CHAPTER I

INTRODUCTION

A large number of geochemical processes attributed to the weathering of rocks take place in the formation of soils. These changes give rise to various kinds of chemical compounds including the simple soluble salts. Of the soluble salts, those of alkali and alkaline earth metals are of particular interest in soil salinity consideration.

In arid regions some soils develop under conditions of poor drainage in spots and there is more water evaporating than there is water coming into area as precipitation. Under these conditions soluble salts and exchangeable sodium may accumulate in sufficient amounts to impair plant growth and to alter soil properties. The addition of irrigation water, which contains varying amounts of soluble salts, for crop production in arid regions also creates the potential for the accumulation of soluble salts and exchangeable sodium.

Saline soils contain sufficient soluble salt to impair plant growth and sodic soils contain sufficient exchangeable sodium to impair plant growth and alter soil properties. The quantity proportion, and nature of salts present may vary in saline and sodic soils. This gives rise to three kinds of soils, namely, saline, saline-sodic, and sodic soils.
Classification of soils have been attempted on various lines. The problem is perhaps more complicated than the problem involved in the classification of elements or plants or animals. According to American (United States Department of Agriculture) system of classification (48), soils are first divided into three great groups.

(a) Zonal groups are primarily influenced by climate in which they develop.

(b) In the intrazonal groups, drainage contributes to the nature of the soil.

(c) Azonal soils are without profile characteristics.

According to Russian workers (36) the 'Solonchak' 'Solonetz' and 'Solod' applied to genetic types of the saline alkali and de-graded soils and express three stages in the evolution of salt affected soils. The first stage consists of the process of salinization, i.e., the accumulation of soluble salts at the surface, such soils are called SOLONCHAK. The second stage consists of desalinization, whereby the soluble salts are removed and the complex becomes progressively saturated with sodium ion. Such soils are called SOLONETZ. In the third stage, soluble salts are completely removed and due to hydrolysis the silicates splits and SiO$_2$ is released. Such soils are called SOLOD.

The above system is broadly followed by Sigmond (76), who describes the various stages as follows:
(i) **SALINIZATION (saline soils):** The first stage consists of accumulation of sodium salts.

(ii) **ALKALINIZATION (salty alkaline soils):** In the second stage of alkali soil formation, the nature of absorbing complex is changed by sodium salts.

(iii) **DE-SALINIZATION (leached alkali soils):** The third stage of alkalinization is due to the intensive leaching of salts when the soil becomes of solonetz type.

(iv) **DEGRADATION (degraded alkali soils):** The leaching of soluble salts is followed by the hydrolysis of sodium complex. This results in sodium being replaced by hydrogen and soil reaction becomes acidic.

(v) **REGRADATION (regraded-alkali soils):** If owing to some reasons water level rises up again, the degraded alkali soils becomes regraded and the soils become saline again.

According to U.S. Salinity Laboratory (94), saline and alkali soils are divided as follows:

<table>
<thead>
<tr>
<th>Soil class</th>
<th>Ec</th>
<th>pH</th>
<th>ESP</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saline Soil</td>
<td>&gt; 4</td>
<td>&lt; 8.5</td>
<td>&lt; 15</td>
<td>These soils contain soluble salts in such quantities that they interfere with the growth of crop plants.</td>
</tr>
</tbody>
</table>
These soil contain appreciable quantity of soluble salts and sufficient exchangeable sodium to interfere with the growth of crop plants.

These soils do not contain appreciable quantity of soluble salts but contain sufficient exchangeable sodium to interfere with the growth of crop plants.

Morss (56) has critically reviewed all the factors leading to formation of various types of saline and alkali soils, taking into consideration the geographical situation, climate topography, and hydrological factors as well as local vegetation. The diverse factors enunciated by him are as follows:

(a) **Temperature:** This exerts a profound effect in places where the ground is not regularly submerged. In central continental regions, a high summer temperature are of great significance.
(b) **Rainfall:** This will be responsible for downward leaching salt in the upper layer of the soil.

(c) **The height of the marsh in relation to sea level:** Lower marshes are flooded more frequently than upper marshes, but in the former, a continuous influx of the sea will maintain a steady saline content, whilst in higher marshes the long periods of continuous (non-tidal) exposure, specially in summer result in evaporation and an increased salt concentration.

(d) **Nature of soils:** A marsh built of a fine silty mud retains more salt than one having a high proportion of sand.

(e) **The presence or absence of vegetation:** The presence of plants brings about a rise in the soil water and reduce the rate of evaporation from soil surface. Bare soils always attain a higher salt concentration in summer than the vegetation covered marsh.

(f) **Inclination of the ground:** The greater the slope, the more rapidly the salt water drains off.

(g) **Depth of the soil water table:** High water table is responsible for more salinity of soil.
In case of inland saline soils, factors (a), (b), (e), (f), and (g) operate while the following additional factors will also have to be considered for coastal marshes.

(h) **Depth of sub-surface salt deposits:** The greater the depth, the less saline will be the surface layers.

(i) **Inflow of streams into the area:** The streams bring salt with them or they may dilute the salt water already in the basin.

Alkali begins to appear within a few years after irrigation is introduced in a given area and this fact has been observed in many parts on semi-arid regions of the world (39).

Although irrigation is useful and practised in various areas of heavy precipitation, it becomes an indispensable requirement in arid zones. The aridity of a region depends upon temperature as well as precipitation. Thornthwaite (87) formulated the effectiveness of rain in terms of the mean monthly temperatures. As defined by him, the effectiveness varies directly with precipitation and inversely with temperature. Many alternative methods of defining aridity have been suggested by different workers, but all involve temperature and precipitation, where rainfall is less than 10 inches desert conditions prevail (21).

Saline and alkali soils occur in arid regions. About
one fourth area of the world is classified as arid zones, while one third as semi-arid zone (86). Thus, more than half of the land of the world falls under these two categories. The main cause of the formation and occurrence of salt affected soils is the accumulation of sodium ion in the solid and/or liquid phase of the soils. Water plays a decisive role as a reactant, solvent and transporting agent in salinization and alkalinization process.

According to FAO/UNESCO (28), under arid or semi-arid conditions and in regions of poor natural drainage, there exists potential possibilities and a real hazard of sodium salt accumulation in soils from the saline or brackish irrigation water or from the shallow saline ground water. The main reason for the formation of saline soils is the upward and downward movement of soil solution and salts get distributed and/or accumulated either in the surface layers or in the sub-soil, and during dry period, the surface of the soil is covered with salt crust.

Leather (45) summarised the origin of salts in the soils of North India in the following four ways.

(a) From a sub-soil bed of salts for which no possible evidence existed.
(b) Brought down by the rivers, obtained from rock dissolution, and deposition along with the alluvium.
(c) From the soil itself by further decomposition of soil minerals.
(d) From the canal water.

Richard (65) explained that when excess soluble salts
accumulate in the soil, sodium frequently becomes dominant cation in the soil solution and thereby results in alkali soils. Howard (35) reported that anaerobic bacteria, bringing about a reductive phase in the soil, are the real agents, which give rise to a harmful salt level which occur in alkali tract. These bacteria are also responsible for conversion of fresh water into salty lakes. Sokolovsky (77) studied the rock weathering and considered that the primary source of all kinds of salts in soils is due to weathering.

All soils of the dry climate are not necessarily affected by alkali. The first requirement for the occurrence of saline and alkali soils is the accumulation of soluble salts (15). An additional factor essential for the development of saline alkali soils is the existence of impervious structure in sub-soil, which prevents the penetration of water underground and results in high ground water level. Agrawal et. al. (10) reported that a combination of factors such as geological climatic and hydrologic are involved in the formation of saline and alkali soils.

As early as 1892 Hilgard published a report on the relation between soil and climate, in which he discussed studies on alkali soils started by him in 1888. Vilenski (97) and De Sigmond (75) cite references to alkali soils dating back to the 18th century. Hilgard divided the alkali soils into two groups, white alkali and black alkali soils, the former containing sulphate and chloride of sodium and sometime magnesium, and the latter containing carbonate of
sodium. In 1912 Gedroiz (30) presented his views on the
genesis of the soils based upon the phenomenon of
exchangeable cation.

From time to time different workers have reported the
accumulation of salts in soil. Raychaudhari et. al. (62)
pointed out that the accumulation of soluble salts at the
surface was high due to capillary rise of water and its
evaporation from the surface. Razumoya (63) studied that
raising the level of ground water, above an average depth of
3 meters may cause secondary salinization and impair the
physio-chemical properties of soil. Chaudhary and Kheper
(23), found in Punjab soils that salt accumulation depends
on texture, water table and salt concentration of ground
water. Dhir et. al. (24) summarised that the salinity is
high to very high and ranges from exclusively Na-Cl type to
Na-Ca-Cl-SO₄ type. Distribution of salt affected lands of
Pali block, Western Rajasthan appears to be related to down
slope nature of the sites and poor surface drainage.

A high percentage of alkali soils in the world is
alluvial. These soils could be reclaimed under artificial
irrigation. Artificial irrigation is both a friend as well
as a potential enemy. In the absence of adequate drainage,
artificial irrigation may raise the ground water level and
may render the otherwise fertile soils unproductive. Thus
the utilization of land requires careful consideration of
irrigation, and what is more important of an adequate and
suitable system of drainage. Neglecting the later factor
results in the spread of the alkali soils.
Bhadrapur and Seshgirirao (16) reported that in a number of locations in the Tungabhadra project area in Karnataka, the lower land soils were affected by salinity and alkalinity due to seepage from uplands. Thus reclamation programme can be taken after a thorough geo-chemical classification of soil and water in the area.

Saline and alkali soils have been extensively studied by workers of the U.S. Salinity Laboratory (94), Antipov Karataev and Kader (11), Szabolcs (80), Elegably (26), Varallyay and others (95,96).

Saline and alkali soils are found distributed in all parts of India. It has been estimated that an approximate area of 7 million hectares are covered by such soils all over the country(79). The problem has been studied in the past by a number of important commissions notably Reh Commission (69), Usar Land Reclamation of UP (93), and recently by the Waste Lands Survey and Reclamation Committee of the Planning Commission. The area under the affected soils continue to increase each year due to introduction of irrigation in new areas. Among the earlier studies on this problem could be included those of Medlicott (51) in Upper India, Leather (44,46) in North Western Province and U.P., Taylor, et. al (91) and Menon (55) in the Punjab, and Mann, Tamhane (47), Talati (83,84) and Basu and Tagore (13) in former Bombay Province. Among the recent studies mention could be made of Agarwai and co-workers in UP (6,7,8,9), Hoon (34) and Uppal (92) in the Punjab, Bannerjee (14) in West Bengal Shah and Trivedi (68)
in Gujarat: Kameshwar and Sastry (27) in Madras. and
Raychaudhari and associates (57,58,59,60,61) in Delhi. In
addition Mathur and co-workers (49,50), Mehrotra and
coworkers (52,53,54), Bhumbla (17,18,19,20), Yadav (98,99,
100). Abrol (1,2,3) have also made significant contributions
towards the study of saline alkali soils.

A general distribution of saline and alkali soils in
India has been furnished by Abrol and Bhumbla (1). Nature
of problems in regard to the saline and alkali soils vary a
great deal and are not the same in different parts of the
country. Abrol et. al. (5) have grouped the different salt
affected soils in India into the following four categories:

(1) Salt affected soils occurring in the Indo-Gangetic plains
of Punjab, Haryana, UP and Delhi.

(2) Salt affected soils occurring in the medium and deep
black soil regions of Madhya Pradesh, Maharashtra,
Karnataka and Andhra Pradesh.

(3) Salt affected soils occurring in the arid regions in
the states of Haryana, Punjab, Rajasthan and Gujarat.

(4) Salt affected soils in the coastal regions of the
states of West Bengal, Orissa, Andhra Pradesh, Kerala,
Gujarat, Karnataka and Maharashtra.

Saline and alkali soils are known by different names in
different parts of India, such as thur, kallar, rakar, reh, karl
and chopan.

Saline alkali soils in Gujarat state have been
critically studied by Shah and co-workers (69,70,71,72,73,
74) and Trivedi et. al. (88,89), Talati (81,82,83), Hoon (34), Satyanarayana (66), and Bapat (13). Moreover the study on the rann of the Kutch and masterplan for this have been carried out by FAO team (Dutch experts), headed by Prof. Vlugter (29). A serious problem is of sub surface salinity ingresses in open well of Southern Saurashtra have been studied by high level committee headed by Shri H.K.L. Kapoor (31). Similarly studies on coastal saline area in the western and northern coast of Saurashtra as well as in Kutch has been carried out by Committee II (32). Expert Committee of Khar land board have studied the coastal belt from Bhavnagar to Valsad (41).

According to an estimate by Central Soil Salinity Research Laboratory Karnal, there are one crore acres of salt affected soils in the whole of India, out of which thirty lac acres are located in Gujarat State.

Gujarat state is situated on the west coast between $20^0 6'$ to $24^0 42' \text{N}$ latitude and $68^0 10'$ to $74^0 28' \text{E}$ longitude (78). It is bounded by the Arabian sea in the west, by the state of Rajasthan in the north and north east, by Madhya Pradesh in east and by Maharashtra in the south and south east, and occupy 19.59 million hectares (79). In respect of area Gujarat is the seventh largest state of India.

Total area of the land under utilization in Gujarat is about 18.81 million hectares of which about 12.45 million hectares is cultivable. About 1.214 million hectare area suffer by the saline and alkali problem (78) (in which 302, 255 hectare area is coastal saline).
In Gujarat, salinity problem has originated from many sides.

Talati (84) has indicated that problems of salinity in Gujarat may be either due to water logging consequent on the introduction of irrigation or due to deposition of sea salts, as in the coastal areas of the state. In Banaskantha district areas affected due to water logging consequent on obstructed drainage are above 4000 hectares. The soils are mostly sandy or sandy loam. The water logging occurs in saucer shaped valleys with no proper drainage outlets.

Nearly 800,000 hectares of coastal lands in Gujarat are affected by salinity in the districts of Surat, Broach, Ahmedabad, Mehsana, Banaskantha and Anwali. The cause has been ascribed to the silting up of the Gulf of Cambay. The water of the gulf and the river estuaries are surcharged with silt which is deposited in the form of thin film on the surface at the turn of the tide. This thin film on drying up forms a fine mixture of salt and clay dust which eventually blows interior during the dry summer months and is deposited on cultivated lands. Shah and co-workers (70, 71, 72) have examined the nature of saline and alkaline soils of south-west Gujarat. Satyanarayana (67) has surveyed the soils of Kutch and showed that surface deposits of salts of appreciable thickness occur over an area of 40,000. The predominantly component of total salts consists of sodium chloride. There is considerable accumulation of gypsum in the profile. There is a saline area of about 60,000 hectares in the south-east corner of
Saurashtra called Bhal area.

The arid and semi-arid regions of Kutch and north Gujarat are salty because of the existence of old sea in the area. The land of Bhal Pradesh and Nal-Kantha is a saline land due to sea water inundation, as it is the land which is a connecting link between the Gulf of Kutch and Gulf of Cambay. In addition, the oil exploration in areas like Cambay, Ankleshwar, Sanand, Mehsana, Dholka, Kalol, Navagam has brought out the oil fields waters, which are prominent in sodium carbonate content which turns an area saline-alkali within 5-6 years usage of irrigation water of tubewells (depth 200'-600').

Hollant and Christie (33), teakle (85) and Erik Eriksson (27) concluded that one of the important factors responsible for further spread of salinity in non-saline region is the wind borne salt particles from adjoining sea shores or salty deserts. This conclusion supports increasing salinity of the soil of Kutch because salt particles, carried by wind deposited on fertile agricultural soil and renders the soil unfit for cultivation. According to CSSRI Karnal ICAR Bull no. 13 (22), Saurashtra region faces highest wind speed in all over the India and peak in between the month of April to July 20-28 Km/hr.

Some of the important sources contributing towards salinity in arid and semi-arid tracts of Gujarat state are as follows:

(i) Salinity develops in the area of Kutch, Amreli and North Gujarat, where evaporation exceeds precipitation
(ii) Small rivers disappear in the area and accumulate salts in the region.

(iii) The high water table in Bhachau taluka and in parts of little Rann of Kutch augment the salts in the surface soils.

(iv) One of the principal factors is that the whole area remained under sea at one time, and sudden rising of the land locked large quantities of sea water underground. A high Cl/HCO₃ index suggests intrusion of gypsum is a direct proof of the existence of sea in the region.

Trivedi and Shah (88), Shah (73) reported the existence of brine well water near 'Kharaghoda' and various salt pans in Little Rann of Kutch which supports the above hypothesis.

Man Made Salinity

Over irrigation in Command Areas: The problem of the water logging and of salinity in irrigated command areas was not severe till 1972. Now, with the construction of reservoirs like Ukai, Karina, Dharoi, Panam water has been made available round the year and large quantities of water starts flowing through commands and the problem of water logging and/or salinity started coming up in various major irrigation projects since last decade. At present 10,000 hectare of land under various irrigation projects commands have indicated water table within 1.5 meters and other about 1.2 lakh hectare between 1.5 to 3 meters.
Use of Saline Waters: Due to high aridity and low erratic rainfall conditions in North Gujarat viz. Banaskantha, Mehsana, North Saurashtra and Kutch districts the farmers are required to avail of a reliable source of water. The tubewell water which draw the water from very deep aquifers have slightly saline to saline water (Ec ranging from 1500 to as high as 7000 micro ohms). As there is hardly any other source of water available, the farmers in these tracts are using these water for irrigation.
LEGEND
1. DESERTATION
2. INHERENT SALINITY
   (a) MARSHY LANDS
   (b) OLD SEA BEDS COVERED WITH ALLUVIUM
3. SURFACE SEA WATER-INGRESS.
4. SUBSURFACE SALINITY-INGRESS.
5. MAN-MADE SALINITY
   (a) OVER-IRRIGATION.
   (b) USE OF SALINE WATERS.

MAP OF GUJARAT
(SALINITY VARIATIONS)

PLATE I 1-1
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