was conducted to investigate the impact and spatial distribution of discharging untreated industrial effluent in the soils of Sreepur and Gazipur Sadar upazila of Gazipur district. The research findings might increase public awareness and foster social pressure against environmental pollution as well as promote policy ensuring the mandatory installation of effluent treatment plants in all industries for sustainable and congenial production environments both in agriculture and industrial sectors.

Materials and Methods

Experimental Site

The study was done in two upazilas of Gazipur district for the assessment of the spatial distribution of soil chemical properties in industrially contaminated and uncontaminated soils. Gazipur is situated at the centre of the Agro-ecological Zone-28 (AEZ-28) Madhupur Tract, about 24.12˚ N latitude and 90.26˚ E longitudes having a mean elevation of 8.4 meters above the mean sea level.

Soil sample collection

A total of 104 representative soil samples were collected using grid technique from the Sreepur and Gazipur sadar upazilas of Gazipur district (Fig. 1). Latitudes and longitudes of each sampling point were recorded using a global positioning system (GPS). The grid size was 4x4 km and within the grid, the contaminated and uncontaminated sites were identified based on baseline survey of study areas. For sampling map and grid preparation, the ArcGIS software was used. Total 10 contaminated and 44 uncontaminated samples from Gazipur sadar and 10 contaminated and 40 uncontaminated samples from Sreepur upazila were collected.

Analysis of soil samples

The collected soil samples were air dried, sieved using a 2mm sieve and kept in

Fig. 1. Study area showing sampling points.

polythene bags with proper labelling. The samples were analyzed in the laboratory of Soil Science Department of Bangabandhu Sheikh Mujibur Rahman Agricultural University to determine soil pH, percent organic carbon (%OC), % nitrogen (N), available phosphorus (P), sulphur (S), potassium (K), calcium (Ca) and magnesium (Mg) using the methods described below.

Soil pH was measured by a glass electrode pH meter (Horiba Model NO.M-8L) fitted with an electrode using a soil: water ratio of 1:2.5 (Jackson, 2005). Ten grams of air-dry soil were taken in a 100 ml beaker separately and mixed with 25 ml of distilled water to prepare the suspension for determining soil pH. Soil organic carbon was determined by the wet oxidation method (Walkley and Black, 1935) outlined by Piper (1950). Organic carbon was estimated through the oxidation of organic matter with potassium dichromate ($K_2Cr_2O_7$) in presence of H_2SO_4 and excess dichromate was titrated with Mohr's salt (Ammonium ferrous sulfate, AFS). The total N content of the collected soil sample was determined by the Semi Micro Kjeldahl method (Bremmer, 1965). Extraction for available P in the soil sample was determined by Bray and Curtz Method at a nearly constant pH of 6.5. A spectronic 21D spectrophotometer was used to measure the intensity of the colour developed by ascorbic acid (Bray and Kurtz, 1945). Sulphur content in the extract was determined by developing turbidity by adding acid solution (20 ppm S as K_2SO_4 in 6N HCl) and $BaCl_2$ crystal. The intensity of turbidity was measured by spectrophotometer at 420 nm wavelength and the readings were calibrated with the help of a standard curve of S. Exchangeable K, Ca and Mg were extracted with neutral 1N NH_4OAc as described by Jackson (1973) and was measured by Atomic Absorption Spectrophotometer (Model No. 170-30. HITACHI. Japan).

Statistical analysis and GIS mapping

All statistical analyses in this study were performed using Statistix 10 software. Altogether the spatial distribution maps of the soil's chemical properties were prepared using the ArcGIS software. Inverse distance weighted (IDW) interpolation was used to generate the field's contour maps to illustrate the spatial distribution of the soil chemical properties in the study areas.

Results and Discussion

The spatial distribution of major chemical properties and their concentrations is a useful aid to assess the impact and possible sources of enrichment and to identify hot-spot areas (Burgos *et al*., 2008; Li *et al*., 2010).

Soil pH

Soil pH value was higher in the contaminated soil as compared with the uncontaminated control soil of the study sites. The soil pH was found less than 5.5 in more than 90% samples of Sreepur upazila (Fig. 2). The soil pH values in Gazipur Sadar upazila showed that more than 60% samples had pH values less than 5.5, while the remaining parts had pH values ranging from 5.5 to 6.5, as illustrated in Fig. 2. In Sreepur upazila, the pH values in uncontaminated soil ranged from 4.08 to 5.48, while in contaminated soil, the range was from 4.08 to 6.74, as shown in Table 1. On the other hand, uncontaminated soil in Gazipur Sadar upazila had pH values ranging from 4.22 to 6.02, whereas contaminated soil had higher pH values ranging from 4.92 to 6.71 (Table 2).

The increased soil pH in the industrial effluents contaminated soils might be due to the presence of strong salt(s) in the effluents which on dissociation might have released the basic cations in the soil solution. Our results were in harmony with the findings of Singh *et al*. (2017) who described that soil pH increased in industrial effluents contaminated soil might be due to residual alkalinity in industrial effluents.

Organic Carbon

The content of soil organic carbon (OC) in uncontaminated soils of Sreepur upazila ranged from 0.42% to 1.53%, while in contaminated soil the OC value ranged from 0.23% to 2.61% (Table 1). In contrast, the content of OC in soils of Gazipur Sadar upazila ranged from 0.48% to 1.54% in uncontaminated soil, whereas in contaminated soil it ranged from

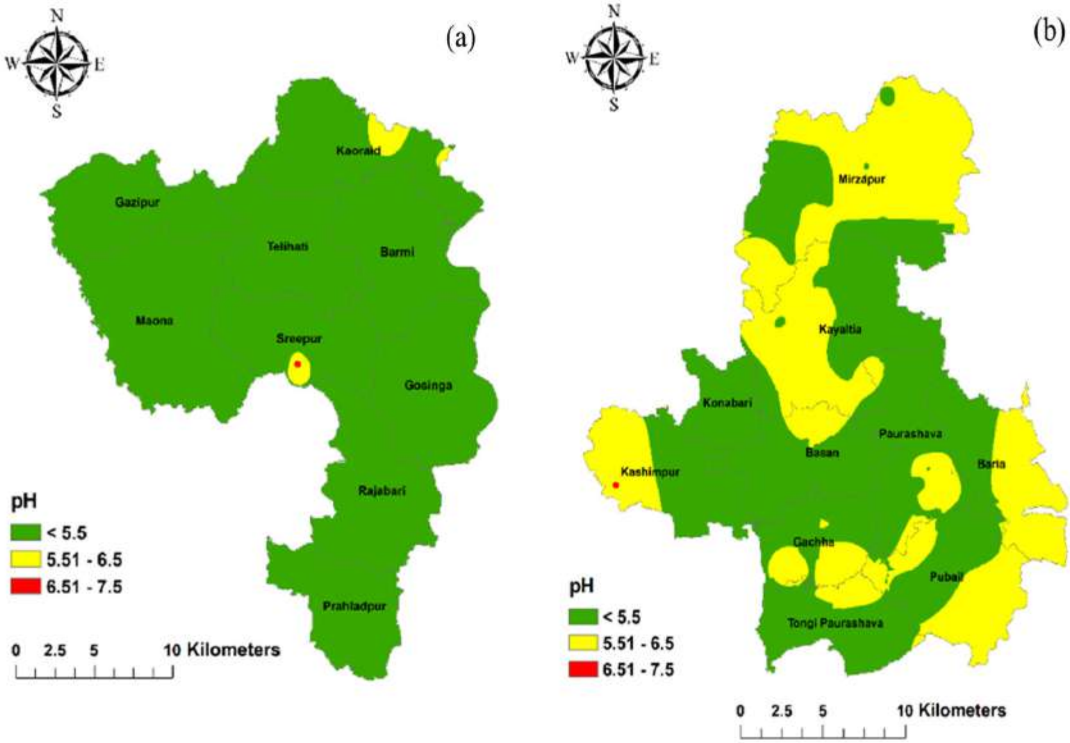

Fig. 2. Spatial distribution of pH in the soil of (a) Sreepur and (b) Gazipur Sadar upazila.

Table 1. Major chemical properties of soils collected from Sreepur upazila

Parameters	Uncontaminated Soil			Contaminated Soil			Significance level
	Max.	Min.	Mean	Max.	Min.	Mean	
pH	5.48	4.08	4.85	6.74	4.08	5.15	ns
OC (%)	1.53	0.42	0.80	2.61	0.23	1.96	***
N (%)	0.23	0.06	0.11	0.28	0.17	0.23	***
P (ppm)	13.34	3.41	6.08	21.31	3.22	14.2	***
S (ppm)	48.15	6.8	26.5	218.17	143.39	187.61	***
K (meq/100g soil)	0.16	0.11	0.13	0.16	0.13	0.15	*
Ca (meq/100g soil)	0.62	0.43	0.53	0.68	0.53	0.64	**
Mg (meq/100g soil)	0.20	0.17	0.18	0.21	0.19	0.2	*

***, **, and * indicate the significant difference between mean value of contaminated and uncontaminated at 0.1%, 1% and 5% level of significance, respectively and 'ns' indicate non-significance.

0.96% to 2.18% (Table 2). The content of OC was low to medium ranging from 0.81% to 1.10% in soils of more than 80% samples of Sreepur upazila. In some areas, the content of OC was found less than 0.80% indicating the areas with the lowest OC content. The OC content in soils with the range of 1.11% to 1.40% and >1.40% was found in the greater part of Rajabari, Sreepur and Kaoraid union (Fig. 3).

In Gazipur Sadar upazila, OC content was found low to medium (0.81%-1.10%) in more than 75% samples. In some areas, it was found <0.80% which indicated the lowest OC content in these areas. Soils in some areas of Tongi Pourashava, Kayaltia, Kashimpur and Konabari had medium to high (1.11%-1.40%) and higher (>1.40%) OC content (Fig. 3). High load of organic matter in industrial effluents resulted in an improvement of OC in soils. Some researchers also observed that the organic carbon content of industrial effluents-fed soils was found to be higher than in the soil irrigated through tube well water and this was possible due to the incorporation of organic matter through industrial effluents (Singh *et al*., 2017).

Nitrogen (N)

The content of N in Sreepur upazila ranged from 0.06% to 0.23% in uncontaminated soil, whereas in contaminated soil the value ranged from 0.17% to 0.28% (Table 1). On the other hand, the content of N in Gazipur Sadar upazila ranged from 0.06% to 0.23% in uncontaminated soil, while in contaminated soil the value ranged from 0.08% to 0.46% (Table 2). N content in more than 60% samples of Sreepur upazila ranged from 0.091% to 0.18% which indicated that the area was low in N content.

In some parts of studied area, the value was found medium which ranged from 0.18%-0.27% (Fig. 4). N content in most of the parts of Gazipur Sadar upazila ranged from 0.091% to 0.18% which indicated that the area was low in N content. In some parts N content was found medium which ranging from 0.18%-0.27% (Fig. 4). Rahman *et al.* (2012) found that nitrogen content varied from 0.02% to 0.88% in the close vicinity of Dhaka Export Processing Zone (DEPZ). Our results were in agreement with the findings of Tabassum *et al.* (2015) who described that the average N content was 0.11% to 0.15% in industrially contaminated soil.

Available phosphorus (P)

In Sreepur upazila, the concentration of P in soil fluctuated from 3.41 ppm to 13.34 ppm in uncontaminated soil, however, the value ranged from 3.22 ppm to 21.31 ppm in contaminated soil (Table 1). On the contrary, in Gazipur Sadar upazila, the concentration of P ranged from 3.09 ppm to 11.61 ppm in uncontaminated soil, whereas the value fluctuated from 7.81 ppm to 14.48 ppm in contaminated soil (Table 2).

The P concentration was low in more than 70% samples of Sreepur upazila, ranging from 3.76 ppm to 7.5 ppm. In some areas, the concentration was medium (7.51-11.25 ppm). P concentration was low in soils of more than 50% samples of Gazipur Sadar upazila. The concentration ranged from 3.76 ppm to 7.5 ppm. The concentration of P was medium in most of the parts of the Mirzapur,

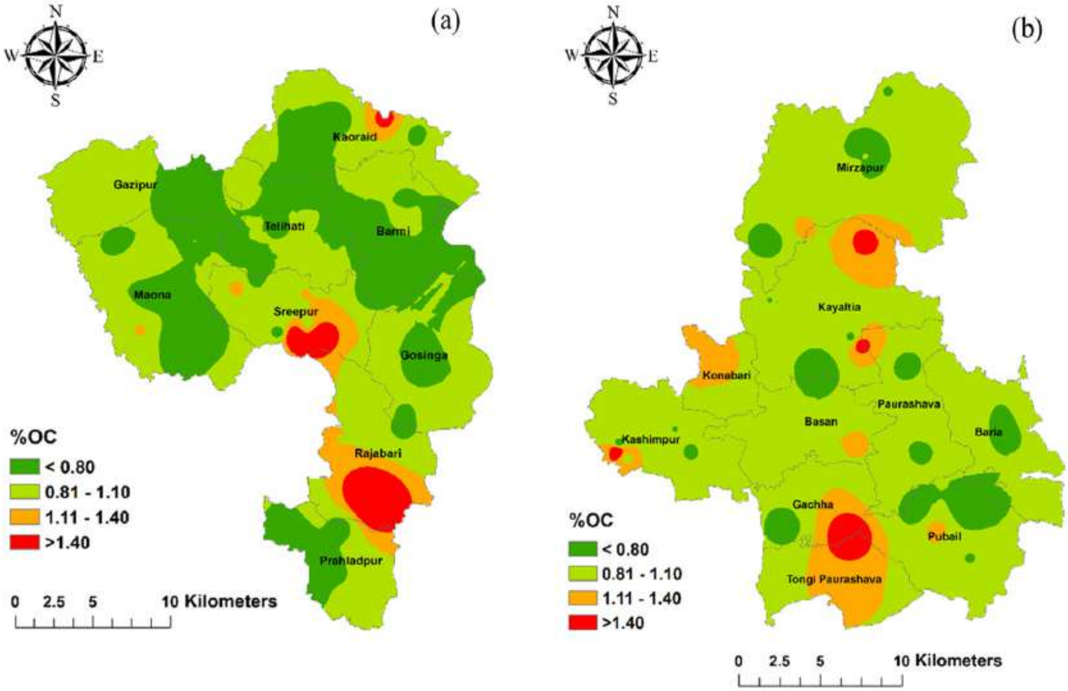

Fig. 3. Spatial distribution of OC (%) in the soil of (a) Sreepur and (b) Gazipur Sadar upazila.

Table 2. Major chemical properties of soils collected from Gazipur Sadar upazila

Parameter	Uncontaminated Soil			Contaminated Soil			Significance level
	Max.	Min.	Mean	Max.	Min.	Mean	
pH	6.02	4.22	5.41	6.71	4.92	5.94	**
OC (%)	1.54	0.48	0.86	2.18	0.95	1.39	***
N (%)	0.23	0.06	0.12	0.46	0.08	0.17	*
P (ppm)	11.61	3.09	6.99	14.48	7.81	11.19	***
S (ppm)	62.17	7.20	37.28	234.65	82.44	151.98	***
K (meq/100g soil)	0.17	0.11	0.14	0.22	0.16	0.17	***
Ca (meq/100g soil)	0.98	0.84	0.92	1.0	0.97	0.98	**
Mg (meq/100g soil)	0.27	0.22	0.24	0.29	0.25	0.26	*

***, **, and * indicate the significant difference between mean value of contaminated and uncontaminated at 0.1%, 1% and 5% level of significance, respectively.

Konabari, Gacha, Kashimpur and Kayaltia union (Fig. 5). P concentration was found below the critical limit (FRG, 2018) might be due to P fixation by aluminium or iron oxides in these acid soils. Islam *et al*. (2016) found that the level of P was considerably higher in industrial effluent-contaminated soils than that in uncontaminated soils.

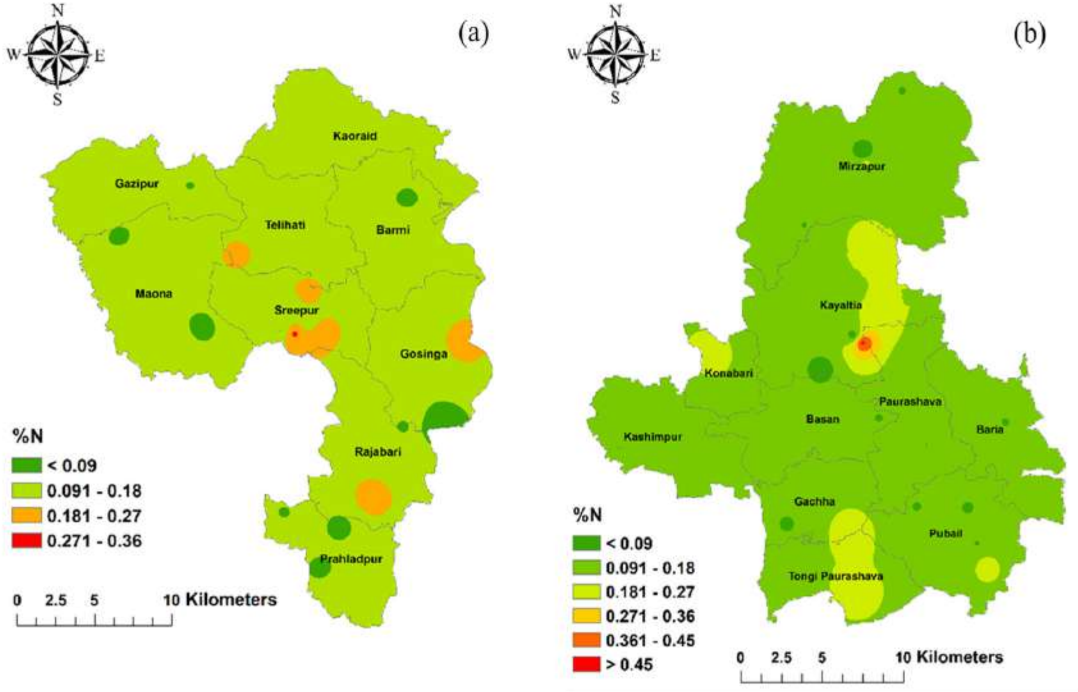

Fig. 4. Spatial distribution of N (%) in the soil of (a) Sreepur and (b) Gazipur Sadar Upazila.

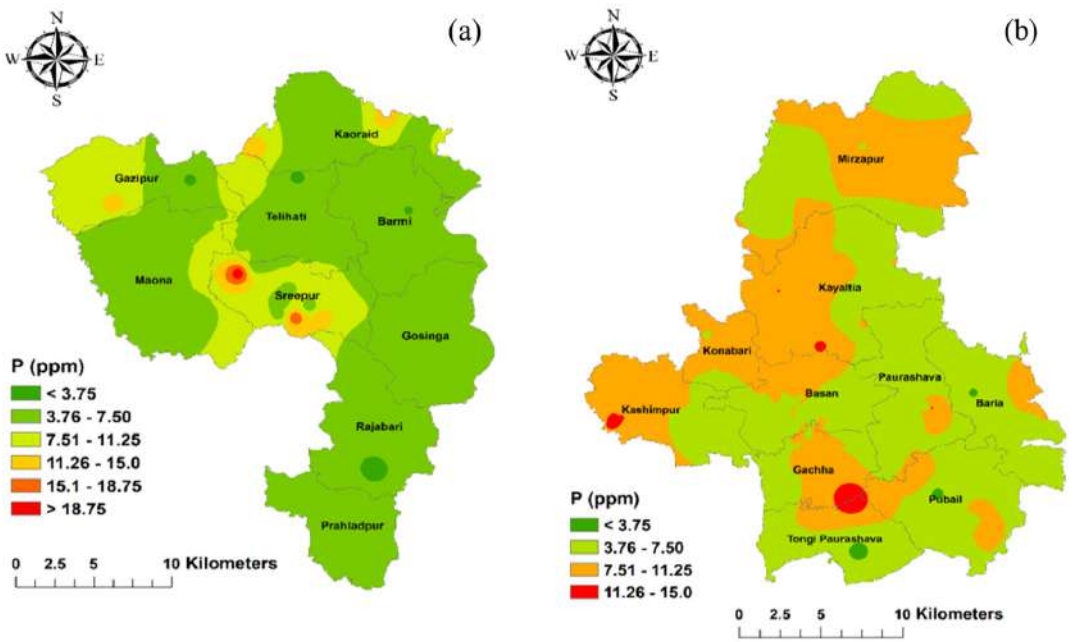

Fig. 5. Spatial distribution of P (ppm) in the soil of (a) Sreepur and (b) Gazipur Sadar Upazila.

Sulphur (S)

The concentration of S ranged from 6.8 ppm to 48.15 ppm in uncontaminated soil of Sreepur upazila, while the value ranged from 143.39 ppm to 218.17 ppm in contaminated soil (Table 1). On the other hand, the concentration of S in Gazipur Sadar upazila fluctuated from 7.20 ppm to 62.17 ppm in uncontaminated soil, however, the value ranged from 82.44 ppm to 234.65 ppm in contaminated soil (Table 2). The concentration of S was low (9.1-18.0 ppm) in some areas of Kaoraid, Maona, Gazipur and Prahladpur unions. The highest concentration (>45.0 ppm) was found in most of the areas of Sreepur and Rajabari unions (Fig. 6).

Potassium (K)

The concentration of K in Sreepur upazila fluctuated from 0.11 meq/100g soil to 0.16 meq/100g soil in uncontaminated soil in Sreepur upazila, whereas in contaminated soil the value ranged from 0.13 meq/100g soil to 0.16 meq/100g soil (Table 1). On the other hand, the concentration of K in Gazipur Sadar upazila ranged from 0.11 meq/100g soil to 0.17 meq/100g soil in uncontaminated soil, however, in contaminated soil the value fluctuated from 0.16 meq/100g soil to 0.22 meq/100g soil (Table 2). The concentration of K was low (0.076-0.15 meq/100g soil) in most of the part of Sreepur upazila (Fig. 7). The concentration of K was low (0.076-0.15 meq/100g soil) in more than 70% samples

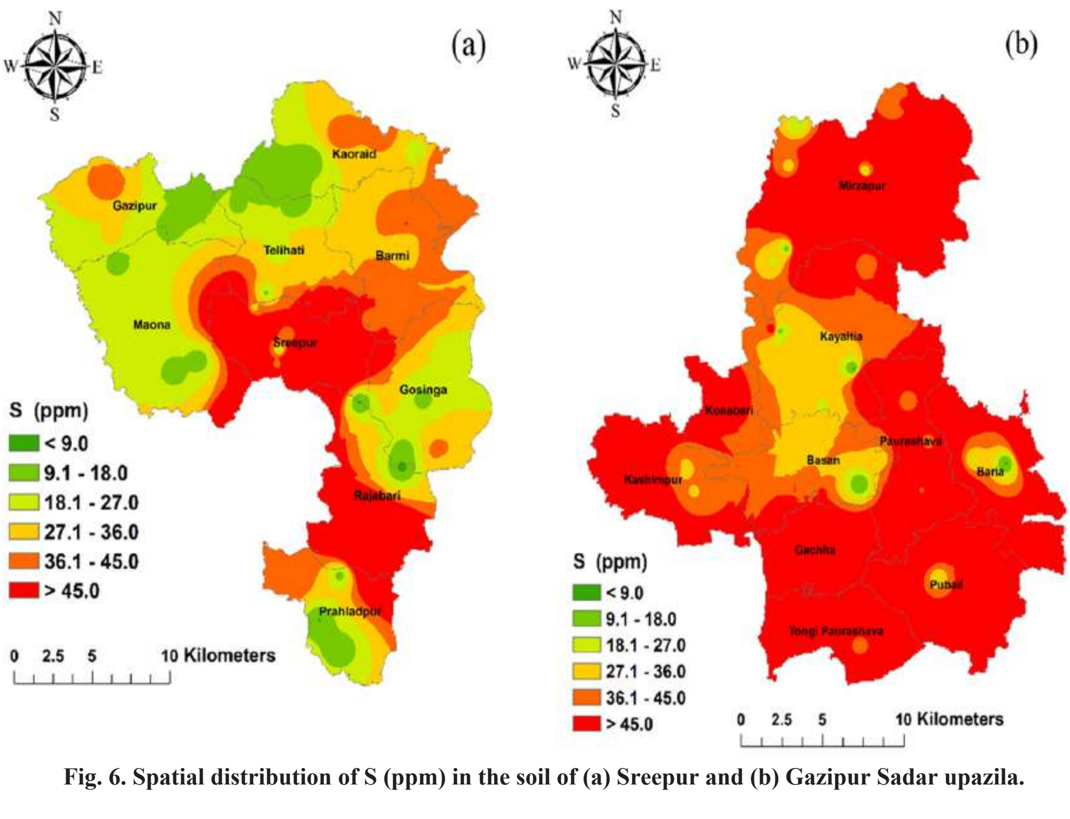

Fig. 6. Spatial distribution of S (ppm) in the soil of (a) Sreepur and (b) Gazipur Sadar upazila.

and in the other areas the concentration was medium (0.15-0.23 meq/100g soil). Overall concentration of K was low to medium in soils of Sadar upazila (Fig. 7). This indicated that there was little effect of industrial effluent on K content and sources of K might be due to adding fertilizer. Our outcome was also in harmony with the findings of Islam *et al.* (2016) who found that in all the soil depths, the exchangeable K had a noticeably higher value in industrially contaminated soils than that in uncontaminated soils.

Calcium (Ca)

In Sreepur upazila, the concentration of Ca ranged from 0.43 meq/100g soil to 0.62 meq/100gsoil in uncontaminated soil, while in contaminated soil the value ranged from 0.53 meq/100g soil to 0.68 meq/100g soil (Table 1). The concentration of Ca in Gazipur Sadar upazila fluctuated from 0.84 meq/100g soil to 0.98 meq/100g soil in uncontaminated soil, however, in contaminated soil, the value ranged from 0.97 meq/100g soil to 1.0 meq/100g soil (Table 2). The concentration of Ca was found low in both the upazilas (<1.5 meq/100g soil) (Fig.8) while the critical limit of Ca was 2.0 meq/100g soil (FRG, 2018). This might have resulted due to lack of natural sources of Ca. This slight difference might be due to adding fertilizer or other environmental factors and thus indicated low effect of industrial effluents on Ca content. Islam *et al*. (2015) found that considerable amount of P was increased with effluent-contaminated soils than with uncontaminated soils.

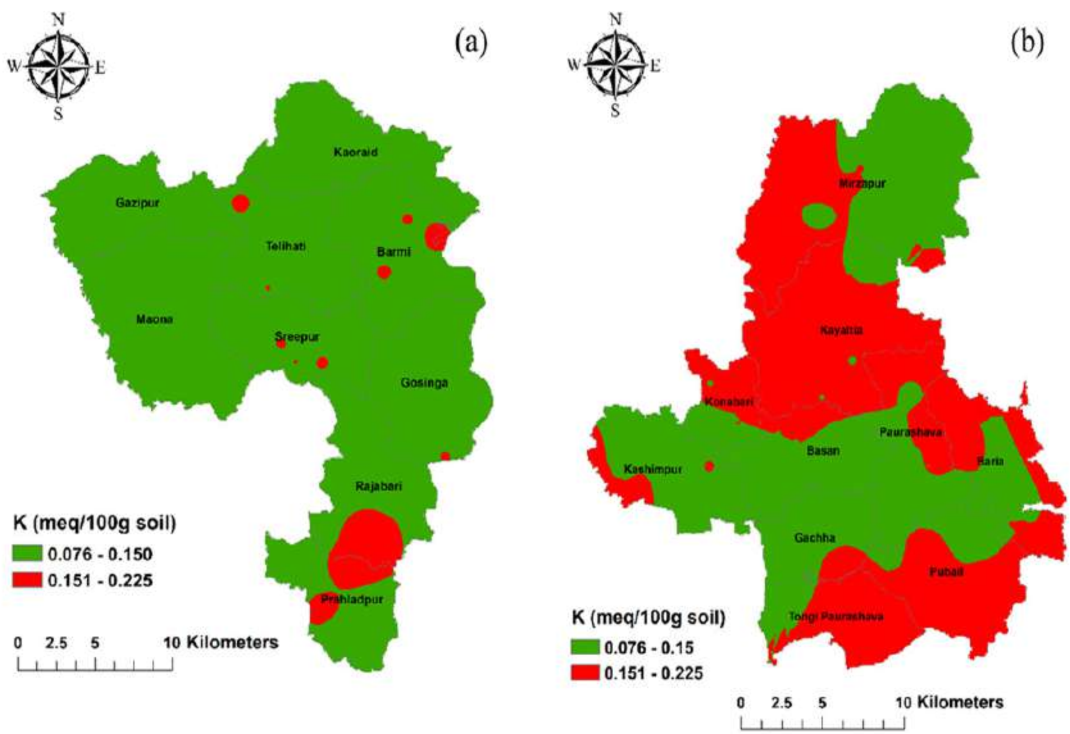

Fig. 7. Spatial distribution of K (meq/100g soil) in the soil of (a) Sreepur and (B) Gazipur Sadar upazila.

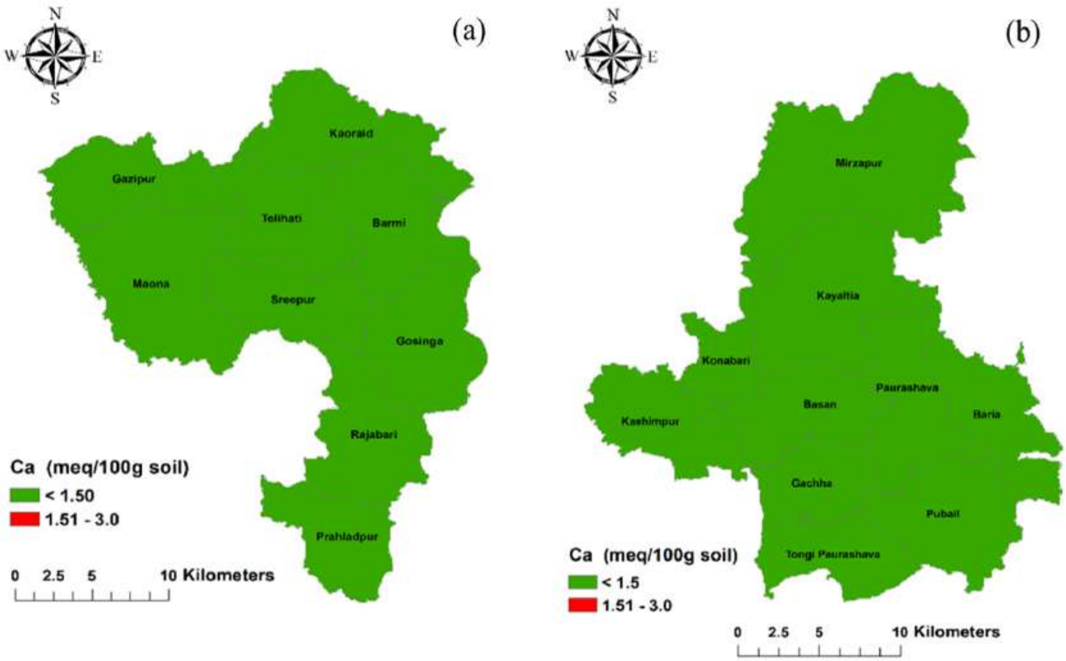

Fig. 8. Spatial distribution of Ca (meq/100g soil) in the soil of Sreepur and Gazipur Sadar upazila.

Magnesium (Mg)

The concentration of Mg ranged from 0.17 meq/100g soil to 0.20 meq/100g soil in uncontaminated soil, whereas in contaminated soil the value ranged from 0.19 meq/100g soil to 0.21 meq/100g soil in Sreepur upazila (Table 1). On the contrary, the concentration of Mg in Gazipur Sadar upazila fluctuated from 0.22 meq/100g soil to 0.27 meq/100g soil with an average value of 0.24 meq/100g soil in uncontaminated soil, while in contaminated soil the value ranged from 0.25 meq/100g soil to 0.29 meq/100g soil (Table 2). The concentration of Mg was found low in both the upazilas (<1.5 meq/100g soil) (Fig. 9) while the critical limit of Mg was 0.50 meq/100g soil (FRG, 2018). This indicated that there was little or no effect of industrial effluent on Mg content and sources of Mg might be due to adding fertilizer. Our results were in agreement with the findings of Islam *et al.* (2015) who described that the concentration of Mg was noticeably higher in industrial effluent-contaminated soils than in control or uncontaminated soils.

Conclusion

Soil pH, OC, N, P, S, K, Ca and Mg were found to be higher in industrially contaminated soils as compared to uncontaminated soils indicating the increasing trend in accumulation of these chemical properties from industrial effluents. A positive impact of industrial effluents and a wide range of spatial variation of major chemical properties was detected which indicating improvement of soil fertility but some pollution may occur due to heavy metal contamination from untreated effluents.

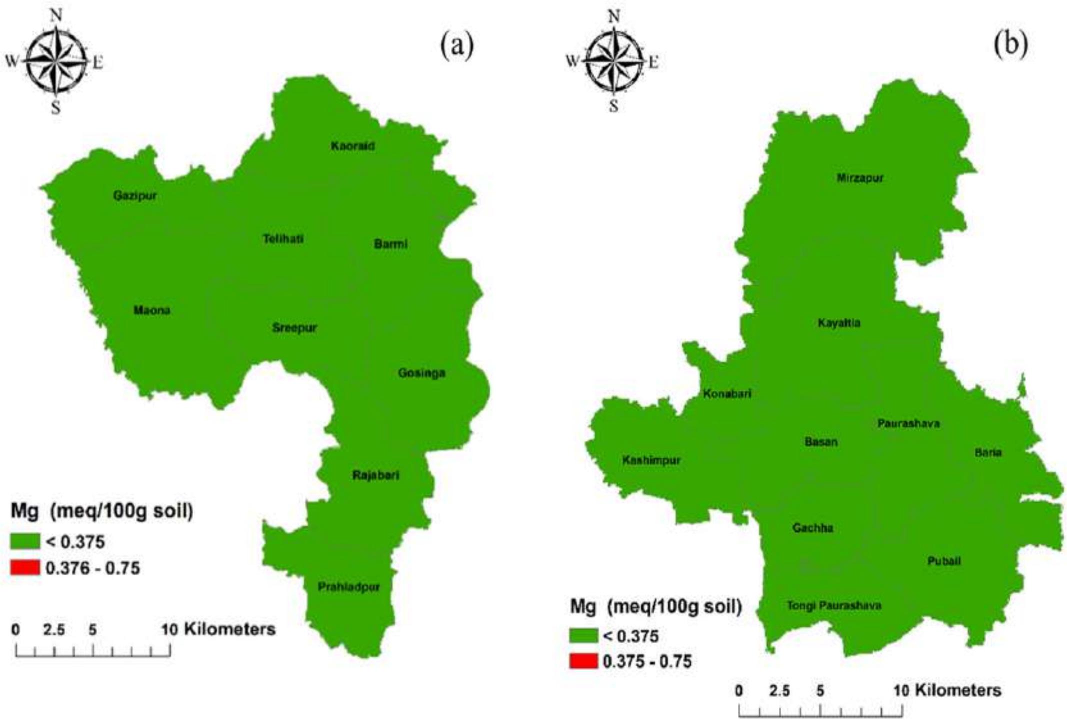

Fig. 9. Spatial distribution of Mg (meq/100g soil) in the soil of (a) Sreepur and (b) Gazipur Sadar upazila.

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