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RISING NITRATE & FLUORIDE LEVELS IN GROUND WATER – A CHALLENGE AHEAD FOR SUSTAINABLE HEALTH & SOCIO-ECONOMIC DEVELOPMENT OF RAJASTHAN

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ABSTRACT

In present context ground water is only source of dependence and sustenance of life. Advancement of human civilization has put serious questions to the safe use of ground water for drinking. Apart from its depletion due to excessive use, the quality has degraded due to transport of various organic and inorganic pollutants to ground water. The largest state of India, i.e. Rajasthan is facing both the problems of quantity and quality of potable ground water. Water and health of living organisms are directly related. The major hydrochemical parameters for ascertaining the quality of water for potable purposes are – Total dissolved solids, Nitrate & Fluoride. Alarming nitrate concentrations are reported from several area sin Tamil Nadu, Orisa, Karnataka, Maharashtra, Bihar, Gujarat, Madhya Pradesh & Rajasthan. High solubility of nitrate in water and its low retention by soil particles make it a major component of ground water in areas of high nitrate formation. Nitrate enters the human body through the use of ground water for drinking and causes a number of health disorders, viz. methemoglobinemia, gastric cancer goiter, birth malformations and hypertension etc., when present in high concentration in drinking water. With the increasing use of nitrogenous fertilizers by Indian farmers in general and Rajasthan in particular, nitrate toxicity has been observed in ground water of major part of Rajasthan. Likewise, fluoride is also another hydrotoxicant, whose alarming concentration has been observed in nearly 20 states of India and Rajasthan is amongst severely affected ones. In Rajasthan, due to very high concentration of fluoride in ground water cases of dental, skeletal and non-skeletal malformations are quite prevent. In fact the increased concentration of hydrotoxicants have created socio-economic problem and adversely affected the livelihood of inhabitants. Therefore, for sustainable health and development, immense and immediate efforts are required to combat the problem. In the present communication the extent of problem, distribution of various hydrochemical parameters, their health effects, and remedial measures will be discussed comprehensively.

Key words : Aquifer, nitrate toxicity, methemoglobin, Fluorosis, Socio-economy

INTRODUCTION

Nitrate is a compound of nitrogen and oxygen, being normal part of human diet, found in many foodstuff, particularly in leafy vegetables, fish & meat. Three quarters of the world population live in developing countries and a majority (60%) are engaged in farming. Farmers in developing countries possess nearly 54% of the arable land available in world and produce as much cereals as in developing countries[1]. Cropping systems based on nutrient supply through chemical fertilizers, when superimposed on the natural

ecosystem, can create a modified ecosystem that may not be in harmony with other environmental entities. Due to excessive use of fertilizers in developing countries during the last 2-3 decades, ground water at major places is already polluted with nitrate that has leached particularly from intensively or over irrigated soils[2].

Rajasthan is considered as a major nitrate and fluoride affected state in the country. The most oxidizing state of versatile element nitrogen is nitrate therefore, nitrate represents a stabilized product. It is very difficult to remove nitrates from water because it is chemically non-reactive in dilute aqueous solutions. Nitrate levels in ground waters of Rajasthan have caused a great concern particularly in arid and semi-arid climates. Nearly whole Rajasthan is suffering from problem of high nitrate with its concentration ranging from 10 to 2870 ml/l. Severally affected areas are viz. Nagaur, Barmer, Churu, Bikaner, Hanumangarh, Ganganagar, Alwar and Bharatpur districts. The high concentration of nitrate in ground water is directly related to health of human beings, livestocks and aquatic animals. It has also an adverse effect on environment.

Fluoride is an another hazard of ground water which has affected more than 2.5 crores people of India. Rajasthan, being largest State of India with 5.2 percent of country's human population has been recognized as a State endemic for Fluorosis. The State ranks second amongst the most endemic areas of country and shares approximately 10 percent of the world fluorosis problem. In Rajasthan, due to excessive fluoride concentration in ground water cases of both dental and skeletal fluorosis are quite prevalent. Most severely affected areas are of Nagaur, Barmer, Dungapur, Tonk, Dausa, Sirohi, Udaipur, Sawai Madhopur and Karauli district. It seriously affects bones and problems like joint pain, muscular pains and non-skeletal manifestations. It not only affects the body of a person but also renders them socially, economically and culturally crippled.

In the present communication on attempt has been made by authors to carry out hydrochemical studies of ground waters of Rajasthan in a comprehensive manner with special reference to rise in nitrate and fluoride levels their sources, effects and suggestive mitigating measures. The results obtained are presented this communication.

SOURCES OF NITRATE IN GROUND WATER

1. There are numerous sources in environment that contribute to the total nitrate content of natural waters, e.g. atmosphere, geological features, anthropogenic sources, atmospheric nitrogen fixation and soil nitrogen. However, detailed hydrogeological studies conducted have indicated a heterogeneous pattern of nitrate distribution. It has been observed that in sandy soil with low water holding capacity and high permeability, movement of pollutants like chloride and nitrate is much quicker than in clayey soil. This is probably the main cause for high nitrate in areas with sandy soil.

2. **Sewage and Industrial Effluent** : Direct discharge of septic tanks, sewage and industrial effluent causes pollution of surface water, ground water and wells through percolation.

3. **Nitrogenous Fertilizer** : Unprecedented progress in agricultural production in the several parts of India in the last 2-3 decades has become possible due to several fold increase in fertilizer application[3] to crops besides adoption of high yielding varieties, agricultural mechanization and plant protection techniques and very high level of ground water development. Fertilizers, however, have never been applied in a balanced manner; there has been always a bias towards application of large doses of nitrogen vis-à-vis phosphorus and potassium. Harvesting high yields by applying only nitrogen is a t best a short lived phenomenon and N-driven systems are not sustainable. Unfortunately, fertilizer N use efficiency by crops is very low and decreases further at high N application levels.

As a consequence of applying heavy dose of N fertilizers in several regions of India with irrigated coarse textured soils, nitrate content in ground waters is continuously increasing[4] and has exceeded the permissible level for drinking water. Therefore, brining down the amount of nitrate N in the root zone during times of potential high leaching hazards is extremely important. The use of nitrogenous fertilizer in past decade (2001-2010) in Rajasthan is depicted in Table-1.

Table-1 :Use of Nitrogenous fertilizer in Rajasthan

Year	N-Fertilizer (MT)
2000-2001	568103
2001-2002	675431
2002-2003	761232
2003-2004	1050982
2004-2005	1070499
2005-2006	1159222
2006-2007	1241167
2007-2008	1381662
2008-2009	1414318
2009-2010	1431122

A perusal of Table-1 reveals that during past one decade the use of nitrogenous fertilizer has increased drastically which can very well be correlated with increasing level of nitrate in ground water.

4. **Sources of Nitrate in Food**

a. **Vegetables** – The common vegetables are lettuce, spinach, beetroot, celery, eggplant, beets, banana, strawberry, tomato.

b. **Preservative of foods** – Nitrate and nitrite are widely used in preservation of some food materials, especially meat and fish. Nitrate is used in meat curing, which gives pink colour and flavour to cured meat. Such preservatives are also used for preserving cheese.

5. **Cooking** : Cooking in aluminum utensils increases the reduction of nitrates to nitrite (WHO, 1985) which results in an increase in intake.

SOURCES OF FLUORIDE

It is obvious that surface water is not contaminated with high fluoride whereas, ground water is contaminated with high fluoride because the usual source of fluoride is fluoride rich rocks. In Rajasthan the fluoride rich rocks are viz. Fluorospar (CaF_2, Sedimentary rocks, limestones & sandstones), Cryolite (Ca_3 $AIFPO_6$, Igneous, Granite) and Fluorapatite (Ca_3 $(PO)_2$ $Ca(FCI)_2$). When water percolates through rocks it leaches out the fluoride from these rocks. Main sources of fluoride for human are water, Food, Air, Medicament and cosmetics etc. It is estimated that nearly 60% of the total intake of fluoride is through drinking water. The fluoride of food items depends upon the fluoride contents of soil and water used for irrigation, therefore, the fluoride content of the food items may vary from place to place.

Prolonged use of certain drugs has been associated with the chronic adverse effects of fluoride e.g. sodium fluoride for treatment of osteoporosis, Ni-flumic acid for treatment of rheumatoid arthritis, use of mouthringe (proflo) and mouth wash to render the tooth stronger.

The use of fluorides in industry leads to occupational exposure e.g. inorganic fluoride compounds are used in the production of aluminium. Fluorides are also released during the manufacture and use of phosphate fertilizers.

Highly significant associations were found between estimated fluoride ingestion from toothpaste and fluorosis.

MATERIAL AND METHODS

For carrying out systematic study of ground water quality in Rajasthan 12,000 water samples were collected per annum during hydrogeological survey of all the 32 districts of Rajasthan comprising different hydrogeological formations. These water samples were analysed for physico-chemical constituents using standard methods[5] and precise instruments.

RESULTS AND DISCUSSION

The minimum and maximum values of nitrate and fluoride in ground water samples are shown in Table-2.

Table-2 : Minimum and maximum values of nitrate & fluoride in ground water of Rajasthan.

S. No.	Name of district	Nitrate (mg/l)		Fluoride (mg/l)	
		Minimum	Maximum	Minimum	Maximum
1	Ajmer	4	670	0.40	12.6
2	Alwar	2	405	0.10	7.52
3	Banswara	2	210	0.10	4.20
4	Barmer	5	1180	0.40	15.40
5	Bharatpur	4	320	0.10	17.0
6	Bhilwara	5	880	0.10	13.4
7	Bikaner	7	2840	0.02	15.90
8	Bundi	4	280	0.20	3.60
9	Chittorgarh	7	620	0.20	5.60
10	Churu	3	1351	0.04	6.60
11	Dausa	2	480	0.15	11.0
12	Dholpur	4	405	0.10	6.80
13	Dungarpur	4	350	0.10	8.60
14	Ganganagar	4	1237	0.12	8.20
15	Hanumangarh	4	2870	0.08	7.24
16	Jaipur	1	1215	Tr.	16.50
17	Jaisalmer	4	780	0.20	10.8
18	Jalore	6	1120	0.20	20.0
19	Jhalawar	5	585	0.20	2.56
20	Jhunjhunu	2	740	0.10	5.40
21	Jodhpur	7	1457	0.20	12.60
22	Karauli	11	370	0.20	2.60
23	Kota	6	410	0.20	3.60
24	Nagaur	7	981	0.20	18.80
25	Pali	7	1680	0.20	18.0
26	Rajsamand	5	1080	0.20	15.4
27	Sawai Madhopur	2	960	Tr.	6.40
28	Salumber	2	510	Tr.	7.20
29	Sikar	1	738	0.2	9.16
30	Sirohi	1	511	0.2	7.04
31	Tonk	12	990	Tr.	10.60
32	Udaipur.	4	650	Tr.	8.60

Various zones of Nitrate and Fluoride depending upon the distribution of nitrate and fluoride the whole state can be classified into five quality zones. Each district was divided into a number of blocks and these blocks were further categorized into following four zones.

1.	Zone I	-	Safe zone
2.	Zone II	-	Mild problematic
3.	Zone III	-	Moderately Problematic
4.	Zone IV	-	Highly problematic

The percentage of zonewise distribution of nitrate and fluoride are depicted in Table-3. It is quite obvious from Table-3 that severity of nitrate toxicities are observed in Jodhpur, Nagaur, Barmer, Tonk, Jhunjhunu, Sikar, Sawai Madhopur, Alwar, Bharatpur, Jalore, Karauli, Churu, Bikaner, hanumangarh, Ganganagar, Bhilwara district. Whereas fluoride toxicity is more prevalent in Nagaur, Barmer, Sirohi, Sawai Madhopur, Pali, Tonk, Bhilwara, Dungarpur, Churu districts. Highest nitrate value of 2870 mg/l was observed in Hanumangarh district and highest fluoride value of 18.80 was observed in Nagaur district respectively.

Table-3 : Percentage of different zones of nitrate & fluoride

District	Nitrate zone				Fluoride zone			
	0-20	21-45	46-100	Above 100	0-1.0	1.01-1.50	1.51-3.0	Above 3.0
	Zone-I	Zone-II	Zone III	Zone IV	Zone-I	Zone-II	Zone III	Zone IV
Ajmer	19.13	25.17	30.20	25.49	50.18	30.24	9.58	10.00
Alwar	26.78	31.15	24.04	18.03	87.43	7.10	3.28	2.22
Banswara	36.78	41.15	20.04	3.00	88.43	6.10	4.48	1.00
Barmer	22.14	31.07	10.21	36.58	30.89	20.19	30.91	17.3
Bharatpur	21.26	35.27	23.67	19.81	71.98	14.01	9.66	4.34
Bhilwara	40.21	13.98	30.79	15.02	60.34	10.84	20.1	9.65
Bikaner	14.86	27.93	22.53	34.68	65.77	17.12	13.96	3.10
Bundi	40.17	23.17	30.81	5.85	85.43	8.10	6.10	0.40
Chittorgarh	38.21	15.98	20.33	25.43	60.14	12.84	20.33	6.6
Churu	6.12	12.24	15.65	65.99	55.78	17.01	20.41	6.80
Dausa	42.11	34.74	15.79	7.37	58.00	24.21	10.42	7.37
Dholpur	29.57	26.96	29.57	13.90	65.23	20.87	9.56	4.34
Dungarpur	30.57	27.96	31.57	10.90	70.34	10.34	15.31	5.00
Ganganagar	29.13	15.53	25.24	30.10	61.16	11.65	18.45	8.74
Hanumangarh	12.99	16.88	41.56	28.57	61.04	5.19	19.48	14.29
Jaipur	33.47	30.05	22.88	14.02	66.53	10.59	13.98	9.89
Jaisalmer	12.14	41.37	31.77	14.71	35.35	40.17	20.71	4.74

District	Nitrate zone				Fluoride zone			
	0-20	21-45	46-100	Above 100	0-1.0	1.01-1.50	1.51-3.0	Above 3.0
	Zone-I	Zone-II	Zone III	Zone IV	Zone-I	Zone-II	Zone III	Zone IV
Jalore	7.66	26.58	21.62	44.14	26.58	6.76	25.22	41.44
Jhalawar	26.76	35.35	25.25	12.63	49.49	26.26	24.24	-
Jhunjhunu	21.58	28.42	26.84	23.16	44.74	22.63	25.26	7.37
Jodhpur	3.58	25.34	33.61	37.47	38.84	14.05	33.33	13.78
Karauli	4.85	20.39	56.31	18.45	81.55	8.74	7.77	1.94
Kota	15.85	35.41	32.33	16.40	80.60	10.91	8.00	0.40
Nagaur	5.35	26.75	32.92	34.98	40.33	21.40	19.75	18.52
Pali	13.08	32.69	29.23	25.00	20.77	6.54	30.38	63.81
Rajsamand	11.08	30.69	31.23	27.00	18.77	8.54	32.38	61.08
Salumber	15.08	30.69	31.23	21.00	20.77	10.54	66.38	30.08
S. Madhopur	13.89	22.22	44.44	19.44	66.67	5.41	19.44	8.48
Sikar	24.69	24.07	34.57	16.67	53.70	16.67	22.84	6.79
Sirohi	12.42	32.77	36.16	18.64	31.64	15.25	37.85	15.25
Tonk	20.13	26.17	30.20	23.49	39.60	8.72	23.49	28.18
Udaipur.	25.13	31.00	33.37	20.49	45.60	29.49	15.72	21.18

TOXIC EFFECTS OF HIGH NITRATE

It has been observed that ingested nitrate is reduced to nitrite by nitrate reducing microflora present in saline at the base of tongue. The factors which influence the oral microflora and hence the reduction of nitrate are nutritional status, infection, environmental temperature and age[6].

Nitrate reacts with haemoglobin leading to formation of methaemoglobin in which iron is in ferric (III) state, greatly lessening the capacity of the blood to carry oxygen and causing chemical suffocation very young children are susceptible because foetal haemoglobin has a great affinity for nitrite than normal haemoglobin. This disease is called nethaemoglobinaemia.

High risk of Cancer : Nitrate itself is not carcinogenic, but instead acts as a “procarcinogen”, i.e. it reacts with other chemicals (amines and amides) to form carcinogenic compounds (N-nitroso) compounds. The physiological studies provide strong support indicating the association between nitrate contamination of drinking water and increased cancer rates. N-nitroso compounds has been associated with 15 different types of cancers, including tumors in the bladder, stomach, brain, esophagus, bone and skin, kidney, liver, lung, oral and nasal cavities, pancreas, peripheral nervous system, thyroid, trachea, acute myeleocytic leukemia and T and B cell lymphoma[7]. More than one hundred of these N-nitroso compounds have been tested for carcinogenicity in animals and 75-80% of them have been found to be carcinogens.

Abortions : Spontaneous abortions in animals due to ingestion of high nitrate contaminated water have also been observed. It has also been observed that in many herbeivorous animals excess of nitrate ingestion through fodder and drinking water causes severe ailments. Therefore, it has been suggested that women who are pregnant or trying to become pregnant should not consume water containing high levels of nitrate.

Other diseases : Cases of incidence of type-I diabetes, thyroid and cardio-vascular system disorder and embryo toxicity have also been observed due to drinking of high nitrate water[8].

TOXIC EFFECTS OF FLUORIDE

High fluoride (> 1.5 mg/l) may cause various types of fluorosis manifestations including motling of teeth called dental fluorsis and skeletal fluorosis. The manifestations of non-skeletal fluorosis are often overlooked due to the misception that fluoride affects only bones and teeth. Fluorides in excess can cause several ailments, viz. neurological, muscular, allergic, gastrointestinal complaints and flatulence in expectant and lactating mothers, hardworking young adults, urinary tract infections and headaches. Population affected by fluorosis are over 2.5 crores and it has become a serious socio-economic problem.

MITIGATION OF PROBLEM FOR SUSTAINABLE FUTURE

Indeed high nitrate and high fluoride contents in drinking water has created not only dealt problem but it has become a serious livelihood problem for the consumers which inturn has adversely affected the socio-economical status of the state. Therefore, for combating this problem, following mitigating measures are suggested.

1. Inculcation of awareness amongst rural and urban population regarding harmful effects of quality parameters.
2. Popularising simple and handy defluoridation techniques at domestic and community level in an endemic areas.
3. Avoid the habit of open air defecation.
4. Avoid the sewage disposal directly to ground water.
5. Installation of reverse osmosis, Ion-exchange and electrodialysis plants in affected areas.
6. Avoid indiscriminate use of nitrogenous fertilizers and promotion of use of bio-fertilizers and bio-pesticides.
7. Construction of wells/tubewells in low nitrate & fluoride areas.
8. Prohibition on use of fluoride rich edibles, cosmetics and luxury items.
9. Supplementation of ascerbic acid, methionine, and methylene blue has been found to be effective in overcoming the problem of nitrate toxicity.
10. Promotion of breast feeding at least upto the age of 6 months of the infant.
11. Promulgation of Aquifer Protection Policy (APP) to avoid over-exploitation of ground water to alleviate ingress of fluoride.
12. Mandatory provision of construction of Rain water harvesting structures at domestic, official and community levels.

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