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Impact of increased fluoride concentration in groundwater on human health: A review article

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Abstract

With increasing population and technological advancement, natural resources are in the process of depletion and deterioration. Fluoride is one of the common constituents of groundwater and sources of elevated concentration of fluoride include geological, geochemical and volcanic processes in groundwater, but several human-induced processes and practices also contribute to contaminating groundwater with fluoride. Millions of people are suffering from fluorosis around the world due to the intake of fluoride majorly from the consumption of fluoride-rich groundwater. Consuming water with high fluoride concentrations can cause dental and skeletal fluorosis. High fluoride concentrations are critical especially in developing countries, largely because of lack of awareness and treatment facilities. This review demonstrates the sources of fluoride, its health impacts and the current status of fluoride concentration in the groundwaters of Pakistan.

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Introduction

Water is a vital component for all living organisms and required for the maintenance of life quality. Water scarcity is a global phenomenon and has been affecting adversely to all populations and countries [1]. According to Abbasi et al, [2] 748 million people do not have access to safe water whereas 2.5 billion peoples living without access to enough water supply. Half of the population of the world consume groundwater as drinking water [3]. Due to several natural and anthropogenic reasons, the depletion of groundwater occurring specifically in Asian and North American countries [4]. The deteriorating quantity and quality of groundwater are leading to further burden on existing resource and thus demand is increasing [5]. The contaminants fluoride, nitrate, arsenic, iron, sulfate, manganese, selenium, chloride, radioactive materials, and other heavy metals deteriorate groundwater quality are produced by natural processes and anthropogenic sources such as industrialization, rapid urbanization and use of agriculture practices. Among these pollutants fluoride and arsenic are the most significant regarding human health. Groundwater quality essentially depends on its geological setting and varies place to place. The consumption of polluted water for longer causes diseases to consumers [6].

Groundwater naturally and commonly contains fluoride ion. The lightest and most reactive element fluorine occurs as a negatively charged ion in groundwater either in small concentrations or in high concentration as a major ion [7]. This review article discussed the possible sources of fluoride contamination in groundwater and related global health consequences of fluoride in special context with Pakistan.

Fluoride intake

Humans receive 70 to 90 % of daily intake of fluoride through drinking water whereas, remaining through air, dental products, foods and beverages [8]. The daily exposure is variable depending upon region, diet and water quality. An adult can expose 0.6 -2.0 mg of fluoride per day depending on water quality [9]. The World Health Organization (WHO) permissible level of fluoride in drinking water is 0.5 to 1.5 mg/L, moreover higher or lower fluoride concentration can cause numerous health effects [10].

Impact of Fluoride intake on health

Drinking water is the main source of fluoride for humans, so concentration of fluoride in water chooses its impact, whether it is damaging or constructive to health [11]. The appropriate concentration of fluoride is useful for health in case of teeth and bone development. More than 1.5 mg/L concentration of fluoride in water can be hazardous and cause fluorosis. Fluorosis is being a threat to more than 200 million people globally [12].

Dental fluorosis

The discoloration, blackening or chalky whitening of teeth indicates dental fluorosis during childhood in developing stage of teeth as a consequence of consumption of high fluoride-containing water [13]. If teeth are already grown fully before the exposure to fluoride the above-stated symptoms will not appear, therefore, no symptoms do not guarantee the person have been not consuming excess amount of fluoride [14]. Fluoride being strong electronegative ion has strong affinity towards calcium ion of bones and teeth thus tooth enamel is adversely affected since 87% of tooth enamel is made up of calcium phosphate called hydroxyapatite [15]. Fluoride displaces the hydroxide ions and forms fluorapatite due to this continuous process for longer teeth are subject to become rigid and fragile called dental fluorosis. In dental fluorosis, tooth may develop horizontal streaks of different colors like yellow, brown or to black and in severe stages pits may appear. Studies showed Enamel mottling of teeth occurred at the concentration of 0.5 mg/l of fluoride [16].

Skeletal fluorosis

Permanent and severe joints and bone deformations cause skeletal fluorosis. It occurs due to a chronic overdose of fluoride. It includes intermittent pain of joints and bone, toughness of joints, stomach-ache, headache and muscular weakness. According to a study by Shivarajashankara et al, [17] in the children of Kheru Thanda, dental fluorosis was 89% (41 out of 46) and skeletal fluorosis in children with severe symptoms was (39%) with 5.98 ppm of fluoride level. Skeletal fluorosis was more prominent in Men. Skeletal fluorosis apart from consumption of drinking water occurs due to the consumption of tea or fluoride-rich foods and from inhalation of airborne fluoride, indoor air or occupational exposure in industries and factories.

Osteosclerosis

Skeletal fluorosis leads to osteosclerosis which causes hardening and calcification of bones resulted in impairment of major joints, spine, muscles and nervous system. Both dental and skeletal fluorosis are irreparable and there is no treatment yet, only prevention by consuming fluoride within safe limits could help. Several studies show the excess fluoride not only damages teeth or bones but also alters the structure of DNA, causes cancers and paralysis of volition. The toxicity of fluoride depends on daily intake of it and daily intake largely depends on fluoride content in drinking water and total amount of water utilized per day by consumer. The quantity of water consumption also depends on body size, diet, weather and degree of physical workout for instance in hot season [18].

Other impacts

The other problems may be observed due to excessive fluoride intake including skin rashes, headache, reduced immunity, non-ulcer dyspepsia, vomiting, nausea, stomach bloating and gas formation, diarrhea, constipation, abdominal pain, neurological manifestations, nervousness, depression, intelligence effected in children, frequent urination (polyuria) which leads to polydipsia (excessive thrust), formation of kidney stones, tingling sensation in fingers and toes, diabetes and risks of male infertility [19-22].

Sources and factors affecting fluoride in groundwater

Hydro-geology

Fluorine content in groundwater depends on rock composition and geological setting. Apatite fluorite and micas minerals containing rocks having a higher concentration of fluoride. Fluoride adds up in groundwater from weathering of rocks when water comes to contact with them.

The fluorine concentration of volcanic and igneous rocks is in range of 100 to 1000 mg/ kg due to the presence of minerals containing fluoride, cryolite (Na_3AlF_6), granite and fluorapatite ($Ca_5(PO_4)_3F$). The fluorine concentration of sedimentary rocks because the presence of fluorspar (CaF_2) in limestones and sandstone whereas sellaite (MgF_2) in sedimentary rocks is in range of 200 to 1000 mg/l. The fluorine concentration of metamorphic rocks is 100 to 5000 mg/ kg due to the fluorapatite ($Ca_5(PO_4)_3F$) [23].

Retention time in the aquifer

Fluoride concentration also depends on contact time of groundwater with fluoride bearing minerals. Longer residence time, slow movement of groundwater and deepness of aquifers causes excess accumulation of fluoride in groundwater. On the other hand shallow aquifers have low concentration of fluoride similarly freshly rainwater infiltration also contributes to dilution of fluoride concentration in groundwater [24].

Temperature

Fluoride is usually higher in dry regions because the groundwater movement is slow as well as longer reaction time with minerals of rocks. Evaporation of solution having alkalinity more than the hardness of that solution and calcite concentration in balance also increases the concentration of fluoride and dissolution of such evaporative salt also adds fluoride in groundwater. On the other hand, the areas which receive high precipitation like humid tropics have less fluoride due to dilution factor [7].

Anthropogenic activities

There are many anthropogenic activities that can increase fluoride concentration in groundwater. Overutilization of groundwater can transfer heavily mineralized water from adjacent rocks to the aquifer [25]. Mishandling and improper burial of fly ash cause the leaching which ends up with contamination of groundwater [26]. Improper and overutilization of fertilizer as well as inappropriate practices of irrigation significantly contribute to a higher level of fluoride concentration in groundwater [27].

Global Fluoride Contamination

Fluorosis has been affected more than 311 million people in many countries such as Afghanistan, Algeria, Argentina, Canada, China, Egypt, India, Iraq, Iran, Japan, Jordan, Kenya, Libya, Mexico, Morocco, New Zealand, northern Thailand, Pakistan, Saudi Arabia, Sri Lanka, Sudan, Syria, Tanzania, Thailand, Turkey and USA [28-34]. A large population, around 66 million and 45 million peoples are suffering from fluorosis in India and China, respectively [29, 35]. In India people from 17 out of 32 states are suffering

from endemic fluorosis whereas, in china peoples from 29 provinces are prevailing endemic fluorosis.

Fluoride Contamination in Pakistan

Pakistan has two sources of drinking water, groundwater, and surface water. In Pakistan, there are several regions where peoples totally depend on groundwater, and 70% of drinking water supplies of Pakistan are satisfied by groundwater. Groundwater resources in Pakistan are getting contaminated because excessive usage of fertilizers, pesticides, indiscriminate waste disposal, and industrial effluent, moreover, over-extraction of water leads to saline water intrusion into the freshwater zone [43].

Pakistan experiencing water stress situation and per capita, water availability is declining [44], therefore qualitative and quantities assessments of drinking water are crucial. Many studies have been conducted in Pakistan for fluoride determination, and results showed great variation in different areas of Pakistan (**Table 1**). Generally, groundwater from most of the locations contains acceptable levels of fluoride. Few locations in Sindh and KPK showed a high level of fluoride concentration than acceptable.

Table 1: Fluoride concentration in different areas of Pakistan [36-42]

No	Location	Mean (mg L^{-1})	No	Location	Mean (mg L^{-1})
1	Attock	10.35	31	Loralai	1.08
2	Bahawalnagar	1.67	32	Mianwali	1.4
3	Bahawalpur	0.67	33	Mithi	5.86
4	Chakwal	1.02	34	Mirpur Khas	0.03
5	Chachro, Tharparkar	28.24	35	Mir pur khas	0.74
6	Dera Ghazi Khan	0.96	36	Mastung	1.13
7	Faisalabad	0.89	37	Mithi and Nangarparkar sub-districts of Tharparkar	26.93
8	Faisalabad	0.76	38	Mianwali	1.37
9	Faisalabad	0.2	39	Naranji, KPK	10.67
10	Ganderi Union Council, Nowshera	1.86	40	Naranji village and surrounding areas, Nowshera	8.15
11	Gujranwala	1.58	41	Nagar parkar	3.33
12	Gujranwala	0.29	42	Peshawar	0.15
13	Hasilpur	0.6	43	Peshawar	0.29
14	Hyderabad	0.16	44	Peshawar	0.29
15	Islamabad	0.07	45	Quetta	2.47
16	Jhelum	0.37	46	Quetta	0.91
17	Jehlum	0.1	47	Rahimyar Khan	0.22
18	Kalanwala	1.47	48	Rahimyar khan	2
19	Karachi	0.15	49	Risalpur	1.27
20	Karachi	0.48	50	Sialkot	0.14
21	Karachi	1.16	51	Sialkot	0.68
22	Kasur	1.11	52	Sukkur	0.3
23	Kasur	4.38	53	Sahiwal	0.33
24	Khairpur	0.73	54	Sammundari	0.53
25	Khanpur	0.4	55	Shaikhopura	3.58
26	Khushab	1.09	56	Sargodha	1.62
27	Lahore	2.96	57	Thar desert	4.49
28	Lahore	2.62	58	Umarkot	5.22
29	Lahore	3.07	59	Ziarat	0.39
30	Lahore	0.15			

Defluoridation techniques

Defluoridation of water is useful both by the state-level as well as individual level. Many techniques are available for defluoridation such as adsorption, coagulation, electrocoagulation, ion exchange, and membrane processes [45-47], all of them have their own suitability according to the concentration of fluoride ions in drinking water and expected extent of removal. Similarly chemical methods should also be coupled with these technologies to increase the removal of F^- outcome [48]. As described by Fawell et al, [49], bone charcoal, activated alumina, precipitation, electrodialysis reverse osmosis, and distillation can be used to treat fluorinated water.

Conclusions

With increasing population and technological advancement, natural resources are facing severe shortage and quality degradation. Water shortage and poor quality is among the top most environmental catastrophe which global communities are facing and suffering population. Many people are dependent on the hidden sea of earth i.e. groundwater for drinking i.e. 70% of drinking water supplies are fulfilled by groundwater, in Pakistan which is deteriorated and is known for causing severe damages to consumers. In groundwater contamination, fluorine contamination is of utmost importance. The main sources of fluoride contamination are natural resources including geological, geochemical and volcanic processes in groundwater but several human induced processes and practices are also contributing to contaminate groundwater with fluoride which needs to be identified and studied to overcome the problems associated. Many problems like skeletal, dental fluorosis and other damages are reported in Pakistan. There are many treatment technologies which can be used to treat fluoride in drinking water including chemical and mechanical processes like adsorption, coagulation, electrocoagulation, ion exchange and membrane processes which can be opted to make citizens' life better.

Conflict of interest

The authors declare no conflict of interest.

References

[1] Scheffran J, Battaglini A. Climate and conflicts: the security risks of global warming. Regional Environmental Change. 2011;11:27-39.

[2] Organization WH, UniCeF. Progress on sanitation and drinking water: 2014 update: World Health Organization; 2014.

[3] Nolan BT, Hitt KJ. Vulnerability of shallow groundwater and drinking-water wells to nitrate in the United States. Environmental science & technology. 2006;40:7834-40.

[4] Gleeson T, Wada Y, Bierkens MF, van Beek LP. Water balance of global aquifers revealed by groundwater footprint. Nature. 2012;488:197.

[5] Qureshi AS, McCornick PG, Sarwar A, Sharma BR. Challenges and prospects of sustainable groundwater management in the Indus Basin, Pakistan. Water resources management. 2010;24:1551-69.

[6] Abbasi HN, Lu X, Xu F, Xie J. Wastewater treatment strategies in china: An overview. Sci Lett. 2016;4:15-25.

[7] Edmunds WM, Smedley PL. Fluoride in natural waters. Essentials of medical geology: Springer; 2013. p. 311-36.

[8] Health UDo, Fluoridation HSFPoCW. US Public Health Service recommendation for fluoride concentration in drinking water for the prevention of dental caries. Public Health Reports. 2015;130:318-31.

[9] Viswanathan G, Jaswanth A, Gopalakrishnan S, Aditya G. Determining the optimal fluoride concentration in drinking water for fluoride endemic regions in South India. Science of the total environment. 2009;407:5298-307.

[10] Carton RJ. Review of the 2006 United States National Research Council report: fluoride in drinking water. Fluoride. 2006;39:163-72.

[11] Palmer CA, Gilbert JA. Position of the Academy of Nutrition and Dietetics: the impact of fluoride on health. Journal of the Academy of Nutrition and Dietetics. 2012;112:1443-53.

[12] Dehbandi R, Moore F, Keshavarzi B. Geochemical sources, hydrogeochemical behavior, and health risk assessment of fluoride in an endemic fluorosis area, central Iran. Chemosphere. 2018;193:763-76.

[13] Ranjan R, Maiti SB, Vala D, Jain A, Shrivastava S. FLUORIDES IN HEALTH AND DISEASE-A REVIEW. Journal of Advanced Medical and Dental Sciences Research. 2016;4:43.

[14] Browne D, Whelton H, O'Mullane D. Fluoride metabolism and fluorosis. Journal of Dentistry. 2005;33:177-86.

[15] Ghosh A, Mukherjee K, Ghosh SK, Saha B. Sources and toxicity of fluoride in the environment. Research on Chemical Intermediates. 2013;39:2881-915.

[16] Fordyce F, Vrana K, Zhovinsky E, Povoroznuk V, Toth G, Hope B, et al. A health risk assessment for fluoride in Central Europe. Environmental geochemistry and health. 2007;29:83-102.

[17] Shivarajashankara Y, Shivashankara A, Rao SH, Bhat PG. Oxidative stress in children with endemic skeletal fluorosis. Fluoride. 2001;34:103-7.

[18] Latzka WA, Montain SJ. Water and electrolyte requirements for exercise. Clinics in sports medicine. 1999;18:513-24.

[19] Waugh D, Potter W, Limeback H, Godfrey M. Risk assessment of fluoride intake from tea in the Republic of Ireland and its implications for public health and water fluoridation. International journal of environmental research and public health. 2016;13:259.

[20] Varol E, Varol S. Water-borne fluoride and primary hypertension. Fluoride. 2013;46:3-6.

[21] Xiang Q, Liang Y, Chen L, Wang C, Chen B, Chen X, et al. Effect of fluoride in drinking water on children's intelligence. Fluoride. 2003;36:84-94.

[22] Xiong X, Liu J, He W, Xia T, He P, Chen X, et al. Dose–effect relationship between drinking water fluoride levels and damage to liver and kidney functions in children. Environmental Research. 2007;103:112-6.

[23] Ayenew T. The distribution and hydrogeological controls of fluoride in the groundwater of central Ethiopian rift and adjacent highlands. Environmental Geology. 2008;54:1313-24.

[24] Jia H, Qian H, Qu W, Zheng L, Feng W, Ren W. Fluoride Occurrence and Human Health Risk in Drinking Water Wells from Southern Edge of Chinese Loess Plateau. International

journal of environmental research and public health. 2019;16:1683.
[25] Mahlknecht J, Steinich B, De León IN. Groundwater chemistry and mass transfers in the Independence aquifer, central Mexico, by using multivariate statistics and mass-balance models. Environmental Geology. 2004;45:781-95.
[26] Morar DL. Release of inorganic and organic contaminants from fly ash amended permeable reactive barriers 2008.
[27] Li P, Wu J, Qian H, Zhang Y, Yang N, Jing L, et al. Hydrogeochemical characterization of groundwater in and around a wastewater irrigated forest in the southeastern edge of the Tengger Desert, Northwest China. Exposure and Health. 2016;8:331-48.
[28] Ahada CP, Suthar S. Assessment of human health risk associated with high groundwater fluoride intake in southern districts of Punjab, India. Exposure and Health. 2017:1-9.
[29] Adimalla N, Venkatayogi S. Mechanism of fluoride enrichment in groundwater of hard rock aquifers in Medak, Telangana State, South India. Environmental Earth Sciences. 2017;76:45.
[30] Narsimha A, Sudarshan V. Contamination of fluoride in groundwater and its effect on human health: a case study in hard rock aquifers of Siddipet, Telangana State, India. Applied Water Science. 2017;7:2501-12.
[31] Ayoob S, Gupta AK. Fluoride in drinking water: a review on the status and stress effects. Critical Reviews in Environmental Science and Technology. 2006;36:433-87.
[32] Carrillo-Rivera J, Cardona A, Edmunds W. Use of abstraction regime and knowledge of hydrogeological conditions to control high-fluoride concentration in abstracted groundwater: San Luis Potosı basin, Mexico. Journal of hydrology. 2002;261:24-47.
[33] Abdelgawad AM, Watanabe K, Takeuchi S, Mizuno T. The origin of fluoride-rich groundwater in Mizunami area, Japan—Mineralogy and geochemistry implications. Engineering Geology. 2009;108:76-85.
[34] Fantong WY, Satake H, Ayonghe SN, Suh EC, Adelana SM, Fantong EBS, et al. Geochemical provenance and spatial distribution of fluoride in groundwater of Mayo Tsanaga River Basin, Far North Region, Cameroon: implications for incidence of fluorosis and optimal consumption dose. Environmental geochemistry and health. 2010;32:147-63.
[35] Xiang J, Yan L, Wang Y, Qin Y, Wang C, Xiang Q. The effects of ten years of defluoridation on urinary fluoride, dental fluorosis, defect dental fluorosis, and dental caries, in Jiangsu province, PR China. Fluoride. 2016;49:23.
[36] Rahman ZU, Khan B, Ahmada I, Mian IA, Saeed A, Afaq A, et al. A review of groundwater fluoride contamination in Pakistan and an assessment of the risk of fluorosis. Fluoride. 2018.
[37] Azizullah A, Khattak MNK, Richter P, Häder D-P. Water pollution in Pakistan and its impact on public health—a review. Environment international. 2011;37:479-97.
[38] Tahir M, Rasheed H. Fluoride in the drinking water of Pakistan and the possible risk of crippling fluorosis. Drinking Water Engineering and Science. 2013;6:17-23.
[39] Khan AA, Whelton H, O'Mullane D. Determining the optimal concentration of fluoride in drinking water in Pakistan. Community dentistry and oral epidemiology. 2004;32:166-72.
[40] Rasool A, Farooqi A, Xiao T, Ali W, Noor S, Abiola O, et al. A review of global outlook on fluoride contamination in groundwater with prominence on the Pakistan current situation. Environmental geochemistry and health. 2018;40:1265-81.
[41] Shah MT, Danishwar S. Potential fluoride contamination in the drinking water of Naranji area, northwest frontier province, Pakistan. Environmental geochemistry and health. 2003;25:475-81.
[42] Rafique T, Naseem S, Ozsvath D, Hussain R, Bhanger MI, Usmani TH. Geochemical controls of high fluoride groundwater in Umarkot sub-district, Thar Desert, Pakistan. Science of the Total Environment. 2015;530:271-8.
[43] Raza M, Hussain F, Lee J-Y, Shakoor MB, Kwon KD. Groundwater status in Pakistan: A review of contamination, health risks, and potential needs. Critical Reviews in Environmental Science and Technology. 2017;47:1713-62.
[44] Din Ahmad M-u, Stewart JP, Podger GM. Modelling the surface water allocations and deliveries in the world's largest continuous irrigation system, Indus Basin Pakistan. EGU General Assembly Conference Abstracts2018. p. 1633.
[45] Chubar N. New inorganic (an) ion exchangers based on Mg–Al hydrous oxides:(Alkoxide-free) sol–gel synthesis and characterisation. Journal of colloid and interface science. 2011;357:198-209.
[46] Gong W-X, Qu J-H, Liu R-P, Lan H-C. Adsorption of fluoride onto different types of aluminas. Chemical Engineering Journal. 2012;189:126-33.
[47] Behbahani M, Moghaddam MA, Arami M. Techno-economical evaluation of fluoride removal by electrocoagulation process: Optimization through response surface methodology. Desalination. 2011;271:209-18.
[48] Islam M, Patel R. Evaluation of removal efficiency of fluoride from aqueous solution using quick lime. Journal of Hazardous Materials. 2007;143:303-10.
[49] Fawell J, Bailey K, Chilton J, Dahi E, Magara Y. Fluoride in drinking-water: IWA publishing; 2006.