Influence of Sulfur on the Nature of Soils.

I. Effect on the reclaimed soils.

By

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The effect of sulfur on the nature of soils has been investigated in America and Europe to some extent especially in connection with the improvement of alkali soils which are found extensively in the western part of the United States. On the other hand, little attention has been given to this subject in this country although it has special interest for this country since she is surrounded by the seas, and is confronted with the problem to improve the reclaimed area on the sea shore.

This investigation was undertaken to see the effect of 'Bac-sulfur'[1], flower of sulfur (commercial), ammonium sulfate and calcium sulfate on the reclaimed soil of recent origin.

Experimental.

Description of Soil Samples.

The samples were taken from the reclaimed land on the sea shore of this prefecture. The land was reclaimed in June 1927 and is located about 250 meters from the present shore line. The samples were collected from the different spots where the salt effect was very marked. The description of composite sample is given below:

Table I.

Description of Soil Samples.

Composite sample.	p_H	Na_2SO_4	NaCl	Carbonates.	Soluble salts.	Organic matter.
5 : 1 water extract.	7.71	0.129%	0.084%	trace	0.243%	0.004%

According to the data given above, it is evident that more sulfate was found than the chloride, which may be due to the heavy application of ammonium sulfate after the reclamation, although the reaction itself was slightly alkaline.

1) 'Bac-sulfur' was presented by Mr. Fuji, an agent of the American Western Sulfur Company.

Method of Procedure.

A flower pot of fourteen centimeters in diameter was filled with three kilograms of soil which corresponds to twenty five thousandth of the surface soil of one Tan or 993 square meters, and watered constantly. The following analytical methods were employed to determine the influence :

a. Determination of hydrogen ion concentration :
The water extract of 1 : 1 was used and the determination was carried out by BILMANN's quinhydrone method.

b. Determination of chlorine compounds :
A definite amount of soil extract was taken and the determination was made by the volumetric method as usual by titrating with silver nitrate using the potassium chromate as the indicator.

c. Determination of sulfate compounds :
The determination was carried out gravimetrically as usual by using barium chloride.

d. Determination of carbonates :
The determination was carried out by titrating with potassium sulfate using phenolphthalein and methyl orange as the indicator.

e. Determination of water soluble salts :
The electric conductivity method was used and from the resistance thus obtained, the amount of soluble salts was calculated from KING and WHITSON's table[1].

f. Microbiological analysis :
The quantitative microbiological determination was undertaken by the plate method using the albumin agar.

Influence of Sulfur on the pH of Soils.

To each pot, 1.5 g. and 7.5 g. of 'Bac-sulfur' was added which correspond to 10 and 50 Kans or 37.5 and 187.5 Kg. per Tan (993 sq. meter) respectively. The P_H was determined periodically as indicated in the following table :

Table II.

Change of Hydrogen Ion Concentration.

Reaction, / Weeks. / Amount* of 'Bac-sulfur.'	P_H									
	Initial.	1.	2.	3.	4.	5.	8.	10.	12.	14.
Control.	7.71	7.71	7.64	7.55	7.53	7.33	7.12	6 84	6.73	6.50
37 5 Kg.	7.68	7.49	6.94	5.41	5.24	5.13	4.82	4.77	4.74	4.64
187.5 Kg.	7.65	7.40	6.73	5.11	5.08	4.71	4.20	3.82	3.41	3.19

* The amount applied per Tan (993.0 sq. m.).

1) DAVIS, R. O. E. and H. BRYAN, Bulltin 61, Bureau of Soils, U. S. D. A., 1910. (KING and WHITSON, Bulltin 85, Wisconsin Agr. Exp. Station, 1901.)

Table II indicates that the application of sulfur increases the acidity markedly and the increase is in parallel with the amount of sulfur used. Thus where 10 Kans (37.5 Kg.) were applied, P_H 7.68 was changed to P_H 4.64, and in case of 50 Kans (187.5 Kg.), P_H 7.65 was changed to P_H 3.19.

Table III.

Analytical Determinations, after Five Weeks.

Amount* of 'Bac-sulfur.'	Percentage. (dry soil)						
	Chloride (NaCl)	Sulfates (Na_2SO_4)	Carbonates.	Organic matter.	Moisture.	Water soluble salts.	Electrical resistance.** (Ohms.)
Control.	0.105	0.124.	trace.	0.004	16.21	0.295	394.69
37.5 Kg.	0.162	0.385	trace.	0.003	17.41	0.554	223.93
187.5 Kg.	0.189	0.625	trace.	0.004	19.59	0.828	159.66

* The amount applied per Tan.

** The electrical resistance was determined by taking 5 : 1 water extract of the soil.

Table III shows that the sulfate salts and the water soluble salts increased markedly and the resistance decreased per the amount of sulfur applied.

Table IV.

Quantitative Determination of Bacteria and Fungi, after Ten Weeks.

Amount of 'Bac-sulfur.'	Control.		37.5 Kg.		187.5 Kg.	
Days.	5.	10.	5.	10.	5.	10.
Bacteria.*	27,361.	40,972.	1,567.	33,333.	11,268.	18,487.
Fungi.**	—	290.	—	502.	—	2,775.

* The number of bacteria is noted per 1 g. dry soil, thousand as the unit.

** Per 1 g. dry soil.

As Table IV indicates, the bacterial number decreased while the number of fungi increased as more sulfur applied. This phenomenon is due to the marked increase of acidity as the larger amount of sulfur used.

Effect of different Sulfur and its Salts.

The effect of 'Bac-sulfur,' flower of sulfur and ammonium sulfate was investigated as to the various properties of soil noted in the previous experiment' and the results are noted in Table V, VI, VII and VIII.

Table V.

Change of Hydrogen Ion Concentration.

Reaction. / Weeks. / Kind of sulfur.*	P_H										
	Initial.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Control.	7.70	7.66	7.59	7.58	7.48	7.28	7.25	7.12	7.08	6.97	6.90
Flower of sulfur.	7.75	7.74	7.60	7.33	7.23	6.70	6.54	6.23	6.08	5.90	5.73
'Bac-sulfur.'	7.76	7.75	7.60	7.36	7.26	6.90	6.73	6.52	6.18	6.00	5.82
Ammonium sulfate.*	7.72	7.71	7.51	7.31	7.06	6.56	6.35	6.23	6.21	6.20	6.20

* The amount of each used was 37.5 Kg. per Tan.

Table V indicates that the addition of ammonium sulfate changed the reaction most markedly at the beginning up to the sixth week. But later the flower of sulfur and 'Bac-sulfur' altered the reaction more than ammonium sulfate.

Table VI.

Electrical Resistance and Soluble Salts.

Weeks.	Kind of sulfur.	Control.	Flower of sulfur.	'Bac-sulfur.'	Ammonium sulfate.
4.	Resistance.*	148.9	103.9	124.6	123.5
	Moisture.**	15.00	16.82	18.64	15.38
	Salts.***	0.167	0.260	0.216	0.210
5.	Resistance.	148.1	95.9	109.1	120.7
	Moisture.	14.72	16.58	18.29	15.26
	Salts.	0.170	0.279	0.250	0.215
7.	Resistance.	142.6	90.6	91.6	95.5
	Moisture.	20.43	19.83	21.04	20.43
	Salts.	0.197	0.308	0.309	0.294
8.	Resistance.	124.6	68.7	71.6	83.1
	Moisture.	18.59	15.50	16.44	16.10
	Salts.	0.216	0.406	0.387	0.322
9.	Resistance.	127.6	67.3	70.2	85.2
	Moisture.	21.28	17.78	18.74	18.15
	Salts.	0.218	0.431	0.406	0.322

* The electrical resistance was determined on 1 : 1 water extract.

** Percentage on dry soil basis.

*** Percentage.

Table VI indicates that the total amount of soluble salts produced was just about the same for all the three substance although it was slightly less in case of ammonium sulfate.

Table VII.

Quantitative Determination of Chloride (NaCl).

Kind of sulfur. \ Weeks.	Percentage.				
	Initial.	7.	8.	9.	10.
Control.	0.095	0.103	0.103	0.105	0.107
Flower of sulfur.	0.135	0.173	0.194	0.219	0.236
'Bac-sulfur.'	0.133	0.157	0.189	0.194	0.230
Ammonium sulfate.	0.124	0.133	0.143	0.145	0.151

Table VII shows that the amount of chlorine salts extracted was largest for the flower of sulfur and least for ammonium sulfate.

Table VIII.

Quantitative Determination of Bacteria and Fungi, after seven Weeks.

Kind of sulfur.	Control.		Flower of sulfur.		'Bac-sulfur.'		Ammonium sulfate.	
Days.	5.	10.	5.	10.	5.	10.	5.	10.
Bacteria.*	701,960.	2,222,220.	204,490.	960,050.	270,890.	1,419,000.	120,600.	1,288,940.
Fungi.**	—	7,840.	—	7,480.	—	7,590.	—	18,840.

* The number of bacteria is noted per 1 g. dry soil, thousand as the unit.

** Percentage.

It is noted in Table VIII that the number of bacteria decreased by the application of any of the sulfur and greatest by the flower of sulfur. On the other hand, the number of fungi was greatest when ammonium sulfate was used and hardly no difference was observed for the others.

Comparative Effect of 'Bac-sulfur' and Gypsum.

A comparative test between 'Bac-sulfur' and gypsum was undertaken in the same manner as the previous tests, and the results are noted in Table IX, X, XI and XII respectively.

Table IX.

Change of Hydrogen Ion Concentration.

Reaction. / Weeks. / Kind of sulfur.	p_H										
	Initial.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Control.	7.54	7.48	7.44	7.42	7.35	7.31	7.22	7.11	6.89	6.85	6.81
'Bac-sulfur.'	7.57	7.30	7.14	7.13	6.70	6.65	6.59	6.58	5.99	5.87	5.64
Calcium sulfate.	7.62	7.37	7.23	7.22	7.21	7.21	7.20	7.10	6.86	6.74	6.63

Table IX indicates that calcium sulfate has little influence on the reaction of the soils while 'Bac-sulfur' changes it to acid.

Table X.

Electrical Resistance and Soluble Salts.

Weeks.	Properties.	Control.	'Bac-sulfur.'	Calcium sulfate.
3.	Resistance.*	199.6	172.5	176.8
	Moisture.**	34.97	34.90	35.25
	Salts.***	0.161	0.189	0,185
4.	Resistance.	192.5	153.3	155.7
	Moisture.	34.65	34.60	35.04
	Salts.	0.167	0.214	0.211
6.	Resistance.	160.5	128.9	128.3
	Moisture.	26.04	25.31	28.34
	Salts.	0.180	0.228	0.238
7.	Resistance.	148.9	115.9	120.4
	Moisture.	22.24	21.71	23.71
	Salts.	0.185	0.243	0.240
8.	Resistance.	141.7	108.8	123.2
	Moisture.	28.36	23.99	26.56
	Salts.	0.210	0.269	0.243

* The electrical resistance was determined on 1 : 1 water extract.
** Percentage on dry basis.
*** Percentage.

Table X shows that the soluble salts increased in both calcium sulfate and 'Bac-sulfur.'

Table XI.

Quantitative Determination of Chlorides (NaCl).

Kind of sulfur. \ Weeks.	Percentage.				
	6.	7.	8.	9.	10.
Control.	0.056	0.068	0.088	0.090	0.091
'Bac-sulfur.'	0.124	0.154	0.181	0.196	0.219
Calcium sulfate.	0.081	0.115	0.112	0.113	0.117

It is shown in Table XI that calcium sulfate has little effect as to the soluble chloride contents.

Table XII.

Quantitative Determination of Bacteria and Fungi.

	Control.		'Bac-sulfur.'		Calcium sulfate.	
Days.	5.	10.	5.	10.	5.	10.
Bacteria.*	490,540.	945,950.	16,240.	456,490.	494,410.	1,350,590.
Fungi.**	—	9,460.	—	9,370.	—	27,930.

* The number of bacteria is noted per 1 g. dry soil, thousand as the unit.

** Percentage.

Table XII indicates that the addition of calcium sulfate increased the number of both bacteria and fungi much more than 'Bac-sulfur.'

Discussions.

As to the influence of sulfur on the reaction of soil, ADAMS[1] noted hardly any change of hydrogen ion concentration although the sulfate salts which were produced as the results of application of sulfur were made water soluble.

LIPMAN and others[2], however noted that when the sulfur is applied to the alkali soils, the sulfur is oxidized and combine with water which is responsible for the increase of hydrogen ion concentration. Subsequently the acid thus produced brings about the formation of soluble calcium salts which is responsible for the improvement of alkali soils.

The results of our investigation seem to substantiate LIPMAN and others view, that is the application of sulfur changes the reaction of soil to acid and increase the amount of dializable salts so that the sodium chloride can be eliminated more readily.

Summary and Conclusions.

The influence of 'Bac-sulfur,' flower of sulfur, ammonium sulfate and calcium sulfate on the newly reclaimed soils as to the hydrogen ion concentration, sulfate salts, water soluble salts and the microbiological change. From the results obtained in these experiments, the following summary may be made:

1. The application of sulfur changes the reaction of soil to acid and increases the dialyzable salts. Consequently the sodium chloride can be eliminated more easily.

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1) ADAMS, H. R., Soil Science 24, 111, 1924.

2) LIPMAN, J. G., ibid 2, 205, 1916.

2. The optimum amount of sulfur used for this purpose is less than 10 Kans (37.5 Kg.) per Tan (993.0 sq. m.). The excess of sulfur changes the reaction too acid and has the detrimental effect on the microorganisms.

3. The elemental sulfur is more effective than the other forms of sulfur compounds.

4. So far as our investigation is concerned, no appreciable difference was observed as to the effect between 'Bac-sulfur,' and flower of sulfur (commercial).