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RESEARCH ARTICLE

CARBON AND NITROGEN MINERALIZATION PATTERN IN POST METHANATED DISTILLERY EFFLUENT (PMDE) INCUBATED CLAY LOAM SOILS OF TRICHIRAPALLI DISTRICT, TAMILNADU

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ABSTRACT

Post Methanated Distillery effluent (PMDE) contains all nutrients and organic matter and used in agriculture as a source of plant nutrients and irrigation water. The effect of different levels of PMDE application on carbon and nitrogen dynamics was examined through a laboratory incubation experiment. Application of different levels of PMDE had significant influence on soil organic carbon and nitrogen in soil. Both the NH_4-N and NO_3-N fractions markedly increased with increase in the levels of PMDE up to 40m^3/ha. Results showed that PMDE application not only adds mineral N (NH_4-N and NO_3-N) to soil, but also promotes the mineralization of soil organic N, thus resulting in large amounts of NH_4-N and NO_3-N in soil.

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INTRODUCTION

Nitrogen plays an important role in increasing the agricultural production and as a constituent of protein, it increases the food value. It also influences the quality of environment. Available N includes NH_4^+, NO_3^- and NO_2^- forms. Since, NO_2 is highly unstable in soil, it is either immediately oxidized to NO_3^- form or reduced to NH_4^+ form. The dynamic of these two forms is influenced by the aeration status of the soil. The predominant form present is NO_3^-. The NO_3^- accumulated in the soil is either taken up by the crop or leached down to the lower soil horizon as it is readily soluble in water. Some amount of NO_3-N is also immobilized by soil microbes during the process of mineralization of organic matter. The spent wash, being loaded with organic and inorganic compounds could bring remarkable changes on the physical, chemical and biological properties of soils and thus influences the fertility of soil significantly. However, indiscriminate disposal results adverse impact on soil and environmental health. Most studies investigating effluent irrigation and leaching losses have focused on NO_3^-N, but in certain situations NH_4-N or organic N may be the dominant form of N to be leached. Informations are scarce on nitrogen dynamics in soil under spent wash application and its environmental significance. Such informations are needed for developing guidelines or strategies for effective utilization of distillery spent wash without any environmental hazards.

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MATERIALS AND METHODS

The Post Methanated Distillery Effluent was characterized for its nutritive value and pollution potential, and was used in incubation experiment (Table.1). The PMDE sample was collected from M/s Kothari Sugars and chemicals Ltd, Kattur, Lalgudi Taluk, Tiruchirapalli District, Tamil Nadu, India. The effect of different levels of PMDE on soil nitrogen and organic carbon dynamics were examined through a laboratory incubation experiment. Initial soil samples were collected from experimental field no. B_2B of Central farm of Agricultural College and Research Institute, Kumulur, Tiruchirapalli District Tamil Nadu, India. The samples were air-dried, powdered using a wooden mallet and sieved (2 mm sieve). The processed soil samples were stored in polyethylene bags and analyzed for soil physical, chemical and biological characteristics.

Five hundred grams of air-dried soil (2mm sieved) were weighed in plastic containers. The PMDE was added at the rate equivalent to 0, 10,20,30,40 m^3 ha^{-1} and thoroughly mixed with soil. Whenever necessary, required quantity of distilled water was added to achieve a final moisture content equivalent to 60 % of field capacity. After adding PMDE, the plastic containers were covered with polyethylene bags containing small pin-sized holes to permit aeration. Four replicates of each treatment were prepared, randomly placed and incubated in the laboratory at 25 ± 2ºC for 90 days. At the end of 30, 60 and 90 days destructive samples (≈100 g) were removed from all the treatments and used for NH_4-N, NO_3 -N and organic carbon analyses. Moisture factor was computed and applied to express the results on oven dry basis.

The contents were allowed to stand for 30 min. Then distilled water 200 ml, 10 ml of orthophosphoric acid and diphenylamine indicator was added. This was titrated against 0.5 N ferrous ammonium sulphate towards the end point of a bright green color.

Mineral –N

The fractionation of soil nitrogen was carried out by the procedure given by Bremner (1965). *Preparation of Equilibrium extract:* A quantity of 10 g of soil (0.2 mm seived) treated with 100 ml of 2 M KCl solution was shaken for one hour and filtered through Whatman No.1 filterpaper. *Ammonical nitrogen (NH_4-N):* An aliquot of 20 ml of the above filterate was distilled with freshly ignited MgO in distillation apparatus and the distillate collected in 2 per cent boric acid containing double indicator was titrated with standard H_2SO_4. *Nitrate nitrogen (NO_3-N):*

Table 1. Characteristics of post methanated distillery effluent (PMDE)

S.No	Parameters	Raw Effluent	Post Methanated distillery Effluent
1	pH	5.18	7.71
2	Electrical conductivity (dS m^{-1})	30.9	30.1
3	Organic carbon (%)	0.15	1.48
4	Total Nitrogen mg L^{-1}	307	445
5	Total Phosphorous mg L^{-1}	317	283
6	Total Potassium mg L^{-1}	6950	8350
7	Colour	Dark brown	Dark brown
8	Odour	Disgracable	Unpleasant smell of burnt sugar
9	Chloride mg L^{-1}	6745	4828
10	Sodium mg L^{-1}	450	374
11	Sulphate mg L^{-1}	5157	4274
12	Calcium mg L^{-1}	2529	2162
13	Magnesium mg L^{-1}	1830	1547
14	Total Iron mg L^{-1}	23.51	27.36
15	Total Manganese mg L^{-1}	5.8	7.3
16	Total Zinc mg L^{-1}	7.93	8.21
17	Total Copper mg L^{-1}	3.1	5.9
18	BOD mg L^{-1}	10,565	8565
19	Total Dissolved Solids mg L^{-1}	53,000	50,000
20	Bacteria (x 10^6 CFU /ml of effluent)	10	14
21	Fungi (x 10^4 CFU /ml of effluent)	12	20
22	Actinomycetes (x 10^3 CFU /ml of effluent)	Nil	Nil

Table 2. Organic carbon content (g/kg) in PMDE incubated clay loam soil

S.No	Treatments	Days after incubation				
		0	30	60	90	Mean
1	Control	6.3	5.5	4.9	4.2	5.2
2	Soil+PMDE @ 10m^3 ha^{-1}	7.0	5.8	5.2	4.8	5.7
3	Soil+PMDE @ 20m^3 ha^{-1}	7.9	6.1	5.8	5.0	6.2
4	Soil+PMDE @ 30m^3 ha^{-1}	8.3	7.5	6.1	5.8	6.9
5	Soil+PMDE @ 40m^3 ha^{-1}	9.2	8.8	7.0	6.5	7.9
	Mean	7.7	6.7	5.8	5.3	6.38
		SEd			CD(P=0.05)	
	T	0.041			0.083	
	D	0.037			0.074	
	TxD	0.082			0.165	

Carbon Mineralization

The mineralization of C was determined by measuring organic carbon in soil, at 0, 30, 60 and 90 days. Organic carbon content of the soil was estimated by the wet digestion method. A 0.5 g of soil (<1 mm) was taken in a 500 ml conical flask and added 10 ml of 1 N $K_2Cr_2O_7$ and 20 ml of conc. H_2SO_4.

On removal of NH_4 from the sample, added a pinch of devarda's alloy and continued the steam distillation. The amount of NO_3-N was determined as described for NH_4-N.

RESULTS AND DISCUSSION

Effect of PMDE on Soil organic carbon dynamics

Initially the organic carbon content was only 6.3 g kg^{-1}. Due to the application of PMDE, it was increased significantly, ranging from 7.0 to 9.2 g kg^{-1}. Irrespective of treatments, the organic carbon in soil was found gradually decreased throughout the days of incubation. The interaction effect between treatment and incubation period was significant. Comparison made among the two way interaction showed that the organic carbon content was the highest in soil that recorded 40 m^3 ha^{-1} of PMDE application. The PMDE contains large amount of organic carbon. It increased the soil organic carbon content (Table.2) which in turn stimulated the soil microbial activity by providing a carbon substrate. The balance between N mineralization and immobilization is closely linked to C substrate availability and C/N ratio of the available organic matter.

incubation, the concentration of NH_4-N was lowest in control and the highest in PMDE @ 40m^3 ha^{-1}. The NO_3^- -N in soil was changed significantly due to application of PMDE. Initially the NO_3^- -N in soil ranged between 68 and 97 mg kg^{-1}(Table.4). Increasing the rate of application had significantly increased the NO_3^- -N content of soil. At 90 days after incubation, the concentration of NO_3^- -N progressively increased at all treatments. At the end of incubation, the NO_3^- -N content was lowest in the control and the highest in treatment (T_4).The effect of treatments, incubation period and their interaction had significant impact on NO_3^- -N in soil.

The N dynamics in soil was significantly influenced by the application of PMDE. The data indicated that the mineralization of N occurs continuously in soil during incubation period up to 60 days and thereafter the mineralization rate decreased at 90 days of incubation due to possible net immobilization and microbial uptake. Increase in the levels of spent wash markedly increased the rate of mineralization of N during the incubation period.

Table 3. Ammonical Nitrogen content (g/kg) in PMDE incubated clay loam soil

S.No	Treatments	Days after incubation				
		0	30	60	90	Mean
1	Control	72	76	90	69	77
2	Soil+PMDE @ 10m^3 ha^{-1}	122	148	82	80	108
3	Soil+PMDE @ 20m^3 ha^{-1}	140	183	91	89	126
4	Soil+PMDE @ 30m^3 ha^{-1}	151	198	94	92	134
5	Soil+PMDE @ 40m^3 ha^{-1}	169	211	97	95	143
	Mean	131	163	91	85	116.96
		SEd				CD(P=0.05)
	T	0.679				1.372
	D	0.607				1.227
	TxD	1.358				2.744

Table 4. Nitrate nitrogen content (g/kg) in PMDE incubated clay loam soil

S.No	Treatments	Days after incubation				
		0	30	60	90	Mean
1	Control	68	87	97	117	92
2	Soil+PMDE @ 10m^3 ha^{-1}	71	121	132	145	117
3	Soil+PMDE @ 20m^3 ha^{-1}	84	133	147	172	134
4	Soil+PMDE @ 30m^3 ha^{-1}	93	141	155	185	144
5	Soil+PMDE @ 40m^3 ha^{-1}	97	147	159	191	149
	Mean	83	126	138	162	127.15
		SEd				CD(P=0.05)
	T	0.408				0.825
	D	0.365				0.738
	TxD	0.816				1.650

Effect of PMDE on Nitrogen dynamics

The effect of PMDE on N dynamics in soil is presented in table.3.Application of different levels of PMDE had significant influence on soil. Immediately after application of PMDE, the NH_4-N in soil markedly increased from 72 mg kg^{-1} in control to 169 mg kg^{-1} in 40m^3/ha. The highest concentration of NH_4-N and NO_3^- -N was recorded due to the application of 40m^3 ha^{-1} PMDE.

The PMDE application resulted significant increase in the NH_4-N upto 30 days and thereafter, a declining trend was observed. The treatments and incubation period had significantly affected NH_4-N content in soil. At all days of

Both the NH_4-N and NO_3^- -N fractions markedly increased with increase in the levels of PMDE (Fig.1 and 2). This might be due to the inorganic N present in the distillery PMDE. This result corroborates with the findings of Myers *et al.,* 1982 who reported that under land-based treatment of effluent, NO_3 –N and NH_4-N concentrations in soil may increase as a direct result of inorganic N present in the effluent and increased soil organic matter (SOM) mineralization. Similar results were observed by Degans *et al.*, 2000 who stated that effluent irrigation can significantly increase the total N stored within a soil profile, according to effluent composition, loading rates and solution chemistry. The increased in the NH_4-N fraction was observed up to 30 days of incubation in PMDE applied soils. This was in line with the findings of Chatigny *et al.,* 2001 who reported that addition of pig slurry and composted sewage sludge has resulted in an immediate but short term increases in inorganic N contents, particularly NH_4^+. After 30 days of incubation a decline in the NH_4-N fraction was observed, probably due to the N transformation process through which the NH_4-N is converted into NO_3 –N (or) due to immobilization and microbial uptake. In an incubation experiment Van Kessel *et al.,* 2000 found that various components of dairy compost the bulk mineralized ammonium was observed to have been nitrified to nitrate within 14 to 28 days. The reduction in NH_4-N could also be due to conversion of NH_4-N to NO_3 –N (nitrification) and further the NO_3 –N lost during incubation through biological denitrification, a microbial process through which NO_3 is reduced to nitrous oxide (N_2O) and molecular N (N_2) and lost from soil (Latha *et al*., 2012). The NO_3 –N fraction was found to be increased continuously till the end of the incubation experiment. Nitrification of NH_4-N added through PMDE, and mineralization and nitrification of soil organic N might have increased the NO_3 –N in soil. Hadas *et al.,* 1996 and Marchner *et al.,* 2003 reported that an increase in the rate of PMDE markedly increased the rate of both mineralization and nitrification in soil. However, greater amount of NO_3 –N and NH_4-N was evident particularly at the later stage of incubation.

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