ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 10, October 2014

Impact of Distillery Wastewater Irrigation on Chemical Properties of Agriculture Soil

Shyam Veer Singh[1]*, V.K. Swami[2]

[1]Department of Chemistry, Nehru Memorial Govt. PG College, Hanumangarh, Rajasthan, India

[2]Post-Graduate Department of Chemistry, Govt. Lohia College, Churu, Rajasthan, India

*Corresponding Author

ABSTRACT: The utilization of treated agro-industrial effluents has been recommended as sound option for agriculture irrigations practices and sustainable land management programme. This paper presents the impact of utilizing treated effluent form a distillery industry on physico-chemical properties of soils in an agriculture plot. The effluent was applied in 50 and 100% strength and a control plot received normal groundwater as irrigation water under wheat cropping system. No fertilizer was applied in effluent treated crop while field with groundwater received normal dose of chemical fertilizer. The distillery effluent treated plots showed considerable level of all major soil nutrients. The pH of effluent irrigated soils was in alkaline scale while EC of same soil suggests the high concentration of soil nutrients. The organic carbon (3.25 – 6.75 %) was high in effluent irrigated soils than control. The ranges of important soil nutrients: total P, total N, total K, total Ca, total Fe, total Mg and total Zn were relatively higher in effluent treated soils than control plots. Results suggested that distillery effluent can be a sustainable option for crop irrigation to solve twofold problems of agriculture system: soil nutrient deficiency and supply of water for crop irrigation.

KEYWORDS: Organic farming; Industrial waste utilization; Sustainable soil management; Land fertility; SOM

I. INTRODUCTION

Majority of the agro-industries are water-based and a considerable volume of wastewater is discharged from different operational units of these industries in the environment either treated or inadequately treated forms which leads to the several problems of surface as well as ground water pollution (Rattan et al., 2005). The steady increase in the amount of water used and waste water produced by industries throughout the world poses potential health and environmental problems (Joshi et al., 1996). Various industries have been continuously adding lot of waste water containing high level of nutrients, heavy metals and hazardous substances to the cultivable land (Rattan et al., 2005). High BOD, COD, greases, phenolic compounds, pH, salts, metals and other unwanted chemicals are the major problem of distillery industrial wastewater (Masto et al., 2009). Now days, use of distillery wastewater in agriculture lands with or without dilutions is supposed to be the best practiced solution (Rowe and Abdel-Magid, 1995).

This can be advocated as an environmentally acceptable, economically feasible and non hazardous approach that least influences any component of the environment (Kaushik et al., 2005; Mosse et al., 2012). The diluted distillery effluent irrigation improved the physical and chemical properties of the soil and further increased soil microflora (Barkle et al., 2000). However, being rich in nutrient and organic content, its indiscriminate use for a long period has a risk of deteriorating the physico-chemical properties of the soil (Tripathi et al., 2011). Accordingly nutrient levels of soils are expected to increase with continuous irrigation with distillery wastewater (Yadav et al., 2002). The pollutants present in wastewater may be slowly introduced and accumulated in the soils and cause a potential risk to soil quality and productivity (Friedel et al., 2000). Although there is a strong possibility of agronomic and economic benefits of distillery wastewater irrigation; however, in the effect of dilution and long-term application of wastewater was less investigated. Therefore, the aim of the present study was to see the impact of different strength of distillery effluent on physico-chemical properties of the agriculture soils receiving distillery effluent as irrigation water.

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II. METHODOLOGY

2.1 Effluent and soil sample collection

The experiment was designed using agricultural plots of 10X10 meter. These plots with wheat crop were meant to receive distillery effluents. The wheat crop received distillery effluent in two different strengths. In on plot the efferent was given with 50% dilution (50% normal irrigation water) while another plot received undiluted (100%) distillery effluent. A control plot was also kept irrigated with normal groundwater. No fertilizer was applied in effluent treated crop while field with groundwater received normal dose of chemical fertilizer. All experimental plots were kept in triplicates. For analysis of impact of effluent irrigation on soil the bulk samples of soil were collected from all experimental plots using mechanical auger up to15 cm depth. The samples were taken from three different sites from a same field receiving distillery effluent. The soil sample was passed through fingures to remove stones and pebbles. The soil sample was stored in polythene bags and marked with sampling details. In laboratory, the soil was oven dried at 80 ºC for 48 hrs and then sieved. The processed soil was then analyzed for different soil parameters: pH, conductivity (EC), organic carbon (OC), total nitrogen ($_{tot}$N), total phosphorus ($_{tot}$P), total potassium ($_{tot}$K), total sodium ($_{tot}$Na), total calcium ($_{tot}$Ca), total magnesium ($_{tot}$Mg), total iron ($_{tot}$Fe), and total zinc ($_{tot}$Zn).

2.2 Analytical methods

pH was measured using digital pH meter (Metrohm, Swiss-made). EC was measured using digital conductivity meter (Remi, India). Organic carbon was determined using Walkley and Black's rapid titration method (Allen et al., 1986). Total Sodium, total potassium and total calcium were estimated flame photometrically after extraction with ammonium acetate buffer (Allen et al., 1986). Total phosphorus and total nitrogen was analyzed spectrophotometrically by following standard methods. The Fe, Mg and Zn level was determined by using Atomic absorption spectrophotometer (Thermo Fisher. Model iCE 3000 Series AA System). The soil samples were dried at 70^{o} C and then digested with a HNO_3 and H_2SO_4 solution mixture according. Digested samples were diluted with Millipore water and filtered with Whatman no.42 filter paper. Then the sample was made up to 20 ml. The ready sample was then analysed using AAS. All chemicals were used of AG grade while preparing reagents and standards during chemical analysis.

2.3 Statistical analysis

One-way ANOVA was used to analyse the differences in physico-chemical prosperities of the soil supplemented with different dilution of distillery wastewater. SPSS® statistical package (Window Version13.0) was used for data analysis. All statements reported in this study are at the $p < 0.05$ levels.

III. EXPERIMENTAL RESULTS

The wastewater from distillery industry is a dark coloured effluent rich in organic and nutrient load which can cause severe environmental damage to local fresh water and land resources if discharged directly without any dilution or treatment. The physico-chemical characteristics of undiluted distillery wastewater were presented in Table 1. As per the data sets, the strength of the major contaminant in distillery effluent which is being used for land irrigation purposes in this area was similar to the typical values of a high-strength domestic wastewater as described by Metcalf and Eddy (2003). The distillery effluent of varying concentration intensely affected the chemical and physical properties of the soil. Statistically (ANOVA) there was significant difference among treatment sets for physico-chemical properties of the soil of experimental plots irrigated with different strengths of distillery effluent: pH ($F = 2024.71$, $p < 0.05$), EC ($F = 8837.52$, $p < 0.05$), OC ($F = 83783.54$, $p < 0.05$), $_{tot}$N ($F = 117044.99$, $p < 0.05$), $_{tot}$P ($F = 556555.33$, $p < 0.05$), $_{tot}$K ($F = 44908.09$, $p < 0.05$), $_{tot}$Na ($F = 46070.55$, $p < 0.05$), $_{tot}$Ca ($F = 52993.83$, $p < 0.05$), Fe ($F = 55182.78$, $p < 0.05$), Mg ($F = 183488.11$, $p < 0.05$) and Zn ($F= 2205.08$, $p < 0.05$).

The values of physico-chemical properties of soil extracted from control field were comparatively lower than that of soil irrigated with 50% and 100% effluent (Table 2). The pH of the control soil was observed to be near neutral scale (i.e. 7.38). After the application of 50% diluted effluent, an increased effect on soil pH was observed, the pH was raised up to 8.38 and after the application of 100% raw effluent the pH of the soil increased up to 8.92. Similarly a marginal increase in EC also took place in agriculture soils after applications of distillery effluent which suggest the uploading of inorganic substances in soils. In the soil without distillery effluent application, the EC was recorded as 2.06 dS m^{-1}. However, the shift was observed in EC in soil supplied with 50 and 100% distillery effluent, maximum in 100%

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effluent treated soil (3.76 dS m^{-1}). The total organic carbon in soil was elevated from 3.23% (control) to 4.86% in 50% effluent treatment and 6.89% in 100% effluent application. The maximum organic load was found to be occurring in soil loaded with 100% effluent. Total phosphorus (mg/L) level in 100% effluent treated soil were 510.75, which is comparatively higher than that of 50% effluent treated soil (390.55 mg/L) and control (300.50 mg/L). The control soil exhibited 103.61 mg/L total nitrogen and the concentration elevated significantly up to 156.91 mg/L and 182.93 mg/L on 50% and 100% effluent treatment, respectively. Total potassium concentration in soil without the effluent application was recorded as 212.33 mg/L and after the application of 50% effluent the concentration increased up to 256.67 mg/L which was considerably higher than that of control. Similarly on application of 100% effluent on soil the total potassium concentration was recorded as 295.33 mg/L. Other cations (total Na and total Ca) concentrations in the control soil were recorded as 108 and 250 respectively in the control soil. The soil treated with 50 and 100% distillery effluent exhibited total sodium concentration of 142.56 and 198.25 mg/L, relatively higher than that reported from control. However, in case of total calcium 50% effluent treated soil showcases 287.49 mg/L and 100% effluent treated soil contains 338.94 mg/L, respectively. Iron, magnesium and zinc also showed the increased levels with increasing concentration of effluent in soil. The concentration of iron was 20.13 mg/L in control, 23.38 mg/L in 50% effluent treated soil and 36.87 mg/L in 100% effluent treated soil. In case of magnesium, the concentration was maximum in soil irrigated with 100% effluent i.e. 232.65 mg/L, followed by 207.34 mg/L in 50% effluent treated soil and 202.50 mg/L in control. However, for Zn, control witnessed lowest concentration of 54.96 mg/L, followed by 64.92 in 50% effluent treated soil and 78.50 mg/L in 100% effluent treated soil. It has been validated from the results that the concentrations of different metals in soil were not varying significantly among control and 50% effluent treated soil.

Table 1: Physico-chemical properties of distillery effluent

Parameters	Range
pH	7.22
EC	4.22
BOD (mg/L)	567.66
COD (mg/L)	2156.33
Cl^- (mg/Kg)	349.66
NO_3^- (mg/Kg)	256.33
SO_4^- (mg/Kg)	150.00
$_{tot}$P (mg/Kg)	85.72
$_{tot}$N (mg/Kg)	92.31
$_{tot}$K (mg/Kg)	195.51
$_{tot}$Na (mg/Kg)	138.45
$_{tot}$Ca (mg/Kg)	568.48
TDS (mg/L)	4476
TSS (mg/L)	2912
Fe (mg/Kg)	6.84
Mg (mg/Kg)	122.72
Zn (mg/Kg)	11.75

The irrigation by distillery effluent may help to increases soil fertility amelioration through improvement in soil water-holding capacity, texture, structure, nutrients retention, roots penetration, and reduction in soil acidity (Rowe and Abdel-Magid, 1995). There are several studies, conducted by previous workers, suggested that the distillery discharge after primary or secondary treatment can be utilized as an source of irrigation water loaded with some very essential soil nutrients. (Chhonkar et al., 2000; Friedel et al., 2000; Ramana et al., 2002; Yadav et al., 2002; Tripathi, et al., 2011). Distillery effluent as a bio-fertilizer can be supplemented to the agricultural fields for continuous supply of nutrients in soil ecosystem. However, the strength of distillery effluent and irrigations frequencies may play a vital role

IJIRSET

ISSN: 2319-8753

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towards managing soil properties and plant growth at sustainable basis (Barkle et al., 2000). A study by Mosse et al. (2012) have demonstrated that long-term application of winery wastes was found to have significant impacts on soil microbial community structure, as determined by phospholipid fatty acid analysis, as well as on many physicochemical properties including pH, EC, and cation concentrations. However, the long-term application of distillery effluent enriches the soils with TOC, TKN, K, P and useful soil enzymes but tended to build up harmful concentration of Na, further needed bioamendments (Kaushik et al., 2005). It was suggested that a high dose of the effluent may have some inhibitory effects on microbial activity which may result due to higher concentration of salts, or some organic acids (Juwarkar et al., 1990). Different nutrients present in wastewater may have negative impact on soil and plant when present above certain permissible limit (Friedel et al., 2000). For example, sodium salts in the effluent can cause soil dispersion (Ajmal and Khan, 1984) affecting soil permeability and aeration, which causes hindrance to seed germination (Chandra et al., 2002). Even very high K concentration in the effluent can have deleterious effects on soil as well as crops, since very high exchangeable K can also cause dispersion of soil (Biswas et al., 2009). Higher anionic and cationic concentration can decrease the bulk density as well as water holding capacity of soil by reducing the porosity in clay soil due to deflocculation of clay particles which occurs in presence of higher Na content and the consequent effects are seen in the cation exchange capacity in the soil which adversely affects the seed germination and plant growth (Chandra et al., 2002). The appropriate dilution of distillery wastewater can helps to reduce the nutrient loading in the soil and establishes the correct proportion of nutrient required for normal plant growth and development. Further, an attempt will be made to identify the sensitive soil indicators under distillery effluent irrigation, which helps to mainstream the potential of wastewater as an inland irrigation resource.

Table: 2 Physico-chemical properties of soil at different strengths of distillery wastewater (mean±SD; n=3)

Physico-chemical properties	Control soil	50% effluent treated soil	100% effluent treated soil
pH	7.36 ± 0.05	8.38 ± 0.01	8.92 ± 0.01
EC (dS m^{-1})	2.06 ± 0.15	3.25 ± 0.02	6.75 ± 0.02
OC (%)	3.23 ± 0.15	4.86 ± 0.01	6.89 ± 0.01
$_{tot}$P (mg/Kg)	300.50 ± 0.10	390.55±0.41	510.75 ± 0.02
$_{tot}$N (mg/Kg)	103.61 ± 0.34	156.91 ± 0.04	182.93 ± 0.07
$_{tot}$K(mg/Kg)	212.33 ± 0.57	256.67 ± 0.11	295.33 ± 0.01
$_{tot}$Na (mg/Kg)	108.66 ± 0.34	142.70 ± 0.25	198.25 ± 0.01
$_{tot}$Ca (mg/Kg)	250.33 ± 0.57	287.49 ± 0.02	338.94 ± 0.05
Fe (mg/Kg)	20.13 ± 0.15	23.38 ± 0.15	36.87 ± 0.02
Mg (mg/Kg)	202.50 ± 0.05	207.34 ± 0.01	232.65 ± 0.10
Zn (mg/Kg)	54.96 ± 0.58	64.92 ± 0.01	78.50 ± 0.09

IV. CONCLUSION

The distillery industries produce a huge amount of wastewater rich nutrients and heavy metals. The proper dilution of distillery wastewater reduces the strength of nutrient in it and supported its role in land restoration and sustainable plant production. The present study reveals that application of distillery effluent cause enrichment of soil nutrients in agriculture soils. The levels of important soil nutrient were manifold in plots which received distillery effluent. Results suggested that distillery effluent can solve two major issues of the agriculture management system, i.e. irrigation water availability and soil nutrient supply. However, continuous application of such effluent can cause salt accumulation in agriculture lands which again need further bioremediations. It is suggested that after 3 – 4 years application of such effluent in agriculture lands a gap period of normal fertilizer and irrigation water supply should be maintained in agriculture system to avoid environmental hazards of continuous application of distillery effluent in soils.

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DOI: 10.15680/IJIRSET.2014.0310086