The Journal of Animal & Plant Sciences, 28(1): 2018, Page: 215-221
ISSN: 1018-7081

THE IMPACT OF SUGAR MILLS' EFFLUENTS ON SOIL QUALITY

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ABSTRACT

The industrial pollution, like many other developing countries of the world, is the crucial problem of Pakistan. The current study was aimed to ascertain the impact of pollutants added by effluents from sugar mills in Rahim Yar Khan Region of Punjab province in Pakistan. The electrical conductivity (EC) and pH are the basic parameters to evaluate the soil pollution. To this end, the soil samples were collected from the fixed sites labelled as site I, II, III, IV and V, spaced at fixed distances. Site I was taken as control. From each site the soil samples were taken from the depths ranging between 6 and 48 inches from all the four sugar mills. The samples were examined as per universally used protocols at the regular intervals from May 2007 to April 2008. The results showed the mean highest level of soil ECat Humza Sugar Mills 17.51 dSm^{-1} (above the standard permissible limits 4.12-8.1 dSm^{-1}) followed by 9.82 dSm^{-1} at JDW (Jamal Din Wali) Sugar Mills. On the other hand, the highest value of pH 9 was recorded at JDW sugar mills at 24 inches deep soil samples. But the soil samples collected from 6-18 inches sediments showed the pH ranging between 8.7 at United Sugar Mills and 10.9 at Ettehad Sugar Mills. The findings established that two out of four sugar mills were adding pollutants to the crops cultivation fields via canal water that was being contaminated primarily by effluents. It was hypothesized that the sugar mills in the study area might be engaged in polluting the habitats in their vicinity.

Key words: Sugar Mills, Pollution, Soil Electrical Conductivity (EC), Soil pH.

INTRODUCTION

The industrial pollution has increased world over and is getting bad to worst along the time (Rosenstock, 2003). It is widely accepted that the humankind is more vulnerable to pollution in the present age than ever has been in the near and remote past (Schell *et al.,* 2006). Evidences show that pollution is not only wide spread but also the major source of human health issues (Fereidoun *et al.,* 2007). The health and productivity of a habitat particularly harnessed for agriculture depends upon the health and suitability of irrigation water (Kimani, 2007; Fereidoun *et al.,* 2007). The aggravating trend of human health problems is associated with the pollution (Kimani, 2007) that may be natural or anthropogenic in nature (Fereidoun *et al.,* 2007) particularly due to industrialization (Mishra, 2003). In Pakistan out of total 6634 registered industries, 1228 have been found potentially polluting the environment (Sial *et al.,* 2006). Sugar mills add to the economy of the agricultural countries (Sharif *et al.,* 2014) such as Pakistan where sugar cane contributes 16% of all the staple crops (Sharif *et al.,* 2014). In 2012-13 sugarcane was grown over 1.124 mha providing the raw material for 81 sugar mills of Pakistan (Khushk *et al.,* 2008).

The most important determinants that influence the yield of sugar cane crop are water and soil. The upper layer of land which hosts the roots of plants called soil consists of various minerals, organic matters, water and air (Kopaska-Merkel, 2000). The soil characters such as pH and EC are closely related with the water which is supplied to it, naturally or artificially (Kopaska-Merkel, 2000). The health and productivity of a habitat depends on the appropriate availability of nutrients to the plants. The availability of nutrients is influenced by EC (Ashraf *et al.,* 2010) and pH (David *et al*., 1996) collectively. It is widely accepted that the soil structure, its chemical composition, EC and pH are the most important determinants of the productivity of habitat by influencing the availability of ions to plants. If, for example, the pH is elevated above 7.5 the soluble Ferrous are oxidized to the insoluble Ferric ions. This insolubility of Fe ions leads to a deficiency of iron to flora of the habitat (Kopaska-Merkel, 2000).The vital characters of water namely pH, EC, oxygen contents, total suspended salts (TSS), nitrates nitrites and a broad spectrum of cations as well as anions are disrupted by sugar mills effluents. The polluted irrigation water increases the toxicity of soil particularly by adding the heavy metals and trace elements (Liu *et al*., 2016). As a result the soil experiences the changes in the salinity level, structure and texture leading to the detrimental effects on crops (Kopaska-Merkel, 2000) and thus on the economy of the farmers.

Soil salinity is generally characterized by the total dissolved solids (TDS) in water or electrical conductivity (EC) of soil solution (Zhang *et al.,* 2005). The soil EC is closely associated with the EC of irrigation water. Therefore, any change in the EC of irrigation water leads to the changes in the soil EC. If, for instance, irrigation water contains higher concentration of sodium ions, the sodium ions will not only increase the EC of soil but also will cause poor leaching capacity soil (Ashraf *et al.,* 2010). In the same way the concentration of other ions in soil also might have a marked effect on the soil EC and subsequently the productivity of habitat.

Sugar mills constitute the second largest industry with a major impact on the economy of Pakistan. On the other hand, there is little data published evaluating the environmental impact of sugar industry of Pakistan. The authors of present study hypothesized that the sugar mills, like other industries, might be the polluting the soil of the nearby agricultural areas. Therefore, keeping in view the importance of soil for agriculture in Pakistan the authors selected the current study area where four out of eighty one sugar mills of Pakistan were working as operational units. This study would provide an insight for the further research to investigate the health features of habitat.

MATERIALS AND METHODS

Study area: All the sugar mills included in the current investigation lie in the following quadrants: a) JDW Sugar Mills, N28.41.40.4″, E70.44.41.9″; b) Humza Sugar Mills, N28.41.40.5″, E70.44.42.1″; c) Ettehad Sugar Mills, N28.34.39.9″, E70.19.18.7″; d) United Sugar Mills, N28.15.01.1″, E70.02.25.5″

Soil sampling: For characterization of soil profiles the samples were taken from selected sites fixed as site I, II, III, IV and V within 25 meter horizontal extent along the effluent site of each sugar mills unit. For vertical leaching of pollutants soil samples were taken from the depth of 6, 12, 18,24 and 36 inches employing the iron augur.

Study period: The present study was conducted during the period May2007and April 2008, on the monthly basis. The average values pH and EC obtained during operational and non-operational months of sugar mills were compared.

Samples preparation: Soil samples were dried at room temperature each sample was ground to 2mm particles before the chemical analysis.

Soil samples analysis: The pollutant contents level in the soil samples were estimated by determination of the following chemical characteristics:

Electrical conductivity (EC): Soil EC was evaluated by employing the digital Conductivity Meter (Model OSK 6607, CM-30 ET).

pH: Soil pH was evaluated by using digital CD 640 digital pH meter.

Control measures:
a) The samples were not taken from the freshly irrigated fields.
a) Pebbles and pieces of stones were separated from the soil samples.
c) Samples were applied the chemical tests within 24 hour after collection from the field.

The data taken during 12 months study period were analyzed and the mean values of different sediments were compared at each selected site.

RESULTS AND DISCUSSION

Pakistan is facing not only the shortage of water fit for human consumption but also the issues of contamination of irrigation canals by effluents from various industrial entrepreneurs (Khan, 2004) that are subsequently causing the corruption of soils used for agriculture. According to the Pakistan Agriculture Department Manual for analysis of water and soil, 2007, the permissible limit of EC for water is 1150 uScm^{-1} and for soil it is 4.12-8.1 dSm^{-1}. In the present study, the overall maximum value of water, observed at the rate of EC 1443 uScm^{-1}, was found above the permissible limits at JDW Sugar Mills (Figure 2). The salinity increased by effluents from JDW sugar mills added in canal water showed a marked influence on the soil of adjacent areas (Figure 1). Normally the plants get the nutrients from 18 to 24 inches deep soil sediments. In the current findings the level of soil EC was observed at value 9.82 dSm^{-1} at 18 inches deep sediments in the month of June at JDW Sugar Mills. It was observed that the EC further increased horizontally at site V 25 meter far from the effluent at the rate of 14.20 dSm^{-1} in 36 inches soil sediments (Figure 2). However, at 48 inches deep sediments' soil experienced the EC load at site V with a value 12.67 dSm^{-1} in comparison with all the other sites (Figure 2).

Naturally, the increased evaporation due to elevated mercury in the summer months causes the increase in the water EC (Mezurek *et al.,* 2012). On the other hand, the soil EC increases during winter season, perhaps, as a consequence of higher moisture (Mezurek *et al.,* 2012). But the current findings showed the soil EC levels lower while the JDW unit was operational. While it went higher during the non-crushing period of the mills (Figure 2), justifying the hypothesis that water of the canal added the pollutants by effluents of JDW sugar mills during winter operational season. The results were quite supporting the hypothesis that the effluents from the mills were boosting the EC of soil of habitat (Figure 1).

The effluents from Humza Sugar Mills were disposed into the saline canal that leads to the brackish water lakes called 'dhands' in Cholistan (Ahmad and Tasawar, 2015). The water of saline canal, fed by the tube wells working under Salinity Control and Reclamation Program (SCARP), already having a higher level of EC, hence further increased by addition of pollutants from Humza Sugar Mills unit. This is the reason that the soil samples taken from 18 inches deep sediments showed the EC level at 17.51dSm^{-1} (Figure 3) during the summer months probably due to the seepage of ions added by effluents in the winter season starting in October every year. Soil EC went increasing and showed its elevating trends as 24.96dSm^{-1} at the same sediments at site III (Figure 3). It went to the highest level 25.67 dSm-1 in the soil samples taken from site V (Figure 3) confirming the hypothesis that the effluents from sugar mills were changing the soil profile composition and texture detrimental for the natural habitat as well as cultivated farms.

The soil samples collected from United Sugar Mills and Ettehad Sugar Mills at 12 inches sediment showed, more or less, the EC rates above the permissible level (EC 4.1—8.1 dSm^{-1}) according to the soil quality standards of Agriculture Dept. GOP (2007) throughout the year (Figure 4 & 5) justified with the reason that both United Sugar Mills and Ettehad Sugar Mills deposited the effluents in the deep ponds rather than irrigation canals.

The sugar mills included in the current study were found destroying the quality of water that might be according to Ashraf *et al.* (2010) causing the adverse changes in the characteristics of soil particularlyits pH. The dynamic changes in the soil pH directly affect nutrient availability to the flora of habitats. If for example, the pH is low or acidic, it causes higher availability of some other soil nutrients for plants such as calcium, phosphorus and magnesium. Conversely, the alkaline pH makes some ions such as phosphorus less available to plants. However, the fresh water canals through summer irrigation and monsoons leave the better effects of productivity of soil (Khan and Ali, 2003). According to present findings, generally the pH remains alkaline in the soil fed by the canal receiving the effluents from JDW Sugar Mills. The highest values of pH 9, however, were recorded at 24 inches deep soil samples taken during the months of May to September (Table 1). This alkalinity, as it comes through polluted canal, must be hazardous for fish life as the desirablerange of pH because fish and other aqueous fauna is 6-9 (Boyd, 1979); and subsequently rendering the soil unsuitable for crop farming.

In soil samples collected from Humza Sugar Mills, the highest values of pH 9.1 were found in the months of June and July at 18 inches sediments and in September at 30inches depth (Table 2). As the Humza Sugar Mills is continuously adding the pollutants in the water course ending at some 'tobas' in Cholistan (Ahmad and Tasawar, 2015) might be harmful for the Siberian migratory species of birds (Ahmad and Tasawar, 2015).

However, the effluents discharged from United Sugar Mills and Ettehad Sugar Mills both were accumulated in the dumping pans. The pH values in the soil samples taken from United Sugar Mills and Ettehad Sugar Mills were 8.7 and 10.9 in the upper sediment from 6-18 inches level (Table 4 &5). The highest pH values recorded at these two mills is justified taking into consideration the fact that the effluents are not drained by the canal water. Nevertheless, the habitat was less harmed by these two sugar mills as compared with JDW and Humza Sugar Mills.

In the light of present findings, two out of four sugar industry units were continuously engaged in polluting the agricultural lands as well as natural habitats by boosting the soil EC and soil pH that consequently harm the texture as well as structure of soil. There is dire need to ameliorate the effluent recycling issues before the destruction of crop lands of study area, which harbor the different breeds of sheep and goat farms (Ahmad and Tasawar, 2016), causing the economic losses to the human population of the area in particular and the exchequer of the Pakistan in general. It further suggested that the agricultural department of Pakistan and authorities must address the issue.

Table 1. Monthly variation of soil pH at JDW Sugar Mills, Rahim Yar Khan

Depth	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	March	April
6"	8.4	8.4	8.4	8.4	8.4	8.3	8.3	8.4	8.1	8.1	8.2	8.3
12"	8.6	8.8	8.5	8.5	8.5	8.9	8.7	8.5	8.2	8.3	8.3	8.4
18"	8.5	8.5	8.5	8.5	8.5	8.6	8.6	8.6	8.1	8.7	8.6	8.5
24"	9.0	9.0	9.0	9.0	9.0	8.5	8.8	8.9	7.9	8.0	8.1	8.4
30"	7.9	8.5	8.0	8.0	8.5	8.6	8.2	8.1	7.7	8.2	8.2	8.2
36"	8.4	8.4	8.5	8.0	8.0	8.4	8.3	8.4	7.6	7.9	8.1	8.2
48"	8.2	8.5	8.5	8.6	8.5	8.4	8.5	8.2	7.8	7.9	8.0	8.1

Permissible Limit of pH: 6.5—8.5 (Agriculture Dept. GOP, 2007)

Table 2. Monthly variation of soil pH at Humza Sugar Mills, Rahim Yar Khan

Depth	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	March	April
6"	8.8	8.8	8.7	8.6	8.8	8.7	8.6	8.8	8.8	8.8	8.7	8.7
12"	8.9	8.9	8.8	8.8	8.5	8,7	8.2	8.5	8.5	8.8	8.6	8.6
18"	8.8	9.1	9.1	8.8	9.0	8.8	8.8	8.7	8.5	8.6	8.7	8.6
24"	8.2	8.3	8.4	8.4	8.4	8.8	8.4	8.5	8.5	8.5	8.3	8.5
30"	8.8	9.0	8.8	9.0	9.1	8.8	8.5	8.4	8.2	8.4	8.5	8.5
36"	8.3	8.4	8.5	8.7	8.8	8.8	8.5	8.3	8.2	8.2	8.2	8.3
48"	8.6	8.6	8.6	8.7	8.8	8.5	8.4	8.3	8.8	8.4	8.4	8.5

Permissible Limit of pH: 6.5—8.5 (Agriculture Dept. GOP, 2007)

Table 3. Monthly variation of soil pH at United Sugar Mills, Rahim Yar Khan

Depth	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
6"	8.5	8.6	8.6	8.4	8.5	8.5	8.4	8.5	8.5	8.6	8.6	8.6
12"	8.5	8.7	8.6	8.6	8.7	8.6	8.1	8.2	8.3	8.3	8.4	8.4
18"	8.6	8.5	8.4	8.7	8.8	8.7	8.6	8.1	8.2	8.2	8.5	8.5
24"	8.3	8.3	8.2	8.4	8.5	8.4	8.3	8.2	8.3	8.3	8.2	8.3
30"	8.2	8.2	8.1	8.3	8.4	8.5	8.4	8.2	8.1	8.2	8.3	8.3
36"	8.2	8.3	8.2	8.3	8.3	8.2	8.5	8.7	8.6	8.6	8.5	8.3
48"	8.3	8.3	8.2	8.2	8.2	8.1	8.4	8.8	8.7	8.7	8.4	8.4

Permissible Limit of pH: 6.5—8.5 (Agriculture Dept. GOP, 2007)

Table 4. Monthly variation of soil pH at Ettehad Sugar Mills, Rahim Yar Khan.

Depth	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
6"	9.8	10.9	10.5	9.5	9.9	9.7	9.8	9.9	9.9	9.9	9.4	9.6
12"	9.9	9.0	9.5	8.7	8.9	9.6	9.7	9.8	9.8	9. 9	9.3	9.4
18"	9.8	10.1	10.0	9.8	9.9	9.9	9.9	9.7	9.8	9.8	9.5	9.6
24"	10.0	10.1	9.7	9.2	8.8	8.7	9.6	9.8	9.7	9.7	9.7	9.9
30"	9.8	10.0	9.9	9.0	9.7	9.6	9.8	9.8	9.7	9.6	9.8	9.9
36"	9.8	9.9	9.2	8.6	8.8	9.4	9.6	9.7	9.9	9.9	9.7	9.8
48"	8.9	9.1	8.9	8.8	9.2	9.5	9.5	9.4	9.5	9.5	9.1	9.0

Permissible Limit of pH: 6.5—8.5 (Agriculture Dept. GOP, 2007)

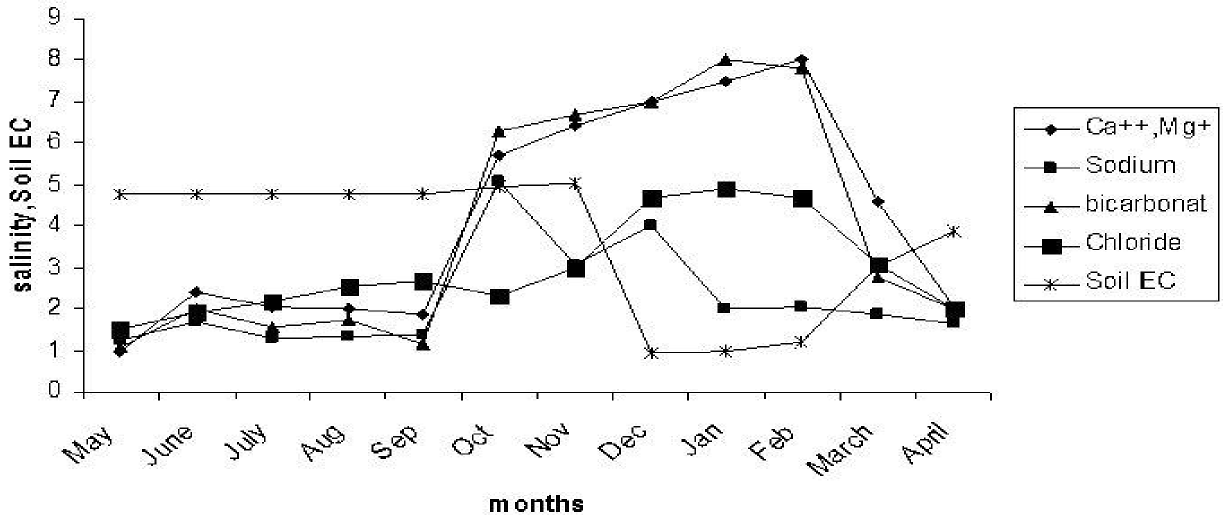

Fig. 1. Comparison of soil EC and mean water salinity at all Sugar Mills of study area

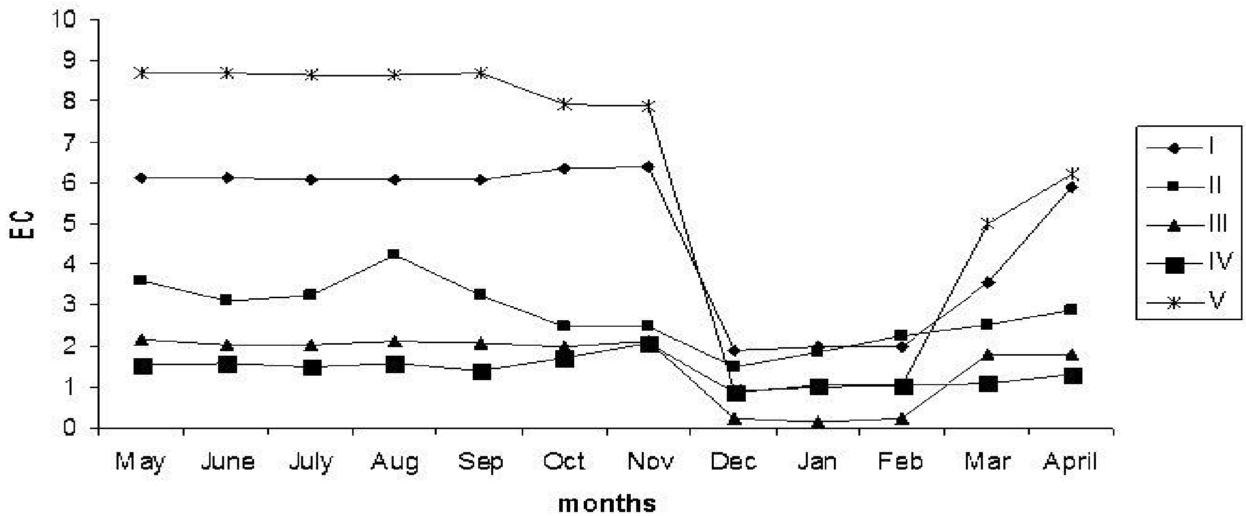

Fig. 2. Soil EC of samples taken from JDW Sugar Mills, Rahim Yar Khan

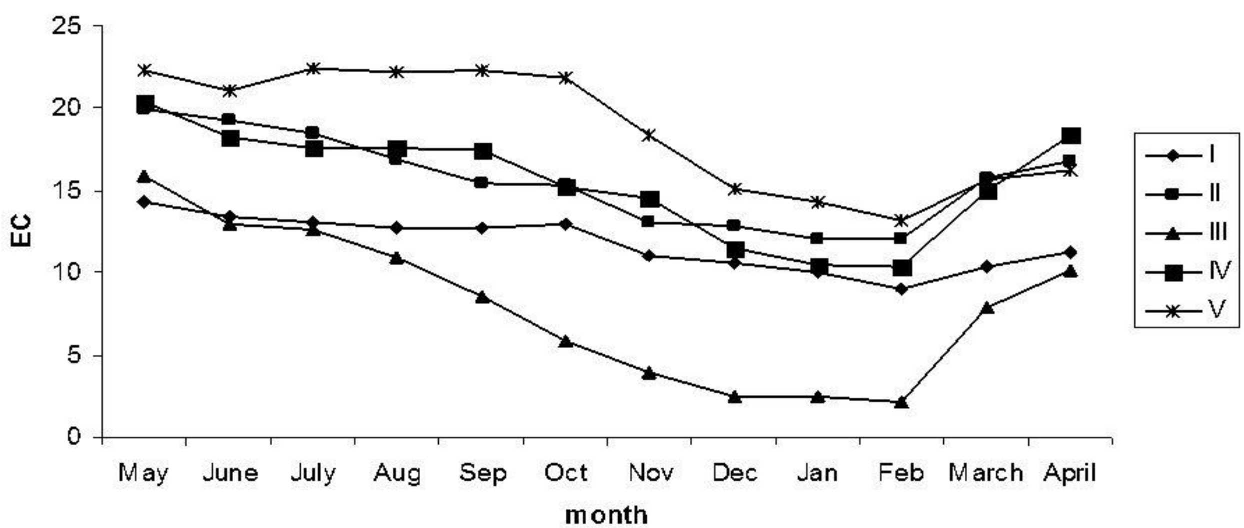

Fig. 3. Soil EC of samples taken from Humza Sugar Mills, Rahim Yar Khan.

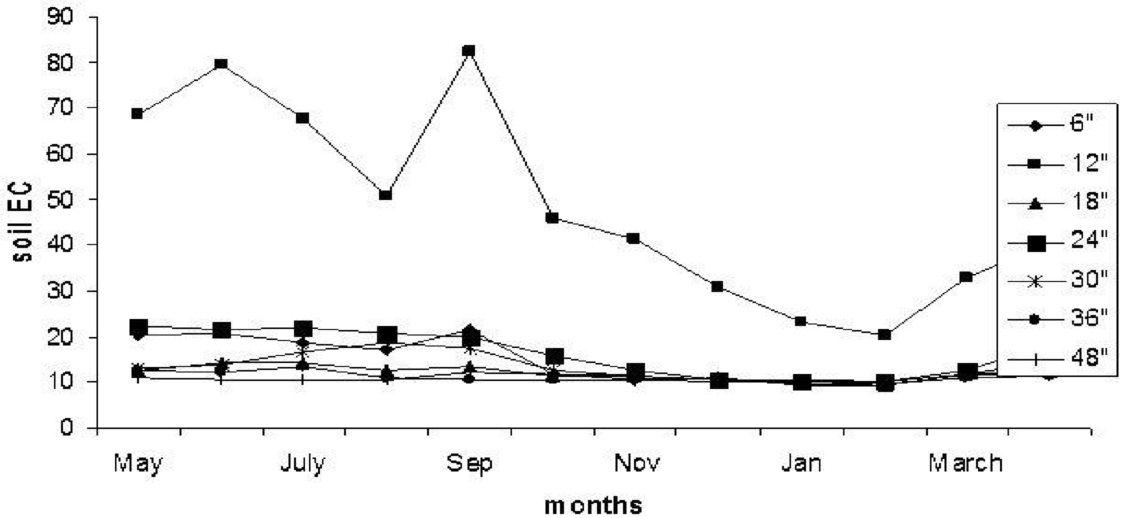

Fig. 4. Soil EC in samples taken from United Sugar Mills, Rahim Yar Khan.

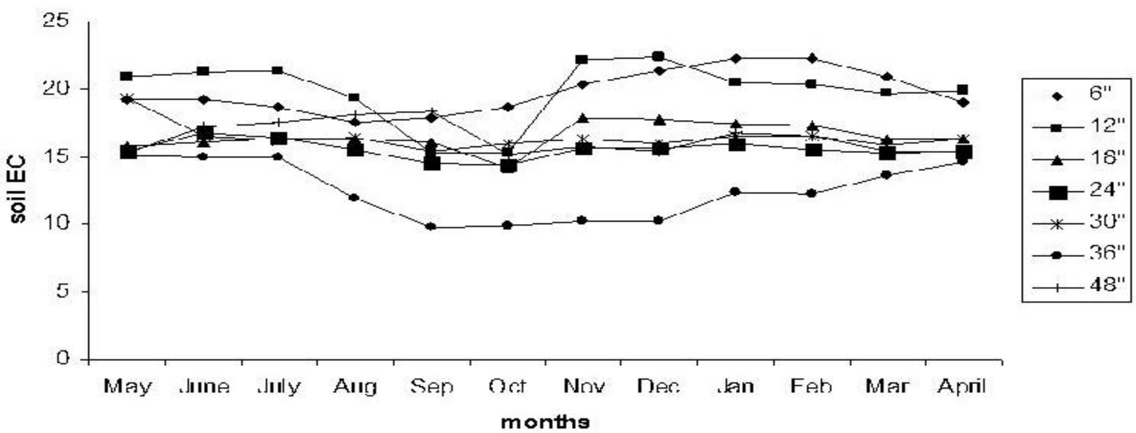

Fig. 5. Soil EC in samples taken from Ettehad Sugar Mills, Rahim Yar Khan.

Conclusion: If unchecked, this constant addition of alkalinity would result in a man-made desert in future on the productive lands and another 'dust bowl' might appear in Pakistan. Therefore, it is suggested that the effluents of sugar industry must be treated properly, as per national environmental quality standards, and be disposed thereafter so that it may not jeopardize the nearby soil, as a natural resource.

Acknowledgements: The Higher Education Commission (**HEC**) of Pakistan provided the funds for the present project during the MPhil leading to PhD under PIN: 063-161120-Bm3-093.The author is indebted to HEC for this generous financing.

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