Influence of Sea Water Ingress: A Case Study from East Coast Aquifer in India

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ABSTRACT

One of the sources of pollution, in addition to organic matter; pathogens and microbial contaminants; nutrients; acidification (precipitation and runoff); heavy metals; toxic organic compounds and micro-organic pollutants; thermal and silt and suspended particles, that impact water resources at local scale in parts of eastern coast of India, is SALINIZATION due to sea water ingress. The eastern coast of India is also hit by the cyclones every year. With the result drinkable water is becoming increasingly scarce. By the year 2025, it is predicted that water abstraction will increase by 50% in the region, as population growth and development drive up water demand. In recent years, the availability of water and its quality have emerged as the major constraints to economic development and quality of life.

In parts of Krishna - Godavari Basin of Andhra Pradesh, number of bore wells have been drilled for drinking water abstraction. Salinity hazards have occurred due to sea water intrusion as the aquifers are open to the sea, entraps sea water in the marine sediments and seawater intrusions through tidal cracks. Indiscriminate pumping has resulted in groundwater overexploitation and sea water ingress with salinization of aquifers and landward movement of saline water – freshwater interface for several kilometres in Krishna - Godavari Basin area. In parts of Krishna - Godavari Bsin bore wells yield saline / brakish water due to seawater ingress. The groundwater is of brakish type, having Na^+ : Cl^- facies. The soils of the area have the ability to pick up these ions during pre monsoon period and during post monsoon period the water becomes more saline thus, suggesting that the ions are leached from the soils by the infiltrating recharge waters and are added to groundwater bodies. The TDS (1912 / 1948 mg/l), TH (365/393 mg/l - Ca^{++} + Mg^{++}), Na^+ (721/ 739 mg/l), Cl^- (781/ 797 mg/l), SO_4^{++} (122/ 112 mg/l) and F(1.6/1.9 mg/l) concentrations are in excess of the safe limit in accordance with the domestic and industrial water quality standard of WHO. Excessive amounts of fluoride (more than 1.5 mg/l) in drinking water is toxic. Discoloration of teeth and crippling skeletal effects caused by long-term ingestion of large amounts are prominent in the region, where millions people suffer from chronic fluorosis disease. Thus, these ground waters are not safe to drink.

The basic problem of groundwater management of the region is its development without disturbing the saltwater / freshwater interface. This may be achieved by limiting the groundwater abstraction through enactment of groundwater legislation and recharging the aquifer artificially by rainwater.

Key words : Salinization, Aquifer, Brakish, Fluorosis, Leaching

INTRODUCTION

Needless to say that water is perhaps the scarcest commodity of the 21st century. On global scale it is assessed that over the next two decades, water use by human beings will increase by 40% and that 17% more water will be needed to grow more food for the increasing population. The World Water Vision Commission drew attention to the "gloomy arithmetic of water" as water demand will out strip its availability. The scenario of water in India is equally gloomy. When India gained independence in 1947, the per capita availability of water was 6000 cubic meters and had only 1000 bore holes in the country but today with population crossing one billion, the per capita availability has fallen to 2300 cubic meters which is further expected to go down to 2000 cubic meters by the year 2015 though the number of bore holes have increased to more than 6 million. The evident reasons for this down fall are attributed to the rapid increase in population since independence and over withdrawal of *under ground water*. In another 15 to 20 years, the country will be in the grip of acute water shortage. The water supply of the eastern coast of India comprising the states of Andhra Pradesh, Orissa and Tamil Nadu is facing the problem of salinization of groundwater due to growing population's demand of water for various uses. The United Nation's recent report stating that about two-third of humanity would suffer from moderate to severe water shortage, is already proving true for India. The freshwater in shallower layers above *saltwater* is useful for agriculture and other industrial purposes until the slat content of the *groundwater* does not exceed certain limits. The *water table* is declining at an alarming rate and if the suitable measures to conserve water and recharge the aquifers are not initiated immediately, then some of the *reservoirs* may deplete permanently and the situation might worsen further.

Wide spread *marine incursions* has caused the water pollution and has resulted in increased water scarcity, poor public health, lower agricultural yields and a declining quality of *aquatic life* in coastal areas of India.

STUDY AREA

In Krishna - Godavari Basin of Andhra Pradesh, number of bore wells have been drilled for drinking water abstraction. *Semiconsolidated* sediments of *fluviomarine* origin of *Tertiary* to *Quaternary* age, comprising thick, coarse, well sorted sand layers ranging from a few meters to nearly 700 meters in thickness build up this eastern part of the Indian coast that serves as the repository of *groundwater* and from *prolific aquifers*. *Salinity* hazards have occurred due to sea *water intrusion* as the *aquifers* are open to the sea, entraps sea water in the *marine sediments* and *seawater intrusions* through tidal cracks. Indiscriminate pumping has resulted in *groundwater* overexploitation and sea water ingress with *salinization* of *aquifers* and landward movement of *saline water – freshwater interface* for several kilometres in Krishna - Godavari Basin area. In parts of Krishna - Godavari Bsin bore wells yield saline / brakish water due to seawater ingress The study area of Krishna - Godavari Basin in Andhra Pradesh experiences *tropical* and *humid* climate with mean monthly *temperature* raging between 25^0C to 38^0C and the mean rainfall of about 900 mm. *Physiographically*, the area has low relief with gentle slope from northwest to southeast making it prone to *flash floods*. *Quaternary alluvium* forms a multi-aquifer system, consisting of alternate layers of *clayey sands* and sandy clays of various thickness. The region is frequently hit by *cyclones* during monsoon period and the high *tides* traversing inland is very common. The average depth of water table in these wells during dry or non-monsoon period varies from 10.50 to 12.40 m and during monsoon period it is elevated between 8.74 to 9.84 m.

OBJECTIVE OF THE STUDY

With the increase in *saltwater* intrusion, the availability of *freshwater* is decreasing in the area particularly in the dry season. Therefore, the objective of the study is to analyze the *groundwater* samples from the existing bore holes situated in the coastal areas of east coast for assessing the water quality which is the key to socio-economic development and quality of life of the habitants of the region.

METHODOLOGY

In order to assess the *groundwater quality* and the affects of *intrusive sea water*, 160 water samples from the bore holes representing shallow *groundwater* zone up to 50m were collected from the coastal areas of Andhra Pradesh from east coast. The *electrical conductivity* of the borehole samples were measured in the field and was found to be around 487 *uS/cm* at 25^0C at a *pH* of about 8.1 as compared to the surface water having more than 3090 *uS/cm* at 25^0C at a *pH* of around 7.2. This itself is an indicative of the higher *salinity* in *groundwater* due to *marine* incursions. The collected water samples were brought to the laboratory and as per standard procedure of APHA, 1985 they were analyzed for *TDS, TH* $(Ca^{++} + Mg^{++})$, HCO_3, CO_3^{--} Na^+ Cl^- SO_4^{++} and *F* and the *ionic ratios* calculated to see the influence of contaminated *marine* incursions in the area.

HYDROGEOCHEMISTRY

The following Table1 summarizes the chemical composition of *groundwater* in the pre and post monsoon periods (all concentrations are expressed in *mg/l*).

Bore Hole No.	*TDS*	*TH* $Ca^{++} + Mg^{++})$	HCO_3	CO_3^{--}	Na^+	Cl^-	SO_4^{++}	F^-
1.	3261 /3301	520/ 522	510/ 515	30/ 30	1011/ 1024	1244/ 1260	268/ 260	1.5/ 1.7
2.	1924 /1965	301/ 352	420/ 427	-------	760/ 785	870/ 895	102/ 90	1.3/ 1.5
3.	1530 /1590	411/ 430	310/ 324	25/ 24	880/ 910	270/ 289	75/ 68	1.6/ 1.8
4.	0758 /0801	256/ 303	212/ 227	20/ 20	180/ 202	160/ 163	23/ 18	1.2/ 1.6
5.	2081 /2022	330/ 355	456/ 467	-------	678/ 680	854/ 864	98/ 88	1.4/ 1.7
6.	1965 /2001	398/ 403	417/ 437	-------	588/ 512	880/ 889	105/ 89	2.1/ 2.5
7.	3940 /3990	512/ 553	556/ 571	30/ 28	1202/ 1245	1544/ 1566	302/ 289	1.4/ 1.7
8.	0748 /0799	219/ 265	217/ 230	-------	167/ 176	167/ 179	58/ 52	1.6/ 1.9
9.	1924 /1965	378/ 401	391/ 403	-------	755/ 790	830/ 855	99/ 88	1.6/ 2.0
10.	0988 /1052	327/ 347	272/ 282	20/ 20	988/ 1012	990/ 1012	89/ 82	2.2/ 2.5
Mean	1912/ 1948	365/393	376/ 388	12.5/ 12.2	721/ 739	781/ 797	122/ 112	1.6/ 1.9

Ionic ratios	*Na /Cl*	*Cl/CO$_3$+HCO$_3$*	*Na/Ca+Mg*	*F*
	0.91/ 0.92	2.0/ 1.9	1.9/ 1.8	1.6 – 1.9

DISCUSSION OF RESULTS

Though there has been tremendous progress in the water supply infrastructure after setting up of the Rajiv Gandhi National Drinking Water Mission in 1986, the goal to provide safe drinking water to all is still to be achieved. India's population has recently crossed one billion. Ever-increasing population and the increased need for agriculture and industries has resulted in water scarcity. The country thus faces a series of threats to the management of water resources. This leads the rural population and even urban also to depend upon water from local tanks and tube wells and the consumption of untreated water for all purposes. Groundwater classification based on *Total Dissolved Solids* categorizes *Freshwater* ranging in *TDS* from 0 to 1,000 *mg/l* ; *Brackish water* from 1,000 to 10,000 *mg/l* ; *Saline water* 10,000 to 100,000 *mg/l* and *Brine* > 100,000 *mg/l.*

The major *ionic ratio Na/Cl* is equal to 0.9 in the samples which is quite comparable to the seawater *ionic ratio* of 0.85. Another important *Na/Ca+Mg ionic ratio* of 1.9 indicate the influence of *tidal* recharge into these waters. In addition, the *ionic ratio* $Cl/CO_3 + HCO_3$ with a value of around 2.0 clearly indicates the injuriously contaminated *marine* incursion. The average *seawater* has a ratio of about 2.3. It is clear from the electrical conductivity values and the ionic ratios obtained from the chemical analyses that the *groundwater* in the bore holes are contaminated and are influenced by the sea proximity. Such water can not be used for drinking purpose and up to some extent for irrigation also without treating it with the desalination plants.

The higher and varying concentration of F^- in *groundwater* in the area is due to varying degree of contamination with *tidal* recharge and also due to *ion exchange* phenomenon affecting intrusive waters prior to contamination with *groundwater*. The ill affects of high *fluoride* content in water are manifested in the form of *'Endemic fluorosis'* which is an acute public health problem in India. Medical advice recommends the drinking water should not contain more than 1.5 ppm of *fluoride*. Concentration of *fluoride* below 1.5 *ppm* are helpful in prevention of *tooth decay*, and such level of *fluoride* also assists in the development of perfect bone structure in human and animals. However, doses of *fluoride* above 1.5 ppm increases the severity of tooth *mottling* and induces the prevalence of *osteoporosis* and *collapsed vertebrae*. The disease resulting from excessive consumption of *fluoride* (found to be in the range of 1.6 to 1.9 *mg/l* in the area) is *"fluorosis*" which has no treatment available at present and is considered to be deadly disease. High *fluorine* consumption leads to the *fluorosis* of the bones which is generally found in Asian region but it is more acute in nine states of India including Andhra Pradesh. Hence, possibilities of reducing the high *fluorine* content of *groundwater* by *defluorination process* / *dilution* with the surface water is one very simple technique but addition of *Ca++* ions to solution in contact with *fluorite* when experimented in *distilled water* caused appreciable decrease in *fluoride* concentration which appears to be more suitable solution to high *fluoride* problem in an otherwise water scarce India.

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