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Studies on Nature and Properties of Salinity across Globe With a View to its Management - A Review

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Studies on Nature and Properties of Salinity across Globe With a View to its Management - A Review

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Abstract- **Salinity is a complication towards evolving a sustainable food production system and habitat management throughout globe. Such problem has its origin from marine, geological and anthropogenic activities. Nature and properties of salinity has been reviewed on global extent with a view to its management in this regard.**

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I. Introduction

Salinity across globe can be broadly grouped as ocean and terrestrial salinity. Terrestrial salinity has its manifestation on land surface and in groundwater [33, 34, 35, 36]. Salinity of ocean is most vividly revealed and which hardly needs a classification, though sea temperature is the crucial factor for which salinity changes from place to place on oceans. Salinity is the outcome of various geological factors in association with atmospheric influence. Atmospheric components along with geological circumstances are the determinants of salinity on land territories including groundwater and in oceans.

The present review work is targeted to find out nature and properties of salinity on global scale with a view to its management, especially managing salinity for sustainable food production through better agriculture and aquaculture, building construction and fresh water harvesting.

II. Materials and Methods

Literature survey is done on studies on geographical expanse of salinity in water and in soil under the various geological and atmospheric influences. Native geological features, territorial water bodies and streams and even oceans and seas are influencers of soil salinity. Thus, literature survey will target to find out those native factors including atmospheric components to study the nature and properties of salinity, especially soil and groundwater salinity, for its management with a view to effective utilization of landmass and water bodies and oceans for a better scope for creation of dwelling places and security of food, fodder and fibres in future for human beings on a global scale. Here, groundwater, mouths of rivers and coastal areas are interfaces between land territory and ocean.

Salinity is the indication of property of both water and soil. It is the saltiness characterized by amount of dissolved salts present and expressed as grams of salt present in one kilogram of water or soil with a unit of parts per thousand or ppt or $^0/_{00}$. Dissolution of salts results in higher density of salty water than freshwater. This property is used to measure salinity of water by hydrometer. Similarly salty water refracts more than freshwater and this property is the reason for measuring salinity of water by refract meter. As the property of variation of microwave emissivity with temperature and salinity of sea surface, salinity sensor is mounted on NASA's Aquarius Instrument satellite (June 10, 2011) to measure changes in global sea water salinity. Readings with that instrument can identify roughness created by the shallow pools of freshwater due to intense rainfall on ocean. Carrying capacity of electrical charges by ions in water is employed to measure salinity of water by electrical conductivity meter. This meter is also used to measure salinity of 1:2 soil-water saturation extract. Apparent electrical conductivity of bulk soil in field is done through electrode probes or electromagnetic induction or time domain reflection. Aquarius Instrument satellite also measures global soil moisture status. With the another instrument, Argentine built Microwave Radiometer aboard, in future, that Aquarius will gauge intense rain over ocean simultaneously to salinity readings. After thorough refining microwave emissivity measurements that salinity sensor may succeed in measuring accurate soil salinity over the globe. There is another scope for refining measurement soil moisture content with the help of physical procedures or of certain bacteria like *Escherichia coli* and joint venture of this microbiological method with the microwave emissivity salinity sensor may lead to precise estimation of soil salinity. [1, 2, 3, 4, 5, 6, 7, 8, 9, 10]

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III. Discussion

Nature of Salinity – Salinity is the accumulation of salts above certain level in water or soil matrix and geological formations. Sources of salinity can be broadly classified into salinity of water and salinity of soil. Each has its effect on the other. Thus, the two cannot be segregated in nature. Besides climate has great binding on salinity and, thus, there is soil-water –atmosphere continuum in nature of salinity, studies of which will be effective in its management, especially managing soil salinity. For the purpose of clarity the whole discussion is divided into:

i) Ocean salinity
ii) Terrestrial salinity

a) Ocean salinity

i. *Physical states of water*

There are three physical states of water like liquid, ice and vapour. Water, in its liquid state, dissolves rocks and sediments and reacts with emissions from volcanoes and hydrothermal vents. This results in complex solution in ocean basins. Apart from that salts with minerals are released in oceans as a result of weathering of rocks. Other two states are salt incompatible and, thus, formation of ice through condensation and vapour formation through evaporation are responsible for increase in salt concentration in water.[3, 10, 11, 12]

ii. *Water Cycle*

The globe is broadly composed off one third parts of land and two third parts of water. Global 78% precipitation and 86% evaporation occur over ocean. This difference in fresh water input-output affects the ocean dynamics, where ocean surface salinity is the key factor. Tracking of that salinity helps to directly monitor land runoff, sea ice freezing and melting; evaporation and precipitation over ocean.

Formation of ice and evaporation are responsible for increase in salt concentration in ocean. Processes like input of fresh water from precipitation (rain, snow), surface (river) and sub surface runoff (fresh groundwater flow) and melting of ice are responsible for continually decreasing salinity against different salinity factors. Still it is of great concern that small variations in salinity in ocean surface can eventually affect the circulation in ocean and global water cycle.[5, 7, 10, 11, 12]

iii. *Ocean Circulation and Climate*

Upper ocean circulation is driven by winds. Deep below the surface the changes in sea water density is the casual factor of ocean circulation, while sea water density is dependent on salinity and temperature.

On high latitude regions, such as on the North Atlantic east of Greenland, cold surface ocean waters becomes saltier due to evaporation and/or sea ice formation. In those regions surface water turns dense enough to sink to the ocean depths. That pumping of surface water forces the deep ocean water to move horizontally until it can find areas where it can move up to the surface of ocean. That ocean current is called as 'thermohaline circulation', as that is caused by changes in temperature (thermo) and salinity (haline). It is a very large and slow current estimated to be on the order of 1000 years to complete a full circuit, also called the 'Global Conveyer Belt' as this works as an interconnected system. Such studies can help to emergency preparedness towards disaster management with regard to cyclones, sustainable fishing from seas and estuaries, etc.

Studies on salinity in coastal areas are helpful for planning rain water harvesting for more crop production.[1, 3, 4, 5, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22]

iv. *Salinity Regions*- knowledge base for land salinity management

a. *High Salinity*

a) In centre of the ocean basins, away from the mouths of rivers which input fresh waters.
b) In sub-tropical regions, due to high rates of evaporation as a result clear skies,
c) little rain and prevailing winds. In landlocked seas in arid regions.

b. Low Salinity

a) In high latitudes due to lower evaporation rates and melting of ice which dilutes sea water.
b) In tropical areas dominated by rain.

Such differences in salinity regions have a significant impact on ocean circulation and the global climate.[3, 4]

v. *Sea–land proximity and Geomorphology – knowledge base for land salinity management*

The Bay of Bengal is less saline than the Arabian Sea. Because Bay of Bengal is showered by intense monsoon rains and gets fresh water discharges from the Ganges and other large rivers, whereas the Arabian Sea is laid up against dry Middle East.

Drift of sea water by winds is a major factor for salinization of coastal soils. More sandy soils are less affected by salinity. Large rivers, generally, form delta near its mouth and carry sediments constituting clay fractions in majority, which are susceptible to adhesion of ions of salts, *i.e.* the cause of salinity. For these reasons the coastal soils by the Arabian Sea have less saline area than the coastal soils of Bay of Bengal.

Such examples can be cited for other places which would be of much helpful for managing country wise land salinity.

b) Terrestrial Salinity

Terrestrial salinity may be due to one of the following causes:

i. Marine origin,
ii. Natural terrestrial origin,

iii. Anthropogenic terrestrial origin.
iv. Mixed origin.

a) Manifestations of Terrestrial Salinity

i. Soil salinity
   a. Frozen Soil Salinity
   b. Agricultural Soil Salinity
ii. Surface Water Salinity
iii. Groundwater Salinity

i. *Frozen Soil Salinity*

Continental salinity is concerned mainly for soil and water salinity affecting agriculture. Salinity is the problem for building construction everywhere and especially in arctic coasts for anomalous load bearing property of frozen saline soils. Frozen saline soils are also distributed in Central Siberia, where continental salinization is caused by predominance of evaporation over precipitation and that is characterized by prevalence of sulphate and carbonate ions and such soils are characterised by special engineering property of low bearing capacity. Those soils possess property between frozen and unfrozen soils because of their freezing at lower temperature and contain more unfrozen water than the same soil without salt. On such soil test of bearing capacity should allow constant load for construction of building.[19]

ii. *Agricultural Soil Salinity*

Agricultural Soil Salinity is the manifestation of both the soil and water (surface and ground) salinity, as water is a useful input in irrigated agriculture. In case of non-irrigated agriculture question of water salinity is not concerned.

During the process of weathering of rocks and parent material salts are released which makes the soil saline *in situ* and through transportation by surface and sub-surface runoff salinized azonal soils are formed. For such origin of salinity rainfall, sheet, rill, gullies, streams, rivers and groundwater flows are causing factors. Due to work of wind, moving glaciers, lakes, river, ocean various azonal soils (e.g. alluvial, colluvial) are formed. Contamination of those forceful geomorphic agents is also the cause of origin of saline soils on various parts of the globe. For example, coastal saline soils originated due to closeness of the coasts with the sea. Such geographical situation also affects the salinity of groundwater. Incidental flooding by sea water and high tides in the sea and drifts from seawater by wind are causes of salinity of coastal rivers and groundwater. Impeded drainage condition due to impervious or negligibly permeable soil layer at depth cause collection of salts in soil layers and on drying of surface causes salts to rise up and makes the soil saline which is usually characterised by salt efflorescence which is named in different parts of the globe differently like *reh* in India. Dissolution of calcium from clay complex turned the saline soil sodic (alkali) soil.[23, 24, 25, 26, 27]

Anthropogenic activities are causes of salinity in every parts of the globe right from the snow covered territory to shoreline of the hot continent. Those can be classified as anthropogenic pollutants like road salt (applied in winter in cold countries), fertilizers, domestic, industrial and agricultural effluents spilled oil and gas filled brines and brines from desalination plants and ice making plants, etc. Apart from those over pumping of groundwater in coastal areas may cause saline water ingress in groundwater. Ponding of saline river water or sea water for inland prawn culture, application of saline water for irrigation cause soil salinity. Construction of railways, roads and dams for canal irrigation are some of cause of impeded drainage condition leading to soil salinity. Construction of such canals was identified as main cause of increase in areas of saline as well as sodic (alkali) soils in India.[26, 27, 28, 29]

b) Management of Terrestrial Salinity

Management of land salinity requires area specific characterisation of salinity both in water and soil as well. Because either the salinity of soil or water cannot be separated like dilemma of differentiating flesh and blood. Groundwater is also an important component which needs attention in managing continent salinity, and, thereby using the vast saline tract for useful purpose for growing food mainly through agriculture and aquaculture.

From the generic point of view, as sodic soils are non-separable from saline areas, management of salinity in soils should take care of alkalinity of soil while planning for drainage of saline land.[26, 27, 28, 29]

c) Precautions for Drainage of Saline Soil for Conservation of Agricultural Lands

Through judicious practice of art and science of land drainage, drainage of saline soils can accomplish considerable achievements in conserving agricultural lands, in improving marginal agricultural lands, and in mitigating effects of other lands and water development projects.[30] This can be explained with the following six examples.

Example 1: Drainage of pilot area of Chacupe, in the arid coastal area of Peru.

For the reclamation of that strongly salinized sodic soil following were done:

i. Preparation of water and salt balance,
ii. Preparation of Leaching Curve,
iii. Estimation of required Leaching Time,
iv. Estimation of Lime Requirement of soil for application of necessary Ca amendments.

Example 2: Drainage for sugarcane cultivation in coastal low lands of Guyana.

Establishing a critical value of the seasonal Number of days with a High Water Level in open collector drains (NHW, above 90cm below soil surface), by relating it to production of sugarcane.

The critical NHW value was found to be 7 days, below which production was not affected and above which production showed a declining trend.

That example showed a good use of water level (instead of discharge flow) as a criterion for land drainage.

Establishment of that criterion helped to determine corresponding discharge by standard hydrological procedures.

Such criterion helped to classify estates with excessive, good and deficient drainage systems and to recommend required remedial measures.

Example 3:_Subsurface drainage for water logging and salinity in the Nile Delta, Egypt.

Thatstudies in Mashtul Pilot area showed that

i. Examining the modestly deep water table (about 0.8m as a seasonal average) sufficient to control soil salinity at a safe level as well good crop production,
ii. Imposing deeper water level for intensive drainage would have the negative side effects towards higher drainage losses as well as lower irrigation efficiency,
iii. Merit of such drainage criterion was found to be also effective in areas under crops other than rice.

Example 4: Subsurface drainage for water logging and salinity control in northwest India.

To reclaim seriously salinized soil in Sampla Pilot area, Karnal, Haryana with upward seepage of salty groundwater a subsurface drainage was commissioned manually.

i. Collection of drained water in a sump from the system, which is ultimately pumped out into the open drain.
ii. Drainage of salty water is done only during the rainy season (monsoon period, June-September), when rivers and canals carry a large amount of fresh water, so that mixing of that water will do no harm. During that season almost all the river water (Yamuna river, a tributary of the Ganges) reaches the sea (Bay of Bengal).
iii. Draining huge amount of salty drainage water in dry season, was cautioned to be more harmful for surrounding soil. On the other hand irrigation water, being scarce in that season, salty drained water is used for irrigation, having no danger of undue salinization of soil, as once in two or three years the monsoon gives sufficient rainfall to leach the soils and to evacuate the accumulated salinity.
iv. This is the example of a restrained operation of drainage system, where water table is permitted to be as shallow as possible and it is environment friendly with savings for irrigation water and operational costs as well.

Example 5: Subsurface drainage of acid sulphate and muck soils in southwest India.

That drainage system was installed in farmers' fields to improve acid sulphate and muck (peat) soils in La poder area, 1 to 2m below mean sea level, in Kerala.

i. Traditionally only surface drainage is practised for that purpose,
ii. Due to high rainfall (about 3000mm/year) with plenty of fresh water in ring canals the area maintained almost permanently under water to yield two rice crops a year, with duck rearing in between.
iii. Temporary lowering of water table in the December (dry month) helps

a) to increase crop yield from 1.5 t/ha to about 2.5t/ha,
b) to wash down acids and toxic elements to deeper depth with the next flooding of the field,
c) to contribute to better aeration of the soil, with a subsequent improvement of the quality of the organic matter.

Similar phenomenon, by tradition, is possibly occurring in restrictively drained areas of Pulau Petak, south Kalimantan, Indonesia.

Example 6: Subsurface drainage in winter for wheat production in England.

In a pilot area near Drayton, England following were observed:

i. Winter wheat is sown in previous autumn.
ii. Summer production of winter wheat was correlated with depth of water table in Winter.
iii. In summer there is no problem of water logging due to higher evaporation.
iv. Production only decreased when the average depth of the water table in winter was less than about 0.5m.
v. With the deeper water table production was not affected.

Such area specific studies on identifying minimum average depth of water table is helpful for designing suitable drainage system for better crop production.

VI. Conclusions

i. Studies on marine and estuarine and coastal salinities have good bearing on sustaining food production.[31, 32]
ii. Management of salinity needs location specific establishment of criteria for reclamation and/or drainage to obtain higher efficiencies both for drainage and irrigation with regard to crop cultivation.
iii. Aquaculture should also take of judicious application of science of soil and water salinity management as per need.
iv. Construction of building on frozen saline soil must undertake tests of bearing with fixed load in contrast to increasing load.
v. Environment friendly approach should aim at lowering operational cost for managing salinity for increasing production of food through agriculture and

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aquaculture, which would ultimately take care of minimizing salinity pollution from anthropogenic activities.

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