INFLUENCE OF INDUSTRIAL WASTES ON PHYSICO-CHEMICAL PROPERTIES OF SOIL AND GERMINATION AND MINERAL COMPOSITION OF WHEAT

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Abstract. The effect of chemical effluents discharged from a chemical and fertilizer factory on physico-chemical properties of soil and germination and mineral composition of wheat was studied at Varanasi, India. Forty times higher concentration of Na was observed in the effluent than that of the nearby well water. It showed a positive (significant) correlation with Na and a negative (significant) with K and Ca of the soil. Cation exchange capacity (CEC), porosity and water holding capacity were reduced by effluent affected soil. the germination percentage of wheat was negatively correlated with the Na of effluent and Na+Mg/Ca of the soil. A significant (positive) correlation existed between Na of effluent and Na content of the plants. Calcium percentage on the other hand, exhibited a reverse trend.

1. Introduction

Waste materials released from the industrial sources either in the form of harmful gases such as SO_2, Co, F etc. or dust particles or liquid effluents containing several acids, alkalies, organic and inorganic compounds, color producing substances etc. pollute the environmental components, where ever they are discharged. One of the important environmental components is soil which is being polluted by these industrial effluents and the pedoecosystem around factories are disturbed. Sodium is one of the strongest monovalent cations whose higher concentration upsets the mineral composition of soil (Black, 1968; Kelly, 1963; Hesse, 1970). Singh 1972 reported a positive and significant correlation with Na of water and Mg of soil. The untreated effluent discharged from Hari Fertilizer Factory, Varanasi, India, containing, a high concentration of Na has been deposited over the nearby crop fields. The present investigation evaluates the effects of such effluent on the physico-chemical properties of soil and germination and mineral composition of wheat.

2. Materials and Methods

Two hectares of land in each of the effluent effected areas (polluted soil) as well as in an area not so effected and irrigated by well water (control soil) were examined for the present investigation. Ten samples from each of the polluted and the control soils were taken randomly at fortnightly intervals through out the period of investigation (November 1986 to October 1988) by means of a graduated ($10 \times 10 \times 30$ cm) iron core sampler. All the samples were analyzed for various physico-chemical

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properties of the soil.

For the germination studies, twenty replicates of 50×50 cm quadrat were sown with 100 seeds of wheat in polluted and control soils. Seedlings were counted for calculation of percentage germination after a week. Germination was also investigated under laboratory condition. Wheat seeds were grown in petridishes on blotting papers moistened with fresh effluent collected from the discharge point and with well water. Each petridish contained 100 seeds. The percentage of germination was observed after 72 h.

Fresh samples of the effluent were collected in glass stoppered bottles from the discharge point and properties such as pH, carbonate, bicarbonate, K, Na, Ca, Mg, nitrate and total N were analyzed following the methods given in APHA (1985). Soil samples were analyzed for pH, exchangeable Na, K, Ca, Mg, nitrate, total N, porosity and water holding capacity. All the determinations were made according to the methods outlined by Hesse (1970).

Five seedlings 7 days old from each replicate were collected, dried at 60 °C, ground and analyzed. Calcium was determined by the oxalate method, Mg by gravimetric method (Piper, 1966), Na and K by using a flame photometer (Jackson, 1958).

3. Results and Discussion

The data set in table 1 indicate higher concentration of Na and carbonate. In the effluent Na is found to be 40 times higher than that of the well water. It gives positive and significant correlation (r = +0.795) with the Na of the soil. It is significantly but negatively correlated with K (r = +0.852) and Ca (r = +0.882) of the soil. Similar observations have been reported by Singh and Singh and Singh (1971), Agr*a*wal *et al.* (1964) and Tripathi (1978). In the present investigation depletion of K (2.4 m.e. 100 g^{-1}) and Ca (2.5 m.e. 100 g^{-1}) of the effluent affected soil in comparison with the control soil (4.8 m.e. 100 g^{-1} and 17.4 m.e. 100 g^{-1}, respectively in highly associated with the high percentage of Na in the soil (8.2 m.e. 100 g^{-1}) (Table II). A significant and negative correlation has also been obtained

TABLE I

Chemical properties of effluent and Well water (± = standard deviation)

Properties		Effluent	Well water
pH		9.5 ± 0.5	7.2 ± 0.5
Carbonate	(mg L^{-1})	101.3 ± 10.5	5.3 ± 1.6
Bicarbonate	(mg L^{-1})	586.7 ± 30.0	49.0 ± 10.4
Na	(mg L^{-1})	295.5 ± 28.5	7.3 ± 1.2
K	(mg L^{-1})	22.0 ± 5.5	2.5 ± 0.8
Ca	(mg L^{-1})	122.4 ± 10.5	95.0 ± 5.2
Mg	(mg L^{-1})	25.3 ± 2.8	24.3 ± 2.5
Nitrate nitrogen	(mg L^{-1})	14.5 ± 4.8	0.2 ± 0.1
Total N	(mg L^{-1})	138.5 ± 6.4	12.5 ± 3.8

TABLE II

Psysico-chemical properties of polluted and control soil
(± = standard deviation)

Properties		Polluted soil	Control soil
Porosity (%)		34.7 ± 4.2	48.5 ± 4.5
Water holding capacity (%)		15.3 ± 4.0	25.0 ± 2.5
	(m.e. 100 g^{-1})		
pH		9.4 ± 0.5	6.9 ± 0.2
Na	(m.e. 100 g^{-1})	8.2 ± 2.0	0.4 ± 0.1
K	(m.e. 100 g^{-1})	2.4 ± 0.2	4.8 ± 0.3
Ca	(m.e. 100 g^{-1})	2.5 ± 0.5	17.5 ± 2.6
Mg	(m.e. 100 g^{-1})	2.2 ± 0.6	2.2 ± 0.5
Nitrate	(mg L^{-1})	36.0 ± 6.5	24.0 ± 4.8
Total N	(mg L^{-1})	2020.0 ± 25.8	200.0 ± 18.0

for Na with K ($r = -0.752$) and Ca ($r = -0.824$) of the soil. Cation exchange capacity is found to be associated with Na of the soil. It shows negative and significant correlation with the Na of the soil ($r = -0.655$) (Table III). Singh (1972) and Tripathi (1978) have reported similar association of cation exchange capacity (CEC) with Na of soil. Porosity of effluent affected soil is found to be about 14% less than that of the control soil. This decrease in porosity percentage may be on account of deflocculation of clay particles in the presence of high Na content. Kelly (1963), Black (1968), Hesse (1970) and Tripathi (1978) have also pointed out that the high Na content adversely affects the physical properties of soil. It decreases the permeability and pore spaces. Clay particles fill up the porespaces between the soil blocks. Thus the high Na content (more than 15 ESP) appears responsible for the decrease in porosity which obviously is harmful for plant growth. The water holding capacity of effluent affected soil decreases about 20% of that of the control soil (Table II). Water holding capacity is directly related with the porosity percentage of the soil. Hesse (1970) has described the drastic change in physical properties of the soil by high Na content and has concluded that the soil particles shrink into a hard prismatic surface leaving very little space and thus the water holding capacity is reduced. The rise in pH (upto 9.5) is found to be associated with the increasing concentration of carbonate and Na in the soil. Higher percentage of soil carbonate is associated with the higher concentration of the carbonate and bicarbonate in the effluent. Total N content of soil (including organic and inorganic from) was recorded about ten times higher (Table II) than that of the control soil. It is on account of high N in the effluent. But nitrate and ammonium N did not show any marked increase in comparison with the control soil. Mostly the N is fixed in the form of inorganic N in such a soil which is nonavailable to the plants. Chapman and Liebig (1952) reported that nitrite accumulates in alkaline soil after application of high rates of ammonium fertilizers. Recent work has shown that ammonium inhibits the oxidation of nitrite by *Nitrobacter* species (The second stage

TABLE III

Correlation coefficients between characteristics of industrial effluents, soil properties germination percentage and mineral composition of plants

Correlation between	Coefficients (r)
Na of effluent and Na of soil	+0.795[b]
Na of effluent and K of soil	−0.852[b]
Na of effluent and Ca of soil	−0.882[b]
Na of effluent and Mg of soil	+0.325[a]
Na of soil and K of soil	−0.752[b]
Na of soil and Ca of soil	−0.824[a]
Na of soil and Mg of soil	+0.214[a]
Na of soil and C.E.e. of soil	−0.655[b]
Na of effluent and germination percentage	−0.642[b]
Na of soil and germination percentage	−0.653[b]
Na + Mg/Ca of soil and germination percentage	−0.851[b]
Na of effluent and Na percentage of plants	+0.952[b]
Na of soil and Na percentage of plants	+0.798[b]
Na of effluent and Ca percentage of plants	−0.385[a]
Na + Mg/Ca of soil and Ca percentage of plants	−0.682[b]
Na of soil and Ca percentage of plants	−0.842[b]

[a] Significant at 5% level.
[b] Significant at 1% level.

of nitrification) and suggested that the nitrite accumulation is likely to result from the application of high rates of ammonium or ammonium producing fertilizers to any soil which has an alkaline reaction.

Wheat plants grown in effluent affected soil showed higher percentage of Na (1.62%) than that of the control plants (0.7%) (Table IV). Sodium of effluent showed positive and significant correlation with the Na of soil and Na percentage of the plants, respectively, ($r = +0.795$ and $r = +0.952$) as set in Table III. From the same table it is also clear that Na of soil and positive significant correlation ($r = +0.798$) with the Na percentage of plants while it was negatively correlated ($r = -0.842$) with Ca percentage of plants. Similar findings have also been reported by Singh and Singh (1971) and Tripathi (1978).

Darra *et al.* (1970) have reported increase in Na content and decrease in Ca content of wheat plants irrigated with Na rich water. Similar findings are observed in the present work. Calcium of the plants grown in soil affected with Na rich effluent was less (0.72%) than that of the plants grown in control soil (0.89%) (Table IV). Calcium percentage of plants did not show significant correlation ($r = -0.385$) with the Na of the effluents as shown in Table III.

Germination percentage of wheat in effluent (Lab. condition) as well as in the effluent affected soil (field condition) was found to be lower than that of the control (Table V). Sodium of effluent was found to be negatively correlated ($r = -0.642$) with germination percentage. Present findings support the observation of Elgabaly and Wiklander (1949), Heimann (1958) and Tripathi (1978). In the present work

TABLE IV

Mineral composition of 7 days old Wheat seedling (% dry weight)

Minerals	Polluted soil plants	Control soil plants
Na	1.62 ± 0.24	0.71 ± 0.15
K	0.15 ± 0.02	0.75 ± 0.06
Ca	0.72 ± 0.08	0.89 ± 0.06
Mg	1.31 ± 0.21	1.05 ± 0.20

TABLE V

Germination percentage of Wheat (± = standard deviation)

Laboratory condition		Field condition	
Effluent	Well water	Polluted soil	Control soil
90 ± 2.0	98 ± 1.5	52 ± 4.2	86 ± 2.5

Na+Mg/Ca of soil showed negative correlation (r = −0.85) with germination percentage of wheat. Heimann (1958), Sing (1972) and Tripathi (1978) have also reported adverse effect of Na and Mg and favorable effect of Ca on the germination of seeds.

Exchangeable Na of the soil was found to be significantly (negative) correlated with the germination percentage (r = −0.65) as well as Ca percentage (r = −0.842) of the plants, where as the Na percentage of the plants showed significantly positive correlation (r = −0.682) with Ca percentage of plants. The present finding agrees with the results of Black (1968). Agrawal *et al.* (1964) have reported that Mg accumulates in plants growing in the Na carbonate rich soil with high ESP (45.4).

From the present observation it is concluded that the effluent discharged from Hari Fertilizer Factory contain higher concentrations of carbonate, bicarbonate and Na. Higher percentage of carbonate and Na is incorporated in the soil by effluent which results in the deficiency of K and Ca and reduction in physical properties i.e. porosity and water holding capacity. Ultimately they become responsible for the depletion in germination percentage and upset of the mineral composition of wheat.

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