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Original Research Paper

Studies on the Effects of Land Application of Sugar Factory Waste on Physicochemical Properties of Soils Under Crop of *Cicer arietinum* L.

S. D. Bavare (Nee S. M. Kulkarni) and P. K. Goel

Deptt. of Pollution Studies, Yashwantrao Chavan College of Science, Vidyanagar, Karad-415 124, Maharashtra, India

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ABSTRACT

Sugar factories generate usually high quantities of organic waste, which is often used for irrigation with or without treatment. Such irrigation practices, if carried out unscientifically, can deteriorate physicochemical properties of soils and affect the plant growth and beneficial soil micro-flora. In this study, effects of sugar factory waste on physicochemical properties of soils under crop of gram (*Cicer arietinum* L.) have been evaluated. The soil showed marked changes in its physicochemical properties after application of the waste. The soil has shown an increase in organic matter, chlorides, calcium, magnesium, sodium and potassium. However, nitrogen and phosphorus grossly remained unaffected as compared to control soil. The pH in all the soils remained neutral or slightly acidic. The increase in total solute concentration is the result of continuous evapotranspiration, which leaves salts behind in the soils. These salts accumulate in long run making the soils unsuitable for plant growth. Sodium blocks the exchange sites of soils, minerals and organic matter that make the soils to disperse and impermeable to water. Such soils develop a dark brown surface crust of salts and usually called as sodic or black alkali soils. Ca : K ratio was found to be decreased with the wastewater irrigation. The usefulness of wastewaters in irrigation can be a good means of their recycling as has been suggested by several workers, but the irrigation cannot be carried out indiscriminately with wastewaters. It is often necessary to give some degree of treatment to most wastewaters before using them for irrigation. Dilution can also be carried out in case of high quantities of salts present in wastewaters. This will help in preventing deterioration of soils in long run.

INTRODUCTION

Discharge of industrial effluents leads to conspicuous effects on environment. Soil pollution is usually a consequence of insanitary habits, bad agricultural practices and incorrect methods of disposal of solid and liquid wastes, fall out from atmospheric pollution, and dumping of solids from treatment of sewage and industrial wastes on land. Sugar factory wastes are heavily laden with organic matter, BOD, suspended solids, alkalinity, salts and heavy metals. These constituents may prove to be harmful to crops and soils, if present beyond certain limits.

Some studies have also shown adverse effects of wastes on soil characteristics, especially with untreated or undiluted wastes (Trivedy et al. 1986). Irrigation waters containing more than 1500 mg/L of dissolved salts may be of concern as they rapidly increase soil salinity. It was found by Hegade & Patil (1983) that with a continuous wastewater irrigation by sugar factory waste, there is a gradual build-up of non-volatile and oily substances, which cause clogging of soil pores. Many dissolved ions present in wastewaters show their combined effects in the form of pH and total dissolved solids. The distillery waste in irrigation water slightly increased the pH, organic matter and conductivity of soils (Naidu & Raman 1995). The paper mill effluent was also found to alter soil colour, consistence, texture, pH, organic carbon, available potassium and phosphorus leading to change in soil physicochemical characteristics, with decline in fertility due to induction of chemical changes (Baruah & Das 1998).

A large quantity of wastewater in sugar factories, up to the extent of almost 90% of the total intake, comes out in the form of effluents originating from leakages, spill-over, overloading and indifferent handling during crushing and extraction operations, pumping, evaporation, crystallization, molasses storage and handling, blow off operations, and filter washings. The sugar factory waste is quite clear in appearance as it essentially contains dissolved carbohydrates and sugars. However, due to poor maintenance and bad operating conditions, and with the passage of time, the biological activity leads to black colouration because of generation of hydrogen sulphide gas. Composition of waste and its volume differ widely from factory to factory.

There may be much variation in the waste arising from sugar factories. It may be acidic or alkaline and at times BOD may exceed 10,000 mg/L. Because of the organic nature of the waste, it causes severe pollution problems in the receiving waters. Putrefaction of the polluted stream, caused by heavy discharge of organic wastes, results in odour nuisance near the sugar mills. The anaerobic conditions created by sudden discharge of large quantities of the waste can lead to heavy damage to the whole aquatic ecosystem.

Most often the sugar factory waste is used for irrigation of the nearby crops. Though, the wastewater irrigation can provide fertilizer constituents to soils if it is properly diluted, but indiscriminate and unscientific use of wastes may lead to deterioration of soil characteristics, which in the long run develops soil salinity. The present study has been aimed to study the effects of sugar factory waste irrigation on physicochemical properties of soils under the crop of gram (*Cicer arietinum* L.).

MATERIALS AND METHODS

The experiments on sugar factory waste irrigation were conducted in earthen pots having a diameter of 24cm. The black cotton garden soil with an organic compost in the proportion of 1:5 was used for the experiment. Irrigation was made with 25% and 50% dilutions as well as undiluted waste (100%) along with tap water control. The untreated sugar factory waste was collected from the Sahyadri Sahakari Sakhar Karkhana Ltd., Karad and subjected to chemical analysis for various parameters according to the methods given by APHA (1981) and Trivedy & Goel (1984).

Five harvests of the crop were made at the interval of 15 days and one month. To evaluate effects of the wastewater on physicochemical properties of the soil, the samples were collected from the pots after each harvest. All samples of the soil, original and after the irrigation with sugar factory waste, were air-dried, ground and sieved for chemical analysis following the methods given by Trivedy & Goel (1984). pH was determined in 1 : 5 soil solution.

RESULTS AND DISCUSSION

Some of the prime important factors on which proper utilization of wastewaters for irrigation usually depend are climate and soil characteristics. The climate will decide the rate of evapotranspiration, which greatly affects the salt build-up in soils. Soil is the storage medium of nutrients, and vegetation depends upon it right from the germination of seeds. The soil characteristics such as texture will define the properties of infiltration, water holding capacity, porosity, etc., which are important factors governing the fate of water in soils. The use of raw wastewater in irrigation can cause several harmful effects on crops as well as on soils. For utilization of wastewaters in crop irrigation, it is necessary that they are first carefully and completely characterized with reference to important parameters, which are known to influence the soil conditions and plant growth. Some derived parameters like sodium adsorption ratio (SAR) and percent sodium are also of great significance, which influence development of salinity and alkalinity in soils with prolonged irrigation.

The chemical characteristics of the sugar factory waste and the tap water (control) used in the present study are given in Table 1, which show that the effluent is a concentrated organic waste having high quantities of organic matter, solids, chlorides, calcium, magnesium, sodium, potassium and TDS much above the standard limits of normal irrigation. The oxygen remains invariably absent at all the times whenever the analysis was carried out. The chemical analysis of the tap water used for control showed slightly higher values of dissolved solids, but rest of the parameters were quite low.

The variations in the physicochemical properties of the waste irrigated soils and the control are given in Fig. 1. pH did not show much variation and ranged between 6.0 and 7.0 only. This is due to buffering capacity of the weak acids produced by microorganisms activated by large quantities of organic matter in soil. Many workers have found a slight decrease in pH when the soils are irrigated with organic wastes (Mahida 1981, Trivedy & Shinde 1983).

Nitrogen concentration in 25% waste irrigated soils ranged from 147mg/100g to 186mg/100g, in 50% waste irrigated soils from 140mg/100g to 210mg/100g, and in 100% waste irrigated soils from 137mg/100g to 217mg/100g showing that its concentration in the soils increase with increase in concentration of the waste. Phosphorus values did not show much variation and remained almost in the same range in all the soils treated differently as well as control. In control soils, organic matter values ranged from 0.09% to 0.33%, while in 25%, 50% and 100% waste irrigated soils, the values were 0.22% to 0.39%, 0.17% to 0.35% and 0.15% to 0.34%.

Table 1: Chemical characteristics of sugar factory waste and the tap water (control) used in the experiment.

Parameter	Untreated Sugar factory waste	Tap water
pH	5-9	7.0
Total Solids	1343-3899	449.0
Total Dissolved Solids	1007-3643	429.0
Total Suspended Solids	58-336	20.0
Dissolved Oxygen	0.0	5.8
BOD	290-370	1.8
COD	1360-3200	28.0
Chlorides	355-1136	45.4
Calcium	240-521	24.0
Magnesium	73-243	8.7
Sodium	161-483	11.04
Potassium	230-339	1.87
SAR (Sodium Adsorption Ratio)	2.5-5.8	0.5
% Sodium	19-37.7	19.6

All values are in mg/L except pH, % Sodium and SAR.

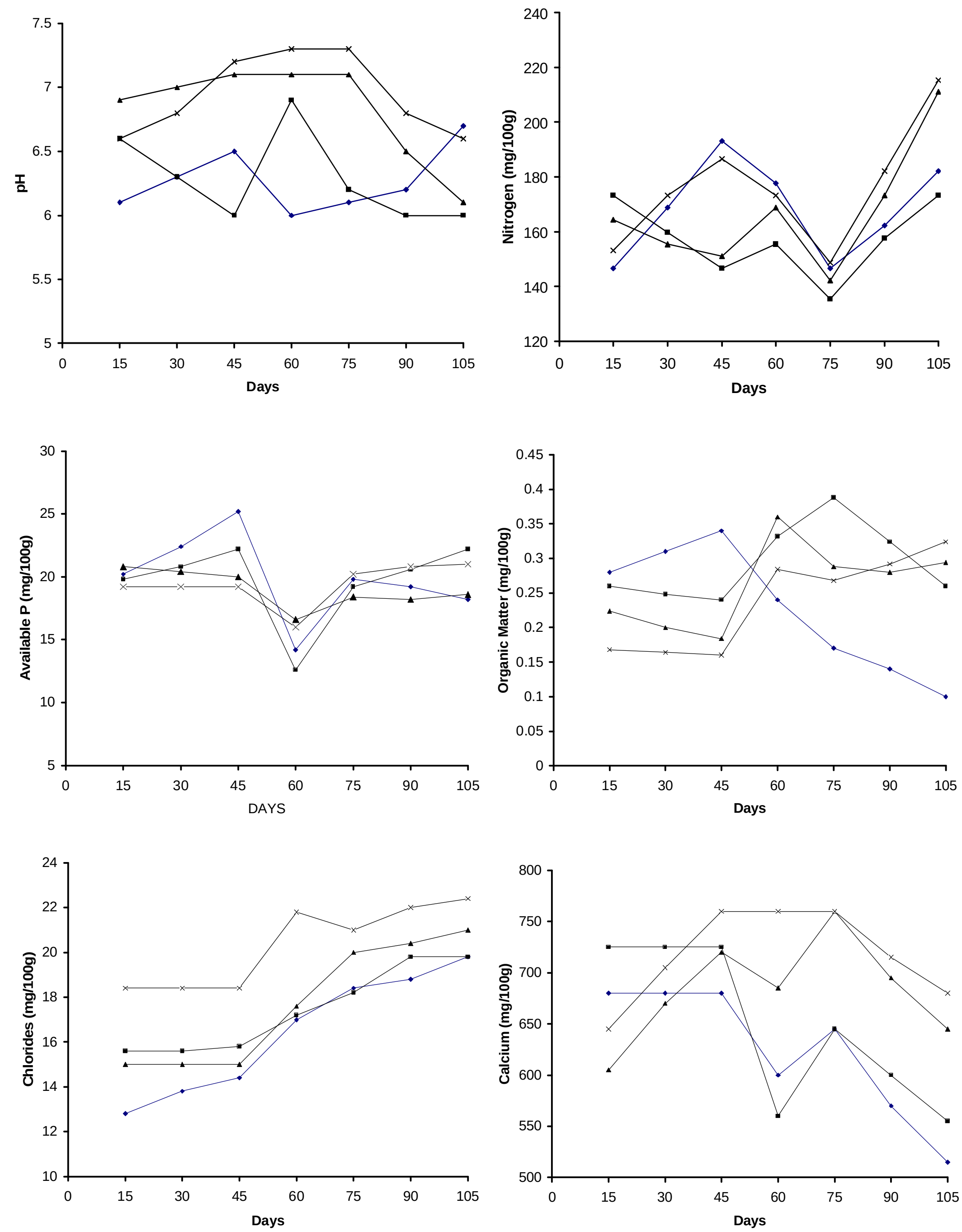
pH
Days
Nitrogen (mg/100g)
Days
Available P (mg/100g)
DAYS
Organic Matter (mg/100g)
Days
Chlorides (mg/100g)
Days
Calcium (mg/100g)
Days

Fig. 1 Cont....

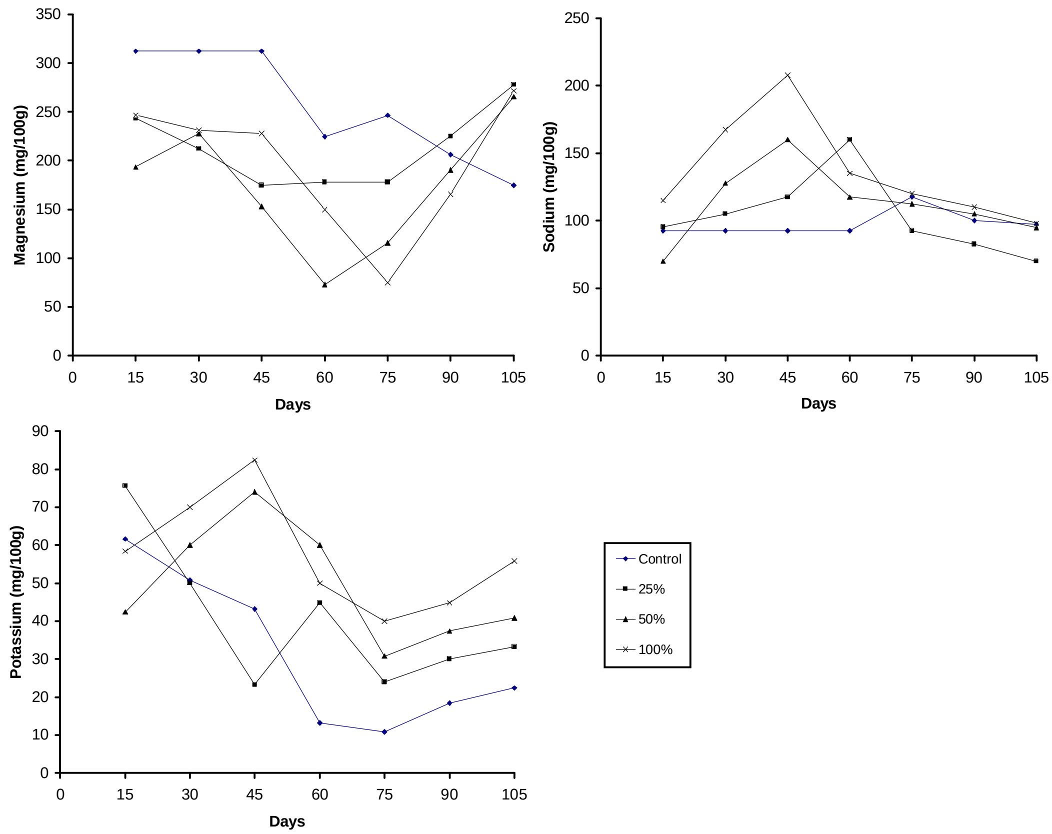

Fig. 1: Physicochemical characteristics of soils irrigated with variously diluted sugar factory waste and the tap water control under crop of *Cicer arietinum* L.

Chloride concentration of the soils showed almost the same trend with progressive increase from the sowing till the final harvest. In 50% waste irrigated soils the chloride ranged from 17.04mg/100g to 21.30mg/100g with higher values usually at the end of the experiment. The chloride concentration showed further increase in the 100% waste treated soils with values ranging between 8.46mg/100g and 22.72mg/100g. The results clearly indicate that there is an increase in chloride content with the sugar factory waste irrigation.

Concentration of calcium in 25% waste irrigated soils and control were higher in the beginning, but decreased later. In control, the values of calcium were 521.04mg/100g to 681.36mg/100g, and in the soils of 25% treated waste from 561.12mg/100g to 721.44mg/100g. In case of 50% and 100% waste treated soils, concentration of calcium remained low in beginning of the experiment, but later increased successively with irrigation of the waste.

The magnesium concentration varied from 70.55mg/100g to 316.74mg/100g in the soils of control, but showed an increase in the soils after irrigation with the waste. There was a wide difference in the concentration of magnesium in 25% waste treated soils ranging from 170.55mg/100g to 341.1mg/100g, but in 50% and 100% waste treated soils, the minimum and maximum values were almost the same.

The concentration of sodium in the soils of control did not vary much with all the values showing 92.0mg/100g except one higher value of 115.0mg/100g. The soils treated with 25% and 50% waste were exactly in the same range with values ranging from 69.0mg/100g to 161.0mg/100g. In case of 100% waste, the soils showed higher values ranging from 92.0mg/100g to 207.0mg/100g. In all the cases of treated soils, the higher values of sodium were found during middle of the growing period. Hazarika et al. (2008) found that soluble sodium in soils under different treatments of paper mill effluent was highest among three basic cations (Ca, Mg, K) studied, and the values were higher in soils of third season than that the first season of crop harvest. Higher loading of soils with paper mill effluent in subsequent seasons resulted in higher exchangeable Na, K and Ca ions in soil.

The values of potassium ranged from 11.7mg/100g to 62.4mg/100g in control soils. The 25% waste treated soils showed higher values of potassium fluctuating between 23.4mg/100g and 78.0mg/100g. The 50% waste treated soils showed highest value of 74.1mg/100g, while the soils of 100% waste registered further rise in potassium level with the values ranging from 39.00mg/100g to 87.9mg/100g. Increased potassium content in soil was also observed by Dongal & Savant (1978) when the soils were treated with spent wash.

Kanwar & Deo (1969) reported that potassium can also act in the same way as sodium but its effects are not as pronounced as that of sodium. Calcium usually has an antagonistic effect on the potassium uptake. Similarly, magnesium may also exhibit an antagonistic effect on potassium. Low Mg : K ratio causes a slower absorption of potassium resulting in potassium deficiency. In the present study, the Ca : K ratio was found to decrease with the wastewater irrigation revealing that the potassium uptake may not be hampered by this waste. Higher sodium accumulation in paper mill effluent treated soils resulted in greater occupancy of it in exchange sites (Hazarika et al. 2008), but at 75% dilution this effect was invisible. Pawar et al. (1992) observed that there are marked changes in exchangeable K, Ca and Mg, and the DTPA extractable Fe, Zn and Mn contents of soils, which significantly increased at all stages of crop growth treated with spent wash.

The '*t*' test of significance shows that none of the soils have significant difference from control for any chemical parameter at 5% level of probability. The greater fluctuations in the values and lesser number of total readings make the value of '*t*' greater. However, chlorides, organic matter and calcium show the value of obtained '*t*' very near to critical '*t*' indicating that these parameters increase with the wastewater irrigation. The values of sodium and potassium also showed clear increase on an average basis in the treated soils as compared to the control.

The overloaded soils with organic matter, caused due to high BOD effluents, usually develop anaerobicity, clogging and ponding, thus, reducing soil permeability and causing damage to the crop. The waste with high organic matter caused damage to the soils, which may be more severe in the clayey soils than the sandy soils those are comparatively more permeable. Soil structure and its physical and chemical properties are greatly affected by application of wastewater in the long run due to high content of organic matter, chlorides, Ca, Mg, Na, and K. According to Hazarika et al. (2008) the decline in crop productivity in pots with wastewater irrigation could be attributed to progressive deterioration of soil due to presence of soluble salts, different cations and chloride in the higher concentrations. The pots were closed system and the soils in them accumulated higher levels of salts leading to damage to crop and lesser quantity of grain production. Soil salinity imposes both ionic and osmotic stresses on plant (Hazarika et al. 2008).

High sodium in effluents replaces calcium and magnesium from soils through the exchange reactions resulting excess accumulation in the exchange sites of soil minerals and organic matter causing the soils to disperse and become impermeable to waters. The excess sodium breaks down the clays by deflocculating soil particles, thus, reducing soil porosity and infiltration rate. The soil structure is ultimately impaired and soil becomes a puddle when wet, and hard when dry. The sodium hazard of the irrigation waters is usually dependent on the sodium concentration in relation to concentration of calcium and magnesium, and can be evaluated by two common parameters, sodium adsorption ratio (SAR) and percent sodium (U.S. Salinity Laboratory Staff 1954). Sometimes, by irrigation with high pH wastewater, the calcium and magnesium can be precipitated in soil solution, thus, further increasing the SAR value of the soil solution. The 'ISI' limit for percent sodium is 60 for the irrigation waters, and the values above 70% are considered to be dangerous. The waste used in the present study does not show high values of percent sodium.

In a short term experiment like this, only an evidence of salt accumulation could be evaluated, but the prolonged application of wastewater will certainly accumulate sodium and other salts to make the soils saline or sodic.

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