CHAPTER VIII

RECLAMATION OF SALINE-ALKALI SOILS.
A saline soil is one which contains a high percentage of salts that can impair plant growth. An alkaline soil is one having a high level of exchangeable sodium. An alkali soil may also have high pH. The limits of salinity and alkalinity as given by USDA Laboratory (1) are: conductivity above 4 mmhos/cm, pH value above 8.5 (for the saturation extract at 25°C), and exchangeable sodium percentage (ESP) above 15. A higher percentage of insoluble carbonates is another problem relating to soils of the arid and semi-arid zones. The level of CaCO$_3$ at which p-fixation becomes an agricultural problem is perhaps the margin at which a soil can be considered calcareous. A limit of 8-10 percent of CaCO$_3$ is suggested by Hilar et al. ($^x$) as the margin for defining a calcareous soil.

The conventional methods existing for the reclamation of such soils are: exhaustive tilling followed by drainage, mulching with plant materials so as to increase the organic matter content, mixing with sand, sugar-cane waste etc. and with chemical amendments containing sulphur such as gypsum, Ferrous sulphate, Aluminium sulphate, sulphuric acid followed...
by drainage. Various scientists have showed different methods in this field to evolve an easy and economic reclamation. A review of the contemporary literature on the subject has been attempted here under.

Tisdali and Samak (3) compared the effect of various S-containing amendments for soil reclamation and water treatment. They found that S compounds (CaSO₄, S, H₂SO₄, NH₄Sₓ, CaSₓ, (NH₄)S₂O₃, Al₂(SO₄)₃ and FeSO₄) increased the availability of plant nutrients such as P, Mn, Zn and Fe. Mamukyan studied (4) the reclamation of 'sode salonchak solonets' with inorganic acids and FeSO₄·7H₂O. According to him, desalination was highest when treated with FeSO₄·7H₂O and H₂SO₄ and removal of total salts was highest after treatment with N₂H₄, HCl, NH₄NO₃ or FeSO₄·7H₂O. The exchangeable Na content decreased due to formation of finely divided and dispersed gypsum in the soil solution. Generally FeSO₄·7H₂O was most effective reclaiming agent, which not only removed substantial amounts of salts, especially toxic ones, but improved soil structure, filtration capacity and other soil physical properties. Poonia and Bhumble (5), while studying the Ca uptake of dhaincha observed that application of CaCO₃ and a lime subliming agent (H₂SO₄, HCl, Al₂(SO₄)₃ etc.) to a saline-alkali soil, increased
dry matter yield of the plant. The effectiveness of the agents in increasing yields was in the order

\[ \text{HCl} > \text{H}_2\text{SO}_4 > \text{Al}_2(\text{SO}_4)_3 \].

They also increased Ca-content, \( \text{H}_2\text{SO}_4 \) being the most effective and HCl the least. The P-content of the plant was increased by \( \text{H}_2\text{SO}_4 \) and HCl, while Na and N-contents decreased. Mishra and Khan (6) studied leaching properties of solutions of \( \text{CaSO}_4 \), \( \text{Al}_2(\text{SO}_4)_3 \), \( \text{FeSO}_4 \) and \( \text{H}_2\text{SO}_4 \) and spartin (an alkaloid not identified). Al and Fe sulphates gave highest percolation rates and water alone made the saline soil impervious. The efficiency was in order:

\[ \text{CaSO}_4 > \text{Al}(\text{SO}_4)_3 > \text{FeSO}_4 > \text{H}_2\text{SO}_4 > \text{Spartin}. \]

Ghitchyan et al. (7) and Patrov (8) also noted the efficiency of \( \text{FeSO}_4 \) in improving soil particle size distribution, and permeability. However, effect of \( \text{FeSO}_4 \) decreased sharply after the 2nd year.

Tsaimurov et al. (9) suggested an HCl treatment followed by \( \text{H}_2\text{SO}_4 \) (2 percent) and subsequent leaching where \( \text{Ca(} \text{HCO}_3)\text{_2} \) and \( \text{Na}_2\text{SO}_4 \) were decreased by the 1st treatment and \( \text{NaCl} \) and \( \text{Ca(} \text{HCO}_3)\text{_2} \) in the second the soil gaining in \( \text{CaSO}_4 \) and \( \text{MgSO}_4 \) contents. By this method 3 m depth of the soil was demineralized to 0.4-0.6 percent solid residue. Nemes et al. (10) successfully
reclamined saline alkali soils of Demir and Tundra using HCl absorbed on saw-dust. Cultivation of m-
malbus for 2-3 years followed by means to washout NaCl, contributed to the improvement of soils and prepared the soil for other plants.

Tonkonozhenko, et.al(n) while studying the salinized soils in the delta of the river Kuban and changes in their properties during reclamation observed that natural desalination of soils was limited and often an increased solonchak and solonetz formation was observed. The seasonal migration of soils resulted in Na incorporation into sorption complex, increased the Na$_2$CO$_3$ content of the soils and increased solonetzicity. This occurred especially during desalinization of solonchaks which contained very high Na and relatively high Mg. They have also found that secondary salinization of the upper soil layers after through washing and leaching out of the salts into the drainage system. As chlorides and sulphates were easily leached out, the relative carbonate and bicarbonate contents of the soil increased. For this they have suggested gypsum treatment and acid treatment.

Semendiya N.V. (12) while studying the effectiveness of the gypsum to low sodium solonetz soils observed that calculated amount of gypsum had improved the soil
fertility and the crop yield. A decrease in gypsum doses led to decreased effects of its application. He has observed that application of 9 ton gypsum and 80 ton manure/hac. gave the best results.

Bhumbla, D.R. and Poonia S.R. while studying the effect of ESP on the availability of Ca from gypsum and CaCO$_3$ applied to barley, dhaicha and Maize on a sandy loam soil observed that Ca availability decreased with increasing ESP in the CaCO$_3$ treated plot. In gypsum treated plots the Ca availability increased with ESP in case of bearlay, was unaffected in case of Dhaicha and decreased in case of Maize. The uptake of Ca from gypsum was always higher than CaCO$_3$. Abrid. I.D. Bhumba. (12)

D.R. observed that on application of gypsum, the production of both kharif and rabi crops of rice has improved by about 30 per cent.

Sharma A.K. and Fecherehabherr J.B. (15) gave the following order for improvement of silt loam soils of Illinois: Slurry = gypsum > hydrated lime and the improvement due to rate of application was

2 percent > 1 percent > 0 percent (control).

Grierson. T.T. observed that application of gypsum resulted in the reduction in soil pH, ESP and EMgP, and surface runoff. He had also observed considerable increased in yield of the crop and dry matter.
Sidlo. A. A. et al. (17) while studying the experimental leaching of saline, deeply solonetzic soil in the Caspian lowland using chemical amendments observed that the soils cannot be leached with water alone. Addition to the leaching water applied at a rate of 17,500 m³/ha of 135 metric tons of gypsum, 130 metric tons of HCl, 68 metric tons of H₂SO₄ or 130 tons of HNO₃ increased the I.R. from 10 to 30 fold. This amendment desalinized and desolonetzized the upper meter of the soil with 1.3 per cent of salts and 16 meg of adsorbed Na per 100 g of soil within 16-63 days of leaching. Shilnikova, V. K. and Babaeva, R. A. on studying the alternation of microflora of a heavy clayey Solonchak of Karabakh steppe during reclamation observed that washing and application of H₂SO₄, gypsum (alâne), or gypsum-dung, or an organomineral by product of the petroleum industry, increased the number of N-fixing micro-organisms. Washing with water together with the application of gypsum at 15-20 tons/ha, dung at 40 tons/hr or together with 20 tons/ha of oil product was recommended by them.

Weiss, W. while studying the rice seedling-chlorosis connection by Fe, Zn and H₂SO₄ application observed that rice has shown chlorosis due to deficiency of Fe and Zn. Application of 5 or 10 Kg. Zn, 40 Kg. slow-release Fe or 100 Kg. Fe₂(SO₄)₆ were effective in increasing yield and combination of both these more effective. Application of H₂SO₄ also may result in release of Zn and Fe from soil.
Miyamotto and Rayan suggested the use of $\text{H}_2\text{SO}_4$ for the treatment of ammoniated irrigation waters. Ammoniated water cause precipitation of $\text{CaCO}_3$ and increase in exchangeable Na and $\text{NH}_4$, thus causing low infiltration in soils. $\text{H}_2\text{SO}_4$ application reduced Ca-precipitation and exchangeable Na by neutralising OH-produced by $\text{NH}_3$ and consequently preventing decline in infiltration rates. Gumma et al. (21) also observed that in calcareous soils when irrigation is done with salty water (salts = 7 to 34 megl, SAR = 4.6.4) $\text{H}_2\text{SO}_4$ applied at rates sufficient to prevent Ca-precipitation (2.1 - 4.7 meq/l) maintained pH slightly above neutral and reduced SAR and ESP in all the cases studied and increased hydraulic conductivity of some soils where SAR of original waters was greater than 7.0.

The advantage of using $\text{H}_2\text{SO}_4$ as an amendment and its relative merits over other methods were studied by many workers. The USDA laboratory had suggested the use of $\text{H}_2\text{SO}_4$ as a soil amendment long before. (26)

Reutlan and Allain in 1965 observed the relative advantage of using sulphuric acid for soils rich on $\text{MgCO}_3$. Kulench et al. (26) observed that on meadow solonetz soils best results were obtained by use of 1 percent $\text{H}_2\text{SO}_4$ solution applied at rates equivalent to the sum of toxic ions in the 60 cm layer (50-100 ton/ha) followed by washing with water at 4500 m$^3$/ha. Similar observations were made by workers like Karpal et al. (24)
Kuni et al. (25) Onanssyan, Alkhnoyan et al. (26) and many others. Korobkin observed that soil washing treatment with \( \text{H}_2\text{SO}_4 \) (5.5 ton/ha) worsened the filtration characteristics of weakly and medium solonetzie soils, while that of strongly solonetzie soils was increased by 9-10 fold. Gypsum treatment (9.2 ton/ha) under similar conditions did not improve permeability of weakly solonetzie soils while that of medium and strongly solonetzie soils improved only 2-fold, that showing that \( \text{H}_2\text{SO}_4 \) is more suited to a highly solonetzie soils.

Mehrotra C.L. while studying the effectiveness of \( \text{H}_2\text{SO}_4 \) at 80 percent of the theoretical gypsum requirement (10.6 t/ha) and gypsum at 20, 40, 60 or 80 percent of the theoretical requirement (24 t/ha) in reclaiming saline-alkali soils observed that \( \text{H}_2\text{SO}_4 \) almost completely reclaimed the soil in the 1st year and resulted in a marked increase in paddy field. The ameliorative effect of gypsum was slow as evidenced by the gradual increase in yield.

Prather R.J. et al. (29) while studying effective and efficient amendments used in sodic soil reclamation by using \( \text{CaSO}_4, \text{CaCl}_2 \) and \( \text{H}_2\text{SO}_4 \) singly and in combination with respect to amount of amendment, time and leaching observed that as a single amendment \( \text{H}_2\text{SO}_4 \) was effective than \( \text{CaSO}_4 \) and resulted in a more desirable ESP profile than \( \text{CaCl}_2 \).
Agababiyan and Rajadyan observed that application of diluted H$_2$SO$_4$ (1st time 1 percent and 2nd time 3 percent solution) followed by washing with water rates 12,800; 18,860, and 27,600 m$^3$/ha. resulted in reduction of exchangeable Na in soil from 40 to 12 percent in the 1st and 2nd year after reclamation. After application of H$_2$SO$_4$ and washing the amount of CO$_3^{2-}$, HCO$_3^-$, Cl$^-$ and SO$_4^{2-}$ were reduced by 97.3–100, 67.5–90.3, 95.2–98.3 and 65.8–82.9 percent respectively. The Ca and Mg contents in the 0–200 cm layer were increased by 85 and 212 percent respectively.

Different other methods have also been tried by many workers in reclaiming the saline-alkali soils. Yaksmov and Tornovenko reclaimed Na$_2$CO$_3$ containing soils with NaCl solutions followed by Gypsum application and water washings. The best rates were 4500–5000 m$^3$ NaCl soln/ha containing 30–35 tons NaCl and 40 ton gypsum/ha and 6000–8000 m$^3$ washing water/ha. After treatment almost all carbonates were removed and Cl$^-$ content decreased from (3800) to 1.2 mg/l and pH from 9.2 to 8.

Alperovich and Shainberg suggested the use of concentrated CaCl$_2$ solutions for the reclamation of red-brown solonetz soils. However, it was observed
that Mg and Na cannot be completely removed by this method. Salt water dilution method for reclamation has been successfully carried out by many workers. Sandu et al. noticed that tunnel drainage can be used for the reclamation of saline soils. Vadyunin et al. studied the ameliorative effect on a d.c. of 0.01 mA/cm² at a rate of 7A/ha and found it to be equivalent to the use of 30 tons of gypsum of 10-20 tons of H₂SO₄/ha. A high current density of 0.1-0.5 mA/cm² achieved desalination and dealkalinization; improving the soil structure and permeability and reducing the soil pH from 10 to 7.5. Vadyuntha observed that d.c. (0.5 mA/cm²), gypsum (60 tons/ha) and a combination of gypsum (30 tons/ha) with d.c. increased soil aggregation and percentage of water-stable aggregates. Application of 36 tons/ha of H₂SO₄ was as effective as 50 tons/ha of gypsum.

Wyn Jones observed the influence of chloride and relative compounds (betaine hydrochloride, acetyl cholin, chloroeholine, chloride) and found that it reduced the pH of the root medium both with presence and absence of NaCl and without decreasing the uptake of Na into plant roots.

Patnaik, S., Sahoo. observed that prolonged and excessive leaching of saline-alkali soils followed
by the application of industrial by-product such as 
basic slag and paper mill sludge gave high yield of 
rice comparable to those of gypsum.

Gora and Alfred observed that physical co-
efficient limiting the performance of clay rich soils 
can be improved by application of synthetic formed plastics 
(polystyrene granules). It increased pore space and 
water availability to plants. Boeski and Jozef suggested 
the use of acid resings, a biproduct of petroleum industry 
for the amendment of non-calcareous solonetz. The high 
yield increase was shown on soils where acid resin and 
lime stone were applied.

Islam HI Haq et. al. observed that Kallar glass 
(deplanchan fusa) can be used for desalanization because 
of its ability to absorb, considerable amount of Na from 
the soil. Jadav et. al. showed that saline sodic soils 
can be ameliorated by combined treatment with S (1 
percent) and thiobasillus novellab and/or T-thio-
oxidane culture. After 56 days the thiobasillus + S 
treatment soil pH reduced from 9.4 to 7.7-5 and ESP 
decreased from control value of 54.58-55.06 to 10.35-
11.88 with the combined treatment or thiobascillus 
alone was effective.

Another important lead in the reclamation of saline 
alkali soils is the utilization of industrial wastes 
for the reclamation purpose. Ekateriuone et. al. observed
that industrial wastes containing CaSO₄, Fe-oxide, and trace metals was found to be better than even gypsum treatment. Ca and Fe in soil increased, while Na and Mg decreased causing improvement in soil properties and crop yield. Vasilava found that addition of 0.6 percent gypsum + sugar beat producing waste or 0.25 percent of the latter alone caused the highest evolution of CO₂ from soil. Addition of Ca and S compound to such plots increased soil bacterial activity, soil respiration, microorganism count, and accumulation of available materials.

Yehia et al. (45) used H₂SO₄ waste from copper smelters and found that the rate of water penetration into Na - affected soils could be increased considerably. Petrosyan showed that waste H₂SO₄ and FeSO₄ were the most efficient amendment for improving soda-saline soils. The increased desalinization improved infiltration rates and resulted in high yields. He also showed that desalinization of saline water can be accomplished by mixing waste H₂SO₄ with irrigation water. Barozin and Rychkova suggested that H₂SO₄ from petrochemical industrial wastes can be used as a substitute for gypsum for the amelioration of solonetz soils. In field experiments 50 percent H₂SO₄ wastes (5.6 tons/ha) increased wheat yield by 22-54 percent.
The acid waste may contain toxic hydrocarbon substances, but they are microbically degraded and do not affect plant growth.

Shah and co-workers suggested first the use of H$_2$SO$_4$ from dairy industry for the reclamation of saline and alkali soils. In the first successful reclamation test in the field of patan and Zilia (North Gujarat) the waste H$_2$SO$_4$ from Dudhsagar dairy, Mehsana was used. Later acid waste from detergent slurry industries were also tried. The percentage composition of the acid waste from the former sources was:

1. Sulphuric acid 60-65 percent.
2. Milk solids - 5 percent.
3. Remaining — water.

While that from the latter was:

1. Sulphuric acid 60-70 percent.
2. Alkylbenzene sulphonate - 4-5 percent.
3. Remaining — water.

A systematic process of reclamation of a saline or saline-alkali soil may involve the following operations.

1. Prevention of inundation and spread of brackish water by constructing bunds or walls (near coastal areas).
2. Picking out suitable amendments such as sulphur
Powder, Gypsum, FeSO₄ or H₂SO₄ depending on the soil structure and requirement so as to make the soil permeable.

3. Installation of an efficient leaching and drainage system which may prevent the formation of high water table and hence water logging and

4. Choice of crops according to salt and alkali resistance power e.g. growing of alfalfa, Dhaincha etc. as a first crop after reclamation.

In addition to the waste sulphuric acid treatment a new treatment based on the results of hydraulic conductivity (presented in Chapter IV), it was decided to use Iron sulphate prepared by using waste sulphuric acid, waste sulphur from industries and gypsum were taken as a combined treatment. The application of such a acid powder treatment was taken up simultaneously with the waste sulphuric acid treatment on different plots.

The waste acid treatment was given on fields at Baratwada (501) and Juna Maka (502) samples given in table No. VIII A. These samples are saline soils, and this salinity is due to old sea-water intrusion on this area. The acid powder treatment containing 33 percent Iron sulphate, 33 percent sulphur, and 33 percent gypsum was tried on sites at Gujarat Vidyapeeth Randheja
sample (503, 504) where the soils have been spoiled due to the use of alkali tube-well water in that area.

The same acid powder treatment was also given on plots at Rupal (505) and Bhayla (506), which are salty soils where the origin of salts is due to the old sea being present in that area about 300 years.
<table>
<thead>
<tr>
<th>S.No.</th>
<th>Location</th>
<th>Depth</th>
<th>S.P.</th>
<th>pH</th>
<th>TEC</th>
<th>Ga + Mg</th>
<th>K</th>
<th>Na</th>
<th>(mEq/l)</th>
<th>Alkali earth carbo nates</th>
<th>Texture</th>
</tr>
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<tr>
<td></td>
<td></td>
<td>(inch)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>501 A</td>
<td>Baratwada</td>
<td>0-6&quot;</td>
<td>51.0</td>
<td>8.4</td>
<td>32.0</td>
<td>19.0</td>
<td>0.8</td>
<td>12.2</td>
<td>39.0</td>
<td>12.3</td>
<td>Sandy loam</td>
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<tr>
<td>501 B</td>
<td>Baratwada</td>
<td>6-15&quot;</td>
<td>55.0</td>
<td>8.3</td>
<td>30.5</td>
<td>16.9</td>
<td>1.0</td>
<td>12.6</td>
<td>41.4</td>
<td>13.4</td>
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</tr>
<tr>
<td>502 A</td>
<td>Juna Maka</td>
<td>0-6&quot;</td>
<td>60.0</td>
<td>8.1</td>
<td>41.7</td>
<td>21.0</td>
<td>1.3</td>
<td>19.4</td>
<td>45.0</td>
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<td>6-15&quot;</td>
<td>59.0</td>
<td>7.9</td>
<td>41.3</td>
<td>19.8</td>
<td>1.5</td>
<td>20.0</td>
<td>48.5</td>
<td>10.0</td>
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**TABLE No. VIII A**

**STUDY OF SOIL SAMPLES BEFORE AND AFTER RECLAMATION TREATMENT**

**BEFORE TREATMENT**

**AFTER TREATMENT**
### TABLE No. VIII A (Contd.)

**STUDY OF SOIL SAMPLES BEFORE AND AFTER RECLAMATION TREATMENT.**

**BEFORE TREATMENT**

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Location</th>
<th>Depth</th>
<th>EC$10^2$ at 25°C (mmhos/cm)</th>
<th>Saturation Extract Analysis (meq/l)</th>
<th>SAR (Satd. Extract)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Ca$^{2+}$</td>
<td>Mg$^{2+}$</td>
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<tr>
<td>501 A</td>
<td>Baratwada</td>
<td>0-6&quot;</td>
<td>9.22</td>
<td>6.4</td>
<td>2.2</td>
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<td>6-15&quot;</td>
<td>7.52</td>
<td>5.2</td>
<td>1.0</td>
</tr>
<tr>
<td>502 A</td>
<td>Juna Maka</td>
<td>0-6&quot;</td>
<td>16.84</td>
<td>8.2</td>
<td>14.1</td>
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<td>502 B</td>
<td>Juna Maka</td>
<td>6-15&quot;</td>
<td>13.44</td>
<td>10.8</td>
<td>19.2</td>
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</table>

**AFTER TREATMENT**

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Location</th>
<th>Depth</th>
<th>EC$10^2$ at 25°C (mmhos/cm)</th>
<th>Saturation Extract Analysis (meq/l)</th>
<th>SAR (Satd. Extract)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
<td>Ca$^{2+}$</td>
<td>Mg$^{2+}$</td>
</tr>
<tr>
<td>501 A</td>
<td>Baratwada</td>
<td>0-6&quot;</td>
<td>5.66</td>
<td>12.4</td>
<td>2.4</td>
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<td>501 B</td>
<td>Baratwada</td>
<td>6-15&quot;</td>
<td>4.18</td>
<td>11.8</td>
<td>2.2</td>
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<td>Juna Maka</td>
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<td>4.52</td>
<td>16.4</td>
<td>5.1</td>
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<td>Juna Maka</td>
<td>6-15&quot;</td>
<td>4.76</td>
<td>18.6</td>
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TABLE No. VIII B
STUDY OF SOIL SAMPLES BEFORE AND AFTER RECLAMATION TREATMENT
BEFORE TREATMENT

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Location</th>
<th>Depth</th>
<th>S.P.</th>
<th>PH(Satd) extract at 25°C</th>
<th>TEC mer/100g</th>
<th>Exchangeable Cations $\text{Ca+Mg} \text{K}^+$</th>
<th>Naas TEC (ESP)</th>
<th>Alkaline Soil earth Textures</th>
<th>Carbonates re.</th>
<th>Soil Texture</th>
</tr>
</thead>
<tbody>
<tr>
<td>503 A</td>
<td>Gujarat Vidya-apeeth (Randheja)</td>
<td>0.6&quot;</td>
<td>54</td>
<td>8.0</td>
<td>46.4</td>
<td>21.2, 0.2</td>
<td>54</td>
<td>9.8</td>
<td>Sandy loam</td>
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</tr>
<tr>
<td>503 B</td>
<td>Gujarat Vidya-apeeth (Randheja)</td>
<td>6-15&quot;</td>
<td>52</td>
<td>8.1</td>
<td>45.4</td>
<td>21.8, 0.2</td>
<td>50</td>
<td>9.6</td>
<td>Sandy loam</td>
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<tr>
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<td>Gujarat Vidya-apeeth Randheja</td>
<td>0.6&quot;</td>
<td>51</td>
<td>8.3</td>
<td>21.6</td>
<td>14.4, 0.2</td>
<td>32</td>
<td>9.4</td>
<td>Sandy loam</td>
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<tr>
<td>504 B</td>
<td>Gujarat Vidya-apeeth Randheja</td>
<td>6-15&quot;</td>
<td>48</td>
<td>7.9</td>
<td>21.6</td>
<td>14.6, Tr</td>
<td>31</td>
<td>8.9</td>
<td>Sandy loam</td>
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AFTER TREATMENT

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Location</th>
<th>Depth</th>
<th>S.P.</th>
<th>PH(Satd) extract at 25°C</th>
<th>TEC mer/100g</th>
<th>Exchangeable Cations $\text{Ca+Mg} \text{K}^+$</th>
<th>Naas TEC (ESP)</th>
<th>Alkaline Soil earth Textures</th>
<th>Carbonates re.</th>
<th>Soil Texture</th>
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<td>503 A</td>
<td>Gujarat Vidya-apeeth Randheja</td>
<td>0.6&quot;</td>
<td>51</td>
<td>7.5</td>
<td>44.0</td>
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<td>Sandy loam</td>
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<td>Gujarat Vidya-apeeth Randheja</td>
<td>6-15&quot;</td>
<td>50</td>
<td>7.6</td>
<td>33.9</td>
<td>27.3, 0.4</td>
<td>38.4</td>
<td>8.6</td>
<td>Sandy loam</td>
<td></td>
</tr>
<tr>
<td>504 A</td>
<td>Gujarat Vidya-apeeth Randheja</td>
<td>0.6&quot;</td>
<td>48</td>
<td>7.7</td>
<td>22.6</td>
<td>19.2, 0.2</td>
<td>18.0</td>
<td>8.2</td>
<td>Sandy loam</td>
<td></td>
</tr>
<tr>
<td>504 B</td>
<td>Gujarat Vidya-apeeth Randheja</td>
<td>6-15&quot;</td>
<td>46</td>
<td>7.7</td>
<td>21.1</td>
<td>18.8, 0.2</td>
<td>19.0</td>
<td>7.4</td>
<td>Sandy loam</td>
<td></td>
</tr>
</tbody>
</table>
### TABLE No. VIII-B (Contd.)

**STUDY OF SOIL SAMPLES BEFORE AND AFTER RECLAMATION TREATMENT**

**BEFORE TREATMENT**

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Location</th>
<th>Depth (in/cm)</th>
<th>EC (cm²/s)</th>
<th>Saturation Extract Analysis (meq/litre)</th>
<th>SAR (Satd. Extract)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Ca²⁺</td>
<td>Mg²⁺</td>
</tr>
<tr>
<td>503 A</td>
<td>Guj.Vidyapeeth</td>
<td>0.6</td>
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<td></td>
<td>Randheja</td>
<td></td>
<td>6.15</td>
<td>11.1</td>
<td>5.0</td>
</tr>
<tr>
<td>504 A</td>
<td>Guj.Vidyapeeth</td>
<td>0.6</td>
<td>8.11</td>
<td>4.5</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>Randheja</td>
<td></td>
<td>6.15</td>
<td>7.94</td>
<td>3.5</td>
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</table>

**AFTER TREATMENT**

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Location</th>
<th>Depth (in/cm)</th>
<th>EC (cm²/s)</th>
<th>Saturation Extract Analysis (meq/litre)</th>
<th>SAR (Satd. Extract)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Ca²⁺</td>
<td>Mg²⁺</td>
</tr>
<tr>
<td>503 A</td>
<td>Guj.Vidyapeeth</td>
<td>0.6</td>
<td>6.08</td>
<td>12.5</td>
<td>7.5</td>
</tr>
<tr>
<td></td>
<td>Randheja</td>
<td></td>
<td>6.15</td>
<td>6.0</td>
<td>11.5</td>
</tr>
<tr>
<td>504 A</td>
<td>Guj.Vidyapeeth</td>
<td>0.6</td>
<td>4.53</td>
<td>5.7</td>
<td>2.4</td>
</tr>
<tr>
<td></td>
<td>Randheja</td>
<td></td>
<td>6.15</td>
<td>4.42</td>
<td>6.1</td>
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</table>
### STUDY OF SOIL SAMPLES BEFORE AND AFTER RECLAMATION TREATMENT

#### BEFORE TREATMENT

<table>
<thead>
<tr>
<th>S.No. Location</th>
<th>Depth (inches)</th>
<th>SP</th>
<th>pH (Saturated Extract) at 25°C</th>
<th>TKC (meq/100mL)</th>
<th>Exchangeable Cations</th>
<th>Na as TEC (ESP)</th>
<th>Alkali Earth Exchangeable Carbonates</th>
<th>Soil Texture</th>
</tr>
</thead>
<tbody>
<tr>
<td>505 A Rupal</td>
<td>0.6' 50</td>
<td></td>
<td>8.1</td>
<td>21.7</td>
<td>15.0 0.5</td>
<td>6.2</td>
<td>34 7.5</td>
<td>Sandy loam</td>
</tr>
<tr>
<td>505 B Rupal</td>
<td>6.15' 46</td>
<td></td>
<td>8.0</td>
<td>21.3</td>
<td>14.0 0.5</td>
<td>6.8</td>
<td>32 7.3</td>
<td>Sandy loam</td>
</tr>
<tr>
<td>506 A Bhayla</td>
<td>0.6' 48</td>
<td></td>
<td>8.4</td>
<td>29.1</td>
<td>17.1 Tr</td>
<td>12.0</td>
<td>40 8.2</td>
<td>Sandy loam</td>
</tr>
<tr>
<td>506 B Bhayla</td>
<td>6.15' 48</td>
<td></td>
<td>8.4</td>
<td>28.6</td>
<td>16.8 Tr</td>
<td>11.8</td>
<td>41 8.3</td>
<td>Sandy loam</td>
</tr>
</tbody>
</table>

#### AFTER TREATMENT

<table>
<thead>
<tr>
<th>S.No. Location</th>
<th>Depth (inches)</th>
<th>SP</th>
<th>pH (Saturated Extract) at 25°C</th>
<th>TKC (meq/100mL)</th>
<th>Exchangeable Cations</th>
<th>Na as TEC (ESP)</th>
<th>Alkali Earth Exchangeable Carbonates</th>
<th>Soil Texture</th>
</tr>
</thead>
<tbody>
<tr>
<td>505 A Rupal</td>
<td>0.6' 46</td>
<td>7.6</td>
<td>21.2</td>
<td>0.4 3.4</td>
<td>18.0 6.0</td>
<td>6.0</td>
<td>6.0</td>
<td>Sandy loam</td>
</tr>
<tr>
<td>505 B Rupal</td>
<td>6.15' 44</td>
<td>7.7</td>
<td>26.8</td>
<td>23.0 0.3</td>
<td>3.5 18.0</td>
<td>5.8</td>
<td>5.8</td>
<td>Sandy loam</td>
</tr>
<tr>
<td>506 A Bhayla</td>
<td>0.6' 44</td>
<td>7.9</td>
<td>26.2</td>
<td>23.0 Tr</td>
<td>3.2 22.0</td>
<td>7.1</td>
<td>7.1</td>
<td>Sandy loam</td>
</tr>
<tr>
<td>506 B Bhayla</td>
<td>6.15&quot; 42</td>
<td>7.8</td>
<td>26.2</td>
<td>23.3 Tr</td>
<td>2.9 23.0</td>
<td>6.8</td>
<td>6.8</td>
<td>Sandy loam</td>
</tr>
</tbody>
</table>
### TABLE No. VIII - C (Contd.)

**STUDY OF SOIL SAMPLES BEFORE AND AFTER RECLAMATION TREATMENTS**

**BEFORE TREATMENT**

<table>
<thead>
<tr>
<th>S No.</th>
<th>Location</th>
<th>Depth (inches)</th>
<th>$E_{0}^{25\degree C}$ (mhos/cm)</th>
<th>Saturation Extract Analysis (meq/litre)</th>
<th>SAR (Satd. Extract)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>$Ca^{2+}$</td>
<td>$Mg^{2+}$</td>
<td>$Na^{2+}$</td>
</tr>
<tr>
<td>505 A</td>
<td>Rupal</td>
<td>0.6&quot;</td>
<td>5.87</td>
<td>2.5</td>
<td>2.0</td>
</tr>
<tr>
<td>505 B</td>
<td>Rupal</td>
<td>6-15&quot;</td>
<td>6.13</td>
<td>2.8</td>
<td>2.1</td>
</tr>
<tr>
<td>506 A</td>
<td>Bhayla</td>
<td>0.6&quot;</td>
<td>11.79</td>
<td>2.3</td>
<td>1.8</td>
</tr>
<tr>
<td>506 B</td>
<td>Bhayla</td>
<td>6-15&quot;</td>
<td>12.28</td>
<td>2.4</td>
<td>1.7</td>
</tr>
</tbody>
</table>

**AFTER TREATMENT**

<table>
<thead>
<tr>
<th>S No.</th>
<th>Location</th>
<th>Depth (inches)</th>
<th>$E_{0}^{25\degree C}$ (mhos/cm)</th>
<th>Saturation Extract Analysis (meq/litre)</th>
<th>SAR (Satd. Extract)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>$Ca^{2+}$</td>
<td>$Mg^{2+}$</td>
<td>$Na^{2+}$</td>
</tr>
<tr>
<td>505 A</td>
<td>Rupal</td>
<td>0.6&quot;</td>
<td>3.54</td>
<td>6.4</td>
<td>4.0</td>
</tr>
<tr>
<td>505 B</td>
<td>Rupal</td>
<td>6-15&quot;</td>
<td>3.87</td>
<td>6.2</td>
<td>3.8</td>
</tr>
<tr>
<td>506 A</td>
<td>Bhayla</td>
<td>0.6&quot;</td>
<td>7.90</td>
<td>4.8</td>
<td>1.0</td>
</tr>
<tr>
<td>506 B</td>
<td>Bhayla</td>
<td>6-15&quot;</td>
<td>6.00</td>
<td>4.4</td>
<td>1.2</td>
</tr>
</tbody>
</table>
3-1. UNTREATED PLOT OF RUPAL REGION.

3-2. PROFUSE GROWTH OF COTTON AFTER ACID TREATMENT (RUPAL).

3-3. STANDING BRINJAL CROP IN ACID TREATED PLOT (RUPAL).

1. A TYPICAL SALINE-ALKALI TRACT DURING SUMMER (DHANDHUKA REGION).
Discussion:

Table No.VIII A presents the data for reclamation of two sites viz. Baratwada and Juna Maka, which are saline soils. Before the reclamation the growth of the crops were uneven and very poor yields were obtained. The sites are in very bad conditions because they are very hard to till and poor water permeability was there.

Addition of 2 tons of industrial waste sulphuric acid (adjusted to 50 percent strength) plus 3 percent organic matter per acre reclaimed the soils within a period of ten days. A 6 inch water layer was kept for leaching out the salts for a period of seven days. A ditch of 2.5' depth and 2.0' width was made covering the total length of the plot so as to lead the salts away from the plot.

In Baratwada soils the acid treatment shows a quick reclamation and the salinity level decreased from 9.2 to 5.6 in the 0.6 inch layer, and from 7.5 to 4.2 in the 6.15 inch layer. The presence of CaCO₃ to the extent of 12 - 13 percent is a source of Ca supply and we find that there is decrease in salinity and increase in the Ca content in the soluble salts. Similarly in Juna Maka experiment the salinity has been decreased from 18.3 to 4.5 in the 0.6 inch layer and from 18.4 to 4.3 in 6.15 inch layer. Here also the saturated extract shows a
significant amount of Ca which raises from 3.2 to 16.4 and there is decreases in Na ion from 184.2 to 20.2. The pH also decreases from 3.4 to 7.5 showing reduction in ESP which is also supported by ESP measurement. There is decrease in CaCO₃ content which also supports formation of fresh gypsum which will be useful in subsequent years.

Again a very important results of reclamation is the availability of the higher amount of yields from the crops at both the sites. The farmers who were getting cumin worth Rs. 600/- in the untreated plots used to get cumin worth Rs. 6000/- by this treatment indicating a tenfold increase in the crop yield of cumin. There has been an economical revolution in this area of North Gujarat. After this 1st successful experiments about 150 acres of land has been improved by this acid treatment in this area.

Table No. VIII -B shows the results of the new acid powder method of reclamation at the Gujarat Vidyapeeth (Randheja) soils (503, 504). These are the two plots of alkali soils in the Gandhinagar district of Gujarat which have been spoiled by the high percentage of sodium carbonate content that is present in the tube-well waters in that area. These tube-well waters contain the high Na₂CO₃ content because the area is potential in oil fields. Addition of 1 ton of this acid powder per acre
is used to reclaim the soils of Randheja of Gujarat Vidypapeeth.

In sample No. 503 the salinity had decreased after treatment but to a lower extent than the plot No. 504. There is also increase in Ca contents in the soluble cation extract and decrease in soluble Na after the treatment. The change in $\rho_H$ also significantly shows improvement in lowering down alkalinity. Of course due to heavy texture 38 percent clay Randheja soils have not improved as much as those of Rupal and Bhayla which are sandy loam soils (12 and 15 percent clay respectively).

In Table No. VIII-C presents the data for reclamation of Rupal (505) and Bhayla (506) soils by the acid powder method. Here also 1 ton of acid powder per acre was used to reclaim the salty soils which are due to the old sea being present in that area about 300 years ago.

In case of Rupal soil (505), the soluble salts have decreases from $6.8 \ \text{ECX} \ 10^3 (\text{mmhos/cm})$ to $3.5 \ \text{ECX} \ 10^3 (\text{mmhos/cm})$ to $3.8 \ \text{ECX} \ 10^3 (\text{mmhos/cm})$ in 6 - 15 inch layer. The $\rho_H$ changes from 8.1 to 7.6 in the 1st layer and from 8.0 to 7.7 in the second layer. As compared to Rupal the Bhayla soil (506) soil has not improved to the same extent, considering the aspects of salinity level. However, increase in Ca content and decrease in Na content as well as increase in $SO_4^-$ content after treatment are
direct evidences for making a bold conclusion that acid powder treatment can turn a dispersed Na-soil into a aggregated Ca-soil which can support better plant growth. At Rupal 1st crop of Paddy increased from 35 monds/acre to 85 monds/acre and the subsequent crop of wheat also increase from 21 monds/acre to 49 monds/acre. In fact, the acid powder method is convenient to use and it works on the basic principle, that $H_2SO_4$ is released on the hydrolysis of Iron Sulphate and also $H_2SO_4$ is formed by oxidation of sulphur and interaction of $SO_2$ with soil moisture.

In fact the superiority of acid method and acid powder method can be proved very easily even though the quickness of acid method is comparatively much higher than acid powder method. One point to note is that the treatment and controlled plots should be kept far away because the leaches from the treated plots can effect the untreated plots which has been observed fact at other sites.
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