ANTHROPOGENIC IMPACT ON HYDROLOGICAL BALANCE AND WATER QUALITY IN SAMBHAR LAKE, RAJASTHAN

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ABSTRACT

Sambhar Lake covers an area of about 90 km^2 is the Largest Saline Playa Lake in India extending in SW-NE direction. The lake represents a closed drainage basin receiving the major sediment and water influx by the monsoonal precipitation through two main streams namely Mandha and Rupangarh. The annual precipitation over this region ranges from 100 mm to 500 mm, while the temperature averages around 23^0 C with a maximum of 45^0 C. (Biswas et al. 1982). The major rock assemblage of Sambhar Lake catchment area mainly comprises of Precambrian quartzite, mica schist and quaternary sand dunes. Sambhar Lake plays an important roll in hydrological biological and climatic process in the desert. Therefore Sambhar Lake was designated as a Ramsar site in 1990. Presently Sambhar Lake faces serious threat for its existence, because manmade small dams restrict water availability in the lake from natural sources. Simultaneously government and private salt production firms are involved in overexploitation of ground water that caused deep water levels. We made an effort to monitor the hydrological balance in Sambhar Lake using 50 year rainfall and lake level data; simultaneously we collected shallow and deep subsurface water samples from Sambhar lake area to assess water quality. We find that the annual rain fall and lake level is not matching with each other after 1984, simultaneously the production of brine was increased. The geochemical analysis of water samples show 3 ppm to 6 ppm fluoride concentration in the shallow lake subsurface water, while Sambhar Lake city drinking water samples contain fluoride concentration between 1 to 7 ppm. Similarly Nawa and Guddah Salt drinking water contain fluoride concentration around 5 ppm. Two very deep (225 and 245 feet) subsurface water from Nawa salt production area has unusual fluoride concentration 13 and 14 ppm. Hence we concluded that the mixing of deep ground water in fresh drinking water around Sambhar Lake is responsible for the fluoride contamination. Also the overexploitation of water and construction of small dames are responsible for disturbance in the water balance in the region.

INTRODUCTION

The Sambhar is the most important, extensive and the largest playa lake of the Thar Desert, Rajasthan, located about 85 km northwestern of Jaipur, India (**Fig 1**). The playa is bordered by long ridges of sand brought in by wind through the gaps in the Aravalli Range, which intervenes between the playa and western desert. The playa is spread over transitional climate zone of semi-aridity in the west semi humid in the east. The annual precipitation over this region ranges from 100 mm to 500 mm, while the temperature averages around 23^0 C with a maximum of 45^0 C. (Biswas et al. 1982). The maximum length of the Sambhar Lake basin is 34 km while the width ranges from 3.2 km to 11.2 with its main axis along NE-SW direction.

It is a shallow basin reaching only about 3 m at its deepest part with an average depth of 1m and is completely dry in summer months. The Sambhar Lake is fed by two major rivers namely Mandha and Rupangarh flowing from the Aravalli ranges and then disappears in aeolian sand covers. The major rock assemblage of Sambhar Lake catchment mainly comprises of quartzite and mica schists with occasional amphibolite dykes. The southern part of catchment rock (Rupangarh catchment) show relatively higher abundance of mafic constituents such as biotite, amphibole than the northern part (Mandha catchment). Sinha et al., (2003).

As semiarid climatic condition are prevailed in the Sambhar Lake and surrounding in Thar Desert of India that is fed by small and large streams, (Aggarwal, 1995), which are highly seasonal and flow only for a few days during the SW monsoon between July and September (Yadav, 1996). Hence the physical weathering is restricted to a few days of the monsoon season. The lake undergoes complete desiccation in summer months forming an efflorescent crust, which is preserved as a thin layer of sediment (Sinha and Raymahashay, 2003).

In present study we tried to make an effort to asses the anthropogenic impact on Sambhar lake hydro geological system using resistivity survey, water quality analysis and past rainfall and lake level data.

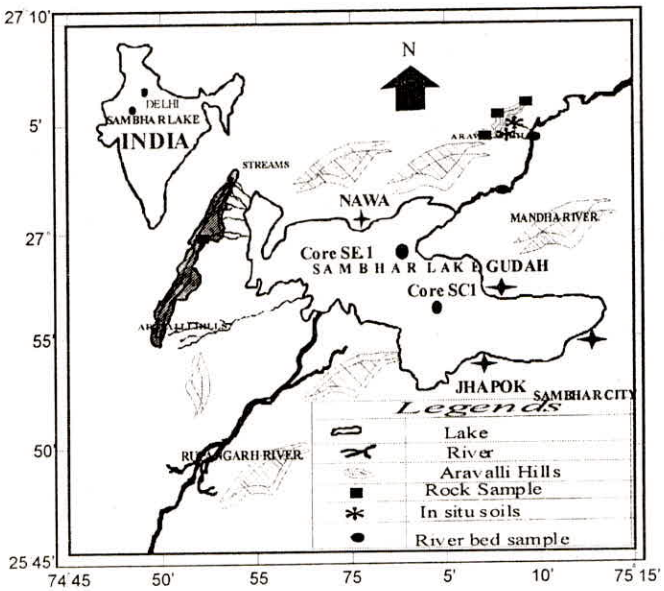

Fig1. Map of Sambhar lake basin with watershed and geomorphic features.

SAMPLING AND METHODOLOGY

The water samples were collected in January 2004 and December 2004 in acid washed plastic bottles. pH,EC and bicarbonate were measured in field using portable pH.EC meter. The samples filtered by .45 micron cellulose nitrate filter papers in lab. Fluoride measurement of

collected samples was done using Oriaon model 710 ion selective meters. The resistivity survey in the Sambhar lake conducted by Sambhar salt limited to discover brine bearing strata using digital deep resistivity meter in 1986 and another in 2002. The water level data also collected by authors in 2003, water analysis conducted in geochemical lab IIT, Roorkee.

RESULTS AND DISCUSSIONS

Relation between past rainfall and lake levels

The water balance of the Sambhar is controlled by many factors. 45 year rainfall and lake levels data **Fig 2** suggest that the lake level and follows intensity of rainfall till 1984. After 1984 the lake level and rainfall does not have any relation. The salt production in the Sambhar lake increased since 1982 when a number of privet firms started salt production by ground water exploration. At the same time by 1984 government started water harvesting schemes through small check dames and anicuts. The initial bad level of lake measured by Sambhar salt limited in 45 year ago was 1180 feet from mean sea level. The annual rain fall data recorded by Sambhar salt limited since the existence of the company. The water level in 1959 to 1972 is indicating increase in the monsoonal rain fall in the region, because lake level also follows this trend. Hence the anthropogenic impact during this time was negligible. The chief region for this was production of salt by lake surface brine that could affect the hydrological water balance of the region. During 1972 to 1984 the lake received maximum water input and kept lake level highest also, still the influence of the anthropogenic impact on the Sambhar lake watershed less. During 1984 to 2004 the lake received average rainfall but the lake level remains very low. The low lake level during this period clearly suggests that the anthropogenic activity in the lake disturbed the water balance of the lake. **Fig 3** indicates that the high rain fall events in the Sambhar lake occurred in 1892, 93, and 1997 that suggest that the monsoonal precipitation is dominantly responsible for ground water recharge in the region.

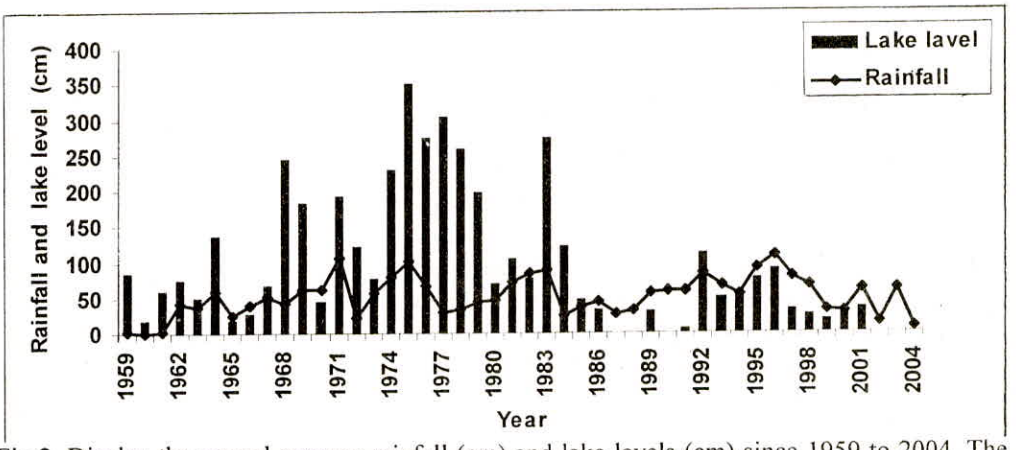

Fig 2. Display the annual average rainfall (cm) and lake levels (cm) since 1959 to 2004. The 1959 to 1972 show low rain fall and low lake level, while 1972 to 1984 show high intensity of rainfall and high lake levels. After 1984 to 2004 the rainfall remains high but lake level does not follow the same due to anthropogenic growth in the anthropogenic activity in the Sambhar lake watershed (salt production by ground water evaporation).

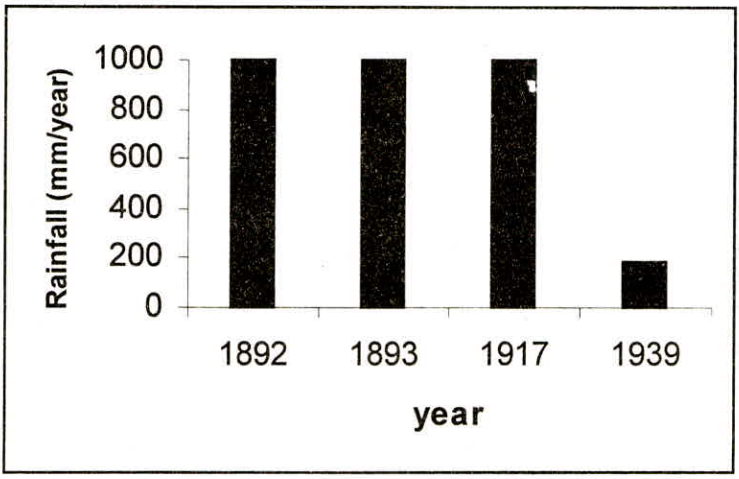

Fig3. Display the high intensity rain fall in 1892 and 1917(after Sinha et al 2004).

Deep digital resistivity survey

The main difference between the different type of inland lakes or playas is the elevation of ground water in relation to elevation b of the surface of parlays (Rosen, 1994). Hence the Sambhar lake can classified as an discharge Palays Lake in which level of capillary fringe is coincident with the playa floor (Yechieli et al., 2002). The deep resistivity survey has been conducted in Sambhar lake by Sambhar salt limited in 1986 for investigation of brine potential area in the Sambhar lake basin, **Fig 4** shown the map of 1 km^2 area where deep digital resistivity survey was conducted. **Fig 5** shown the an resistivity survey profile of the Sambhar lake, in this profile the water level 35 of the lake is 2 meter below surface, while the Sambhar lake classified as an discharge lake playa lake. The fall in water level in the Sambhar lake in 1986 in indicates the consumption of the water for salt production. Also the figure show the different lithology and associate brine potential strata. According to on another resistivity survey conducted in 2002 by the Sambhar salt limited **Fig 6** the water table in the lake fall very drastically 6 meters and water bearing formations empty. The **Fig 6** clearly indicates that overexploitation of water for salt production in the Nawa region of the Sambhar lake is responsible for the hydrological imbalance. According to private source, about 1500 tubewells are working day and night in the 30 km^2 area near Nawa region and producing about 1.8 million ton salts per year. To produce this much of salt they have to evaporate average 85% of water content. Hence we can assume that how much water is need to produce this much amount of salt. In the **Fig 6** the tubewells are constructed in the water bearing strata.

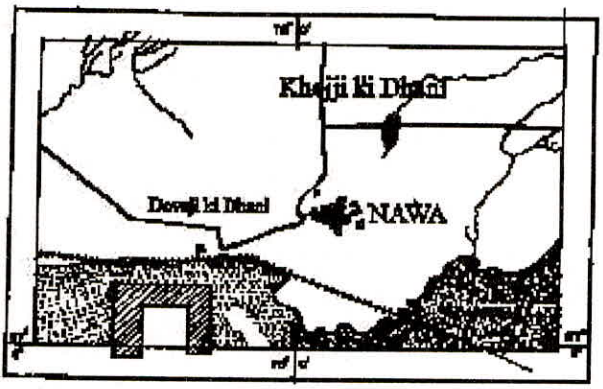

Fig 4. Map of a part of Sambhar lake basin that used for deep digital resistivity survey in 1986 and 2

According to one another resistivity survey profile **Fig7** the brine bearing strata and the other liologic formations displayed. In the Sambhar lake silt, clay, soil gravel and kanker are dominant lithologies. These all formations make a thick sedimentary pile over the one of one of oldest formation BGC (Banded Gneissic Complex). Maximum ground water in the Sambhar lake region found in the lake based sedimentary formations, but the resistivity survey significantly show the water availability in these old rocks. This Water can be classified as old fossil water as it has trapped in deformed space and remain untouched since years. These water reservoirs are highly enriched in dissolved solutes. Present day the Salt production firms penetrated the Basement rocks and explicating the old water for salt production.

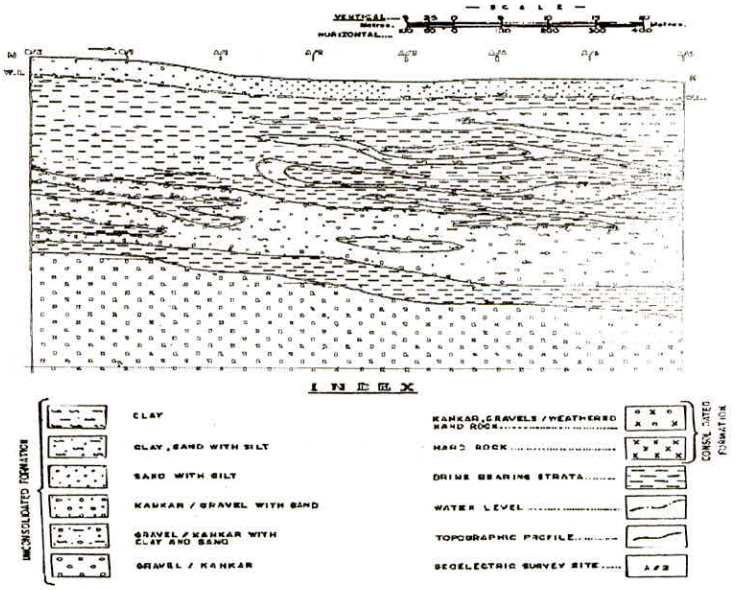

Fig 5. Deep digital resistivity survey profile from western part of the Sambhar lake basin. The survey showed different lithologic units and basement rock (BGC) with there subsurface water bearing capacity.

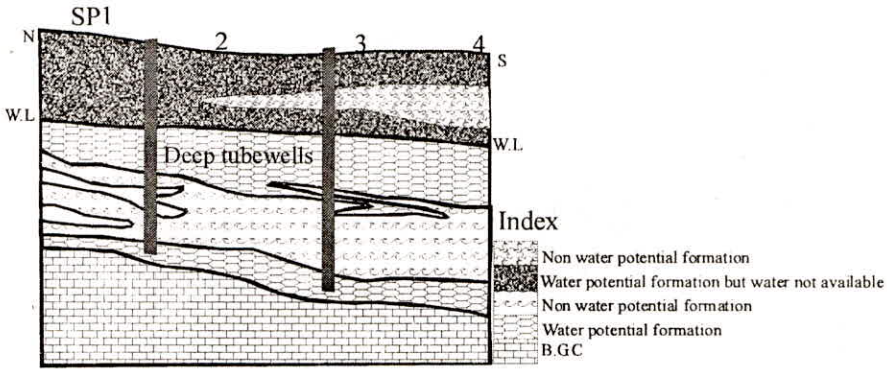

Fig. 6: Resistivity survey profile indicates the water table in 2002 form Sambhar Lake. Water table falls drastically since 1986. Deep tube wells are indicating the level of water exploitation in the western part of Sambhar lake.

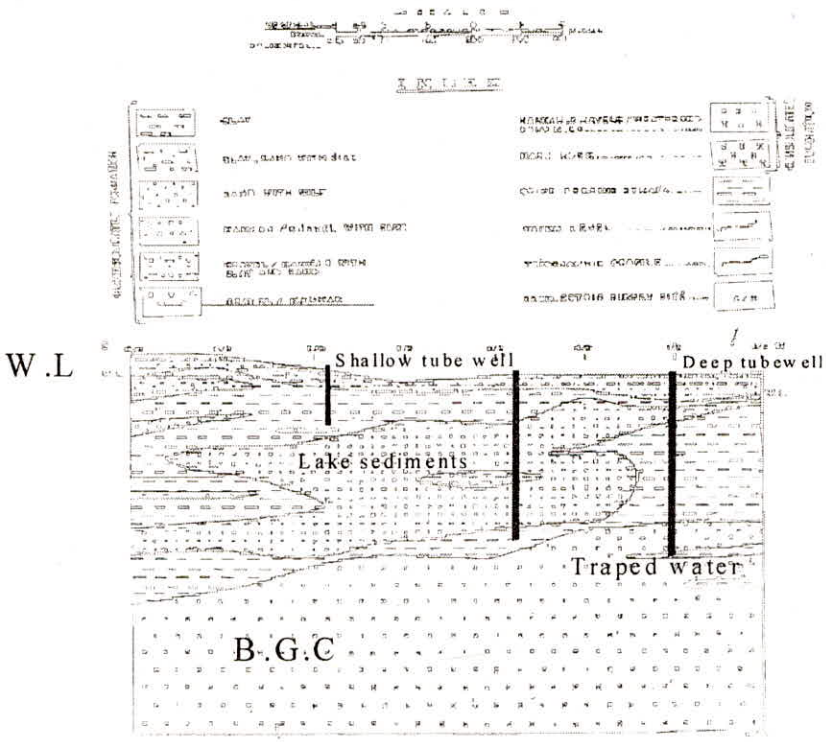

Fig.7: Deep digital resistivity profile from western part of sambhar lake Rajasthan indicated the availability of subsurface water. One significant water reservoir in BGC (hard rock) occurred and using for salt production, this may termed as trapped old water reservoir highly enriched by dissolve solutes.

Distribution of fluoride in the Sambhar watershed

The fluoride concentrations in the wells and hand pumps of Sambhar lake region villages were found to be much higher than the permissible limits of 1.5 p.p.m. (Kumaran et al., 1971). Within distance of the lake, **Table 1** summarized that Sambhar lake city have fluoride concentration .15 to 7.4 ppm in drinking water samples. The Guddah salt drinking water samples have quite high concentration 2.9 to 5.85 ppm; the lake surface water samples significantly show very high fluoride concentration between 2.03 to5.85 ppm. Highest concentration of the fluoride concentration recorded in the deep lake ground water samples 13 to 14 ppm, Nawa city water pump samples also having high value of the fluoride concentration. The concentration of the fluoride samples shows some trends such as it is increases with distance of main lake basin and also shows higher value towards western direction. High fluoride concentration in the drinking water samples is dangerous for the human health.

Table 1. Fluoride concentration in and around Sambhar lake, the concentration of fluoride shown with sample location in ppm.

Sample ID	Location Name	Fluoride conc.(ppm)
S-1	Sambhar city	3.1
S-2	do	1.57
S-3	do	0.15
S-4	do	1.4
S-5	do	0.88
S-6	do	7.4
S-7	Dhaninagorian	6.8
S-8	khandel	3.7
S-9	Lake subsurface	2.95
S-10	Guddah	5.79
S-11	Lake water	5.85
S-12	Lake water	2.03
SS-1	Sambhar city	0.647
SS-2	Nawa	6.8
SS-3	Sambhar city	2.04
SS-4	Khandal	0.843
SS-5	Deep lake subsurface	14
SS-6	do	13
SS-7	Guddah	6.91

Reason of fluoride contamination in the Sambhar lake watershed

Geological sources deep wells, mineral springs and hot water geysers which may be used for tapping geothermal energy may release large amounts of fluorides into the atmosphere. The weathering of fluoride-bearing rocks, particularly fluuorapatites, also releases fluoride into the eco-system Sinha et al., (1997). The high concentration of the fluoride in the Sambhar lake

region is not forever, the contribution of the natural processes can not underestimate in the Sambhar lake region of course but the resent anthropogenic impact may responsible. (1) The over exploitation of the deep ground water can cause high fluoride concentration because deep ground waters are trapped in the BGC that has fluoride bearing minerals. The ground waters that are interact with these rocks, have high value of fluoride. The deep ground water does mixed with shallow low concentration ground waters, resulted the shallow ground waters get contaminate. (2). Decrease in water table can also be cause higher concentration of the fluoride because within exploitation of shallow ground water the concentration of the ground water increases. (3) Disturbance in the natural water moment also contaminates the water by the fluoride.

CONCLUSIONS

1. Past rainfall and lake levels clearly indicates the anthropogenic activity on the Sambhar lake watershed.
2. The digital deep resistivity survey in 1986 and 2003 indicates that the water level in the Sambhar lake decreasing gradually.
3. The anthropogenic overexploitations of the shallow and deep ground water cause the hydrological imbalance in Lake Watershed area.
4. The higher concentration of fluoride in mainly manifested due to contamination of shallow fresh water by deep ground water and hydrological imbalance.

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