

Groundwater Quality Evaluation in Relation to Health Hazards : A Case Study

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Abstract : It is well known that Mansa and Bathinda districts of Punjab, shows very high incidence of cancer. In order to evaluate the quality of groundwater in relation to health hazards, the eighty representative groundwater samples from study area are collected and analysed for major cations and anions. Groundwater is unfit for drinking purpose as higher than permissible values of EC (93% samples), NO₃ (43% samples), SO₄ (46% samples), Na (72% samples), Uranium (93% samples), F (93% samples). These higher concentrations may attributed due to subsurface geology, higher use of NPK fertilizers, pesticides etc. There appears to be correlation between these high values and uranium and radon activity in ground water. (Kochhar and Dadwal, 2004). The interaction of groundwater with the soils formed from the weathering of Malani granites and basement rocks (Delhi quartzite) encountered in the region might have been the cause of uranium and radon values recorded in groundwater. Further, the evaporites and foetid limestone/dolomite might have been the cause of salinity, and high SO₄, Mg, Na and F content in groundwater. (Kochhar et. al. 2007, Kochhar and Dadwal, 2011).

INTRODUCTION

Ground and surface water are among the most important media that act as bridge between rock and soil geochemistry and human physiology. In addition to anthropogenic sources, the natural baseline geochemistry of ground waters and surface waters resulting from interaction with rocks and soils create widespread environmental and there by health problems in parts of the world on a regional scale (Edmunds and Smedley 1996). One of the main causes for the enhancement of such health problems is the specific geochemical conditions which have lead to excessive concentrations of toxic or undesirable elements such as Uranium, Radon, lead, Nickel and Chromium etc. (Dissanayake, 1991; Edmunds and Smedley, op cit: Apambire et al., 1997; Rao et. al. 2004). The present investigation is aimed at detailed hydrogeochemical investigations to understand the quality of ground water in the area in relation to the health hazards. The main geoenvironmental problems of the study area include high soil and ground water salinity contamination of ground water with F, NO₃, SO₄ etc. (Singh, 2001; CGWB 2000 a, CGWB 2000 b).

STUDY AREA

The study area (Fig 1) sited between latitudes 29° 32' and 30° 12' north and 74° 57' and 75° 57' east longitudes, forms parts of blocks of Bhikhi, Sardoolgarh, Budhlada, Mansa and Jhunir of Mansa district and Talwandi Sabo block of Bathinda district of Punjab state (Statistical Abstract of Punjab, 2010). The study area is bounded by Haryana state in the south, district Bathinda (Punjab) in the northeast and west and district Sangrur (Punjab) in the east and north in all the aquifers.

Geology

The Siwalik Hills form a narrow tract on the northeastern side of the state. The rest of state is a vast alluvial plain which is composed of Quaternary alluvium deposits – Older alluvium (Bhanger), Newer Alluvium (Khadar) and the Aeolian Deposits. The Quaternary sequence is underlain by Tertiary deposits which in turn are underlain by a thick sequence of Vindhyan evaporites and halites, with cumulative thickness

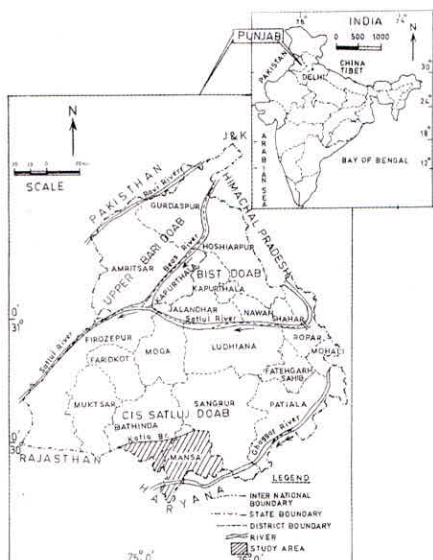


Fig. 1. Map showing location of study area and various doabs.

of 130.77 in (Dey et. al., 1991). The scattered outcrops of the Aravalli-Delhi Supergroup occur at Tosham (Haryana) just south of the study area i.e. the Bathinda and Mansa districts. According to Krishna Brahamam and Kochhar (1989), the Aravalli-Delhi strike turns northwest from Tosham. Further the gravity data show that Tosham lies on triple gravity junction and a considerable portion of gravity low is caused by arcuate granitic intrusion (240 km long and 6 km wide). There is a trifurcation of gravity trend from Tosham marked by the extension of Aravalli basement towards Himalaya in the form of Delhi-Hardwar ridge, Delhi - Moradabad ridge in the eastward direction and Delhi-Lahore ridge in NW direction (Mishra and Laxman, 1997). The Delhi-Lahore ridge is a broad regional basement high separating Rajasthan platform (of the Indus basin) from the Punjab platform of Himalayan basin. On the Rajasthan side, to the SW of basement high, sedimentary formations from Paleozoic and Mesozoic to Tertiary ages occur. On the other hand, under the Punjab platform, on the NE side of the basement

ridge, no rocks older than Siwaliks have been found over the basement. East of Sirsa, rocks of Delhi Supergroup and Malani suite of rocks is encountered just below the Quaternary overburden (Dey, 1991). Under a thick blanket of Quaternary sediments (305- 350 m) of SW Punjab (Faridkot and Ferozepur districts) and SW Haryana (Sirsa district), a thick sequence of halite and associated evaporites (polyhalite, anhydrite, limestone and dolomite) homotaxial to Hanseran Group overlie Jodhpur group (Dey, 1991). Five cycles of evaporites with a cumulative thickness 130.77 m occur under Punjab plains, and three cycles of evaporites (cumulative thickness 50 m) occur under Haryana plains. The dolomite/dolomitic limestone are of foetid character which probably represents basin limestone subjected to bacterial reduction in the subphotic zone or was probably deposited in restricted/ euxenic environment.

HYDROGEOCHEMISTRY

Sampling and analytical methods: Representative groundwater samples were collected Hand Pumps (HP) and Tube Wells (TW) .Locations of the sampling sites are illustrated in Figure 2. The parameters like temperature, pH and EC were measured at the sampling point using a portable Soil and Water Analysis Kit (Electronic India,

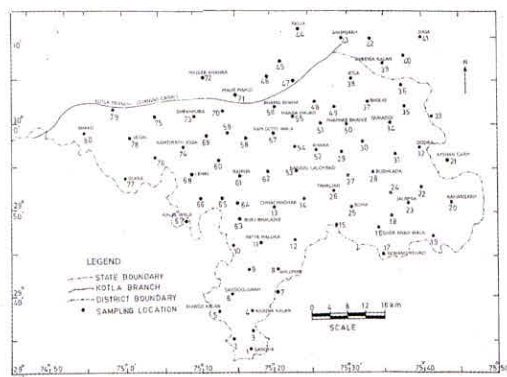


Fig. 2. Location of water sampling points

Model 161E) and remaining parameters have been estimated in laboratory.

RESULTS AND DISCUSSIONS

The groundwater quality of a particular region is important to determine its suitability for various purposes like drinking and irrigation etc. The main geoenvironmental problems of the study area include high soil and ground water salinity, contamination of ground water with F, NO₃, SO₄ etc. (Singh,2001; CGWB 2000, CGWB,2000). Table 1 shows the levels of various parameters analysed, including permissible limits for drinking water.

pH: The pH value is the measure of relative acidity and alkalinity. The pH of water mainly depends upon (i) temperature and nature of water (ii) relative concentration of acids and of bases and (iii) degree of dissociation of acids or association of bases. Voznay (1981) pleaded that alkalinity of natural waters mainly depends upon the presence of carbonates and bicarbonates in waters. The desirable limit of pH recommended by BIS (IS 10500: 2004) in drinking water supply varies from 6.5 - 8.5. The pH in groundwater of study area varies from 7 (Sample No. 70) to 9.1 (Sample No. 70). 49% samples show pH value more than of 8.5, which is permissible limit prescribed by Bureau of Indian Standards (IS: 10500: 2004).

Table 1. Distribution of groundwater samples showing various parameters against Permissible Limits (PL) and Desirable Limits (DL) (IS : 10500 : 2004) for drinking purposes of study area.

parameters	PL	DL	Analytical results		% of samples above PL
			minimum	maximum	
pH	6.5 -8.5	6.5- 8.5	7(s.p. 70)	9.1 (s.p.17)	49%
EC	1000	500	410 (s.p.20)	12280 (s.p.63)	93%
Ca ²⁺	200	75	1 (s.p. 17)	147 (s.p. 78)	Nil
Mg ²⁺	100	30	4 (s.p. 17)	259 (s.p. 72)	28%
Na ⁺	200*	-	19 (s.p. 20)	1533 (s.p. 4)	72%
K ⁺	200*	-	3 (s.p. 17)	700 (s.p. 13)	14%
Cl ⁻	1000	250	BD (s.p. 24)	3315 (s.p. 63)	6%
SO ₄ ²⁻	400	200	31 (s.p. 20)	1815 (s.p. 31)	46%
NO ₃	no relaxation	45	2 (s.p. 29)	1250 (s.p. 4)	43%
TDS	2000	500	109 (s.p.20)	5109.22(s.p. 63)	39%
F	1.5	1	BD(s.p.5)	15.1 (s.p.57)	54%

* WHO standards,

s.p. means sample number BD = BELOW DETERMINATION
All values are in mg/l except EC (µS/ cm)

Total dissolved solids (TDS): The total dissolved solid is a measure of total concentration of all constituents dissolved in water and has bearing on its colour, odour and taste. Water with high TDS values has laxative effect on human system and does not quench thirst. For drinking water, Bureau of Indian Standards (IS: 10500: 2004) and ICMR (1975) have prescribed the highest desirable limit of 500 mg/l but in the absence of alternate sources of supply, this limit may be extended upto 2000 mg/l. In the domestic water supplies, WHO (2004) has prescribed maximum permissible limit of 1500mg/l. Several processes may cause an increase in the dissolved- solids content of groundwater. These include movement of water through rocks containing soluble mineral matter, concentration by evaporation, and contamination due to influx of sea water and industrial and municipal waste water disposal. The total dissolved solids concentration in groundwater of study area varies from 108.76 mg/l (Sample No.20) to 5109.22 mg/l (Sample No.63). 39% samples show more than 2000mg/l of total dissolved solids, which is permissible limit prescribed by Bureau of Indian Standards (IS: 10500: 2004).

Calcium :Calcium is an essential element required for good health and its daily requirement varies from 0.7 gm to 2.0 gm. Insufficient amount of calcium may induce adverse physiological effects. On the contrary excess amount of calcium in body results in formation of urinary bladder stone and irritation in urinary passage. WHO (2004), ICMR (1975) and Bureau of Indian Standards (IS: 10500: 2004) have recommended the highest desirable limit of 75 mg/l and maximum permissible limit of 200mg/l calcium in drinking water. The calcium concentration in groundwater of study area varies from 1mg/l (Sample No.17) to 147(Sample No.78). No sample has value exceeding the maximum permissible limit of 200mg/l. At places where water samples have low values of calcium and comparatively high salinity (Singh, 2001) precipitation of calcium carbonate or ion exchange

reaction with sodium have taken place. Because of its abundance in most rock types, soils and its solubility, calcium is present almost everywhere in groundwater. Calcium carbonate continues to dissolve as long as there is carbonic acid in the water, but precipitation of calcium carbonate may occur once the acid is used up. The causes for the precipitation of calcium carbonate from groundwater are evaporation, increase in temperature, decrease in pressure, and pH beyond 8.2, the presence of sulphuric acid in ground water, due to oxidation and hydrolysis of sulphide minerals, may also cause dissolution of calcium carbonate. Gypsum and anhydrite, occurring as evaporites in sediments of arid regions, are important sources of calcium in ground water (Dey, 1991). Under ground water conditions, where partial pressure of carbon dioxide is low and water is saturated with respect to calcium carbonate, calcium has a tendency to get precipitated as calcium carbonate in the form of concretions.

Magnesium: It is an essential to plant and animal nutrition. In some aspects of water chemistry, calcium and magnesium may be considered as having similar effects, as in their contributions to the property of hardness. Magnesium is an essential element for good health with average daily adult requirement of 200 mg to 300 mg. Its deficiency may lead to many structural and functional changes as it is considered as an activator of enzyme systems. The chronic mal-absorption syndrome, severe diarrhea, chronic renal failure and protein-calorie malnutrition are some of the diseases related with Mg- deficiency. High magnesium content acts as laxative and its salts are cathartics, diuretic etc. WHO and ICMR linked magnesium limits with sulphate levels in water while BIS (IS 10500: 2004) prescribed a maximum permissible limit of 100 mg/l. The magnesium concentration in groundwater of study area varies from 4mg/l (Sample No. 17) to 259mg/l (Sample 32). 28% samples show more than 100mg/l of magnesium, which is permissible limit

prescribed by BIS (IS 10500: 2004). The geochemical behavior of magnesium is substantially different from that of calcium. Magnesium ions are smaller than calcium and sodium ions and have stronger charge density and greater attraction for water molecules.

Sodium: Sodium is required for normal functioning of human body but higher concentration is harmful for people suffering from cardiac, renal and circulatory diseases. WHO (2004), ICMR (1975) and BIS (IS 10500: 2004) have not recommended any limit for sodium in drinking water; hence it is difficult to evaluate the domestic water supply critically. Hart (1974) proposed that waters with less than 270 mg/l sodium are good for drinking purposes and this limit is taken into consideration here. In Mansa district (Singh, 2001; CGWB, 2000) and Bathinda district (CGWB, 2000) the concentration of sodium ion is very high. The sodium concentration in groundwater of study area varies from 19mg/l (Sample N. 20) to 1533mg/l (Sample No. 4). 72% samples show more than 270mg/l of sodium, which is permissible limit given by Hart (1974). Sodium ions are not precipitated in ground water like calcium ions. However, sodium ions undergo ion- exchange reactions as a result of which clay minerals exchange sodium ions with alkaline earth ions and vice-versa. The highest value can be linked with salinity of groundwater. The abnormally high concentration may be attributed to the exchange of calcium in waters for sodium of base exchange minerals in the rock material and to presence of thick evaporate sequence in those localities where clay minerals act as natural water softness (Back, 1960). Sodium concentration is also an important criteria used for classifying irrigation water.

Potassium: The concentration of potassium in natural waters is less than that of sodium. It can be due to greater resistance offered by potassium bearing minerals to weathering (Golditch, 1938) and also because it enters into clay minerals during weathering. Sodium tends to remain in

solution rather persistently once it has been liberated from silicate mineral structures. Potassium is liberated with greater difficulty from silicate minerals and exhibits a strong tendency to be reincorporated into solid weathering products, especially certain clay minerals. Potassium is an essential nutrient and its salts have therapeutic value in the treatment of many diseases but excessive concentrations are cathartic. WHO (2004), ICMR (1975) and BIS (IS 10500: 2004) have not prescribed any limit for potassium level in drinking water. Very high potassium concentrations may be harmful to human nervous and digestive systems (Anderson et. al., 2002). As no standard have been prescribed by any agency, it is difficult to assess the suitability of water for drinking purposes with respect to potassium. The potassium concentration in groundwater of study area varies from 3mg/l (Sample No. 17) to 700 mg/l (Sample No. 13) but in most of the analyzed samples potassium concentration is below 100 mg/l. Potassium is an essential plant nutrient and is required by all plants continuously. The requirement is greatest during the fast growth stages. Potassium is the only solute element built up in guard cells and thus plays a vital role in the opening and closing of the stomata, thereby controlling rate of transpiration. Potash deficient plants respire excessively and wilt during drought and hot periods.

Bicarbonate and Carbonate: High contents of carbonate and bicarbonate ions in irrigation water result in precipitation of calcium and magnesium carbonate by evapo-transpiration. The pH of the water indicates the form in which carbon dioxide is present. Presence of carbonic acid is indicated when pH is less than 4.5, of bicarbonate in pH between 4.5 and 8.2, and of carbonate in pH over 8.2. Carbonate dissolution from rocks and precipitation from water is a two-way process dependant on the partial pressure of carbon dioxide. Under usual conditions the bicarbonate concentration in ground water ranges from 100 to 800 ppm. W.H.O. (2004), ICMR (1975) and BIS (IS

10500: 2004) have not prescribed any desirable limits for bicarbonate in drinking waters. The US Public Health Standards (USPHS, 1962) prescribed desirable limit for carbonate as 610 mg/l. The bicarbonate concentration in groundwater of study area varies from 0mg/l (Sample No. 21) to 1258 mg/l (Sample No. 75).

Chloride: It is presumable that the bulk of the chloride in groundwater is either atmospheric sources or sea- water contamination. Sea water may also get trapped as connate water during the deposition of sediments. Desiccation of inland basins with initial fresh waters may give rise to highly saline waters. Solutions of halite and other evaporite deposits in sedimentary rocks also give rise to high chloride contents in groundwater. Chloride salts, being highly soluble and free from chemical reactions with minerals of reservoir rocks, remain stable once they enter into solution. Most chloride in ground water is present as sodium chloride. In study area, chloride ions increase with increase of salinity and this is the major anion contributing towards salinity (Kumar et. al. 2011). The source of the abnormally very high chloride in the groundwater of the study area is gypsum, halite and potash of evaporite sequence in these quaternary sediments as well as underlying basement rocks is the cause of high chloride values (Dey, 1991, Thussu, 2004). These salts which occur as part of evaporite sequence have come up through capillary action from depth. Under normal circumstances, chloride concentration in human body remains constant with average approximate value of 100 mg/ l. Along with other additional functions chloride plays an important part in osmotic shifting of extra-cellular fluids. Although, tolerance limit of chloride depends upon the climate, BIS (IS 10500: 2004) suggested the highest desirable limit of 250 mg /l and maximum permissible limit of 1000mg/l in drinking water. The chloride concentration in groundwater of study area varies from 0 mg/l (Sample No. 24) to 2315 mg/l (Sample No. 63). Only 6% show more than 1000 mg/l of chloride, which is permissible limit, prescribed by BIS (IS 10500: 2004).

Sulphates: The main source of sulphate in the groundwater of study area is presence of gypsum as a part of evaporites sequence present in quaternary sediments as well as in underlying basement rocks. (Dey, 1991, Thussu, 2004, Kochhar and Dadwal, 2004. Kochhar et. al. 2007). There are several layers of lamsoid kankar of variable thickness in between the fluvial layers. These salts are part of evaporite sequence and have come up through capillary action from depth. Long continuous evaporation of the brines results in precipitation of less soluble salts followed by highly soluble potassium and magnesium sulphate and highly soluble chlorides. In general the average daily intake of of sulphate from drinking water, air and food is approximately 500 mg, food being the major source. However, in the areas with the drinking water supplies containing high levels of sulphate, drinking water may constitute principal source of intake (WHO, 2004). Sulphate ions in association with higher concentrations of magnesium and sodium ions act as a laxative and may cause gastric disorders. It has been proposed that presence of moderately high concentrations of sulphate ions (200– 300) mg/l in drinking waters may result in a cathartic effect to human beings (McNeely et. al., 1979, Morris and Levy, 1983). WHO (2004), ICMR (1975) have proposed the highest desirable limit of 200 mg/l and maximum permissible limit of 400 mg/l for sulphate in drinking water. BIS (IS 10500: 2004) have fixed the highest desirable limit of 150 mg/l and maximum permissible limit at 400 mg/l of sulphate provided magnesium content does not exceed 30 mg/l in drinking water. Sulphate concentration in groundwater quality of study area varies from 31 mg/l (Sample No. 31) to 1815 mg/l (Sample No. 26). 46% samples show more than 400 mg/l of sulphate, which is permissible limit prescribed by BIS (IS 10500: 2004). Distribution of sulphates in the ground water of study area is shown in map 3.

Nitrate: People may be exposed to nitrate with both food and water. Exposure to fairly large amount of nitrate for short term is not usually

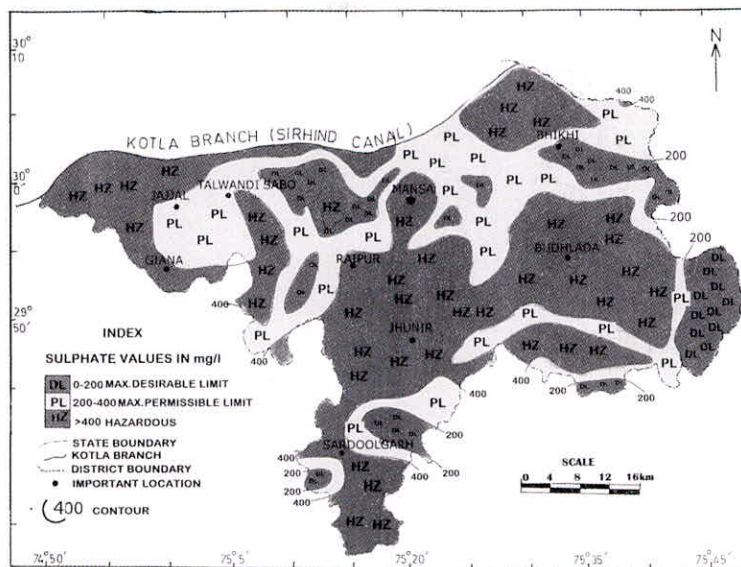


Fig. 3. Map showing distribution of sulphate in study area

associated with short term adverse effects. Infants younger than six months of age however, are sensitive to nitrate poisoning, which may cause *methaemoglobinaemia* or *blue baby syndrome* and results in serious illness or death. Nitrate is not normally dangerous for the health unless reduced to nitrite. The stomach acid of infants is not as strong as in older children and adults. This causes an increase in bacteria that can readily convert nitrate into nitrite (NO_2) (Bruning et al., 1993). Shuval and Gniener (1975) advocated that nitrate toxicity may cause cancer. WHO (2004) and BIS (IS 10500:2004) fixed maximum limit for nitrate in drinking water at 45mg/l while the prescribed limit of ICMR (1975) is at 50 mg/l. In areas where no alternate sources exist, this limit can be extended upto 100 mg/l. The nitrate concentration in groundwater of study area varies from 2 mg/l (Sample No. 29) to 1250 mg/l (Sample No. 4). 43% samples show more than 100 mg/l of nitrate, which is permissible limit prescribed by BIS ((IS 10500:2004)). In the study area there seems to be no genetic relationship of nitrate with groundwater. High concentration of attributed to use of

fertilizers, anthropogenic activities and atmospheric nitrogen fixation etc. Regarding *geologic sources*, in the Indo-genetic plain no palaya or cave deposits containing nitrogen species are known to occur. The soil by itself is not a good source of N-species to ground water. Distribution of Nitrates in the ground water of study area is shown in map 4.

Fluoride: There has been a long debate about implications of fluoride contaminated water/ groundwater. Fluoride is a double edged sword. Ingestion of large amount of fluoride is as harmful as ingestion of its inadequate amount. It helps in normal mineralization of bones and formation of dental enamel. About 96% of the fluoride in the body is found in the bones and the teeth. The distribution of fluoride in study area is shown in map 5. With the concentration of fluoride of certain enzymatic processes are either inhibited or stimulated and inter reaction with other organic/ inorganic component occur. According to guidelines prescribed by world health organization WHO (2004) fluoride is an effective agent for

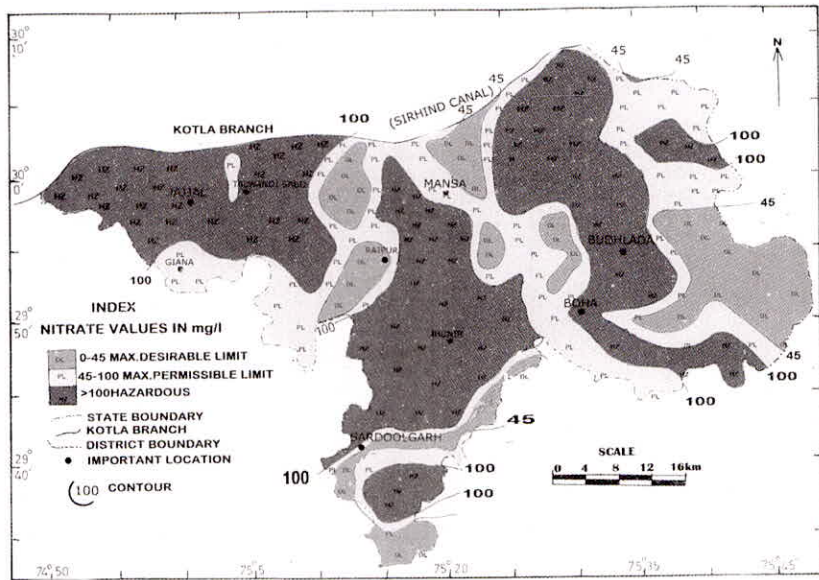


Fig. 4. Map showing distribution of nitrates in study area

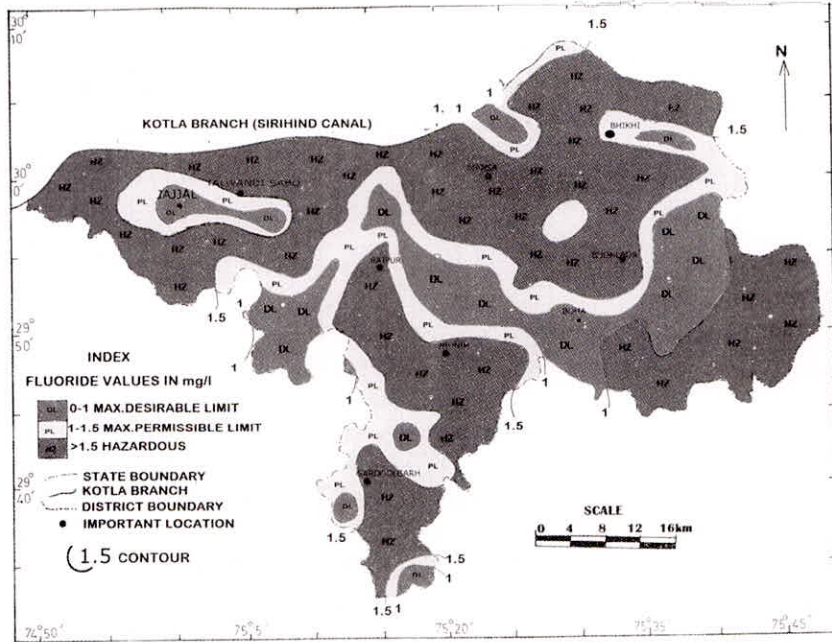


Fig. 5. Map showing distribution of fluoride in study area

preventing dental caries if taken in optimal amounts but a single optimal level for daily intake cannot be agreed because the nutritional status of the individual, varies greatly, influences the rate at which fluoride is absorbed by the body, e.g., A diet poor in calcium, increases the body's retention of fluoride. Evidence so far accumulated shows that the upward adjustment of fluoride in water supplies to 1.0 mg/l results in a great reduction in the incidence of dental caries. In general fluoride should not exceed 1.5mg/l. At fluoride concentrations between 1.0 & 1.5 mg/l and severe mottling has been noted at concentrations greater than 3.0 mg/l. Very high concentrations cause other physiological change. For a community, optimum fluoride level depends upon the prevailing climatic conditions because the amount of water (consequently the amount of fluoride) ingested is controlled by the air temperature. The permissible limit of fluoride content in drinking waters is 1.5mg/l. fluoride concentration in groundwater of study area vary from below determination level (Sample No. 5) to 15.1 mg/l (Sample No. 57). 54% samples show more than 1.5mg/l of fluoride, which is permissible limit prescribed by BIS (IS 10500:2004). It is evident that increase in calcium ions results in decrease of fluoride ions to maintain equilibrium. As a result of this, fluoride ions generally have positive correlation with bicarbonate ions and negative correlation with calcium ions after equilibrium is attained. In other words, there could be a positive correlation between Ca^{2+} and F^- ions till the saturation stage is reached but beyond this there will be a negative correlation between the two ions; Fluoride concentration in the aquifer waters of the study area is correlated with the concentration of certain dissolved constituents and other Parameters.

Trace elements: Chemical quality and radon activity of groundwater along with F , NO_3 , SO_4 , U , Pb , Cr , Ni was monitored to assess the role of these elements in causing cancer in Jajjal and Giana villages of Bathinda district Punjab (Kochhar and Dadwal, 2004; Kochhar et al., 2007, Kochhar and Dadwal, 2011). The work shows

that contents of U , Pb , Cr , Ni , F , SO_4 and NO_3 are above the permissible limit.

Lead: It is cumulative poison and accumulates in the skeletal structures of man and animals. It has adverse effect on the central nervous system, kidney and may cause cancer and brain damage. The BIS (IS 10500:2004) had prescribed maximum permissible limit 0.05 mg/l for drinking water. Concentration of Pb greater than this has been observed in six samples (33%) out of 18 samples.

Uranium: Uranium concentration in samples studied varies from 0.007 to 0.316 ppm. All the samples have higher uranium than the permissible limit. The general public ingestion of soluble uranium compounds should not exceed the tolerable intake of 0.5 mg/kg of body weight per day. Whereas in case of insoluble compounds a tolerable intake is 5mg/kg of body weight per day. The high values of uranium have been attributed to Kota nuclear power plant; Khushab heavy water plant in Pakistan; and uranium-carrying winds from Afghanistan, without any scientific basis. Though Malwa is a part of Punjab, geologically it is more akin to Haryana and Rajasthan. Uranium is a naturally occurring radioactive element which is present in traces in rocks, minerals plants and natural waters. It occurs along with thorium and potassium in granitic rocks.

It has the property to get dissolved in water in hexavalent form at a normal pH of 5 to 7). It gets precipitated in the reducing environment in tetravalent form and form complexes such as hydroxides, Phosphates, sulfate, Carbonate etc. Uranium compounds are soluble in water, very mobile and travel kilometers. When the bed rocks containing uranium, thorium and other elements are exposed to sun, rain, and wind they get weathered and breakdown to form soil. Uranium gets dispersed in matrix, soil and finally gets re-deposited in areas/ pockets where reducing conditions are present. Hence we get higher concentration of uranium in pockets. The Tusham

granites are high heat producing granites, that is, they are enriched in uranium, thorium and calcium. The uranium concentration in the granites is 8-11.5 parts per million (ppm) as compared to the normal values of 4.5 in granites in general. The average crustal value is 2.7 ppm. The main source of uranium appears to be Tusham granites of Malani suite (Kochhar et. al. 2007, 2011). There is indiscriminate quarrying of granites being done at Khanak and adjoining areas of Tusham causing a lot of dust due to crushers. Besides, there is a thick evaporites (salt) sequence with a total thickness of 130 m occurring at a depth of 305-350 in. below alluvium in Faridkot and Firozpur districts. Evaporites also occur near Sirsa in Haryana. The evaporites have limestone, shale, gypsum, halite, sulfates etc. Limestone has 2.2 ppm and shale has 3.2 ppm of uranium. Another natural source of uranium is the thick sediments under alluvium brought down by Satluj and Beas rivers. In addition, Satluj flows through Siwalik rocks which have dispersed uranium in them. Apart from these another source could be fly ash coming out of the Bathinda thermal plant. Uranium gets concentrated after burning of coal. One kg of coal ash produced 2000 Bq of radioactivity whereas one kg of granite produced 1000 Bq of radioactivity in the environment. Phosphate fertilizers in use also contribute to uranium in soil and water. A collaborative study' undertaken by the present authors and other scientists reveals that most water samples tested for uranium had higher concentration than the WHO-prescribed tolerable limit of 0.015mg/l, With some showing a value 20 times higher, that is 0.316 mg/l. Interestingly, in spite of high concentration of uranium in water, the radon activity is within permissible limits (less than 400Bq/l), because the gas escapes into the atmosphere (Bajwa et. al., 2003). In general, the high concentration of hazardous elements in the region can be attributed to the reactions of groundwater with the rocks of buried Aravalli — Delhi ridge and uranium-rich granites of Tusham area along with the evaporites including sulphur-

rich limestone and dolomite which could contribute sulfate, carbonate, flouride and salinity to the groundwater. It is unfortunate that we neither have authentic data on human misery nor a systematic scientific study of the cause thereof. There is urgent need for credible research carried out by an interdisciplinary team comprising geologists, medical doctors, nuclear scientists, biologists, anthropologists, agricultural scientists and others.

Chromium: According to BIS ((IS 10500:2004)) the permissible limit of Cr in water is 0.05 mg/l. All 18 samples are under permissible limit. Hexavalent form of Cr⁶ is toxic to men and main adverse effects are on skin, mucos membrane and lungs. Hexavalent form of Cr is more mobile in surface and subsurface environment than the trivalent form. Cr is skin allergen, next to Ni (NRCC, 1976). Trivalent Cr³ has essential biological role. Oxidation of Cr³ does not take place in living matter. Role is played by Cr³ only. High concentration of Cr in water may be due to the thermal plant. In phosphate fertilizer Cr is 30-300 ppm in super phosphate it is 60-250 ppm, in bone meals <20-500 and limestone <1 to 200.

Nickel: BIS or any other agency has not prescribed any limit of Ni in drinking water. In absence of any prescribed standard it is difficult to evaluate the harmful effects in study area. The source of Ni in the area under study may be due to fly ash from the thermal plant, as Ni gets concentrated in it after combustion of coal.

CONCLUSION

Chemical quality and radon activity of groundwater along with F, NO₃, SO₄, U, Pb, Cr, Ni monitored shows the role of these elements in causing cancer and other health hazards in study area. The work shows that contents of U, Pb, Cr, Ni, F, SO₄, NO₃ are above the permissible limits. There appears to be correlation between high values and high uranium and radon activity in groundwater. The interaction of groundwater with

the soils formed from the weathering of Malani Granites and the basement rocks (Delhi quartzite) encountered in study area might have been the cause of high uranium and radon values recorded in the groundwater (Kochhar and Dadwal, 2004; Kochhar et. al., 2007, Kochhar and Dadwal, 2011). Besides this thick sequence of five cycles of evaporites under Punjab plain comprising halite with polyhalite, anhydrite, limestone, dolomite including foetid limestone would certainly contribute to Na, K, Ca, Mg, F and SO₄ in the groundwater (Dey, 1991; Thussu, 2004; Kochhar et. al., 2007). Human activities and urbanization is responsible for increase in EC, pH, and the concentration of bicarbonate, nitrogen and pesticides. The Jajjal and Giana villages of Talwandi Sabo block of Bathinda district record the maximum number of cancer patients in the region. The area falls in cotton belt of Punjab and there is wide spread use of pesticides such as diammonium phosphate and cyhalothrin, and fertilizers such as urea, super phosphate and NPK. The fertilizers also contribute lead, arsenic, and nickel to the water/soil system. People attribute cancer to the groundwater quality. The present work shows that chemical quality i.e. higher values of SO₄, NO₃, and F of water including radon activity coupled with effects of pesticides may be responsible for the cancer incidence and other health hazards in the region.

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