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RESEARCH PAPER

Mineralization of native soil sulphur under different temperature and moisture regimes

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Abstract : An investigation to quantify the changes occurring in native soil S over a range of time interval was carried out with twenty soils of Jharkhand at two temperature regimes *i.e.* 25 +1° C and 45+ 1 °C. The soils were incubated at field capacity and under flooded condition. Incubation of all the soils in aerobic condition for 14, 28, 42 and 56 days period resulted in mineralization of native S at a varying rate. The rate of mineralization of native organic S ranged from 0.8 µg S $cm^{-2}d^{-1}$(after 2 weeks) at 25 °C to 2.18 µg S $cm^{-2}d^{-1}$ (after 8 weeks) in aerobic moisture regimes. However, rate of mineralization increased to 9.92 µg S $cm^{-2}d^{-1}$ (after 8 weeks) at 45 °C. Under flooded condition, native S immobilized and it was higher at 45 °C compared to 25 °C. The amount of native S immobilized ranged from 0.25 to 3.47 µg S g^{-1} at 25 °C for two weeks of flooding to 2.15 to 6.80 µg S g^{-1} at 45 °C for eight weeks of flooding.

Key Words : Organic sulphur, Mineralization, Immobilization

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INTRODUCTION

Organic constituents are the predominant form of sulphur in soils. The transformation of soil organic sulphur to inorganic sulphate S (S mineralization) and the reverse process (S immobilization) wherein the incorporation of sulphate into soil organic compounds happens, play important roles in the cycling of S within the soil. Both S mineralization and immobilization are microbiologically mediated and thus depend on the type and size of soil microbial population and the physiological state of the organisms. The activity of the microbial population is affected by the prevailing soil physical and chemical conditions. The main controlling factors are temperature, moisture content and compaction of soil.

Of the factors mentioned soil temperature and moisture content are the most important in temperate and tropical situations. It is essential to quantify the influence of temperature and moisture on net mineralization to improve our prediction of mineralization under field conditions. The need to distinguish between net and gross mineralization and immobilization rates over a period of time assumes greater significance in order to synchronize the availability of S with plant need (Deng and Dick, 1991). The present study was aimed to quantify the net mineralization/immobilization occurring at different temperature and moisture regimes and at different time intervals.

MATERIALS AND METHODS

Surface soil samples (0-15 cm) were collected from twenty different sites from plateau region of Jharkhand comprising the districts of Dhanbad, Giridih, Hazaribagh and Ranchi. The collected samples were air-dried after mixing them thoroughly. The air-dried samples were passed through 2 mm sieve. A brief important characteristic of the sampled soils is being given in Table A.

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Table A : Native S mineralized in aerobic moisture regime over different time periods of incubation at 25 ^{0} C (µg g^{-1})

Soil No.	2 wks (25 °C)	4 wks (25 °C)	6 wks (25°C)	8 wks (25°C)
1.	9.25	25.25	32.00	32.50
2.	3.75	8.75	12.00	14.50
3.	9.25	11.00	14.00	14.50
4.	0.75	2.50	5.50	9.75
5.	4.75	8.52	11.00	12.5
6.	5.25	6.00	6.85	9.75
7.	11.00	21.25	24.00	25.25
8.	4.25	5.00	6.23	6.75
9.	7.35	12.65	20.40	22.40
10.	2.50	4.80	7.25	8.75
11.	9.25	15.00	21.00	24.25
12.	17.75	24.75	28.00	28.25
13.	10.20	17.25	18.75	19.50
14.	5.50	15.75	18.00	19.50
15.	6.00	11.50	19.00	20.25
16.	12.00	16.50	17.50	21.50
17.	10.50	14.50	18.00	19.75
18.	13.25	17.75	19.00	19.75
19.	14.36	18.50	21.00	21.25
20.	8.39	16.50	18.50	21.25
Range	0.75-14.36	2.50-25.25	5.50-32.00	6.75-32.50
Mean	8.21	13.08	16.10	17.86
SEM for weeks	2.15	SEM for soils	4.81	
CD for weeks at 1%	5.96	CD for soils at 1%	7.85	

Incubation studies:

All the twenty samples were subjected to incubation studies for different periods of time interval (2, 4, 6 and 8 weeks) in both aerobic and anaerobic moisture regimes and at two temperature levels at 25+1^0 C and 45+1^0 C. For the mineralization studies two separate set ups were laid down:

Aerobic moisture regime:

10 g homogenized sample from all the twenty soil samples and were placed in 250ml conical flask, sufficient deionized water was added to bring the moisture content to about 50 per cent water holding capacity, followed by incubation of one set at room temperature and another in oven temperature fixed at 45^{0}C. Aeration of samples was done regularly to prevent excessive build up of CO_2. After the specified time, the sample was taken out and dried in an oven. 10 g of the dried soil sample was mixed with 50ml of 0.15 per cent $CaCl_2$. The suspension was shaken on a shaker for 30 minutes and subsequently filtered. The aliquot was then analyzed for sulphate –S following the method of Chesnin and Yien (1951). Mineralization of native organic S determined as the increase in 0.15 per cent $CaCl_2$ extractable S compared to the initial value of S status.

Anaerobic moisture regime:

The procedure followed for homogenization of the samples was same as aerobic moisture regime. The only difference was samples were flooded with deionized water by keeping the water level in the conical flask to 2 cm. Water was regularly added to maintain the level of flooding. Aeration of sample was done to prevent excessive build up of CO_2. After the specified time, the sample was taken out and dried in an oven. 10 g of the dried soil sample was mixed with 50ml of 0.15 per cent $CaCl_2$.The suspension was shaken on a shaker for 30 minute and subsequently filtered. The aliquot was then analyzed for sulphate –S following the method of Chesnin and Yien (1951). Immobilization of native organic S was determined as the decrease in 0.15 per cent $CaCl_2$ extractable S compared to the initial value of S status.

Mineralization rate:

The rate of net mineralization was calculated according to the equation given by Janzen and Bettany(1971) which is

$$K= (1-(1-m/m_o)\ 1/3)\ zDo/2t$$

where K= mineralization rate(ìg S cm^{-2}d^{-1})

m=amount of mineralized sulphur ìg (calculated as an increase in 0.15 per cent $CaCl_2$ extractable S concentration)

m_o =amount of sulphur at the beginning of each incubation period µg(calculated as the 0.15 per cent $CaCl_2$ extractable S concentration).

Z= density of S(2.07 x 106µg cm^{-3})

Do=particle diameter at the beginning of each incubation period(0.075cm by assuming spherical particles)

T=time of each incubation period.

RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been discussed under following heads :

Mineralization of native S under aerobic conditions:

Incubation of all the soils in aerobic condition for 14,28,42 and 56 days period resulted in mineralization of native S. Mineralization of native organic S was then determined as the increase in 0.15 per cent $CaCl_2$ extractable S in all the soils. Similarly, the immobilization was determined as the decrease in 0.15 per cent $CaCl_2$ extractable S in all the soils. The rate of mineralization during the successive incubation periods(0-14,14-28,28-42 and 42-56 days) was then calculated using Janzen and Bettany equation(1987). The results (Table 1) indicated that in aerobic moisture regime and at 25^0 C, the

Table 1 : Native S mineralized in aerobic soil condition under different time periods of incubation at 45 ^{0} C (mg kg^{-1})

Soil No.	2 wks (45 °C)	4 wks (45 °C)	6 wks (45°C)	8 wks (45°C)
1.	17.38	38.25	34.26	34.00
2.	20.20	26.00	22.00	2150
3.	22.40	24.25	20.00	18.75
4.	22.59	30.25	21.00	20.75
5.	23.57	24.75	21.00	20.00
6.	23.27	24.50	22.00	20.55
7.	15.44	24.25	20.00	19.50
8.	13.72	20.65	18.54	18.00
9.	14.07	25.26	24.56	23.80
10.	12.45	21.50	2025	19.58
11.	14.25	24.25	22.05	20.75
12.	22.53	27.75	20.0	19.75
13.	19.66	25.50	20.50	20.00
14.	16.64	24.25	25.25	24.00
15.	18.60	21.25	20.50	19.00
16.	16.11	30.50	18.50	10.00
17.	21.99	33.50	32.00	24.75
18.	16.63	26.25	21.75	20.50
19.	12.99	25.65	20.25	17.50
20.	24.51	44.50	23.50	13.75
Range	12.45-25.29	20.65-44.50	18.50-34.26	10.00-34.00
Mean	18.59	27.13	26.59	22.40
SEM for weeks	2.06	SEM for soils	4.61	
CD for weeks at 1%	5.71	CD for soils at 1%	7.52	

amount of native soil organic S mineralized ranged from 0.75 to 14.36 µg S/g (after 2 weeks) to 6.75 to 32.5 µg S/g (after 8 weeks). The mean value varied from 8.21 µg S/g(after 2 weeks) to 17.85 µg S/g (after 8 weeks). Mineralization of native S significantly increased up to 6 weeks of incubation in all the soils at 25^{0}C. The net mineralization rate was also determined to augment the rate of native S mineralized (Table 4) and it ranged from 0.84 to 12.34 µg S cm^{-2}d^{-1} (after 2 weeks) to 2.18 to 8.01 µg S cm^{-2}d^{-1} (after 8 weeks) (Table 3). This suggested that under investigation the potential of mineralization of native organic S of soils, even after two months of incubation under aerobic moisture regimes. This is probably due to the fact that under aerobic condition, the soil is in direct contact of oxygen of the atmosphere and as the microbial activity is more the mineralization showed significant increase. Mineralization of native S was faster during the initial 4 weeks as the accumulation of SO_4^{2-}S was high. The initial rapid rate of organic S mineralization was presumably the result of short period of rapid decomposition that follows re-moistening, which in present investigation was done regularly. Many microorganisms satisfy their S requirement from SO_4^{2-}S and microbial activity may decrease with prolonged incubation. Although the mineralization of organic S in acidic soils was much slower, an average accumulation of around 27.00 µg S/g suggested the adoption of the indigenous S mineralizing population to the prevailing soil pH. Similarly, incubating all the soils under aerobic soil condition at 45^0 C resulted in marked increase of native S mineralization. The data presented in Table 2 indicated that native S mineralized rapidly up to 28 days (4 weeks) of incubation. and thereafter showed the reverse trends, ie the mineralization of native S started decreasing beyond 4 weeks of incubation. Similar reports have been reported by De Neve *et al.*(2000). Soil manipulation also is associated with temporary immobilization which is a transient phenomenon. For majority of the soils, the mineralization of native S remained unchanged after 6 weeks of incubation. The amount of native S mineralized ranged from 12.45 µg S/g (after 2 weeks) to 20.65 to 44.5 µg S/g (after 4 weeks). After 6 weeks, it ranged from 18.5 to 34.26 µg S/g, whereas after 8 weeks of incubation it ranged from 10.00 to 34.00 µg S/g. These results are in confirmatity with the indings of Jaggi *et al.* (1999). Pirella and Tabatabai (1988) have also shown that mineralization of S was significantly higher at 30^0 C than at 20^0 C. The rate of mineralization of native organic S

Table 2 : Rate of mineralization of organic S by Janzen and Bettany equation (µg S cm $^{-2}$ d^{-1}) incubated at 25 ^{0} C

Soil No.	2 wks (25 °C)	4 wks (25 °C)	6 wks (25 °C)	8 wks (25 °C)
1	10.05	44.75	33.73	25.46
2	3.86	5.07	5.14	5.17
3	12.07	7.64	7.47	5.99
4	0.80	1.39	2.18	3.30
5	5.64	5.63	5.31	4.84
6	6.65	3.88	3.03	3.57
7	18.26	47.25	33.38	25.57
8	6.01	3.62	3.13	2.59
9	11.64	13.77	32.18	25.18
10	3.45	3.55	3.90	3.77
11	17.24	40.19	33.41	26.53
12	95.09	54.53	37.87	28.48
13	11.02	12.11	9.70	8.11
14	4.95	9.16	7.67	6.78
15	5.31	5.72	8.17	7.03
16	11.92	9.37	6.88	8.01
17	9.44	7.16	6.61	5.84
18	12.34	9.37	7.00	5.62
19	13.74	10.03	8.45	6.50
20	6.61	7.69	6.08	5.78
Range	0.80-95.09	1.39-54.33	2.18-37.87	2.59-28.48

Table 3 : Rate of mineralization of organic S by Janzen and Bettany equation (µg S cm^{-2} d^{-1}) incubated at 45^0 C

Soil No.	2 wks (45ºC)	4 wks (45ºC)	6 wks (45ºC)	8 wks (45ºC)
1	25.84	54.15	34.66	26.14
2	75.78	47.27	33.21	22.24
3	90.92	47.56	32.20	19.18
4	97.78	52.67	29.29	24.20
5	95.12	49.62	34.74	22.88
6	96.65	49.27	34.87	24.86
7	40.48	50.51	35.93	23.16
8	33.71	51.87	36.44	25.16
9	38.28	48.55	36.53	25.82
10	27.63	53.15	34.91	25.97
11	73.82	50.62	36.36	24.93
12	105.44	54.14	33.52	25.00
13	33.29	46.71	32.02	23.91
14	20.04	41.89	27.37	19.48
15	23.50	38.22	30.76	6.12
16	18.04	15.49	7.60	2.37
17	29.50	45.07	30.94	16.87
18	16.95	47.07	30.43	22.23
19	12.02	37.94	7.86	4.58
20	32.05	52.09	9.54	3.00
Range	12.02-105.44	15.49-54.15	7.60-36.53	2.37-25.97

was also calculated at two temperature levels following the method of Janzen and Bettany (1987). The rate of mineralization ranged from 1.02to 9.92 µg S $cm^{-2}d^{-1}$ (after 2 weeks) to 1.18 to 6.12 µg S $cm^{-2}d^{-1}$ (after 8 weeks). The mineralization rate of soils incubated at 45^{0}C was initially lower than the soils incubated at 25^0 C but reverse was true after 4 weeks of incubation (Table 3), *i.e.* the rate of mineralization of soils was higher at 45^{0}C than at 25^{0}C.

Immobilization of native S under flooded conditions:

The amount of native soil S immobilized ranged from 0.25 to 5.92 µg S/g(after 2 weeks) to 1.10 to 6.4 µg S/g(after 8 weeks)at 25^{0}C (Table 4). Initially, under flooded condition and at 25^{0}C temperature, the native soil S rapidly immobilized and the mean values were found to be 2.89 µg S/g(after 2 weeks), 4.47 µg S/g(after 4 weeks),4.75 µg S/g(after 6 weeks) and 3.47 µg S/g (after 8 weeks). The results are in confirmatory with the findings of Sachdev and Chabra (1974) and Gupta *et al. (*1988). Similarly, under flooded condition and at 45^0 C, native S immobilized was higher than at 25^{0}C and it ranged from 2.15 to 4.63 µg S/g (after 2 weeks) to 4.20 to 6.80 µg S/g (after 8 weeks) with an average value of 3.21 µg S/g (after 2 weeks) to 5.82 µg S/g (after 8 weeks).The reduction of sulphate under flooded condition may be attributed to the immobilization of native soil S getting immobilized. Sachdev and Chabra (1974). Under

Table 4 : Native S immobilized in flooded soil condition under different time periods of incubation at 25 ºC (mg kg^{-1})

Soil No.	2 wks (25 ºC)	4 wks (25 ºC)	6 wks (25ºC)	8 wks (25ºC)
1.	3.08	7.89	8.13	6.40
2.	1.25	2.73	3.63	2.40
3.	3.08	3.44	3.51	1.10
4.	0.25	0.78	2.44	2.20
5.	1.58	2.66	6.31	1.57
6.	3.67	2.84	1.69	4.80
7.	1.42	2.00	5.60	1.25
8.	2.45	7.08	2.19	4.08
9.	0.83	1.67	6.06	1.45
10.	3.08	4.22	7.06	4.20
11.	5.92	1.60	4.88	5.60
12.	3.40	5.00	4.28	3.75
13.	1.83	8.25	5.06	3.60
14.	2.00	5.76	5.38	3.75
15.	4.00	5.25	4.94	3.60
16.	3.50	5.89	4.15	3.80
17.	4.42	5.50	4.01	3.80
18.	4.79	4.83	4.97	4.20
19.	4.36	5.92	5.30	3.70
20.	2.80	6.17	5.31	4.06
Range	0.25-5.92	0.78-8.25	1.69-8.13	1.10-6.40
Mean	2.89	4.47	4.75	3.47
SEM for weeks	0.81	SEM for soils	1.61	
CD for weeks at 1%	1.98	CD for soils at 1%	2.52	

flooded soil conditions, two genera of sulphur reducing bacteria *Desulphovibrio* and *Desulphotomaculam* reduce sulphate to sulphide ion through the potential inorganic intermediates- thiosulphate, tetrathionate and colloidal sulphur (Postgate,1959; Sokoleva and Sorokin,1958). Many microorganisms satisfy their S requirements from SO_4^{2-} and microbial activity may decrease with prolonged incubation and assimilation of SO_4^{2-} by microorganisms causing concurrent immobilization (Haque and Womsley, 1972). Therefore, due to limitation of oxygen, the reduction of sulphate to sulphide increases to a relatively high amount and combines with iron in soil to form iron sulphide and is thus retained in the soil. Hence, it may be concluded that mineralized organic S is increasingly subjected to immobilization until a new mineralization-immobilization steady state for the new condition is reached.

Conclusion:

From the present study it may be concluded that native

S is subjected to increased rate of mineralization at higher temperature and to immobilization in flooded conditions until a new mineralization-immobilization steady state for the new condition is reached.

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