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Short Communication

Evaluation of industrial effluents for reclaiming salt-affected soil and achieving economic crop productivity

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Abstract

Field studies were conducted to evaluate the industrial effluents (HCl and $CaCl_2$) for reclaiming salt-affected soils for economical crop production. The soil under test was saline-sodic and clay-loam in texture. Four treatments viz., HCl, $CaCl_2$, gypsum and control according to gypsum requirement were applied fifty days before sowing of wheat. Results showed significant increase in wheat yield and improvements in soil EC, pH and SAR by the application of these effluents. Increase in wheat yield was about 54, 96 and 117 % with gypsum, $CaCl_2$ and HCl, respectively. The post harvest analysis of soil samples showed that significant improvement in soil chemical properties was obtained with HCl followed by $CaCl_2$ and gypsum. Results showed that HCl was better in improving soil properties i.e. reduction in pH from 8.5 to 8.08, EC_e from 13.3 to 2.78 dS m^{-1}, SAR from 68.7 to 10.5 (mmol $L^{-1})^{1/2}$, Cl^{-1} from 146.2 to 25.7 meq L^{-1} and SO_4^{-2} from 120.5 to 18.6 meq L^{-1}.

Keywords: Salt-affected soils; Industrial effluents; Hydrochloric acid; Calcium chloride; Soil reclamation

Soil salinity is a world wide problem which causes reduction in crop yield on about 10 million hectares of the worlds irrigated land (Rhoades and Loveday, 1990). In Pakistan, about 14% of irrigated land is badly affected by salinity (Ghassemi *et al*., 1995) and the areas affected by different levels and types of salinity is about 6.3 million ha (Qureshi *et al*., 2008). The shortage of good quality canal water in our country is compelling the farmers to use brackish underground water for growing crops. The continuous recycling and reuse of saline-sodic groundwater causes an imbalance of salts in the root zone. These salt affected soils are not only saline but also impermeable, devoid of organic matter and biological activity and their physico-chemical characteristics have altered so that they have become unproductive. These soils are characterized by high pH, high exchangeable Na, deficient in soluble Ca and poor in soil physical conditions. About 60 percent of the salt-affected soils are sodic and much of this land is cultivated by small holders (Qadir *et al*., 2006).

The most appropriate reclamation procedure depends on the nature of ionic chemistry affecting the soil. Reclaiming sodic and saline sodic soils requires different approachs than saline soils and can considerably be more costly. These soils are reclaimed by increasing soluble calcium in the soil solution which replaces sodium from the exchange complex and physico-chemical properties of the soil are improved. Various amendments like gypsum (hydrated calcium sulfate), calcium chloride (Cardon and Mortvedt, 2000) and acids (HCl and H_2SO_4) can be used for amelioration and drainage improvement of such lands (Muhammad, 1990; Biggar, 1996 and Sharma *et al*., 1996). Being a cheaper source of calcium, gypsum is most commonly used in Pakistan but it is moderately soluble in water. It requires about 1 acre-foot of water to dissolve one ton gypsum. Precipitation of calcium as $CaCO_3$ in the presence of sodium carbonate in soil solution further aggravates the situation (Rafique, 1990) by reducing the availability of soluble Ca^{2+} to replace Na^+, whereas calcium chloride, a source of highly soluble calcium, is fast acting but too expensive to use as soil amendment (Cardon and Mortvedt, 2000). In Pakistan, calcium chloride is not expensive as it is generated as a waste effluent by Sitara Chemical Industries Ltd., Faisalabad, and Ithad Chemical Industries Kala Shah Kaku during the manufacturing of sodium hydroxide from sodium chloride by electrolysis. Hydrochloric acid is a byproduct of both these industries and has limited commercial utilization in our country. The industries waste the major amount of HCl by neutralizing it with marble stones, which is drained out as calcium chloride and creates environmental pollution. Keeping in view the situation, a field experiment was conducted to study the relative efficiency of gypsum, HCl and $CaCl_2$ for reclaiming salt-affected wastelands to achieve economic productivity of wheat. Gypsum application improved grain yield in wheat (Rashid *et al*., 2008) and its application at full rate gave 14.3 % increase in grain yield than that at half rate (Haq *et al.*, 2007).

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The present field experiment was conducted to test the effect of industrial effluent (HCl and $CaCl_2$) on salt-affected waste lands. The tube-well water used for alternate irrigation was analyzed for pH (7.6), EC_e (1.5 dS m^{-1}), SAR [15.05 (mmol $L^{-1})^{1/2}$] and RSC (7.25 meq L^{-1}). The industrial effluents, provided by the Sitara Chemical Industries Ltd., Faisalabad, Pakistan, were analyzed for HCl concentration and calcium chloride content by titrimetric methods as proposed in Hand Book-60. The effluents were also analyzed for heavy metals (Table 1) by Inductively Plasma Spectrometer (ICP), HITACHI, Japan. The soil samples were collected from the experimental site and were analyze for pH_s (8.5), EC_e (17.4 dS m^{-1}), SAR [68.7 mmol $L^{-1})^{1/2}$], Cl^{-1}(146.2 meq L^{-1}), SO_4^{-2} (120.5 meq L^{-1}) and soil texture (clay loam). Treatments of effluents (according to gypsum requirement, 6.8 tons $acre^{-1}$) were applied fifty days before sowing and three consecutive irrigations (with 15 days interval) were given to the field in order to leach down the salts. The experiment consisted of four treatments [i.e. effluent 1 (HCl, 33%), effluent 2 (Calcium chloride, 21.7%), gypsum and control], five replications and contained randomized complete block design (RCBD). Wheat variety Bhakhar was grown in the experimental farm area of NIAB, Faisalabad and harvested at maturity. Before sowing, the soil was deep ploughed, leveled and 90 kg P_2O_5 ha^{-1} and urea were applied as a basal dose in two splits, each dose consisted of 40kg N ha^{-1} imposed at tillering and flowering. The seeds of wheat variety Bhakhar were sown in early November and during the course of study, all the plots were irrigated six times with tube-well water and canal water alternatively. The yield of wheat obtained was calculated on kg ha^{-1} basis. After harvesting the crop, soil samples were again taken and analyzed for the same above-mentioned parameters and effect of HCl, $CaCl_2$, gypsum and control was estimated according to the reduction in pH, SAR. EC_e etc. The collected data was statistically analyzed and means were compared according to Duncan's New Multiple Range Test (Steel and Torrie, 1984).

The physico-chemical analyses of the soil showed that it was clay loam in texture and highly salt affected having ECe of 17.4 dS m^{-1} and pH 8.5. The SAR of the soil was very high [68.7 (mmol $L^{-1})^{1/2}$]. It also contained high concentration of Cl^- and SO_4^{--}. The data indicated that before the application of the gypsum and industrial effluents (HCl and $CaCl_2$) the soil was unfit for crop cultivation. Tube-well water used for alternate irrigation was of high EC, SAR and RSC. Whereas heavy metals in both the effluents (Table 1), were within limits. The application of HCl and $CaCl_2$ tremendously improved the soil properties (Table 2) as compared to gypsum and control. Maximum improvement in soil chemical properties were found with the application of HCl, which reduced ECe from 17.4 to 2.78 dS m^{-1} and pH from 8.5 to 8.08 similarly reduction in SAR [from 68.7 to 10.5 (mmol $L^{-1})^{1/2}$], Cl^- (from 146.2 to 25.7 meq L^{-1}) and SO_4^{--} (from 120.5 to 18.6 meq L^{-1}) was estimated (Table 2).

The results indicated that application of HCl and $CaCl_2$ significantly enhanced the grain yield (Table 3). The maximum grain yield (2565 kg ha^{-1}) was obtained in the plots treated with HCl followed by $CaCl_2$ (2313 kg ha^{-1}) and gypsum (1820 kg ha^{-1}) while, minimum in control (1180 kg ha^{-1}) and the cost benefit ratios of inputs were 1:1.46, 1:1.42 and 1:1.38 while, yield wise it was 1:2.17, 1:1.96 and 1:1.54, respectively, as compared to control. It has been observed that calcium deficiency is associated with sodicity of soil and influenced by plant water status, addition of Ca^{++} directly to soil solution or through foliar application or as amendment in irrigation water could be useful to mitigate damage to the crop (Feigin, 1985; Khan and Ashraf, 1988). Calcium is an essential element and plays an important role in maintaining cell integrity and membrane permeability (Ashraf *et al.,* 1992). By decreasing Na^+ in plant tissue, Ca^{++} enhances pollen formation and growth and activates a number of enzymes for mitosis, division and elongation of cell (Mater *et al.,* 1975; Ashraf *et al.,* 1998). It may be important for protein synthesis and carbohydrate transportations (Hawker *et al.,* 1974; Khan *et al.,* 1995). Its presence may serve to detoxify the action of heavy metals in the plant. The heavy metals were present in very minute amount (Table 1) in the effluents (HCl and $CaCl_2$) used for amendment. Therefore, they may not be toxic if transported in the plants and the grains produced cannot cause any heavy metal hazards. Faisalabad soil contains Cr, 24.1; Zn, 44.5; Pb, 11.6; Cd, 0.21; Ni, 36.2; and Cu, 22.8 mg kg^{-1} (Jeroen *et al.,* 2010) and the effluents contained heavy metals in ppm or fraction of ppm, therefore, with the addition of effluents in the soil under study the increase in their concentration would be negiligable. On the other hand, some of the heavy metals present in the effluents could have been utilized as micronutrients which promoted the plant growth and increased the grain yield. The present finding indicated that amendment of HCl and $CaCl_2$ increased the crop yield which may also be due to the reduction in Na^+/Ca^{++} ratio and is supported by Aslam *et al.* (1993), they also reported that lowering Na^+/Ca^{++} ratio by the addition of Ca^{++} to saline soil increased growth and yield of rice, however, Yeo and Flowers (1985) found no effect of Na^+/Ca^{++} ratio in saline culture solution on the growth or Na^+ concentration of rice shoots. Muhammad *et al.* (1987) advocated that decreasing Na^+/Ca^{++} ratio of saline solution caused improvement in growth of shoot and root of rice. Amount of HCl and $CaCl_2$ to be applied depends upon the soil analysis: greater the quantity of sodium in soil, larger will

Table 1. Heavy metals found in the effluents used for soil reclamation

Metals	Cr	Zn	Pb	Cd	Ni	Fe	Mo	Cu
Concentration (mg L^{-1}) in effluent-1 (HCl)	3.3	0.9	0.7	0.25	0.8	40.0	0.3	0.9
Concentration (mg L^{-1}) in effluent-2 ($CaCl_2$)	3.5	1.2	0.7	0.2	0.8	62.0	0.3	1.0

Results are means of four replicates

Table 2. Soil chemical characteristics after harvesting wheat crop

Treatment	**pH**	**ECe (dS m^{-1})**	**SAR (mmol L^{-1})$^{1/2}$**	**Cl^- (meq L^{-1})**	**SO_4^{--} (meq L^{-1})**
Gypsum	8.26 bc	9.85 b	29.6 b	38.3 b	65.8 b
$CaCl_2$	8.12 a	2.97 a	12.9 a	30.6 a	21.4 a
HCl	8.08 a	2.78 a	10.5 a	25.7 a	18.6 a
Control	8.41 c	13.3 c	46.1 c	86.4 c	94.7 c

Means followed by similar letter(s) do not differ significantly according to DMR test at 5% level of significance

Table 3. Effect of gypsum, HCl and $CaCl_2$ on plant height, number of spikes, number of grains spike^{-1} and grains yield of wheat under reclaimed saline-sodic soil conditions

Treatment	**Plant height (cm)**	**No. of Spikes m^{-2}**	**No. of grains spike^{-1}**	**Grain yield (kg ha^{-1})**	**Increase in grain yield (%)**
Gypsum	81.3 c	197 c	42 b	1820 c	54.24
$CaCl_2$	93.0 ab	210 b	51 ab	2313 b	96.02
HCl	94.2 a	242 a	54 a	2565 a	117.37
Control	62.5 d	176 d	30 c	1180 d	-

Means followed by different letter differ significantly according to DMR test at 5% level of significance

be the amount of Ca^{++} required as a nutrient to improve Ca / Na ratio of the soil. The present study revealed that HCl and $CaCl_2$ (industrial effluents) have improved the soil properties (Table 2) in addition to increase in wheat yield (Table 3).

Conclusion

Hydrochloric acid reacted with calcium carbonate of the soil that produced calcium chloride (100 % soluble in water) therefore the whole Ca^{++} became available which replaced Na^+ from the exchange complex resulting in development of soil aggregates and the toxic Na^+ and Cl^- leached down from the root zone. It is, therefore, concluded that both the industrial effluents (HCl and $CaCl_2$) can safely be utilized for reclaiming saline-sodic soils and achieving economical production for wheat crop.

References

Ashraf M.Y., S.A. Ala and A.S. Bhatti.1998. Nutritional imbalance in wheat (*Triticum aestivum* L.) genotypes grown under soil water deficit. *Acta Physiologiae Plantarum* 20: 307-311.

Ashraf, M.Y., A.H. Khan and A.R. Azmi. 1992. Cell membrane stability and its relation with some physiological processes in wheat. *Acta Agronomica* 41(3-4): 183-191.

Aslam, M., R.H. Qureshi and A. Ahmad. 1993. A rapid screening technique for salt tolerance in rice (*Oryza Sativa* L.) Plant ans Soil 150: 99-107.

Biggar, J.W. 1996. Regional salinity, sodicity issues in Punjab-Pakistan. Report IIMI, Lahore, Pakistan. pp. 1-26.

Cardon, G.E. and J.J. Mortvedt. 2000. Soil and Crop Sciences. Cooperative Extention Soil Specialist, Colorado State University 8/94. online: http://www.Colostate.Edu/Dept/coopExt/PUBS/CROP/00503.html [Accessed 02/05/2010]

Feigin, A. 1985. Fertilizer management of crops irrigated with saline water. *Plant and Soil* 82: 285-299.

Ghassemi, F., A.J. Jakeman and H.A. Nix. 1995. Salinization of land and water resources. Human causes, extent, management and case studies. University of New South Wales. Sydney.

Haq, I, B. Muhammad and F. Iqbal. 2007. Effect of gypsum and farmyard manure on soil properties and wheat crop irrigated with brackish water. *Soil and Environment* 26(2): 164-171.

Hawker, J.S., H. Marschner and W.J.S. Downton. 1974. Effects of sodium and potassium on starch synthesis in leaves. *Australian Journal of Plant Physiology* 1: 491-501.

Jeroen H.J.E., R.W. Simmons and W.V.Hoek. 2010. Wastewater Use in Pakistan: The cases of Haroonabad and Faisalabad. IWMI., South-East Asia Regional Office, Bangkok, Thailand. Online: http://www.idrc.ca/en/ev-68336-201-1-DO OPIC.html Accessed [2/05/2010]

Khan, A.H., M.Y. Ashraf, S.S.M. Naqvi, B.Khanzada and M. Ali. 1995. Growth, ion and solute contents of sorghum grown under NaCl and Na_2SO_4 salinity stress. *Acta Physiologiae Plantarum* 17: 261-268.

Khan, A.H. and M.Y. Ashraf. 1988. Effect of sodium chloride on growth and mineral composition of sorghum. *Acta Physiologiae Plantarum* 10: 259-264.

Mater, Y.M., M. Doring and H. Marschner. 1975. Auswirkungen von NaCl and Na_2SO_4 auf substanzbildung, Minerals toffgehalt und inhalts-stoffe bel spinet und salat. *Pflanzenernaehv Boenkde* 138: 295-307.

Muhammad, S. 1990. Salt-affected and water logged soils in Pakistan. p. 21-37. *In:* Soil Salinity and water Management; Proceeding Indo-Pak Workshop on Soil Salinity and Water Management. February 10-14, 1990. Islamabad, Pakistan.

Muhammad, S., M. Akbar and H.U. Neue. 1987. Effect of Na^+/Ca^+ and Na^{++}/K^{++} ratios in saline culture solution on growth and mineral nutrition of rice (*Oryza sativa* L.) *Plant and Soil* 104: 57-62.

Qadir, M., A.D. Noble, S. Schubert, R. J. Thomas and A. Arslan. 2006. Sodicity-induced land degradation and its sustainable management: Problems and Prospectives. *Land Degradation and Development* 17: 661-676.

Qureshi, A.S., P.G. McCornick, M. Qadir and Z. Aslam. 2008. Managing salinity and waterlogging in the Indus Basin of Pakistan. *Agricultural Water Management* 95: 1-10.

Rafique, M. 1990. Genesis of main kinds of salt-affected soils in Pakistan. p. 55-64. *In:* Soil Salinity and water Management; Proceeding Indo-Pak Workshop on Soil Salinity and Water Management. February 10-14, 1990. Islamabad, Pakistan.

Rashid, M., M.N. Iqbal, M. Akram. M. Ansar and R. Hussain. 2008. Role of gypsum in wheat production in rainfed areas. *Soil and Environment* 27(2): 166-170.

Rhoades, J.D. and Loveday. 1990. Salinity in Irrigated Agriculture. p. 1084-1142. *In:* Irrigation of Agricultural Crops. Stewart, B.A. and D.R. Nielson (eds.). CSSA and SSSA, Madison, WI. USA.

Sharma, R.D., S. Ali and G.B. Plant. 1996. Effect of soil amendments on rice yield. IRRI. Notes. 21(2-3): 72-73.

Steel, R.G.D. and J.H. Torrie. 1984. Principles and Pcedures of Statistics: A biometrical approach. 3rd Ed. McGraw Hill Book Co. Inc., New York.

Yeo, A.R. and T. J. Flowers. 1985. The absence of an effect of the Na^+/Ca^{2+} ratio on sodium chloride uptake by rice. *New Phytologist* 99: 81-90.