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Assessment of Fluoride Contamination of Groundwater at District Lower Dir: Implications for Public Health and Community Well-being

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Abstract
Despite the widespread use of fluoride and its recognized benefits, it has been subjected to debate concerning its effectives and safety. On account of its critical role in dental health, significant public and scientific interest regarding fluoride has been sparked. The current study was carried out to assess fluoride concentration in groundwater of district Dir Lower, Khyber Pakhtunkhwa, Pakistan. During the present study a total number of 33 water samples were collected from different location of the study area. The results of the current study revealed that 21.212% of the total samples were fluoride contaminated while 78.788% were falling in permissible limits of world health organization (WHO), yet comprising of two samples having fluoride concentration below than WHO suggested lower permissible limits. Tehsil wise Munda was having the least (0%) fluoride contamination followed by tehsil Balambat, tehsil Samar Bagh and tehsil Adenzai (16.667%). Tehsil Timergara and tehsil Khall was having the highest fluoride contamination, both having 33.333% samples with fluoride contamination. It was also observed that there is no industrial and other such anthropogenic activities causing fluoride contamination, which suggests that, the fluoride contamination in some sampling sites may be due to geogenic orientation. Yellowing and cracking of teeth has been observed in local populaces of some areas, especially in local communities of riverine areas by the researchers as well. Therefore, it is suggested to employ different defluoridation techniques for fluoride removal, such as Gypsum addition and activated Alumina Treatment to make the water consumable.

Key words: Lower Dir, Groundwater, Fluoride, Fluorosis, Health problems, Pakistan

Introduction

Human life existence primarily depends upon drinking water. Tragically, clean drinking water is scarce and non-available everywhere. It is due to weathering process and deteriorating human activities. Different pollutants such as pesticides, industrial effluents and domestic wastes are contaminating ground water and rendering it unfit for drinking (Afridi et al., 2019). Similarly, contamination of groundwater with fluoride is becoming a serious issue of concern in different parts all across the globe including Pakistan (Sohail et al., 2019). Almost 200 million population of the world is on the divergence of higher risks on account of elevated fluoride concentration in drinking water (Ayoob and Gupta, 2006). Fluorate, flour-apatite, hornblende, mica, serpentine and certain clays are main fluoride sources in groundwater (Janardhan et al., 2009). Hydrogeology, pH, climatic conditions and host rock composition govern fluoride occurrence naturally (Gupta et al., 2006). Most of the time different disturbing anthropogenic activities including pesticides, sludge and sewages, phosphatic fertilizers, and groundwater table depletion also cause fluoride pollution (Ramanaiah et al., 2006).

Fluoride is a naturally occurring mineral found in different biological and geological environments (Qi, 2018). It plays a key role in dental health. On account of its cavity preventing properties, fluoride is a common additive in dental products including toothpaste and mouthwash (Veazey, 2021). However, exposure to fluoride in toothpaste and mouthwashes led to toxicities in over 80% of children under 6 years of age (Martínez-Mier, 2012). Due to its enormous use, it has sparked significant scientific and public interest. Furthermore, fluoride is also added to public water for fluoridation to avoid or reduce tooth decay in the population (ADA, 2024). Although, fluoride is in widespread use and have recognized benefits, it has been widely debated concerning its effectiveness and safety.

Fluoride is required for usual bones' growth and teeth enamel as these two have accumulation of around 96.00% of total fluoride contained by human body but its intake in excessive level can lead to some serious health issues specifically on bones and teeth such as teeth mottling and deterioration, and anomalous bone growth (Ceopalan, 2003). These conditions are termed as skeletal and dental fluorosis, causing severe effects on account of vitamins and calcium deficiency in food (Patel et al., 2017; Mulualem et al., 2022). Continuous consumption of fluorides is also considered to be one of the major reasons for cancer, skeletal changes, cancer, violent allergies, heart diseases, anaemia, abortion, ulcers, goitres and birth defects (Carstairs and Elder, 2008). Its consumption in over permissible range can lead to proteins inhibition, change in pH, imbalance of electrolytes, and disruption of organelles (Johnston and Strubel, 2020). Consumption of fluoride in chronic amount can also cause alterations in animals' cerebral cortex (Hayani et al., 2013).

The current preliminary study was carried out at district Dir Lower Khyber Pakhtunkhwa Pakistan. Previous studies has been carried out on groundwater quality from district Dir Lower on different sources of water such as dug wells, hand pumps and tube wells for various Physico-chemical parameters such as pH, electrical conductivity, dissolved oxygen, dissolved carbon dioxide, magnesium hardness, calcium hardness, alkalinity, salinity, turbidity, colour, odour, taste, chlorides, sulphates, nitrates, phosphates, and nitrate concentration in groundwater (Ullah et al., 2014a; Malik et al., 2010; Sohail et al., 2019; Sarwar et al., 2021). But no data appears in literature regarding fluoride concentration in groundwater of the study area. Therefore the current investigation was aimed to carry out assessment of fluoride concentration in the district.

Materials and Methods

Study Area

Till 1969, district Dir Lower was an independent state. In 1969 it was merged into Pakistan. Later on in 1996, district Dir Lower was bifurcated into two districts, district Dir (Lower) and district Dir (Upper). This beautiful district is located in northern part of the country, Pakistan and is one of main districts of the Khyber Pakhtunkhwa province. It is situated with Longitudes and Latitudes of 34°, 37' to 35°, 07' North and 71°, 31' to 72°, 14' East respectively, with approximate 2700 feet (820 meter) above mean sea level experiencing an annual rain fall of 1468.8mm and 253.7mm during December and March respectively.

It covers a total area of 1,583 square kilometres. District Lower Dir is having seven *tehsil*s: Khall, Timergara, Balambat, Lal Qila, Adenzai, Samarbagh and Munda (Fig. 1). District Lower Dir is bounded by district Upper Dir to the Northern Side, by District Bajaur (Ex- Bajaur Agency – Federally Administered Tribal Area) and Afghanistan to the Western side, by district Malakand to the Southern side and by district Swat to Eastern side (Ullah, 2014).

Water Sampling and Analysis

Water sampling water was carried out of thirty three different locations of the seven *tehsil*s of the district. Water analysis for fluoride concentration was carried out by following Anjum et al. (2013). Water sampling locations are given in Figure 2, modified after Ullah et al. (2014b).

Figure 1: Map showing sub political divisions, tehsils, of District Dir Lower, Khyber Pakhtunkhwa

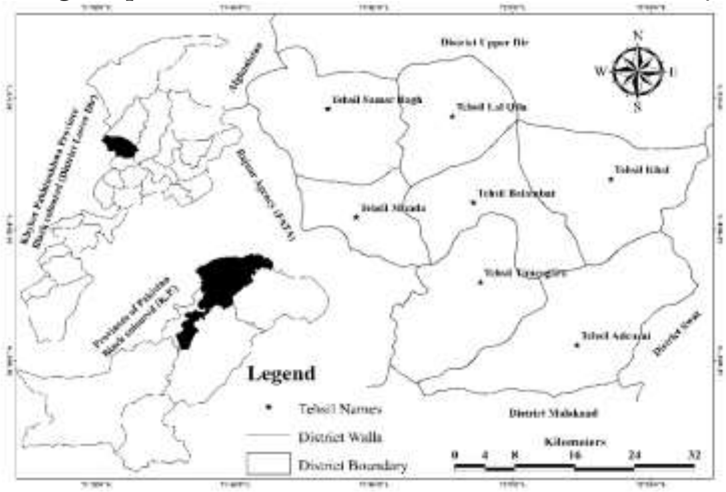
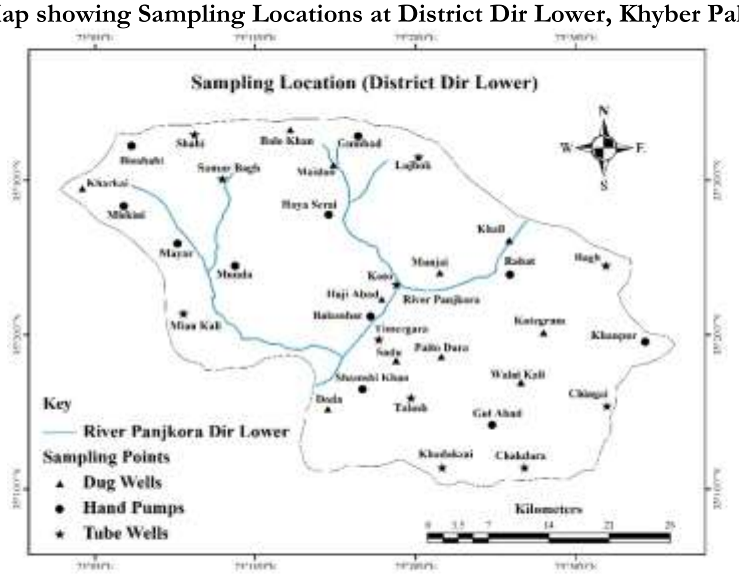


Figure 2: Map showing Sampling Locations at District Dir Lower, Khyber Pakhtunkhwa



Results and Discussion

Fluoride contents of 33 samples from different water sources including hand pumps, tube wells and dug wells and different locations of district Dir lower was assessed, Table 1. Table 2 is showing *tehsil* wise summary of fluoride contamination. Table 3 is showing WHO permissible limits for fluoride concentration in ground water (WHO, 2004). In case of deviation from the permissible limits, it can lead to some serious health hazards, as given in Table 3.

Table 1: Summary of fluoride concentration in groundwater of District Dir (Lower)

S. No.	Location	Value (mg/l)	S. No.	Location	Value (mg/l)
1	Koto	0.9*	18	Doda	2.4**
2	Timergara	3.1**	19	Kharkai	1.7**
3	Chakdara	0.78*	20	Kutegram	0.89*
4	Samar Bagh	0.65*	21	Walikali	1.03*
5	Talash	1.2*	22	Balo Khan	0.52*
6	Lajbok	1.2*	23	Munda	0.91*
7	Khadakzai	1.7**	24	Balambat	0.43***
8	Shahi	0.55*	25	Rabat	1.47*
9	Bagh	0.52*	26	Haya Serai	1.02*
10	Mian Kali	0.64*	27	Gul Abad	1.18*
11	Chingai	1.38*	28	Shamshi Khan	0.69*
12	Khalll	1.81**	29	Mayar	1.21*
13	Munjai	1.21*	30	Binshahi	0.72*
14	Sadu	0.98*	31	Khanpur	0.67*
15	Maidan	0.36***	32	Miskini	1.19*
16	Haji Abad	4.2**	33	Gumbad	2.04**
17	Paito Dara	0.97*			

* = *Safe; ** = ** Unsafe, higher than permissible limits; *** = ***Safe but not suitable, below the lower permissible limits; 1-11 = Tube wells; 12-22 = Dug wells; 23-33 = Hand pumps

Table 2: Summary of fluoride contamination (*Tehsil* wise)

S. No	Tehsil	Location S. No	Safe	% age	Contaminated	% age
1	Balambat	1,6,13,16,24,26	5	83.333	1	16.667
2	Timergara	2,5,14,17,18,28	4	66.667	2	33.333
3	Khall	9,12,25,	2	66.667	1	33.333
4	Lal Qila	15, 22,26,33,	3	75	1	25
5	Samar Bagh	4,8,19,29,30,32	5	83.333	1	16.667
6	Munda	10,23	2	100	0	0
7	Adenzai	3,7,11,20,21,27	5	83.333	1	16.667
	Total	33 Locations	26	78.788	7	21.212

Table 3: Level of fluoride and human physiology

S. No	Fluoride Concentration	Contamination	Physiology
1	0.5-1 mg/L	Safe	Healthier teeth and bones[1]
2	0.7 mg/L	Safe	Considered best for Dental health[2] Adequate daily intake for toddlers[3]
3	1.5 mg/L	Global Rejection Limit	Global Rejection Limit set by WHO[4]
4	3 mg daily	Adequate	Adequate for adult women[3]
5	4 mg daily	Adequate	Adequate for adult men[3]
6	2-3 mg/L	Unsafe	Dental Fluorosis[1]
7	> 4 mg/L	Unsafe	Could be Hazardous[2]
8	3-6 mg/L	Unsafe	Mild Skeletal Fluorosis[1]
9	10-80 mg/L	Unsafe	Cancer, Crippling Fluorosis[1]

[1](Appleo and Postma, 1996), [2](Brazier, 2024), [3](Aoun et al., 2018), [4](Das et al., 2023)

It was observed that 21.212 % of the total water samples were contaminated with fluoride. In *tehsil* Balambat 16.667%, in *tehsil* Timergara 33.333%, Khall 33.333%, Lal Qila 25%, Samar Bagh 16.667% and in *tehsil* Munda 0% water samples were fluoride contaminated. Similarly 83.333%, 66.667%, 66.667%, 75%, 83.333% and 100% water samples of *tehsil* Balambat, *tehsil* Timergara, *tehsil* Khall, *tehsil* Lal Qila, *tehsil* Samar Bagh and *tehsil* Munda were falling in suggested permissible limits. Although two water samples in Maidan (*tehsil* Lal Qila) and Balambat (*tehsil* Balambat) were having fluoride concentration below than WHO suggested lower permissible limits, 0.36 mg/L and 0.43 mg/L respectively.

The values for the fluoride were ranging from 0.36 mg/L to 4.2 mg/L in Maidan and Haji Abad respectively. Lower values of fluoride were observed in areas distant from rive Panjkora while the riverine areas were having higher fluoride concentration. This may be attributed to the groundwater column disturbance on account of water leaching from the river to the groundwater table. The lower and safe level of fluoride in riverine areas of Koto may be attributed to the fact of falling of an another tributary by the name of Konhaye stream into the river, which is having pretty good quality of water and is a bit away of deteriorating anthropogenic activities (Ullah et al., 2014c).

Fluoride can pose a positive or negative impact on human health depending upon its concentration ingested. Aoun et al. (2018) reviewed the pros and cons of fluorides and fluoridation in detail. Fluoride can prevent dental carries (Peterson and Ogawa, 2016). When taken in suitable amount, it can work as a strength factor for teeth and bones of humans while excessive consumption can lead to some serious abnormalities. It can cause fluoride poisoning, termed as fluorosis. Major forms of fluorosis are skeletal and dental fluorosis. Initial sign that appear on teeth is mottling as well as teeth's brownish colouration. This is ultimately preceded by deterioration of teeth. Similarly regular and continuous consumption of fluoride (3-6 mg/L) can lead to softening and deformation of bones, termed as skeletal fluorosis (WHO, 2004). It can cause dental fluorosis, skeletal fluorosis, non-skeletal fluorosis or all or a combination of these three types of fluorosis. Fluoride is known to be an aging inducer as well (Arif et al., 2013). Currently, over 200 million people from 25 nations are suffering from fluorosis (Vithanage and Bhattacharya, 2015). A plethora of research and literature is revealing the hostile effects of fluorides on humans, animals, and plants (Aoun et al., 2018; Zuo et al., 2018; Yadav et al., 2023). Similarly a plethora of well documented literature is available online on the health effects of fluoride (O'Mullane et al., 2016).

Groundwater contamination with fluoride can be due to geogenic or anthropogenic sources and can be attributed to the combine effects of these two (Ali et al., 2016; LaFayette et al., 2020). Higher fluoride may be contributed by the presence of ultramafic, mafic and alkaline rocks present in the study area bearing serpentine, hornblende, biotite, muscovite, flour-apatite and apatite, and all these minerals are having fluoride (Shah and Danishwar, 2003). As for as the study area is concern, there is no industrial zone or other such human activities causing fluoride contamination of water resources, therefore, fluoride concentration may possibly due to fluoride release from basin's soils, specifically from fluoride bearing phases. A plethora of well documented research is available online on the detection, quantification, sources, distribution, characterization, and risk assessment of fluoride in ground and drinking water across the globe (Kumar et al., 2019; McMahon et al., 2020; Hu et al., 2021; Onipe et al., 2021; Ali et al., 2023; Hou et al., 2023).

Conclusion

The present study concluded that 21.212% of the total samples were fluoride contaminated while 78.788% were falling in WHO permissible limits, yet having two samples with fluoride concentration below than lower permissible limits as suggested by world health organization. *Tehsil* wise Munda was having the least (0%) fluoride contamination followed by *tehsil* Balambat, *tehsil* Samar Bagh and *tehsil* Adenzai (16.667%). *Tehsil* Timergara and *tehsil* Khall was having the highest fluoride contamination, both having 33.333% samples with fluoride contamination. It was also observed that there is no industrial and other such anthropogenic activities causing fluoride contamination, which suggests that, the fluoride contamination in some sampling sites may be due to geogenic orientation.

Recommendation

As the researchers are from the same area, therefore yellowing and cracking of teeth has been observed in local populaces of some areas, especially in local communities of riverine areas. Therefore it is suggested to employ different defluoridation techniques for fluoride removal. Classical techniques for fluoride removal including gypsum addition and activated alumina treatment being easily applicable to make the consumable water risk free. Well documented research outlines different defluoridation techniques (Fadaei, 2021; Lacson et al., 2021; Jamwal and Slathia, 2022).

Disclosure

All the authors hereby declare that they are having no competing interest and this paper is the combine efforts of all of them.

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