RAINWATER HARVESTING IN FLOURIDE AFFECTED AREA NAWADA, BIHAR

SANJAY KHANNA* & DR. ARVIND KUMAR NAG
Research scholar, Dept. of Environmental Science, M.U Bodh Gaya*

ABSTRACT

KEYWORDS- Groundwater. Fluoride, human health rainwater harvesting.

Under Ground water is the major source for various purposes in most parts of the world. Presence of low or high concentration of certain ions is a major issue as they make the ground water unsuitable for various purposes. Fluoride is one such ion that causes health problem create in human being in more than twenty country in the world. Fluoride concentration of at least 0.6 mg/l is required for human consumption as it will help to have stronger teeth and bones. Consumption of water with fluoride concentration above 1.5 mg/l results in acute to chronic dental fluorosis where the tooth become coloured from yellow to brown. Skeletal fluorosis which causes weakness and bending of the bones also results due to long term consumption of water containing high fluoride. Presence of low or high concentration of fluoride in ground water is because of natural or anthropogenic causes or a combination of both. Natural sources are associated to the geological conditions of an area. Several rocks have fluoride bearing minerals like apatite, fluorite, biotite and hornblende. The weathering of these rocks and infiltration of rainfall through it increases fluoride concentration in ground water. The improper disposal of fly ash on ground surface contributes to fluoride in ground water. Since ingestion of high fluoride has a long term Affect on human health it is essential to monitor its concentration in ground water used for drinking periodically and take steps to bring them within the permissible range of 0.6 to 1.5 mg/l. There are several methods available for the removal of fluoride from ground water. Dilute the groundwater contaminated with fluoride, artificial recharging structures can be built in suitable places which will decrease its concentration. Rainwater harvesting through existing wells also will prove effective to reduce the ground water fluoride concentration. Fluoride contamination being a prominent and widespread problem in several parts of the world and as causes for this are mostly natural and unpreventable, educating the people and de-fluorinating the groundwater before consumption are essential for a healthy world.

INTRODUCTION

It is well known that about 70% of the earth's surface is covered with water. Most of the water is in the oceans (96.5%) in the unusable form while some of them are frozen (1.74%). Lakes, swamp water and rivers hold 0.014% and soil moisture accounts for 0.001%. Water also exists in the form of vapour in the air (0.001%) and as groundwater beneath the sub surface in the aquifers (1.7%) (Gleick, 1996). World's water needs are met from surface and groundwater resources. However, use of groundwater is advantageous as it is comparatively fresh and widely distributed unlike the surface water. Threats to ground water have been increasing everyday due to raise in population and their needs. Thus with increasing demand of groundwater for domestic, industrial and agricultural needs, the pressure on this resource has become enormous. Overexploitation and improper management has also lead to contamination of this resource. The degradation of groundwater may be due to natural or anthropogenic processes. Natural causes are inherent geological conditions while anthropogenic causes include wastewater from sewage treatment plants, discharge from industries, improper solid waste disposal, agrochemicals, runoff from agricultural fields, leakage from underground storage tanks etc. When the chemical composition of groundwater is not within the prescribed standards for drinking or irrigation or industrial water, they become unsuitable. Arsenic, fluoride, nitrate, iron, manganese, boron, most heavy metals and radionuclides are few contaminants that are of great concern if not present within permissible limits.

Rainwater harvesting is a simple low-cost technique that requires minimum specific expertise or knowledge and offers many benefits. For drinking water purposes in rural areas, the most common technique is small-scale rooftop rainwater harvesting: rainwater is collected on the roof and transported with gutters to a storage reservoir, where it provides water at the point of consumption. Rainwater harvesting for agricultural use see also bunds, field trenches, planting pits, micro-basins, retention basins, sand dams, conjunctive use, gully plug, controlled drainage or fog drip. Collected rainwater can supplement other water sources when they become scarce or are of low quality like brackish groundwater or polluted surface water in the rainy season. It also provides a good alternative and replacement in times of drought or when the water table drops and wells go dry. The technology is flexible and adaptable to a very wide variety of conditions. It is used in the richest and the poorest societies, as well as in the wettest and the driest regions on our earth.

LOCATION

Nawada is located between North Latitudes 24031’: 25008’ and East Longitudes 85000’: 86003’ and falls on Survey of India Degree sheet No. 72 H & 72 G . The district is bounded in north by Nalanda and Sheikhpura district, in east by Jamui district, in west by Gaya district, while southern half boundary of district is bounded by Jharkhand state boundary. The district is having a geographical area of 2494 Sq. Km and occupying 1.43% of the total geographical area of the Bihar State. The total population of district is 22.16 Lakhs. Density of population is 726 per Sq. Km. Nawada is its district headquarter. There are 14 development blocks with 1075 villages.

The northern and southern parts of the district constitute two distinct natural regions. The northern part is plain area underlain by alluvial soils covering Nawada, Warsaliganj, Pakhribarwan and parts of Hisua, Narhat, Govindpur, Akbarpur and Kauakol blocks. Consequently, it is densely populated and has a rich historical background. The southern part is hilly and undulating with a gentle ascend towards the south merging into hills and is part of southern fringes of the Chottanagpur Plateau. The entire southern boundary of the district is a conglomeration of ridges and spurs

RAINFALL & CLIMATE

Monsoon sets sometimes in the third week of June and it lasts till the end of September. The average annual rainfall in Nawada district is 1037 mm. The maximum rainfall in the district comes from South West monsoon with a little about 10% spread over the summer and winter. There is a large variation in the rainfall over year to year. Rainfall increases from Southwest to north-east. After analysis of rainfall data it is revealed that there is a wide variation in the average annual rainfall values, least being at Rajauli and maximum at Nawada.

The climate of the district is sub-tropical to sub-humid in nature. The district experiences severe cold during winter whereas on the other hand in summer it is very hot. The summer starts from the mid of March and it continues up to mid of June, after that monsoon starts and it continues up to mid of October. The nights are generally hot from the end of May till the first break of monsoon.

The climate is generally hot and dry, the winter temperature ranges from 16 Degree C to as low as 4 degree C whereas during the summer the mercury shoots to 46 degree C. During rainy season it becomes cooler and temperature drops to 35 degree C to 25 degree C.

QUALITY OF GROUND WATER

Groundwater in the Nawada district is potable and is also used for irrigation purposes. The chemical analysis of these water samples has indicated that the ground water in the area is alkaline in nature.

The pH of the groundwater varies from 6.96 to 8.41. The chloride in ground water in the area varies from 18 ppm to as high as 270 ppm. Iso-Chlor contours are drawn for the entire area and presented. Concentration of chlorides has been noticed more in south-west and western parts of the district, covering Hisua, west of Kauakol and north west of Rajauli blocks. The bi-carbonates in ground water vary from 195 to 488 ppm. Concentration of bi-carbonate in ground water is more in Hisua and Roh blocks and low concentration in Nawada block. The total hardness as $CaCO_3$ varies from 160 to 390 ppm, minimum at Pakribarwan and maximum being at Hisua. Calcium content in water varies from 16 to 104 ppm, the lowest at Rupau in Roh block and the highest in Hisua block, Magnesium content in these shallow water varies from 15 to 71 ppm. The lowest concentration is marked at Akbarpur and the highest at Rupau.

The overall study of the chemical contents in the shallow water of Nawada district has indicated that they are within the permissible limits for drinking and irrigational purposes as per the standard in our country, except some small patches in Rajauli block where fluoride concentration has been found beyond permissible limit.

PROPERTIES OF FLUORIDE

Fluoride belongs to halogen family represented as 'F' with atomic weight 18.998 and atomic number 9. It occurs as a diatomic gas in its elemental form and has a valence number 1. It is the most electronegative and the most reactive when compared to all chemical elements in the periodic table It has an oxidation state of -1 and occurs as both organic and inorganic compounds. It is the 13th most abundant element in the earth's crust. Its natural abundance in the earth's crust is 0.06 to 0.09% and the average crustal abundance is 300 mg/kg. Fluoride does not exhibit any colour, taste or smell when dissolved in water. Hence, it is not easy to determine it through physical examination. Only chemical analysis of the groundwater samples can determine the concentration of this ion. The widely used method for the estimation of fluoride in groundwater sample is colorimetric SPANDNS (sodium 2-(parasulfophenylazo)-l, 8-dihydroxy-3,6-naphthalene disulfonate) method. The other colorimetric method extensively used is the complexone method. Fluoride is one of the important micronutrient in humans which is required for strong teeth and bones. In humans, about 95% of the total body fluoride is found in bones and teeth. WHO (World Health Organisation, 1984) has prescribed the range of fluoride from 0.6 to 1.5 mg/l in drinking water as suitable for human consumption. BIS (Bureau of Indian Standards, 1992) has set a required desirable range of fluoride in drinking water to be between 0.6 and 1.2 mg/l. However, this standard suggests the maximum permissible limit can be extended up to 1.5 mg/l. This required fluoride is supplied to the human body usually through drinking water. Consumption of water with fluoride below or above the prescribed range is detrimental to human health. Hence, it is essential to monitor the ground water quality regularly which is used directly without treatment as drinking water.

HEALTH IMPLICATIONS

Intake of fluoride higher than the optimum level is the main reason for dental and skeletal fluorosis. Depending upon the dosage and the period of exposure fluorosis may be acute to chronic. approx twenty country all over the world are under the dreadful fate of fluorosis, India most populous countries of the world, are the worst affected. In India 60 million people including 6 million children are estimated to have serious health problems due to consumption of fluoride contaminated water. Dental and skeletal fluorosis was predominant in China due to the indoor burning of coal to make brick tea or for heating purposes.

Dental fluorosis

Tooth enamel is principally made up of hydroxyapatite (87%) which is crystalline calcium phosphate. Fluoride which is more stable than hydroxyapatite displaces the hydroxide ions from hydroxyapatite to form fluoroapatite. On prolonged continuation of this process the teeth become hard and brittle. This is called dental fluorosis. Dental fluorosis in the initial stages results in the tooth becoming coloured from yellow to brown to black. Depending upon the severity, it may be only discolouration of the teeth or formation of pits in the teeth. The colouration on the teeth may be in the form of spots or as streaks. Usually these streaks on the teeth are horizontal. Children who are exposed to excess fluoride from childhood show symptoms of fluorosis very often than compared to adults. Hence the fluoride problem in an area may not be decided on the fact that the adults have good teeth with no symptoms of discolouration. Though the main source for dental fluorosis is fluoride ingestion through drinking water, it can also be ingested through toothpastes containing fluoride. It is common for children to swallow toothpastes which has to be avoided to prevent fluorosis. A significant relationship between fluoride intake by water and the prevalence of dental fluorosis has been reported by several research scholars.

Skeletal fluorosis

Exposure to very high fluoride over a prolonged period of time results in acute to chronic skeletal fluorosis. It was stated in 1993 that crippling skeletal fluorosis might occur in people who have ingested 10 to 20 mg of fluoride per day for over 10 to 20 years (National Research Council, 1993). India and China has been largely affected by crippling skeletal fluorosis with 2.7 million people being affected in China. Of the 31 states in India, 17 have been identified as endemic areas with 6 million people affected by skeletal fluorosis. Apart from ingestion of fluoride through drinking water, skeletal fluorosis also may be caused due to indoor use of coal as fuel and by air borne fluoride. Ingestion of fluoride through inhalation in factories and industries is one of the occupational health problems. Skeletal fluorosis does not only affect humans but also animals fed with fluoride rich water and fodder. Fluorosis is also now associated with heavy consumption of tea. Early stages of skeletal fluorosis start with pain in bones and joints, muscle weakness, sporadic pain, stiffness of joints and chronic fatigue. During later stages, calcification of the bones takes place, osteoporosis in long bones, and symptoms of osteosclerosis where the bones become denser and develop abnormal crystalline structure. In the advanced stage the bones and joints become completely weak and moving them is difficult. The vertebrae in the spine fuse together and the patient is left crippled which is the final stage. Skeletal fluorosis is usually not recognized until the disease reaches an advanced stage.

OTHER EFFECT

Other health disorders that occur due to consumption of high fluoride in drinking water to be muscle fibre degeneration, low haemoglobin levels, deformities in RBCs, excessive thirst, headache, skin rashes, nervousness, neurological manifestations, depression, gastrointestinal problems, urinary tract malfunctioning, nausea, abdominal pain, tingling sensation in fingers and toes, reduced immunity, repeated abortions or still births, male sterility, etc. As fluoride is excreted in urine through the kidneys, they affect the effective functioning of the kidneys. They facilitate in the formation of kidney stones. The presence of excessive fluoride in groundwater has its impact not only on humans but also on soil fertility & plant and animal growth.

MITIGATION MEASURES

Everybody needs clean and drinking water. When high fluoride in the drinking water source has been identified, it is better to avoid that source and look for other sources. But this is not a long lasting solution. Methods are available to treat groundwater with high fluoride and bring it to the usable form.

Treatment and method

Method directly diluting the concentration of fluoride (in groundwater) in the aquifer. This can be achieved by artificial recharge. Construction of check dams in nawada and jamui district, India has helped widely to reduce fluoride concentration in groundwater. Rainfall recharge also called as rainwater harvesting can be adopted using percolation tanks and recharge pits which may prove helpful. Recharge of rainwater after filtration through the existing wells can also be planned to improve the groundwater quality.

Other methods are available for defluoridation of water either at household or community level. Adsorption method involves the passage of water through a contact bed where fluoride is adsorbed on the matrix. Activated charcoal and activated alumina are the widely used adsorbents. Brick, bone char, fly ash, serpentine, red mud, waste mud, rice husk, kaolinite, bentonite, charfines, ceramic etc. are some of the other absorbents capable of effectively removing fluoride from groundwater. The effective removal of fluoride by these absorbents depends on the initial concentration of fluoride, pH, contact time, type of absorbent and its size. In ion exchange process, when water passes through a column containing ion exchange resin, the fluoride ions replace calcium ions in the resin. Once the resin is saturated with fluoride ions, it is backwashed with solution containing chloride such as sodium chloride. The chloride ions thus again replaces the fluoride ions in the resin and is ready for reuse. But the backwash is rich in fluoride and hence care should be taken in disposing this solution. Similarly in precipitation methods, the disposal of sludge with concentrated fluoride is a great problem. Precipitation involves addition of chemicals such as calcium which results in the precipitation of fluoride as fluorite. Aluminum salts are also used for this process. Nalgonda technique which is a well known technique uses alum, lime and bleaching powder followed by rapid mixing, flocculation, sedimentation and filtration. This was developed in India by National Environmental Engineering Research Institute to serve at community and household levels. The resulting sludge from this process contains high amount of aluminium and fluoride, the disposal of which is yet another problem. These above mentioned methods are simple and cost effective. Membrane processes is also a technique which includes methods called reverse osmosis and electrodialysis. These are advanced techniques which require high cost input. Both these methods use a semipermeable membrane which removes dissolved solutes from the water when they pass through them. But the negative point is that even the ions which are essential for the human body are also removed. The difference between these techniques is that reverse osmosis works on pressure while electrodialysis works on direct potential. Also reverse osmosis can be practiced at household level whereas electrodialysis involves huge set up and is even more expensive. All these methods have their own advantages and disadvantages. Hence it is necessary to evaluate the prevailing local conditions and cost effectiveness before choosing a particular defluoridation method for an area.

DESIGN PRINCIPLES

Rainwater harvesting system consists of at least the following components

1. Rainfall
2. A catchment area or roof surface to collect rainwater.
3. Delivery systems (gutters) to transport the water from the roof or collection surface to the storage reservoir.

4. Storage reservoirs or tanks to store the water until it is used.

An extraction device depending on the location of the tank - may be a tap, rope and bucket, a pump or a infiltration device in the case the collected water is used for well or groundwater recharge.

Collected water can also be used for replenishing a well or the excess rainwater during the rainy season is used to recharge a dug well, as well as the groundwater. In this case recharging the groundwater even improved the water quality in the dug well.

User Behaviour

Four types of user regimes can be discerned:

1. Occasional - Water is stored for only a few days in a small container. This is suitable when there is a uniform rainfall pattern and very few days without rain and there is a reliable alternative water source nearby.

2. Intermittent - There is one long rainy season when all water demands are met by rainwater, however, during the dry season water is collected from non-rainwater sources. Rainwater Harvesting can then be used to bridge the dry period with the stored water when other sources are dry.

3. Partial - Rainwater is used throughout the year but the 'harvest' is not sufficient for all domestic demands. For instance, rainwater is used for drinking and cooking, while for other domestic uses (e.g. bathing and laundry) water from other sources is used.

4. Full - Only rainwater is used throughout the year for all domestic purposes. In such cases, there is usually no alternative water source other than rainwater, and the available water should be well managed, with enough storage capacity to bridge the dry period.

HEALTH ASPECT

Rainwater itself is of excellent quality, only surpassed by distilled water, it has very little contamination, even in urban or industrial areas, so it is clear, soft and tastes good. Contaminants can however be introduced into the system after the water has fallen onto a surface.

Firstly, there is the issue of bacteriological water quality. Rainwater can become contaminated by pathogenic bacteria (e.g. form animal or human faeces) entering the tank from the catchment area. It is advised that the catchment surface always be kept very clean. Rainwater tanks should be designed to protect the water from contamination by leaves, dust, insects, vermin, and other industrial or agricultural pollutants. Tanks should be sited away from trees, with good fitting lids and kept in good condition. Incoming water should be filtered or screened, or allowed to settle to take out foreign matter. Water, which is relatively clean on entry to the tank, will usually improve in quality if allowed to sit for some time inside the tank. Bacteria entering the tank will die off rapidly if the water is relatively clean. Algae will grow inside a tank if sufficient sunlight is available for photosynthesis. Keeping a tank dark and sited in a shady spot will prevent algae growth and also keep the water cool. As mentioned above, first flush devices help to prevent the dirty 'first flush' water from entering the storage tank. The area surrounding a Rain water Harvesting should be kept in good sanitary condition, fenced off to prevent animals fouling the area or children playing around the tank. Any pools of water gathering around the tank should be drained and filled.

Secondly, there is a need to prevent insect vectors from breeding inside the tank. In areas where malaria is present, providing water tanks without any care for preventing insect breeding can cause more problems than it solves. All tanks should be sealed to prevent insects from entering. Mosquito proof screens should be fitted to all openings.

SUMMARY AND CONCLUSION

It is evident from studies by several researchers worldwide that fluoride in groundwater has been a potential problem to human society. The main source of fluoride in groundwater is the rocks which are rich in fluoride. Fluoride occurs in sellaite, fluorite, cryolite, fluorapatite, apatite, fluormica, biotite, amphibole and several other rocks. The other sources for fluoride are infiltration of agricultural runoff containing chemical fertilisers, improper disposal of liquid waste from industries, alumina smelting, cement production and ceramic and brick firing. Some amount of fluoride is essential for the human body for healthy teeth and bones. But when they are present above the recommended limit of WHO and BIS i.e. 1.5 mg/l it results in mild dental fluorosis to crippling skeletal fluorosis as the quantity and period of exposure increases. Dental fluorosis is more prevalent in children than in adults. Skeletal fluorosis occurs when an individual is exposed to fluoride of above 10 mg almost every day over a period of one or two decades. Apart from fluorosis there are also several health disorders due to ingestion of drinking water with high fluoride.

REFERENCES

1. Chidambaram, S., Ramanathan, A. L., & Vasudevan, S. (2013). Fluoride removal studies in water using natural materials. Water SA.

2. Datta, P. S., Deb, D. L., & Tyagi, S. K. (2016). Stable isotope (180) investigations on the processes controlling fluoride contamination of groundwater. Journal of Contaminant Hydrology.

3. BIS (Bureau of Indian Standards) (1992). Indian Standard Specifications for Drinking Water, IS: 10500.

4. Burt, B. A. (1992). The changing patterns of systemic fluoride intake. Journal of Dental Research.

5. Handa, B. K. (1975). Geochemistry and genesis of fluoride-containing ground waters in India. Groundwater 13(3), 275-281.

6. Haidouti, C. (1991). Fluoride distribution in soils in the vicinity of a point emission source in Greece. Geoderma, 49, 129-138.

7. Jacks, G., Bhattacharya, P., Chaudhary, V., & Singh, K. P. (2005). Controls on the genesis of some high-fluoride groundwaters in India. Applied Geochemistry, 20, 221–228.

8. Joshi, S., Hlaing, T., Whitford, G. M., & Compston, J. E. (2010). Skeletal fluorosis due to excessive tea and toothpaste consumption. Osteoporos Int, doi:10.1007/s00198-010-1428-6.

9. Krauskopf, K. B., & Bird, D. K. (1995). An introduction to geochemistry. McGraw-Hill Int., Singapore, 647

10. Meenakshi, & Maheshwari R. C. (2006). Fluoride in drinking water and its removal. Journal of Hazardous Materials B.

11. National Research Council, (1993). Health effects of ingested fluoride, National Academy Press, Washington DC.