

EFFECTS OF PAINT INDUSTRY EFFLUENT ON SOIL PRODUCTIVITY

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ABSTRACT

The impact of various dilutions (2.5, 5, 10, 25 and 50%) of paint industry effluent on physico-chemical properties of soil and the germination, growth and dry matter productions of corn (*Zea mays* L.) and rice (*Oryza sativa* L.) have been studied. The effluent was acidic and had low BOD and COD values because of its low content of suspended solid. It contained high concentration of calcium, medium concentrations of nitrogen, sodium, potassium, sulphate, chloride and low concentrations of phosphorus, magnesium and bicarbonate. The trace element like Mn, Ni, Cu, Zn and Pb were measured in the $\mu\text{g L}^{-1}$ level. On irrigation of soil with the effluent an increase in the water soluble salts, pH, electrical conductivity, cation exchange capacity, nitrogen, phosphorus potassium, sodium, calcium, magnesium and iron contents of the soil for effluent concentrations of 2.5, 5 and 10% were observed but all these parameters were found to decrease on treatment of the soil with the effluent concentration of 25% and above. The effluent of the lower concentrations (2.5, 5 and 10%) enhanced the growth of both crops. However, negative effects on seed germination, dry matter production and the yield of both crops were found for the effluent concentration of 25% and above.

INTRODUCTION

The paint industry in Bangladesh since its start around 50 years back is still growing faster than other industries because of the increasing demand of paints locally and internationally. Numerous local and foreign paint industrial units located mainly at Chittagong, Savar, and Gazipur districts of the country are on full swing operation at present. Various waste materials including solid and liquid wastes and volatile organic gases produced in these industries are being continuously released into the environment without or in few cases with partial treatment and affect the basic environmental components such as, soil, water and air^(1,2). As Bangladesh is criss-crossed by rivers, the wastewater discharged into the drains or directly into canals from these industries ultimately get mixed with the river water which subsequently contaminate the agricultural land during the rainy season or when used for irrigation purpose. Soil is an efficient purifying medium with a great capacity to receive and decompose wastes and

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pollutants of different kinds. It can filter out suspended matter, decompose organic matter by its microflora and precipitate out nutrients⁽³⁾. However, if the input of the pollutants exceeds the soil purifying limit, the effectiveness of soil microorganism activity is reduced considerably. As result, there occurs an adverse change in the soil physico-chemical properties which consequently affect the growth and development of the crop plants⁽⁴⁾.

The industrial wastewater is not merely harmful, it may also be useful for our agricultural purpose. There has been a wide use of this wastewater for irrigation of crops under controlled conditions⁽⁵⁻⁸⁾. The present study was undertaken to study the impact of paint industry effluent at varying concentrations on the chemical composition of an agricultural soil as well as evaluate its quality as an alternate means of irrigation for crop cultivation.

MATERIALS AND METHODS

Effluent collection: The effluent used for irrigation of crops in the present investigation was collected from the Berger Paints Bangladesh Ltd., Savar producing both water and solvent based paints. The major contaminants in the effluent streams results from the washing of paint and the resin reactors. The effluent is treated with lime and alum for coagulation of suspended matter and discharged into the environment through a drainpipe after separation of the solid mass. The final effluent after collection in a 20 litre-plastic container was kept undisturbed for about two hours for the settlement of some solid particles at the bottom of the container. The clear effluent from the top was poured into a plastic bucket and diluted as per the requirements to serve the purpose.

Irrigation of agricultural soil with effluent: The soil of 0-30 cm depth for effluent-irrigation was collected from a regularly cultivated agricultural land in Gazaria Upazila, Munshigonj district. The sampling area falls into the agroecological zone- old Himalayan piedmont plain with the dominant loamy and sandy soil texture⁽⁹⁾. This soil occurs on the Tista, Karatoya-Bargali, Jamuna, Meghna and Surma-Kusiyara and parts of old Himalayan piedmont plain, and old Brahamaputra and old Meghna esturine floodplains. The soil type is nocalcareous grey floodplain soil. The subsoil is near neutral to slightly alkaline in reaction. Varieties of crops are cultivated in the soil. The pit method was followed for soil collection. Five square pits, each 0-30 cm depth were dug using a steel-made spade on a land of about 1327 Sq. metres. A sufficient quantity of soil was collected from the sides of each pit. The collected sample from all pits were thoroughly mixed on the spot and carried in thick polyethylene bags. In order to study the impact of the effluent, experiments were carried out on this soil contained in earthen-ware pots having no leakage. Seven kilograms of soil was placed in each of the six 25 cm-diameter earthen pots (soil in each pot was 15 cm deep) and irrigated daily with 500 ml of different concentrations of effluents: 0, 2.5, 5, 10, 25 and 50% (V/V). Two other sets of six pots filled with the same amount of soil were used to grow corn and rice using the same amount of effluent concentrations. The irrigation was continued until the crops were matured for sampling. For control groundwater was used for irrigation.

Collection and preparation of plant and soil samples: When the plants were matured they were cut off at the base and data were recorded for their different parts per plant. Number and mass of seeds produced per plant were recorded. Root system of each plant were carefully taken out of the soil so that fine roots were not removed and washed free of soil by gently soaking it in a bucket of water. All plant samples were dried in an oven at 70°C to constant weight. The samples were ground to fine powder in a carbide mortar by a pestle and preserved in a desiccator until analysis.

The effluent-treated soil samples in the earthen pots were allowed to dry naturally. Each sample was then transferred to a plastic bowl and properly homogenized with a clean wooden spatula. An adequate amount of each sample was collected in a polyethylene bag and preserved in a desiccator until further processing. The samples were dried in an oven at 70°C overnight as per requirements of the methods where necessary before analysis.

METHODS OF ANALYSIS

Analysis of physicochemical characteristics and trace elements in soil: The soil samples were ground in an agate mortar with a pestle and passed through a sieve of 100 mesh. Using standard methods the samples were then analyzed for various physicochemical characteristics including pH, cation exchange capacity (CEC) and organic matter⁽¹⁰⁾ and available Na, K, Ca, Mg, Fe, electrical conductivity (EC) and water-soluble salts⁽¹¹⁾. The dry combustion method was used for organic determination. The available elements Na, K, Ca, Mg, Fe were first extracted through ammonium acetate (NH₄OAc) extraction method. The concentrations of these elements in the extracts were measured by flame AAS method. The available N and P were measured by methods developed by Fox & Piekielek⁽¹²⁾ and Nelson *et al.*⁽¹³⁾, respectively. An isotopic source-excited X-ray Fluorescence method was used for trace element analysis in soil samples⁽¹⁾.

Analysis of protein, carbohydrate and trace elements in plant seeds: The dry corn and rice seed samples were ground to fine powder in a carbide mortar with a pestle. The finely ground samples of both crop seeds were then digested and analyzed for total nitrogen content using Kjeldahl method. The protein content in corn and rice seeds was then calculated by multiplying the percentage in seeds by a factor of 6.25 and 5.95, respectively.

The total carbohydrate content in crop seeds was estimated by difference method. The calculation was done using the formulation: 100- (weight in grams [protein + fat + water + ash] in 100g of sample)⁽¹⁴⁾. Fat was determined by extraction with acetone under refluxing condition⁽¹⁴⁾. Trace elements in seeds of both crops were measured by XRF method⁽¹⁵⁾.

RESULTS AND DISCUSSION

The paint industry effluent used for irrigation of pot soil was analyzed for its various physicochemical characteristics and the results obtained by Jolly *et al* are shown in Table

1 as the average values of eight monthly samples⁽¹⁶⁾. The effluent samples for irrigation purpose and analytical work were collected simultaneously. The effluent was visually found to be almost clear. No odor could be detected in it. It was found to contain much dissolved solid and small amount of suspended solid. The Average BOD and COD values shown by effluent samples were 66 and 101 mg L⁻¹ respectively. The average ratio calculated from BOD₅ and COD values of effluent samples was 0.66 indicating that the effluents contained mostly biologically degradable substances⁽¹⁷⁾. The effluent was acidic and contained small amount of soluble N, P, Na, Ca, Mg, Cl⁻¹ and HCO₃⁻¹. For the disposal of industrial effluents into the irrigation land, the standard values for various physicochemical parameters of the effluents have been recommended by the Department of Environment, Bangladesh (DoE). According to DoE the permissible limits for pH, BOD₅ (20°C), COD, dissolved solid, suspended solid and chloride for effluents are 6.0-9.0, 100 mg L⁻¹, 400 mg L⁻¹, 2100 mg L⁻¹, 200 mg L⁻¹, respectively. It is evident from the effluent characteristic data as described in Table 1 that the values of pH, BOD, total solid and chloride are far below the DoE limits. The trace elements in the effluent samples were also measured and their concentrations were found to be low (Table 1). The only toxic element determined was Pb whose mean concentration was 20 µg L⁻¹ far below its DoE recommended limit (100 µg L⁻¹).

Table 1

Physicochemical Characteristic Values and Trace Element Levels of Paint Industry Effluents Collected from Berger Paints Bangladesh Ltd., Savar^a (the average value of 8 monthly samples)

Physicochemical Parameters	Results Obtained	Trace Elements	Concentrations (µg L ⁻¹)
Colour	Almost Clear	B	<10
Odor	No detectable odor	Cd	<4.5
pH	5.980±07	Cr	<4
EC	1.22±0.13 mS cm ⁻¹	Mn	25.84±2.54
Dissolved + Suspended solids	1244±82	Fe	30.47±2.21
Dissolved solid	1093±70	Ni	6.35±1.67
BOD	66±8	Cu	6.98±1.47
COD	101±8	Zn	59±7
Nitrogen	14.90±0.22	As	<10
Phosphorus	4.43±0.66	Pb	20.54±1.73
Na	46.38±2.81		
K	25.71±3.42		
Ca	558±78		
Mg	11.66±1.46		
Chloride	26.55±1.54		
Bicarbonate	5.63±0.65		
Sulphate	38.96±2.41		

^aThe values except for colour, odor, pH and EC are expressed in mg L⁻¹ otherwise mentioned for soluble constituents of the effluents. The contents of this table are the average of the physicochemical and trace element data reported by Jolly *et. al.* [Ref. 15].

The impact of an effluent on the soil depends on its concentration as well as on the levels and nature of its chemical constituents. Though the effluent from the standpoint of its inorganic chemical composition appeared not to be harmful, its direct use for irrigation of pot soil for crop cultivation was avoided as its organic pollutant levels were not known. In order to reduce any effect that might come from the organic pollutants, the effluent was diluted at different concentrations (0, 2.5, 5, 10, 25 and 50%) with groundwater and the pot soils were irrigated using these effluents during cultivation. The effect of different dilutions of Berger paints industry effluent on the chemical composition of pot soils without crops are presented in the Table 2. The analysis of original soil has shown values for water soluble salts, 149 mg kg^{-1} ; organic matter 1.97%; pH 7.0; electrical conductivity (EC) $233 \text{ } \mu\text{mhos cm}^{-1}$; cation exchange capacity (CEC) 9.5 meq/100g; N 5.8.3%; P 54.31 $\mu\text{g/g}$; Na 0.148 meq/100g; K 0.056 meq/100g; Ca 0.153 meq/100g; Mg .059 meq/100g; Fe 3.21 $\mu\text{g/g}$. The soil was moderately rich in organic matter and hence the medium cation exchange capacity⁽¹⁸⁾. It had medium electrical conductivity due to medium concentrations of most of the elements as mentioned above. If the effects of the effluent on the pot soil without crops are considered, changes in the values for water soluble salts, organic matter, pH, EC, CEC, N, P, Na, K, Ca, Mg and Fe of the original soil are observed (Table2). That is, all parameters showed upward trend for 0-10% effluent irrigated soils and downward trend for 25-50% effluent-irrigated soils. The increasing mineralization rate of organic matter and hence the more availability of nutrients in the soil irrigated with 0-10% effluents and the decreasing rate of mineralization of organic matter and hence the less availability of nutrients in the 25-50% effluent-irrigated soils might be responsible for these observations⁽¹⁹⁻²¹⁾. The pot soils with corn and rice crops were irrigated with various concentrations of the effluent and analyzed for parameters required (Tables 3 & 4). The pot soils without crop plants but irrigated with the same concentrations of effluent were found to show lower values for pH, EC and CEC and contain lower amounts of water soluble salts, N, P, Na, K, Ca, Mg and Fe than the soils of pots with crop plants. This is an indication for the uptake of these nutrients by the crop plants from the effluent-irrigated soils. The data given in Tables 3 & 4 showed that the rice plants took up more nutrients from the soil than those of corn plants during their growth⁽⁴⁾.

The germination of corn and rice seeds was tested using different concentrations of the effluent and the percentage of germination for seeds of both crops are given in Table 4. No variation was found in the percentage of germination of the two crops in the effluent concentration range of 2.5 to 10%. However, higher concentrations of effluent (25 to 50%) were found to increasingly reduce the germination rate.

Corn and rice plants grown on soil irrigated with the concentrations of 2.5-10% effluent showed increase in their heights, leaf areas, seed by weights, root dry weights, number of seeds, seed weights compared to the control plants. Plant height showed a maximum increase of 57% for corn and 14% for rice grown on soil irrigated with 10% effluent concentration. The corn leaf increased by 22% and the rice leaf by 11%. The increased growth response of the crop plants as well as the yield of both crops (number of

Table 2 and Table 3

Table 4 and Table 5

seeds per plant and the dry mass of seeds per plant) grown on soils irrigated with 2.5-10% effluent concentration can be attributed to the effluent's contributing of the nutrients to the pot soil and hence the availability of nutrients for their increased growth and yields. The uptake of some elements, i.e. N, K, Ca, Fe by the crop plants was checked. The concentrations of these elements withdrawn by the plants was found to be related with the effluent concentrations and hence the free nutrients added by the effluent to the irrigated soils (Table 6). Paint industry effluent may thus serve as a source of nutrients for plant growth. However, as the effluent concentration increased to 25% and above a reduction in plant height and leaf areas was recorded. The negative trend in plant growth at higher effluent concentrations (25% and above) is attributed to the interaction of Ca with the other nutrients. At pH above 7.2, due to the addition of high concentration of calcium from effluent to the soil, the additional "free" Ca is not absorbed onto the soil. Much of the free Ca forms nearly insoluble compounds with other elements making them less available⁽²²⁾.

The seed dry weight of plants grown on effluent-irrigated soil increased to a maximum of 20% in corn and 22% in rice at effluent concentration of 10%. The root dry weight also increased to 23% in corn and 24% in rice at the effluent concentration of 10% (Table 7). There appeared a positive relationship between the increments in seed and root dry weights. The crop yields increased on soil concentration of irrigated with low effluent concentration of 2.5 to 10% but decreased as the effluent concentration was raised to 25% and above. A positive yield response to low effluent concentration was reported earlier for these crops in several studies^(4,7).

The results of total protein and carbohydrate content in seeds of corn and rice grown on soil irrigated with effluent are given in the Table 8. The seed protein contents of corn grown on soil irrigated with the effluent concentrations of 0, 2.5, 5, 10, 25 and 50% were 7.22, 8.18, 8.21, 8.43, 6.34 and 6.14%, respectively. The respective values for rice were 4.98, 5.02, 5.36, 5.62, 4.63 and 4.49%. The maximum increase in seed protein content with the increase in seed protein content plant⁻¹ with respect to the control value were 40.44% for corn and 47.83% for rice grown on soil irrigated at the effluent concentration of 10%. However, the seed protein contents of both crops decreased compared to the control values at effluent concentration of 25% and above. The seed carbohydrate contents of seeds from crops grown at the effluent concentration of 0, 2.5, 5, 10, 25 and 50% were 80.62, 81.59, 82.51, 83.49, 78.02, 76.26% for corn and 81.85, 82.92, 84.49, 86.08, 80.82, 77.24% for rice respectively. In terms of the increase in seed content of carbohydrate compared to the control value, corn exhibited maximum increase of 24% and rice of 39% for the effluent concentration of 10%. But when the irrigation was carried out with the effluent concentration of 25 and 50%, the contents of carbohydrate reduced to 22 and 27% for corn and to 13 and 19% for rice. The increase in the protein and carbohydrate contents of seeds of both crops at the low effluent concentration of 2.5, 5 and 10% might be due to the facts that the nitrogen taken by the plants at their later stage of growth was transferred to the seeds^(8,23).

(Table 6)

(Table 7)

(Table 8)

CONCLUSION

It was found from this investigation that the irrigation of agricultural soil with 2.5%, 5% and 10% paint industry effluent enhanced the growth of crops increasingly compared to the water irrigation (control). The irrigation with 10% effluent was the best for this purpose and could fulfil the fertilizer requirements of crops. But a negative effect was observed from the irrigation with 25% and 50% effluent. Soil pH decreased with the increase in effluent concentration. Hence this acidic effluent may be suitable for fields with alkaline soils. This use of the effluent not only solve the disposal problem but also serves as an additional source of liquid fertilizer.

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REFERENCES

1. M. A. HOSSAIN, "Studies on the Heavy Metal Impact of Paint Industry Effluent on Surrounding Water, Aquatic Plant and Agricultural Soil," M Sc Thesis, Islamic University of Kushtia, Bangladesh, 2004.
2. P. M. BHABANI, "Treatment of Waste Water effluents generated due to the Use of Water Based Paints for removal of Toxic Metals and Organic Pollutants," Ph. D. Thesis, Jadavpur University, Calcutta, India, 1977.
3. G. G. ROBECK, J. M. COHEN, W. T. SAYERS, AND R. T. WOODWARD, *J. Wat. Pollut. Control Fed.*, **35**, 1225, 1963.
4. K. K. SING AND L. C. MISRA, *Water Air and Soil Pollut.*, **33**, 309, 1987.
5. E. W. STEEL AND E. J. BEG, *Sewage and Industrial Waste* **26**, 1325, 1954.
6. A. D. DAY, J. L. STRECHLEIN AND T. C. TUCKER, *J. Wat. Pollut Control Fed.*, **44**, 372, 1972.
7. M. AJMAL, M. A. KHAN, AND A. A. NOMANI, *Environ. Pollut.*, (Ser A) **33**, 97, 1984
8. R. SAHAI, N. SHUKLA, S. JABEEN AND P. K. SEXENA, *Environ. Pollut.*, (Ser A) **37**, 245, 1985.
9. M. S. HOSSAIN, *Soil Classification (With Special Reference to the Soils of Bangladesh)*, University of Dhaka, Dhaka, Bangladesh, 1st Edn., 1992, Chap. 9 (p. 371) and Chap. 8 (pp. 343-344).
10. EDWARD J. RUBINS, "Standard Methods of Chemical Analysis," Part B, Vol. 2, edited by Frank J. Welcher (Robert E. Krieger Publishing Co. INC., Huntington, New York), 6th Edn, 1975, Chap. 46 (pp. 2312328).
11. J. D. RHOADES AND D. KNUDSEN, G. A. PETERSON, P. F. PRATT AND R.B. OLSON AND ROSCOE ELLIS JR, "Methods of Soil Analysis," Part 2, edited by Page A L (Madison, Wisconsin, U S A), 2nd Edn, 1982, Chap. 10 (p. 170), Chap. 13 (p. 230), Chap. 17 (p. 308).
12. R. H. FOX AND W. P. PIEKIELEK, *Soil Sci. Spc. Am. J.*, **42**, 751, 1978.

13. W. L. NELSON, A. MEHLICH AND E. WINTERS, *Agronomy*, **4**, 153, 1953.
14. AOAC, Official Method of Analysis (AOAC, International, Arlington, Virginia, USA), 14th Edn, 1984.
15. M. ALI, "X-ray Analytical studies of Trace Elements in Food and Drinks: A Nutritional Assessment in Bangladesh," Ph. D. Thesis, Jahangirnagar University, Bangladesh, 1995.
16. Y. N. JOLLY, A. ISLAM, S. B. QURAIHI AND A.I. MUSTAFA, *Pak. J. Sci. Ind. Res.*, **49(2)**, 82, 2006.
17. J. TOLGYESSY, P. PITTEK AND J. PROUSEK, "Chemistry and Biology of Water, Air and Soil: Environmental Aspects, Studies in Environmental Science 53," edited by J. Tolgyessy, Elsevier Science Publishers, Amsterdam, the Netherlands, 1st Edn, 1993, pp. 224-232.
18. M. ALEXANDER, "Introduction to soil Microbiology," John Wiley and Sons, New York, 1961.
19. A. AJMAL, A. K. MUJAHID AND A. N. AZHAR, *Environ. Pollut.*, Ser A, **33**, 97, 1984.
20. O. IGBOUNAMBA, *Soil Eci.*, **113**, 394, 1972.
21. G. RAJANNAN AND G. OBLISAMI, *Ind. J. Environ, Hlth.*, **21**, 120, 1979.
22. A. SCOTT, "Calcium Basics," Spectrum analytic Inc, 1087 Janison Rd, Washington Court House, OH 43160, (800) 321-1562.
23. J. J. JONKER, *Stikstof*, **42**, 206, 1964.