Application of distillery effluents to agricultural land: Is it a win-win option for soils and environment

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Abstract
Molasses based distilleries in India generate approximately 40 billion litres of effluents annually characterised by high organic load and salts posing a major disposal problem. The post methanation distillery effluent (PME) also being rich in plant nutrients (K, N), its use as ferti-irrigation source in agriculture is an attractive disposal option. The paper discusses the experimental results of effects of PME application (treatments: 0, 10, 20, 30 and 40 per cent of PME (5000 mg/l)) in agricultural field on the soil microbial population and chloride levels; thereby know whether soil is a good sink for recycling this nutrient rich effluent. Microbial enumeration studies revealed a beneficial effect of PME irrigation up to 30 per cent concentration due to the presence of carbon and nutrients that enhanced the soil microbial activity. Soil chloride levels and effluent colour were highest in the 0-30 cm soil depth, and beyond 45 cm their concentration decreased significantly suggesting soil acted as a good medium. Crop growth and soil health were negatively affected at higher PME concentrations or when applied without dilution. Therefore, monitoring and integrated approaches are needed to effectively utilize PME as valuable resource in agriculture and reduce its negative effects on the environment.

Key Words
PME, wastewater, recycling, plant nutrients, ferti-irrigation, microbial population

Introduction
Alcohol production from sugarcane molasses is an important distillery industry in India. For every litre of alcohol produced, 12 to15 litres of distillery effluent are generated. There are 290 distilleries in India generating about 40 billion litres of effluent annually and their disposal is a serious problem. The treatment of this wastewater before disposal is regulatory; however, owing to the high effluent treatment costs and due to elaborate physico-chemical methods, partial treatment is carried out and huge quantities of the effluent is either stored in lagoons, unlined tanks or let out into the surface water bodies or streams, thereby adversely affecting the good quality water resources and environment.

As the distillery effluents have high potential to produce methane, they are subjected to anaerobic digestion for methane recovery (Joshi 1999). The post methanation distillery effluent (PME) produced from the treatment is characterised by high biological oxygen demand (BOD) and chemical oxygen demand (COD), intense brown colour and high salt levels apart from being rich in plant nutrients. Though the bio-methanation of distillery effluent under anaerobic conditions brings down its BOD load from around 50,000 mg /l to 8,000-5,000 mg/l, due to their high organic load and salts, further treatment is still needed. If these effluents are discharged to water streams, the suspended solids present in the effluent would impart turbidity in water, reduce light penetration and impair biological activity of aquatic life. Hence an economically viable and environmentally safe means of disposal is needed to handle such large volumes of PME.

The only feasible alternative for disposal of PME seems to be land. As the effluent is mainly a plant extract, rich in organic matter and plant nutrients like potassium, nitrogen, sulphur and calcium, there is a scope for using it advantageously as a source of ferti-irrigation to agricultural crops (Joshi *et al.* 1996). Though the beneficial effect of distillery effluent on agricultural crops is known, little information is available on PME ferti-irrigation effects on residual salt levels in the soil profile, its degradation and soil microbial health. Therefore, this paper explores the potential advantages or negative effects of PME application in an agricultural field in dryland conditions.

Methods
Laboratory and field experimental methods to assess the effluent characteristics and its application effects in an agricultural field are presented.

Field experiment and soil
Field experiments in maize crop were conducted during rainy season on a sandy loam Ustochrept soil type, at experimental farm site of Indian Agricultural Research Institute, New Delhi, having subtropical, semi-arid type of climate. Surface soil samples (0-15 cm) were collected from selected control points (no fertilizer or effluent applied) and analysed for its initial physico-chemical properties by standard methods (Page *et al. 1982*). The soil was sandy loam in texture, with 0.38% organic carbon, 0.05% total N, ammonium actetate extractable K 159 mg/kg, EC 0.38 dS/m and pH 8.2.

Treatments
BOD of PME was taken as the main factor for the treatments to study the application effects on agricultural land. The treatments consisted of 0, 10, 20, 30 and 40 per cent PME (5000 mg/l) irrigation levels that were tested in a randomized complete block design with three replications in a plot size of 5m x 4m; four PME irrigations were given during the crop period in a maize field.

Soil sampling and analytical methods
To study the effect of PME irrigations on soil microbial health, soil samples were collected in triplicates from the treatment plots after every irrigation during the crop growth period and processed for enumeration of microbial population (total viable and culturable fungi, bacteria, and actinomycetes) using serial dilution and spread plate method (Page *et al*. 1982). To study the effect of PME treatments on chloride levels in the soil profile, after the 4th irrigation, soil samples were collected from the plots at 15 cm depth interval upto 90 cm and analysed for water soluble chlorides. Subsequent soil samples were collected at weekly intervals for 75 days and the water soluble soil extracts were measured for their colour intensity as per the APHA standard methods (APHA 1994).

Results
Review and survey around distilleries revealed that the practice of the use of PME by farmers in India basically emanates from the scarcity of water to meet their irrigation requirements, especially during water shortage periods in the dry regions. With increasing demand of good quality water for industry, potable water supplies and other sectors, there has been use of PME for crop irrigation around the distilleries. As the PME has high amounts of plant nutrients (K>N >P) (Table 1), its application improved crop growth in the maize field study (Karanam 2001). Considering the high cost of plant fertilizers and recognizing the nutrient value in this agro-industrial effluent, use of PME as ferti-irrigation source to agricultural crops is considered a viable option.

Table 1. Chemical composition of the post-methanation effluent (PME).

Parameters	Values*	Parameters	Values*
Organic C	148	Mg	0.61
N	2.0	BOD (mg/l)	5130
P	0.07	TDS (mg/l)	5530
K	3.98	Chloride	2.0
Sulphate	0.6	pH	8.5
Ca	1.1	EC (d S/m)	13.8

*All values except pH or otherwise stated are in g/l

Soil microbial population was studied, as they are an important entity of soil ecosystem helping in nutrient recycling processes and regulating the soil productivity. PME treatments at lower and up to 30 per cent concentrations increased the soil microbial population over control (Figure 1), that may be attributed to the carbon and nutrients present in the PME. An increase in bacterial population over control was found and the highest count was recorded with 20 per cent PME treatment at third irrigation which was significant among different PME treatments. However, 30 per cent PME treatment at third irrigation had higher fungi and actinomycetes (0.425 x 106 and 6.6 x 106 cfu/g of soil respectively) population in soil. The fungal population were in lesser number compared to bacteria or actinomycetes population. This study indicated that higher PME concentrations had a negative impact on soil microflora.

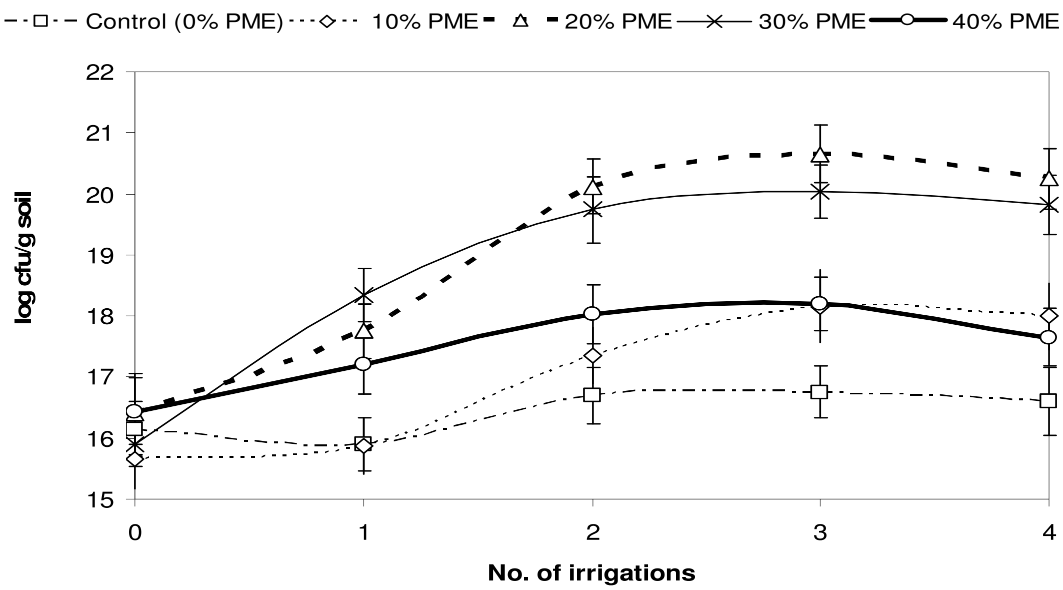

Figure 1. Effect of post methanation distillery effluent (PME) irrigations on the soil microbial population in an agricultural field. Figure adapted from Karanam (2001).

Study of chloride concentration at different soil depths, which get added to the soil through PME irrigation helped in understanding the effect of PME application in the soil profile. Results showed that chloride content in the soil profile increased with PME concentration, highest at 40 per cent PME treatment. Maximum chloride levels were observed in the 0-30 cm soil depth in all the PME treatments and the values were significantly higher in PME irrigated plots over control (Figure 2). Beyond 30-45 cm soil depth, the chloride concentration decreased significantly indicating less possibilities of PME affecting the groundwater.

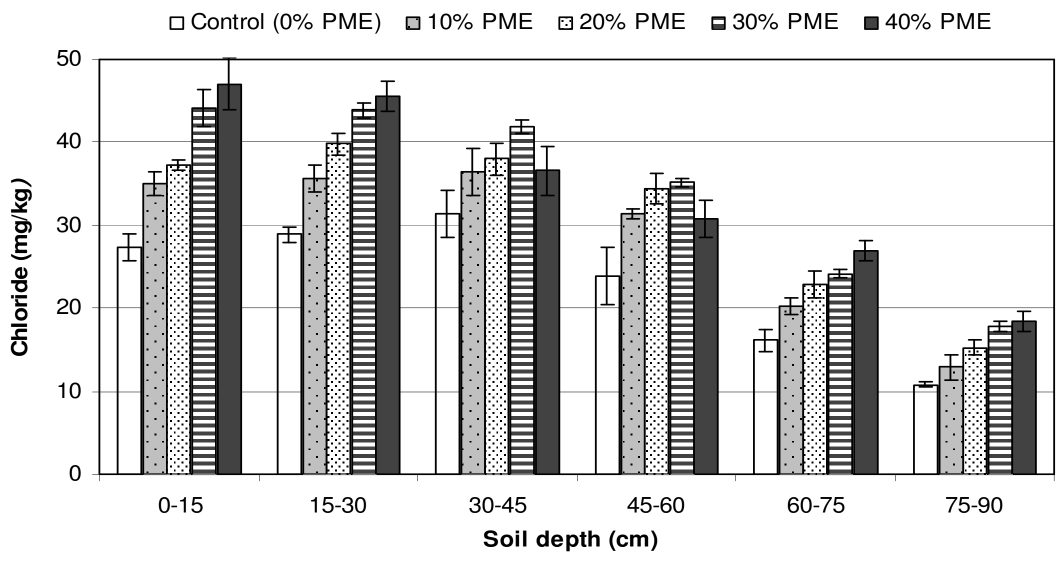

Figure 2. Changes in soil chloride levels at different soil depths with post methanation distillery effluent (PME) irrigations. Figure adapted from Karanam (2001).

In PME irrigated plots, most of the effluent colour remained in the 0-30 cm of soil depth. When irrigated with higher concentrations of PME (40%) treatment, the colour intensity in soil extracts was observed to a soil depth of 60 cm. However with progression of time there was a significant reduction in the residual colour (Karanam 2001). The PME applied to the soil being mostly organic (melanoidins) and interactive in nature, its movement down in the soil profile would be lesser in comparison to chloride ion. When the PME is spread over larger areas as in agricultural land, with processes such as solar radiation effect, crop rhizosphere and biodegradation due to soil microbial activity, and adsorbent nature of the soil, there are less chances of ground water contamination.

Conclusion

The use of PME in agricultural fields with appropriate dilution (upto 1500 mg/l i.e., 30 per cent PME concentration) provides a plausible solution for on-land disposal of the effluents as they have potential to provide major and micro nutrients to crops and save on cost of fertilizers apart from primarily acting as a source of irrigation water in agriculture. This would thereby prevent pollution and improve availability of other good quality water resources, and the approach would prove beneficial for soils and environment. Hence application of nutrient rich PME to agriculture can provide an economic and environmental friendly method of disposal, while at the same time help to improve soil fertility and crop yields. However, monitoring is needed to understand the long term effects of PME use. Also, factors such as organic load of PME, soil type and its properties, water availability, crops grown, rainfall pattern, depth of water table, groundwater quality and environment of the region need to be considered. For adoption success of the research findings, participation of all the stakeholders such as regulatory bodies, industry, farmers, land managers and environmental researchers is very important for appropriate PME disposal or its use in agriculture The way forward is to adopt integrated approaches to manage and effectively utilize this valuable resource in agriculture without posing any problem to groundwater bodies and environment.

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