

Occurrences and Reclamation of Soils of High Exchangeable Sodium Content in India

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Alkali soils of high sodium content are scattered throughout India in the different climatic zones. These soils occur extensively in Punjab, Harayana and Western Uttar Pradesh. The infertility of these soils, but at the same time their potential value drew Government attention as early as 1876, when the "Reh Commission" was set up to investigate the causes of the deterioration of soils of U.P. Though the Commission could not base their findings on any previous scientific research, their Report gave impetus to future action on the problem. LEATHER [7] showed that the injurious salts, which are the decomposition products of igneous rocks under natural weathering processes are present in the soil profile itself and that they become evident on the surface layers under certain condition: (i) arid or semi-arid climate, (ii) an impervious sub-soil or hard pan, or (iii) temporary abundance of humidity interspersed with dry periods. The formation of such soils can be attributed to one or more factors like semi-arid conditions of extreme heat and evaporation, low-lying topography, intensive irrigation practices, high sub-soil water, or poor drainage.

The Usar Land Reclamation Committee of U.P. [9] reviewed the technical work done on such soils and reported that alkaline conditions were mainly due to sodium carbonate and bicarbonate, the exact quantity of which in the soil profile differs according to the nature of the soil and sub-soil such as *kankar* (CaCO_3 concretion), *kankar* beds and high water tables. From a physical point of view, the alkali soils either at the surface or at some depth, within the zone generally occupied by roots, were found to be impervious. The profiles of these soils are generally associated with *kankar* or a hard pan which restrict the upward movement of water by capillary action and the downward flow of water by percolation. The alkali soils of the province have a strongly alkaline reaction characterised by the presence of sodium carbonate and bicarbonate amounting to 0.1–0.4%. The alkali layer extends on an average to a depth of 90–120 cms.

The reclamation of such soils in India has been carried out following three usual methods viz., 1. *Mechanical*, involving heavy applications of water to wash out the salts, 2. *Agronomic*, involving the growth of suitable crops in rotation and 3. *Chemical*, involving application of chemicals e.g. gypsum, calcium chloride etc. to soil. Usually combinations of mechanical and agronomic or chemical and agronomic measures have been advocated. An indication of the ameliorative effect of gypsum applied at the rate of 7.5 tons

per hectare in reclaiming highly alkali soil was obtained by MUKHERJEE and AGARWAL [1]. The reclamation of alkali soils has been carried out successfully near Kanpur and Allahabad by the application of heavy doses of molasses [at 25–37.5 tons per hectare (DHAR and MUKHERJEE [5]). Molasses, which contains 2 per cent lime and 60–70 per cent carbohydrate, when added to the soil creates acidic conditions due to the production of carbonic acid or organic acids like acetic, propionic, butyric etc. The acids so produced neutralise the alkali of the soil and the carbonic acid, produced in large quantities from the decomposition and oxidation of carbohydrates, converts sodium carbonate into bicarbonate. The evolution of excess CO_2 from the molasses treated soil improves soil porosity and tilth. The calcium helps in converting the sodium soil into a calcium one, that is, a normal soil. DHAR further stressed the beneficial effect of molasses by saying that the carbohydrate material present in molasses encourages the growth of nitrogen fixing bacteria like *Azotobacter* thus increasing the total soil nitrogen.

In the Punjab, salinity and alkalinity occur in the canal irrigated areas where there has been a marked rise in the sub-soil water table. It has been found that the alkali soils were not very different from the surrounding good soils with respect to mechanical constituents, but compaction, shrinkage and deflocculation were related to the presence of injurious alkali salts which inhibited bacterial activity. The best method of reclaiming such soils has been found to be artificial drainage, the use of gypsum and the washing out of salts by subsequent flooding. Rice crops are then produced. DALIP SINGH and NIJHAWAN [4] studied the mechanical and chemical composition of some of the alkali soils of the Punjab and came to the conclusion that the alkalinity was mainly due to a deficiency of exchangeable calcium. Reclamation could be affected by the application of gypsum and calcium chloride followed by farmyard manure.

For the purpose of reclamation a scientific definition of saline and alkali soils under Punjab conditions has been framed and five distinct types have been classed as follows:

Type 1. — Soils having a pH value between 7.0 and 8.5 and a salt content not more than 0.2 per cent. This type is capable of producing normal crops.

Type 2. — Soils having a pH value below 9.0 and a salt content of about 0.2 per cent. Such soils are fit for growing rice only, but with a suitable system of cropping can be changed to type 1.

Type 3. — Soils having a pH value between 9.0 and 9.5 and a salt content of 0.2 to 0.5 per cent. These soils require leaching and two or more rice crops must be grown before they give normal yields of rice.

Type 4. — Soils having a pH value less than 9.0 but a salt content of 0.5 per cent or above. These soils are alkali, locally known as *thur* soils, and are economically reclaimable by more or less the same methods adopted for type 3.

Type 5. — Soils having a pH value above 9.5 and a high or low salt content. These soils are very difficult to reclaim.

The methods evolved in Punjab for the reclamation of alkali soils are (i) the application of amendments like calcium chloride, gypsum and pressmud and (ii) agronomic practices like a rice-berseem rotation. The actual procedure consists of flooding the land to remove salts, if present. When the soil becomes wet, gypsum in a well powdered form is applied and the land ploughed up

and watered copiously. This process is continued for 4–6 months. The amount of gypsum to be added depends on the degree of alkalinity and texture of the surface soil but 5 tons per hectare are usually quite sufficient to reclaim alkali soil containing 80–90 per cent exchangeable sodium. Prior to the sowing of the crop, an application of farmyard manure 40 tons per hectare has been found advantageous. It has also been shown that it is not necessary to completely replace sodium by calcium. When the exchangeable calcium content was 55–70 per cent of the total exchangeable bases, the soil began to support normal crops and at this concentration of exchangeable calcium there was a sudden increase in the rate of percolation of water indicating structural improvement. (Committee on Natural Resources, Planning Commission [3]).

The reclamation experiments at Komma and Nilokheri in the Punjab indicate (KANWAR, [6]) that it is possible to reclaim the saline alkali soils of the area and bring them to normal production in paddy-barley rotations by using ordinary amounts of water and normal doses of fertilizer. Experiments with pressmud, gypsum and fertilizers at Komma indicate that in the case of saline-alkali soils in areas of low water table, the best results can be obtained by using fertilizer along with pressmud and gypsum.

Successful reclamation work has been carried out on 80 hectares of highly alkaline and unproductive barren lands, in the village of Nissang in the district of Karnal in the Punjab for five years. The operational procedures followed in the reclamation of the land were (UPPAL, [10]):

1. Initial breaking up and laying out into one-tenth hectare plots.
2. Levelling according to contours.
3. Leaching consisting of flooding, ploughing and reflooding.
4. Green manuring.
5. Raising rice, berseem, gram and wheat.
6. In the post-reclamation phase, cotton, sugarcane, oilseed and fodder crops have been successfully grown.

Saline-alkali and non-saline alkali or degraded alkali soils occur in the Indo-Gangetic alluvium of Western Uttar Pradesh and are locally known as "Usar". The profile characteristics of a typical saline-alkali and a non-saline alkali soil profile along with the chemical composition of the profile samples are given below (RAYCHAUDHURI and MURTHY [8]).

Profile — 1. Saline-alkali soil:

Location: 1.17 miles N.W. of Etawah on Etawah-Agra Road, Dist. Etawah, Uttar Pradesh.

Physiography: Low-lying depression.

Drainage: Very poor and water-logging where there is excess water.

Parent material: Alluvium.

Description

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|-----------|---|
| 0— 5 cm | Pale yellow (2.5 y 8/4); silty loam, dark alkali patches on the surface and superficial cracking, top soil peels off into fine flakes; strong effervescence with HCl. |
| 5— 25 cm | Pale yellow (2.5 y 8/4), clay loam, hard and compact, slight effervescence with acid. |
| 25— 50 cm | Pale yellow (2.5 y 8/4); clay loam, weakly granular, sticky, slight effervescence with acid, fine and faint iron concretions. |
| 50— 80 cm | Light olive brown (2.5 y 5/4), clay, angular blocky, sticky, iron concretions many, medium and distinct. |
| 80—100 cm | Pale yellow (2.5 y 8/4); clay, blocky, very sticky lime concretions few, fine and faint, violent effervescence with acid. |

- 100—155 cm Pale yellow (2.5 y 8/4); clay, blocky, sticky, lime concretions scattered, violent effervescence with acid.
 155—175 cm Pale yellow (2.5 y 8/4); silty clay loam, blocky, sticky, lime concretions many, coarse and prominent, violent effervescence with acid.
 175—185 cm Pale yellow (2.5 y 8/4); silty loam, single grain, loose, strong effervescence with acid.

Profile — 2: Non-saline alkali soil:

Location: 11 miles N.E. Kasganj on Kasganj — Aligarh Road.

Physiography: Low lying, water stored during monsoon.

Drainage: Moderate.

Parent material: Alluvium.

Description

- 0 — 7.5 cm Pale yellow (2.5 y 7/4); silty loam, single grain, loose, few fine scattered iron concretions; no effervescence with acid.
 7.5— 52.5 cm Light olive brown (2.5 y 5/4); silty clay loam, blocky, iron concretions many, few scattered and faint, no effervescence with acid.
 52.5— 75 cm Light olive brown (2.5 y 5/4); silty clay loam, blocky, sticky, iron concretions many, medium and distinct.
 75 — 90 cm Light olive brown (2.5 y 5/4); silty clay loam, blocky, sticky, scattered iron concretions.
 90 —127.5 cm Olive brown (2.5 y 4/4); silty clay loam, blocky, sticky, iron concretions scattered.
 127.5—170 cm Olive brown (2.5 y 4/4); silty clay, massive and very sticky.

Results of pH, electrical conductivity, water extract, exchangeable sodium per cent and clay per cent analyses are shown in Tables 1 and 2.

The above categories of soils with high exchangeable sodium contents occur quite extensively. The saline alkali soil as in profile 1 corresponds to "Black Alkali" as referred to by HILGARD in the United States or „Solonetz" as referred to by Russian workers, while the non-saline alkali soil as in profile 2 corresponds to degraded alkali soil as referred to by SIGMOND.

Table 1

Saline alkali soil profile (Dt. Etawah. Uttar Pradesh)

Depth, cm	pH	Electrical conductivity mmhos/cm (Sat. Ext)	Soluble anions				Soluble cations			Exch. Na m.e. %	Clay %
			CO ₃ O ⁻	HCO ₃ ⁻	Cl ⁻	SO ₄ ²⁻	Na ⁺	K ⁺	Ca ²⁺ + Mg ²⁺		
0— 5	9.2	4.0	6.0	7.0	20.8	5.2	38.3	0.5	0.2	43.3	24.0
5— 25	9.4	4.5	5.0	7.2	18.0	6.2	40.0	0.5	0.5	73.0	25.7
25— 50	9.8	2.5	6.0	4.0	15.0	2.0	26.1	0.4	0.5	68.1	33.5
50— 80	9.9	3.9	10.0	5.0	25.9	2.1	41.9	0.7	0.4	39.3	43.6
80—100	10.1	8.5	39.0	14.0	30.7	2.1	81.1	1.2	3.5	52.4	37.0
100—155	10.1	8.0	10.0	28.0	36.0	4.3	74.2	1.2	2.9	47.8	37.0
155—175	9.3	1.3	tr	5.0	5.5	1.5	6.5	0.4	5.1	14.1	26.8
175—185	9.2	3.0	2.5	11.3	12.0	6.9	30.2	0.4	2.0	3.7	18.6

The Usar soils (Table 3) have attained the last stage of alkalinisation. The exchange complex of the soil at the surface and at some depth below is fully saturated with sodium. The pH value and salt content are highest at the top, decreasing with depth. From textural and structural points of view, the alkali soils of the first and second horizons are found to be impervious

Table 2

Non-saline alkali soil profile (Kasganj. Dt. Etah, Uttar Pradesh)

Depth, cms	pH	Electrical conducti- vity mmhos/cm (Sat. Ext.)	Soluble anions				Soluble cations			Exch. Na m.e. %	Clay %
			CO ₃	HCO ₃	Cl	SO ₄	Na	K	Ca+Mg		
0 — 7.5	7.3	0.6	tr	2.0	1.7	1.4	5.0	0.1	tr	3.5	9.3
7.5— 52.5	7.7	1.8	tr	9.5	5.9	2.7	18.0	0.1	tr	10.4	23.3
52.5— 75	8.3	2.0	tr	10.0	4.0	4.2	19.0	1.0	0.2	69.7	25.1
75 — 90	9.3	1.0	tr	4.0	4.0	3.4	10.0	0.5	0.9	98.6	29.0
90 —127.5	9.0	1.5	tr	5.0	4.2	4.3	11.5	0.1	1.9	83.4	30.0
127.5—170	8.8	1.0	tr	6.5	2.8	1.7	10.9	0.1	tr	28.7	30.9

and the profiles of these soils are generally associated with kankar or a hard clay pan restricting the upward movement or downward flow of water. Utilization of such soils for agricultural purposes is extremely problematic.

There are other milder types which are expected to respond quickly to the corrective methods of reclamation. Development of a planned system of drainage is considered a pre-requisite of the reclamation of such soils (RAYCHAUDHURI and DATTA BISWAS [8]).

Table 3

The salinity and alkali status of an alkali soil profile in the district of Aligarh of Uttar Pradesh

Locality	Local name	Hori- zon	Carbonate Na ₂ CO ₃ %	Bicarbo- nate as NaH—CO ₃ %	Chlorides and sul- phates of sodium %	pH	CEC m.e. %	Ex. bases m.e. %		Na Satura- tion %
								Ca	Na+K	
Pachpera Aligarh Dt. U. P.	Usar Reh	1st	0.39	0.40	0.74	9.6	10.2	—	10.2	100
		2nd	0.11	0.16	0.20	9.5	20.76	1.0	19.6	94.4
		3rd	0.33	0.29	0.58	9.3	15.32	1.0	13.3	86.9
		4th	0.09	0.14	0.03	9.4	13.44	1.4	11.84	88.1
		5th	0.03	0.15	0.01	8.2	10.44	2.6	7.04	67.4

BASU and TAGARE [2] examined a large number of alkali soil profiles on the six major canals of the Deccan. They were able to distinguish two groups of profiles depending on whether the A or both A and B horizons are rendered compact or impermeable. The profile features of the former resemble those of steppe alkali soils, and those of the latter the solonetz. The common characteristic of these soils is the high saturation of the surface soil with Na and a zone of accumulation of salts in the profile. These workers have shown that creating humid conditions by irrigation was a pre-requisite for the reclamation of these soils which formed under arid and semi-arid conditions. Suitable adjustments in cropping practices on the soil with a porous B horizon resulted in the improvement of soil structure by reducing the amount of sodium-colloids and increasing the proportion of Ca-colloids. In the worst type of alkali-soil, where both the A and B horizons are compact and

impervious, the best reclaiming agent was found to be a mixture of sulphur and farmyard manure at the rate of 1.25 and 5 tons, respectively, per hectare.

There was highly alkali barren soil at Coimbatore in Madras State which has been transformed in the course of about 60 years into productive paddy land by intensive cultivation, green manuring and the judicious irrigation-deposition of silt carried by the irrigation water.

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