Indian Journal of Agricultural Sciences **81** (9): 852–4, September 2011

Impact study on groundwater quality and physico-chemical properties of farm lands irrigated with post-methanated distillery effluent

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Received: 7 September 2010; Revised accepted: 11 May 2011

ABSTRACT

The study area is surrounded by distilleries discharging huge amount of post-methanated distillery effluent (PMDE). The distilleries effluents is used by farmers in the surrounding farmlands to supplement irrigation or nutrients in various crops without considering its impact on soil physico-chemical properties as well as the groundwater quality. Therefore, present work was undertaken during 2009 to study the impact of PMDE application as supplemental irrigation on quality of groundwater collected from two sources, ie tube well and hand pump and physico- chemical properties of the study area. The PMDE is being used in the farmland since 2006 therefore; noticeable changes in physico-chemical properties were observed. Chemical analysis of groundwater reveals that salinity, *p*H, bicarbonate and soluble cations increased due to PMDE application and increase was found more in tube well water as compared to hand pump water. *p*H increased by 5.06 to 6.19% while lead, cadmium, nitrate by 62.5 to 66.7, 14.3 to 18.8 and 200 to 250%, respectively. Physical properties of soil like infiltration rate, permeability and aggregate stability were found to deteriorate due PMDE application. Study indicates that continuous application of PMDE in unscientific manner may pose threat to sustainability of ecosystem.

Key words: Distillery effluents, Irrigation, PMDE, Soil properties

Distilleries producing alcohol from molasses are considered among the most polluting agro-based industries due to generation of huge amount of anaerobically digested, foul-smelling, coloured wastewater. The wastewater called post-methanated distillery effluent (PMDE), with high chemical oxygen demand (COD 45000–50000 mg/l) and biochemical oxygen demand (BOD 5000–8000 mg/l) is unsafe for disposal in water course (Joshi *et al.* 1996). However, PMDE also contains appreciable amount of nutrients such as K, N, Fe, Cu, Zn and Mn, which are essential for plant growth. The work conducted in different parts of country reveal that the use of PMDE in agriculture for manuring or as a part of irrigation in a judicious way improves crop growth and affects physical, chemical and biological properties of soil (Kumari and Phogat 2010, Pathak *et al.* 1999). However, non-judicious use of PMDE adversely affects crop growth and increased soil salinity (Joshi *et al.* 2000). Chhonker *et al.* (2000) reported that use of PMDE should be discontinued intermittently for one to two crop-seasons to avoid the deteriorating effects on soil and groundwater quality. Judicious application of PMDE is most important as long-term indiscriminate use of PMDE could lead to significant leaching of inorganic salt into the ground water and thereby polluting the groundwater. (Jain *et al.* 2005).

An apprehension exists that the long-term use of PMDE in farmlands may pose serious threat to the groundwater quality. Similarly, the major risk associated with irrigating with PMDE waste water is degradation of soil health. Available information on the effect of continuous application of PMDE on physical and chemical properties of soil and groundwater quality is meager, therefore, monitoring of groundwater quality and physico- chemical properties have become important to minimize the risk of soil health deterioration and groundwater pollution, Considering this view, present study was made to assess the impact application of PMDE used to supplement the irrigation on groundwater quality and physico-chemical properties of farmland.

MATERIALS AND METHODS

The study was conducted during 2009 at village Kinauni in the district of Meerut, Uttar Pradesh, India where a distillery with spent wash generation capacity of 1 280 kL/day from

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molasses is operating since February 2006. Study area falls under Indo-Gangetic plains of north India approximately at 29° N latitude, 77°28[1] E longitude with an altitude of 227 m above mean sea level (msl). The climate of the region is semi-arid subtropical, with dry hot summers and cold winters. Average annual rainfall is about 805 mm of which 75% is received during monsoon season (June–September). The groundwater hydrology of this region is characterized by unconfined and semi confined aquifers at a depth of about 15–22 m below ground level. The soil of the sites are sandy loam (51–56% sand, 29 –30.5% silt, 15–18.5% clay) to clay loam (35–38.5% sand, 38 –40.5% silt, 24.5–27% clay) in texture. The sites were plain lands with negligible slope and soils are having approximate 8.2 *p*H 0.156dS/m EC, 1.4–1.6 Mg/m^3 bulk density and 0.4–1.7 cm/hr infiltration rate. Sugarcane is the main annual crop while fodder and wheat are grown as per need during *kharif* and rabi seasons in the area. The general pattern of crop of the command area is 65–70% under sugarcane and remaining 30 –35% area mainly under wheat, paddy, pulses and oil seed. PMDE @ 50 m^3/acre/day with 1:3 dilution have been used as pre-sown irrigation 20 days before sowing in the area about 1610 acre once in a year through a 8" diameter HDPE Pipeline. The *p*H of the effluent was 7.6 and EC was 3.7 dS/m. The concentration of Fe, Zn, Cu, Mn, As, Pb, K, and P were found to be 11, 12.4, 2.1, 4.8, 0.02, 1.8, 512 and 12.8 mg/L respectively (Garima *et al.* 2009). Groundwater samples from hand pump and tubewell in the PMDE-treated as well as untreated fields of farmers were collected in sterilized plastic bottles (150 ml capacity) during June 2009 and were stored at 4°C until further analysis. Soil samples from top 0–15 and 15–30 cm depth were also collected in June 2009 with Eijkelkamp make auger. Samples were analyzed for their chemical properties like *p*H, EC, Na^+, K^+, Bicarbonates, Ca^2+, Mg^2+, NO^3-, Cu, Fe, Mn, Zn, Pb and Cd according to the standard methods given by American Public Health Association Washington DC (American Public Health Association,1998) and Singh *et al.* 2005. Similarly soil samples were also collected from PMDE treated and PMDE untreated farmlands and analyzed for the infiltration rate, bulk density, particle density, aggregate stability and hydraulic conductivity in the laboratory of Department of Soil Science of SVPU&AT, Meerut by adopting the standard methods.

RESULTS AND DISCUSSION

In order to study the impact of irrigation with PMDE on physico-chemical properties of soil and groundwater, chemical properties of groundwater and surrounding farmland were analyzed and data are presented in Tables 1 and 2.

Groundwater quality

Analysis of the samples of groundwater taken from PMDE-treated and untreated farmlands reveals that the Alkalinity of hand pump as well as tubewell groundwater increased with the continuous application of PMDE. Higher salinity was recorded in the groundwater of tube well as compared to that from hand pump indicating that soluble salts could not possibly leach in appreciable amount down to lower aquifer. Higher bicarbonate, *p*H, salinity and cations in groundwater of tubewell as compared to hand pump water in PMDE-treated condition were well expected due to restricted movement of salts to lower aquifer (Jain *et al.* 2005). Buildup of bicarbonates, sodium and potassium in groundwater collected from PMDE-treated areas, might have increased the *p*H of groundwater. The nitrate nitrogen level which is responsible for eutrophication, was also found to build up substantially with PMDE application. Level of toxic metals in groundwater of tubewell as well as hand pump increased appreciably due to PMDE application. Maximum increase

Table 1 Chemical properties of groundwater of the study area

Parameter	PMDE treated		PMDE untreated	
	Hand pump	Tube well	Hand pump	Tube well
*p*H	8.24	8.3	7.76	7.90
EC (dS/m)	0.590	0.685	0.284	0.366
Na^+ (me/l)	0.108	1.56	0.104	0.465
K^+ (me/l)	0.110	0.153	0.0641	0.082
Bicarbonates (me/l)	6.05	8.25	4.40	4.95
(Ca^{2+}+Mg^{2+}) (me/l)	4.99	5.769	3.269	4.230
Cu (mg/l)	0.033	0.033	0.019	0.031
Fe (mg/l)	0.91	1.34	0.40	0.50
Mn (mg/l)	0.24	0.28	0.11	0.15
Zn (mg/l)	0.92	1.12	0.62	0.70
Pb (mg/l)	0.10	0.13	0.06	0.08
Cd (mg/l)	0.016	0.019	0.014	0.016
NO^3 (mg/h)	18.0	28.0	6.0	8.0

Table 2. Physico-chemical properties of PMDE-treated and untreated soils

Parameter	0–15 cm depth		15–30 cm depth	
	PMDE untreated	PMDE treated	PMDE untreated	PMDE treated
BD (Mg/m^3)	1.44	1.62	1.53	1.47
PD (Mg/m^3)	2.58	2.50	2.59	2.58
Porosity (%)	44.2	35.2	41.05	43.39
Aggregate stability	0.815	0.655	0.465	0.555
Infiltration rate (cm/hr)	1.10	0.35		
Permeability (cm/hr)	0.65	0.25		
*p*H	7.6	8.1	7.5	7.8
EC (dS/m)	0.25	0.33	0.30	0.36
Na (kg/ha)	156.24	210.92	140.2	170.2
K (kg/ha)	247.08	426.32	144.48	224.77
SO_4 (kg/ha)	15.0	21.0	16.0	22.5
ESP	2.27	3.30	2.00	2.60
Exch Na (meq/100 gm)	0.28	0.38	0.25	0.31
CEC (cmol/kg)	12.33	11.50	12.56	12.00
OC (g/kg)	6.60	5.90	3.40	3.90
N (kg/ha)	219.3	244.71	190.5	216.30
P (kg/ha)	17.58	19.45	20.94	23.08
Zn (ppm)	0.73	0.66	0.34	0.73
Fe (ppm)	1.52	3.16	0.86	2.93
Cu (ppm)	2.99	2.90	2.77	2.83

127.5 to 168.0% was found in case of iron. Next to iron was manganese 86 to 118.2%, followed by lead 62.5 to 66.0% zinc 48.4 to 60% and cadmium 14.3 to 18.8%. Overall enrichment was more in tubewell (shallow) water as compared to handpump (deep) water.

Physico-chemical properties of soil

Analysis of the soil samples taken from PMDE treated and untreated farmlands were performed and results are presented in Table 2. Results reveal that soil physical properties such as infiltration rate and permeability declined due to PMDE treatment while exchangeable sodium in soil increased. Presence of higher sodium owing to PMDE application resulted in poor aggregation and thereby caused poor infiltration. Singh (1992) also reported that infiltration rate decreased from 4.34 to 2.16 cm / hr with increasing distillery effluent level. Salinity in the form of sodium can directly affect soil properties through the phenomena of swelling and dispersion. As sodium concentrations increase, the electrophoretic mobility of the clay platelets increases resulting in swelling and dispersion of the clay particles thus impacting on soil permeability and consequently, this can impact on the ability of water to infiltrate into the soil profile (with subsequent surface pounding problems) and thus, reduce the water availability to irrigated crops, (Halliwell *et al.* 2001). Permeability decline with PMDE treatment. Hydraulic conductivity is an important property that determines the soil health. Poor hydraulic conductivity is viewed as agronomic problems (increased soil salinity, crop water stress and poor soil aeration) with severe economic consequences. A major concern in irrigated agriculture is the maintenance of sufficiently high soil permeability for salinity control and for the reclamation of salt-affected soil. In addition to its dependence on other factors, soil hydraulic conductivity depends on the salt concentration (McNeal and Coleman, 1966). Levy and Watt, 1990 observed that increasing amount of K in the exchangeable phase of soil decreased hydraulic conductivity of three South African soils. In the present study exchangeable K increased appreciably with PMDE application therefore reduced water permeability is well expected. Under PMDE-treated plots aggregate stability is found poor as compared to untreated plots at surface layer while better at sub-surface. It might be due to low OC content in PMDE plots. Low carbon content suppresses stimulation of microbial activity and secretion of microbial polysaccharides which is responsible for aggregate stability. Organic carbon was more in untreated soil at surface layer, while at sub surface it decline and buildup was noticed in PMDE-treated soils. Variability in organic carbon at surface and sub-surface layer in PMDE treated and untreated condition resulted in varying porosity and bulk density. Porosity at surface layer was adversely affected by PMDE application and it decline from the porosity of untreated soil, while at sub-surface layer porosity increased in PMDE-treated soils. Bulk density increased in PMDE treatment in surface soil while at sub-surface decline. Higher porosity and low bulk density of PMDE treated soil at sub-surface may be expected due to movement of humic substance fractions to lower death owing to solubilization of organic matter in presence of high sodium content at surface layer. Improvement in available P and Fe overall, Zn and Cu in sub-surface soil with PMDE treatment indicates its manurial potential provided used judiciously.

Despite of increased NPK availability in soil, soil *p*H, electrical conductivity and heavy metals load is also increasing with PMDE application. Therefore an urgent attention will be required in case of PMDE application so that soil health can be restored. Foreseeing scarcity of water in future and substantial manurial value of PMDE it can be used for pre-sown irrigation with desired level of dilution.

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