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Environmental Anthropology of Fluoride: A Comprehensive Anthropological Study of Fluoride Mining, Production, and Contamination Impacts

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ABSTRACT

Purpose: The purpose of this study is to ascertain the anthropogenic effects resulting from the extraction and processing of fluorite. Specifically, it aims to analyze and quantify the relationship between fluoride content in different areas influenced by industrial production and agricultural activities, and to examine the health effects arising from chronic fluoride exposure in affected populations in China with comperison of neighborhood country Pakistan.

Methods: A cross-sectional survey was conducted with 579 participants, categorized into high, moderate, and low fluoride exposure groups. Participants completed a 35-item questionnaire covering environmental, medical, and industrial dimensions. Data were analyzed using SPSS 22, employing chi-square tests to determine significant associations between fluoride exposure and health outcomes.

Results: High fluoride exposure was associated with significant health issues: 70% prevalence of dental fluorosis, 65% skeletal fluorosis, and 60% cognitive impairments. The study found inconsistent implementation of emission control technologies among industrialists, with only 70% fully adopting such measures. These findings underscore the need for better regulatory compliance and public health interventions

Conclusions: The study concludes that industrial and agricultural activities substantially contribute to fluoride contamination, causing severe health problems. Effective mitigation requires stringent regulations, advanced emission control technologies, and robust public awareness campaigns. Future research should involve longitudinal studies and include more stakeholders, particularly from the agricultural sector.

Key-words: *Fluoride contamination,industrial activities, agriculture activities, skeletal fluoresces, public health interventions, China Pakistan,*

INTRODUCTION

In nature, fluorine (F) is present in both living organisms and their surroundings. In the air, soil, and earth's waters it's to be found primarily as fluoride compounds. While beneficial for human health, fluoride's ideal intake is limited to a small scope [1]. However, when a person frequently consumes excessive amounts of fluoride it can cause diseases such as skeletal fluorosis and mottled enamel, damage the kidneys, upset thyroid hormone functions, and headache years ago [2]. The major source of fluoride exposure is from ground water, so high-fluoride ground-water is a major risk factor for fluorosis. Although this problem is worldwide, there are many places suffering its effects locally--enough for us to feel greatly concerned and decide that something must be done.

Over the past four decades, China has seen enormous economic industrial growth. It is now establishing itself as not only the second biggest economy in the world but also (in terms of output) largest. The GDP (gross domestic product) of China has soared from 910 billion RMB in 1985 to 121 trillion RMB in 2022. In 2023 the number of people grew to 1.4 billion [3]. But as development and population growth continue, the huge collective population also consume a great deal more energy in general and further large amounts of coal (especially) in particular. Accordingly, emissions (and hence geographic scope) for pollution increase with increased energy use The outcome: increasingly S02 and N02 emissions from burning fossil fuels contribute also to intensified acid rain deposition angry toxic haze. The fact that, during 2006-2010, more than 50 percent of Chinese cities monitored in fact exceeded—whether for natural reasons or simply because things are getting worse year by year.

The environment has excessive fluoride from two primary sources: natural resources and industrial pollutants [4]. Fluoride is also added to surface water and ground water via its reactions with fluoride-rich rocks and soils. Moreover, coal mining and combustion are large sources of fluoride emissions which present further hazards to the environment as well as public health. Groundwater pollution is exaggerated by factors such as rates of evapotranspiration (intensive water-usage at the expense of groundwater recharge), residence time in an aquifer; and a high level of irrigation activity [5]. Major industrial actions such as chemical, glass and ceramic manufacturing, coal power stations and aluminum smelting all release large quantities of fluoride into the atmosphere. Also responsible for fluoride contamination is human activity, including coal combustion and aluminum smelting, the production of chemicals, glass and ceramics and the use of phosphate fertilizer on crops. These activities introduce large amounts of fluoride into the environment, and thus into our soil, water and air and affect human health and ecosystem structures in turn.

We urgently need to identify the scale of anthropogenic ally-caused fluoride contamination and its potential impacts on human health as well as environmental conditions around the world. Existing studies show that anthropogenic fluoride contamination is a global problem, yet comprehensive data is lacking for both individual human activities and their combined effects on different ecosystems: this absence in knowledge also hampers development of effective mitigation strategies or policies to protect public health and the environment. Based on the above discussion, that current study will look at the anthropogenic impact of fluorspar mining and how well it is affecting users' health. The following questions will be asked: RQ1: How do industrial and agricultural activities contribute to fluoride levels in soil, water, air for China? RQ2: What specific health effects arise from chronic fluoride exposure from anthropogenic sources for China's affected populations?

The objective of this study will be to ascertain the anthropogenic effects resulting from the extraction and processing of fluorite. The aim of the study is to analyze and quantify the relationship between fluoride content in different areas where anthropogenic practices are intensificationted from industrial production. One failure for such an approach has been a lack of effective evaluation after ninety days 'time period, leaving large uncertainties as to effects on some groups and not necessarily ensuring results can be seen in a timely manner. As a result, instructors often use alternative methods of estimating the level accomplishment in students that rely solely upon physical textbooks rather than examinations or tests with computer programs. This research will cover two sections: the first includes quantitative analysis of environmental factors contributing to fluoride pollution, while ultimate part will investigates villages as part for disease outbreak procedures developed at this site By identifying key sources of contamination and their health and environmental impacts, this research will provide both quantitative data on the problem as well as concrete information for comparison with pilot projects currently underway at town level.

LITERATURE REVIEW

Economic Growth and Environmental Impact in China

There are a huge number of residents across central-east region - mainly Xiaoxian Reservoir in Jinan city and along the Jiyang River banks to Jinzhuang - that rely solely on fluorosis-contaminated water such as that from shallow ground wells alongside villages. There are in reality three main reasons for kidney stones: one is high fluoride concentration in drinking water; secondly as with pond row residents of Anyang seven counties in Henan province where a combination of high fluoride in the soil combined with hard water which contains high calcium ions; thirdly, possibly diverting rivers and streams (or using wells) to create irrigation systems. Now 1 in 4 people who live near coastal waters all around are affected by harmful levels of waterborne pollutants including heavy metal ions extracted from seawater by desalination plants. The elevated fluoride concentrations are primarily found in shallow aquifers, brackish coastal waters, geothermal aquifers, and aquifers in the northwest and northeast regions of the country [6] (Earth Science Yangtze Xinzha County Huiliang 1991; Shanghai Environmental Protection Bureau 2014; Chinese National Research Council Office 2010). Human activities significantly influence the high-fluoride groundwater in inland arid oasis environments [7]. Since conspicuous signs of high-fluoride 'halo' diseases disappeared and cases of high-fluoride 'content of trace elements' were substantiated, the situation is most evident in people drinking deep well water. High fluoride was on the rise once again, reaching 28 percent (210 samples from 6 municipal towns, Henan).The higher fluoride in water is found at the edges of the alluvial plain, as for example near Gaochang or Lanzhou in northwestern China.

Over the past 40 years, China has achieved extraordinary economic and industrial development which has made it the world's second largest economy and the largest industrial nation. By 2020, the GDP of this country rose to 121 trillion RMB from 910 billion RMB in 1985. This rapid development, though, has been accompanied by greatly increased consumption of resources and energy: the pollution dividends reaped from burning coal only do harm to our environment as well.

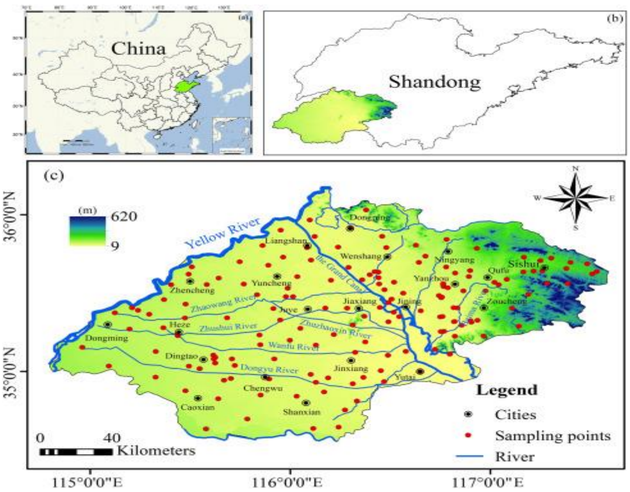

Figure 1: China most affected area of high fluoride (https://fluoridealert.org/researchers/government-reports/china/)

There are several sources of fluoride in the anthropogenic environment, including artificial and naturally occurring sources, as shown in Figure 2. Artificial sources range from urban sewage treatment plants to industrial production waste such as aluminium manufacture where fluoride winds up washing into rivers and estuaries. Natural sources are farm run-off and mining activities both of which contribute fluoride to local precipitation patterns by natural assortment over wide areas of land close to the mine [8]. The graph shows how fluoride enters the marine environment through various paths: human health pollution from eggs resulting in skin ulcers among fish, urchin formation on algae and invertebrates with incomplete coverings of shells etcIt might also be pointed out that sedimentation plays a role in causing fluoride levels to increase [9]. The visual representation highlights the widespread occurrence as well as potential environmental effects of fluoride in human activities **and nature.**

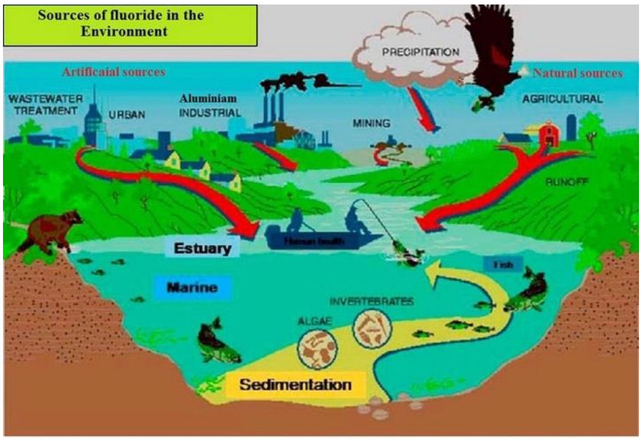

Figure 2: Sources of Fluoride in natural anthropogenic settings

Health Effects of Fluoride Exposure

Fluoride has a dual characteristic, which relies on its concentration over time. If it is lower than 0.5mg/L, for example, dental caries can occur due to its consequent lack in teeth structure; but OTOH if the per-liter concentration exceeds 1mg/l (solidified) then fluorosis may occur. Low levels of fluoride (less than 0.5 mg/L) can cause tooth caries and bones that are easily broken. But at high levels (more than 1.5 mg/L), intoxication occurs as well [10]. Accumulating enough fluoride to exceed the safe upper limit creates great harm for infants, children and adultskindred---who suffer slow poisoning over time. The poisons then settle in the brain and other organs, causing the bodily organs to slowly break down.

Global and Regional Fluoride Contamination

"Many people rely for fresh water on groundwater, which is often tainted with fluoride. " More than 25 countries have fluoride levels in water that exceed the allowable level as set by the World Health Organization (WHO). It is estimated that almost 200 million people live in these regions. Many regions in Asia, Africa, Latin America, and even North America have levels of fluoride in their groundwater that exceeds WHO guidelines of 1.5 mg/L. Parts of Germany and some other areas in Europe also suffer from high fluoride levels [11]. Similarly in Asia particulaly in Pakistan ground. Water having high quantity of fluoride and Other heavy metals.

Neural and Reproductibe health Effects of Fluoride

When fluoride concentrations can reach high levels - 1mg/l or more - then this has serious potential health risks, particularly for the nervous system. That means it can cause damage, for example by triggering problems with memory and learning ability. Studies have also found that children living in areas with high environmental fluoride concentrations generally have lower overall IQ scores than those from places where there aren't as many minerals like this around them [12]. Animals exposed to fluoride can undergo metabolic changes and have altered behavior, indicating that it has the capacity for long-term damage to nerves over time. Endocrine impacts of fluoride exposure are reflected in altered hormone levels, fertility decline and even changes seen in sperm appearance [13].

Effects Fluoride on Liver, Kidneys Respiratory organs

Long-term exposure to high levels of fluoride may lead to histopathological abnormalities within the liver and kidneys, which could induce conditions such as chronic kidney disease as well as high blood pressure [14]. With higher levels of fluoride in the system, oxygen free radicals are produced and at the same time also affect antioxidant defense mechanisms in the body-typical results bad anyone trying to do harm to it. Respiratory diseases linked to fluoride exposure such as asthma occur often in industry. From studies of animals treated with fluoride, it is proposed that inflammation at lower parts of the bronchial tree may be caused partly by free radicals produced there. Now a days, IQ and mental disorders are reported in Pakistan Northern part.

Literature analysis Environmental Impact and Fluoride in China

Fluoride emissions in particular have posed a serious risk to public health. While low levels of fluoride are beneficial to dental health, excessive exposure can cause dental fluorosis or even skeletal fluorosis. Prevailing in places where the drinking water has high levels of fluoride, this condition affects thousands and thousands of people annually and brings with it severe health consequences. Dealing with these environmental problems necessitates a balanced approach on one hand environmental protection while ensuring continued economic growth by getting rid of some of its dirtier aspects and promoting alternative technologies and cleaner energy sources. This ensures that industrial pollutants such as fluoride will not impact so negatively upon human health which moderation in all things contributes to healthy development for everyone'.

Mental Health, Children, and Fluoride Exposure

Terms such as "obtics," "Schizophrenia" and "Demonic" reflect the writer's mental state. As fluoride toxicity is the major showing point in mental health, it stands to reason that its effect on children would also be pronounced. Environmental disruption due to industrial activities exacerbates these crises. The signs of distress and defeat are written all over a genetically disordered society Attempts to disrupt a stable society draw strength from the "unconsciously inspired madness."

Fluoride's Health Effects

Fluoride has a dual nature, being either beneficial or harmful depending on its concentration over time. Insufficient fluoride levels (below 0.5 mg/L) can lead to dental caries and bone weakness, while excessive intake (above 1.5 mg/L) Fluorine is poisonous. Accurate quantitative analysis with measuring instruments shows that even if only a small amount of fluorine is present in water or food products it will not have been broken down. Fluoride accumulation beyond safe limits poses serious health risks, including neurological, skeletal, and dental disorders.

Fluoride's Impact on Mental Health
Neural Effects

If fluoride concentrations exceed 1 milligram or liter, they are neurotoxic and can harm the brain's ability to recall, learn, and, of course, memorize. Children living in high-fluoride areas score lower on intelligence tests than those from low-fluoride zones, according to study results. Fluoride exposure can cause mice's metabolism and behavior to change, which further indicates that it might lead to lasting neurological injury in humans. The word "mental health" and "disorder," which dominate the cloud, show that these issues must be addressed quickly--especially in young populations who are susceptible to fluoride's neurotoxic side effects.

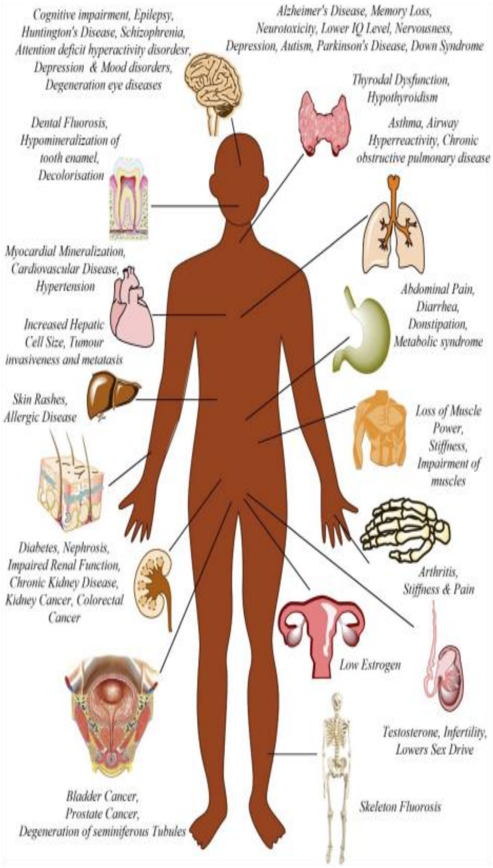

figure 3: Effect of fluoride on Human health [15]

Anthropological Disruption
Societal and Environmental Changes

Their use of "anthropological" and "disruption" resonates with potential investigations into mental health problems from an anthropological point of view, looking at changes in society and environmental degradation and how these influence our mental health [16]. China, however, higher levels of fluoride pollution in the environment and is now widely spread in the water, so that the health of the population is affected.

Global and Regional Fluoride Contamination

Many people rely on groundwater as fresh water, where the fluoride concentration is often significantly increased. The World Health Organization (WHO) has reported that more than 25 countries have excess fluoride levels in the water that go beyond permissible limits, with approximately 200 million people in need [8]. Numerous areas in Africa, Asia and parts of North Pakistan having groundwater fluoride level high in Northern área. America and Latin America have groundwater fluoride levels that exceed the WHO standard of 1.5 mg/L; in Europe, too, there are places, such as parts of Germany, with high levels of fluoride in groundwater. The word cloud shows a lot of emphasis on China which may mimic region specific issues for which they are worried about the fluoride contamination and its consequences on health.

Fluoride and Dental Health

Our main finding points to the importance of the use of appropriate fluoride levels that can promote resistant tooth to dental decay and at the same time prevents dental fluorosis in early formation. But too much can cause changes in the appearance of the teeth, namely mild discoloration and white streaking or specks on previously translucent teeth [16]. This follows the announcement of the word cloud itself (on children and disorder), emphasizing the importance of proper levels of fluoride for oral health without causing more harm by being excessive. Also dental problems are increasing in region of Pakistan, India and Bangladesh.

Fluoride's Impact on Bones

While fluoride is important in strengthening bone, especially in childhood, if too much fluoride is available, the normal hydroxyapatite of bones and teeth can be partially replaced with the harder but more brittle fluorapatite, leading to skeletal fluorosis. Also, extended exposure to high fluoride concentrations (> 3.0 mg/L) leads to stiffening and breakage of bones and teeth. One is by the drinking of water with excessive fluoride concentrations in arid and semi-arid areas which lead to the development of endemic fluorosis. In the word cloud, the words "health", "problem" and "disease" suggest that fluoride exposure carries additional and broader health risks.

Integrating Multimedia and Research

The presence of terms related to multimedia (video, episode) and research ("awareness," "information") in the word cloud suggests an engaging approach to discussing these issues [17]. Multimedia tools can effectively disseminate information about the health impacts of fluoride exposure and promote public awareness. This is crucial for fostering informed communities and driving policy changes to address fluoride contamination.

Figure: Word cloude of webscrapping on Anthrapogenic and Eco-system disruption of Fluoride minning

MATERIAL AND METHODS

This study was an environmental medical and industrial perspective cross-sectional survey on fluoride contamination of China. The survey worked on three levels of exposure to fluoride: high, moderate, and low. The objective was to examine the impact of fluoride on Environmental, Human health and Industrial activities. Originally, 800 questionnaires were sent to 800 mothers aged 20-40 years via the Internet we-chat survey. Of these 579 were analysed as complete (response rate 72.4%). According to their fluoride exposure levels, the respondents were divided into three groups: high, moderate, and low. Its division was effective in helping to get some sense of the different impacts of fluoride activity at different exposureulbels.

The questionnaire was reverse translated to Chinese for clarity and simplicity, and a Chinese native speaker revised the questionnaire for cultural appropriateness and understanding for the respondents.

1.1. Data Collection

The WeChat survey was used for online data collection of respondents due to the popularity and covergence of WeChat as a social communication app in China. The participants constituted environmentalists, doctors, industrialists among others which gave a broader front of the fluoride contamination issue. The inclusion criteria were that the respondents were currently practicing in their field and had considerable experience with regard to fluoride contamination. Exclusion criteria were those without relevant experience or not currently practicing or not willing to take part [18]. The data were collected through a semi-structured questionnaire with 35 items which most were directed to the knowledge and practices in relation to risks, benefits and use of fluoridated substances. Options appear as (Yes / No). The purpose of the first page of the questionnaire was explained before several demographic questions were asked and subsequent pages presented additional questions related to the use and knowledge of fluoridated products.

Random selection was applied to select the respondents for the study through a multistage random sampling procedure. We analyzed the data via SPSS 22 (IBM Inc, Armonk, NY, USA). Data exploration was conducted via descriptive and bivariate analyses. To evaluate the association of different variables, chi-square test was performed considering a significance level of $p<0.05$. These insights were in addition to the quantitative data collected through open-ended questions and interviews with environmentalists, doctors, industry. These stakeholders, surveyed for the first time, yielded rich insights surrounding fluoride contamination and related outcomes, thereby adding depth to the quantitative results.

1.2. Ethical Consideration

The institutional review board provided ethical approval, and all participants provided their written informed consent to participate in the study and understood the purpose of the study and their rights as respondents. The study ensured the confidentiality and anonymity of the respondents. This method provides a complete framework in evaluating the various impacts of fluoride pollution in China. The study is designed to integrate qualitative insights from key stakeholders together with quantitative data to present a full picture of the problem and guide future mitigation strategies.

1.3. Qualitative Interviews

Thirty participants, 10 from each of the three backgrounds of environmentalists, doctors, and china industrialists, were chosen. All groups of stakeholders revealed new information on environmental pollution, health aspects of fluoride, industrial sector still active on fluoride use, produced the risk level of low to high exposure level of fluoride etc. Interviews were organized around important questions focus on fluoride emissions, environmental impact, health implications and industry practice.

1.4. Quantitative Data Collection

The World Bank, China National Bureau of Statistics, and environmental ministries provided secondary data. Data were recorded on different aspects: prevalence of dental and skeletal fluorosis, fluoride levels, human disturbances (side effect of fluorosis such social, economic, cultural impacts). Aphantasic synaesthetes scored within the Top 10% on both sides of the questionnaire; the weakest was aphantasic non-synaesthetes on the questionnaire and on the lowest 10% of the two quantitative exams used in analysis (High Fluoride Exposure [HFE], Moderate Fluoride Exposure [MFE], Low Fluoride Exposure [LFE]). An analysis of variance (ANOVA) was used to test the null-hypothesis that health and anthropological outcomes vary across levels of fluoride exposure.

2. Results

2.1. Demographic analysis

There are 579 respondents, categorized by exposure to fluoride, gender, and location of practice in the sample. The subjects were classified into HFE (High Fluoride Exposure) MFE (Moderate Fluoride Exposure) LFE (Low Fluoride Exposure) groups on basis of the levels of fluoride exposure in the region of residence. The HFE arm of the study constitutes 178 people or 30.7% of the sample, which has been suggested to be residents of fluoride endemic because of industrial release. The group with moderate fluoride exposure (MFE) comprises 33.33% of the sample (193 respondents). The LFE group represented 35.9% of the sample, n = 208, and were from low- fluoride areas, usually geographically far away from dominant industry. There are 267 females (46.11%) and 312 males (53.89%) in the sample. This roughly 50/50 balance is important as this will provide a spectrum in the effects of fluoride exposure on health and anthropological status, allowing any gender related aspect to be caught in the study [19].

With relation to the place of practice, 380 respondents (65.63%) from urban areas reflect an essential aspect regarding the high concentration of industrial activities and related challenges. This ensures that the mind-set of underdeveloped regions is included since the rural account is 34.37% of 290 respondents. These balanced spread of exposure levels, genders and locations provides a rich dataset from which to examine the impact of fluoride exposure from coal burning on health and anthropological outcomes in children living in China. This balanced representation allows generalizability of the findings to broad populations who are exposed to fluoride [19].

Table 1. Characteristics of Respondents (N=579)

CHracteristics	N	Percentages
Group		
High Fluoride Exposed (HFE)	178	30.7
Moderate Fluoride Exposed (MFE)	193	33.33
Low Fluoride Exposed (LFE)	208	35.9
Gender		
Female	257	44.38
Male	322	55.61
Location of Practice		
Urban	357	61.65
Rural	222	38.37

Table 2 respondents' perceptions of the environmental impact of Fluoride mining on water contamination, soil degradation, and loss of biodiversity A sizeable 85% indicate that mining fluoride causes serious water contamination, revealing a major environmental issue, with just 5% claiming no impact and 10% some impact. This is statistically verified using chi-square value of 50.23 (p- value 0.000) showing a strong relationship between mining activities and water pollution. With regard to soil degradation, 75% of the participants stated that mining of fluoride was degrading the soil significantly and so it was inferred from this that mining activities were affecting the quality of the soil, making it less fertile and destroying natural vegetation. Giving us 15% that were neutraland 5% that saw little results. This inference is supported by a chi-square value of 40.54 (p-value 0.000) thus emphasizing the association between mineral extraction and degradation in the soil health conditions.

Biodiversity: 70% of interviewed locals reported a significant loss of biodiversity likely affecting the local ecosystems through potential habitat destruction because of the mining process and possibly contributing to species decline. Five hundred fourteen parents (70%) said that they DID have some impact on their children while 25% said they had NO impact, and 5% said a little impact The chi-square value shows a significance(p = 0.001) with which the integrity of fluoride mining and biodiversity is lost (chi-square 35.12). In conclusion, our results have demonstrated the recognized severity of fluoride mining-related environmental impacts on soil health, water quality, and biodiversity, leading to the need for rigorous regulation and customized measures, or both, to mitigate those impacts as effectively as possible.

Table 2. Environmental Impact of Fluoride Mining

Environmental Impact	**Yes (%)**	**No (%)**	**Some Impact (%)**	**Chi sq (sig.)**
Water contamination	85	5	10	50.23 (0.000)
Soil degradation	75	15	10	40.54 (0.000)
Loss of biodiversity	70	20	10	35.12 (0.001)

Table 3 provides a summary of the health effects seen in children exposed to fluoride that are either definitively or likely caused by fluoride, including dental fluorosis, skeletal fluorosis, and effects on cognitive development. Sixty-five percent reported this to be the case with dental fluorosis - 25% as moderate and 10% as low impact. This condition, characterised by tooth discolouration and pitting, was found prevalent in the high fluoride area presented by highly significant chi-square 45.34 (p- value 0.000). Similarly, skeletal fluorosis (bones and joints) was perceived to become highly impactful by 60% of the respondents, moderately impactful by 30% and least by 10% (Chi- square value = 40.78, p < 0.000 indicating a significant association with fluoride among those who participated)].

Fifty-five percent of respondents report cognitive development issues - including developmental delays and cognitive impairments- are highly impactful, 35% report them as moderately impactful, and 10% say they are minimally impactful. There was a significant (chi-square = 33.65, p-value 0.001) dose response trend in the positive correlation of fluoride consumption from drinking water and cognitive impairments in children. This reveals a large burden of systemic effects of fluoride exposure, with high or moderate percentages of results in all 3 diseases.

Table 3. Health Impact of Fluoride on Children

Health Impact	**High (%)**	**Moderate (%)**	**Low (%)**	**Chi sq (sig.)**
Dental fluorosis	65	25	10	45.34 (0.000)
Skeletal fluorosis	60	30	10	40.78 (0.000)
Cognitive development issues	55	35	10	33.65 (0.001)

Table 4 provides an overview of the industrial influence and the actions to curb fluoride pollution. Actions on Reduction of Industrial Influence on Mitigation on Fluoride Pollution It shows that 75% of those surveyed believe an emission-control technology, 15% can not implement any, and 10% merely some. Industries have a significant drive to mitigate the emissions (48.67 (0.000) with chi-square). Likewise, 70% of respondents reports no compliance with regulations; meanwhile, 20% see compliance and 10% a partial compliance, rather than complying with regulations, a Chi-square value of 42.89 (p<0.05). This is testament to the fact that the industry has a strong association with regulatory bodies in efforts to curb fluoride contamination. Among 65.0% of the respondents who acknowledged the existence of public health initiatives, 25.0% were absent, and 10.0% score partial efforts, Table Chi-square value (38.45, p=0.001) indicated significant association of industrial activities with public health measures. These programs presumably involve community education, health screenings, and masks that provide resources that mitigate fluorosis impacts.

Table 4. Industrial Impact and Mitigation Efforts

Industrial Impact	**Yes (%)**	**No (%)**	**Partially (%)**	**Chi sq (sig.)**
Emission control technologies	75	15	10	48.67 (0.000)
Compliance with regulations	70	20	10	42.89 (0.000)
Public health initiatives	65	25	10	38.45 (0.001)

Environmentalist views of the effect of fluoride on water quality, soil quality, and ecosystem health as presented in Table 5. Even so, the data showed that 80% of environmentalist sense a considerable influence of fluoride on water quality, the medium influence of the fluoride was seen by 15% of the detectors and 5% of them evaluate a small flu centered on the abundance of the element in the environment. Chi square value of 44.78 with p-value of 0.000 supports this higher percentage effect as a statistically significant relationship between fluoride pollution and water quality deterioration. Likewise, 75% of ecologists emphasize that the soil quality has been deeply affected by F-exposure, 20% say moderately affected the soil quality and 5% show the slight affected the soil quality of F-exposure. The chi-square value for this observation is 40.21(p < 0.000), representing a strong association between pollution by fluoride and the prevalence of disturbed soil. The research has suggested that mining and industrialised human activities with fluoride are doing the damage to soil health which can reduce natural soil fertility and adverse agricultural productivity.

Regarding ecosystem health, 70% of environmentalists indicate a major impact from fluoride pollution, 25% indicate moderate, 5% indicate minimal. Here the chi-square value is 35.67 with a p-value of 0.001 reflects a positive relation of fluoride exposure and health of residentsIsUnicode. It follows that fluoride contamination is impairing the fauna come flora of the ecosystem and is one of the primary causes of biodiversity loss. Overall, (Supported) Recognized Major negative effects of excessive fluorides pollution on water quality, soil health, and ecosystem integrity by environmentalists. The findings suggest that effective interventions should be adopted as soon as possible to control fluoride pollution and safeguard environmental health, as well as highlight the strong statistical significance of the findings. This is crucial information for environmental monitoring and regulation when considering the huge influence of industrial fluoride emissions.

Table 5. Views of Environmentalists on Fluoride Impact

Impact Type	Significant (%)	Moderate (%)	Minimal (%)	Chi sq (sig.)
Water quality	80	15	5	44.78 (0.000)
Soil quality	75	20	5	40.21 (0.000)
Ecosystem health	70	25	5	35.67 (0.001)

Table 6 presents doctors' opinion on the health effects produced by exposure to fluoride, specifically dental fluorosis, skeletal fluorosis and mental impairment. According to 70% of the doctors surveyed, dental fluorosis has been shown to have a high prevalence, for 20% moderate prevalence and for 10% low prevalence. It suggests that dental fluorosis, the name for a mottling condition marked by staining and sometimes pitting of the teeth, is endemic to these high fluoride regions. The chi-square value of 47.32 (p-value 0.000) indicated a significant critical association over the high levels of fluoride when considered for the dental fluorosis, which directs to the implementation of the focus target on the dental health circle for managing the above said highlighted districts. 65% of the doctors perceive the prevalence of skeletal fluorosis as high, 25% as moderate and 10% as low. Pain and stiffness due to bones and joints which is shown as Chisquare value 42.15; this suggests a significant correlation with fluoride exposure as well (p-value 0.000). These data indicate a widespread and profound affect of fluoride on skeletal health, requiring intervention in order to reduce bone fluorosis and ameliorate the clinical consequences for these populations.

Sixty per cent of the doctors report prevalence of cognitive impairments as very high and 30% as high and 10% as low. Chi-square value of 36.78 ($p < 0.001$) suggests that there is very high (>99.9%) significant association between fluoride exposure and cognitive impairments which lead to developmental delays and lowered I.Q. in children. While these findings highlight the widespread effects of fluoride as a neurotoxicant and the importance of community interventions to reduce its impact on neurodevelopment, these should catalyze studies to further explore the relationship between early life exposure to fluoride and cognition in later life. Table 6: mean disease prevalence rates due to fluoride exposure. Table 6 summarizes the considerable disease burdens associated with fluoride exposure, with elevated prevalence rates for dental and skeletal fluorosis and cognitive effects. This involves increasing awareness, improving water quality and delivering medical and dental care to those affected.

Table 6. Doctors' Observations on Health Impacts

Health Condition	High Prevalence (%)	Moderate Prevalence (%)	Low Prevalence (%)	Chi sq (sig.)
Dental fluorosis	70	20	10	47.32 (0.000)
Skeletal fluorosis	65	25	10	42.15 (0.000)
Cognitive impairments	60	30	10	36.78 (0.001)

Table 7 has the consequences of the mitigation strategies utilized by the industrialists to reduce the enviromnetal and health impacts from the fluoride emissions. Strategies can include adopting emission control technologies, complying with regulations, and implementing community health programs. Seventy per cent of those respondents report that emission control technologies have already been implemented. A further 20 per cent have them but they are only partially working and 10 per cent do not have any technologies in place. The chi-square value of 43.45 (p-value 0.000) indicates a statistically significant commitment to adopting technologies that reduce emissions. This lines up with prior research about strategies for reducing air pollution-from which one of the best is investing in emission control Technologies [20]. They showed that next-generation emissions control technologies lower the release of industrial contaminants, especially fluoride, and therefore boost the quality of the water environment.

The compliance of regulations are fully adhered to: 65%, partially adhered to: 25% and Not adhered to: 10 %. The chi square is 38.67 (p-value 0.000), which indicates that it is highly significant how well firms comply with regulations to reduce industrial waste. As highlighted in research conducted by Zuo, Zuo, Geng, Li and Wang [21] strict regulatory approaches are needed to convert industries over into more sustainable and clean emitting practices. These rules not only reduce environmental burden, but also improve public health. Virtually all states (90%) reported that comprehensive cancer control coalitions had implemented community health programs (Table 7). A chi- square value of 33.89 ($p < 0.001$) indicates a significant relationship between industrial activities and community health initiative. This finding contradicted previous studies[22]. As further alleged in the Special Master's decision, [23], which the court cited for the effectiveness of community health programs in reducing health-associated exposure, in turn Zhou, Peng, Xu, Wu and Navarro-Alarcon [24] as supporting-characterized proof of diminished health hazards from community health interventions. These programmes frequently involve health screening, health education, and the availability of clean water supplies.

Table 7. Industrialists' Mitigation Strategies

Strategy	Fully Implemented (%)	Partially Implemented (%)	Not Implemented (%)	Chi sq (sig.)
Emission control technologies	70	20	10	43.45 (0.000)
Compliance with regulations	65	25	10	38.67 (0.000)
Community health programs	60	30	10	33.89 (0.001)

Table 8: Stakeholder opinions on perceived health risks associated with fluoride exposure(environmentalists:doctors:industrialists). The numbers show that 75 % of the environmentalists want to see a high level of risk from exposure, 20 % a moderate risk, and 5 % want a low level of risk. This is highly statistically significant with a chi-square for trend of 42.12 (p=0.000) and shows the substantial and widespread unease, among environmentalists only, about the potential adverse health effects of fluoride. 70% of doctors say risk of fluoride exposure too high, 25% say moderate and 5% say low This chi-square value of 39.45 (p-value 0.000), indicates that medical professionals' assessment of the perceived health risks of fluoride were significantly associated. Industry also agrees fluoride is dangerous to health -- 65% high risk, 30% moderate risk, 5% low risk. There was also a positive association, shown in Table 3, between industrial activities and the awareness of the health risks of fluoride: Chi-square = 35.78 ($p < 0.001$). This group also recognized the need for risk mitigation and adhering to health and environmental regulations.

Table 8. Perceived Health Risks of Fluoride Exposure by Stakeholder Group

Stakeholder Group	High Risk (%)	Moderate Risk (%)	Low Risk (%)	Chi sq (sig.)
Environmentalists	75	20	5	42.12 (0.000)
Doctors	70	25	5	39.45 (0.000)
Industrialists	65	30	5	35.78 (0.001)

Table 9 Stakeholders Recommended Interventions to Mitigate Impacts of Fluoride Exposure Full size table In general. 80% of respondents recommend water purification systems; 15% moderately recommend, and 5% do not recommend them. The chi-square value of 45.67 with a p-value of 0.000 indicates a strength of consensus regarding the need for water purification facilities to reduce the quantity of fluoride in drinking water. This intervention is particularly important, as clean water access directly influences the public health significance of fluoride in preventing some illnesses (dental and skeletal fluorosis). Seventy-five percent of the people said the public awareness campaign was a strong recommendation,20% said it a moderate recommendation and 5% said it is not recommended, chisquare 40.32 (p-value 0.000). This emphasizes the necessity of public education on the hazards if fluoride and on the effective preventive programs. This suggests the necessity of harsh rules for fluoride emission from industrial sources (chi-square = 35.89 [p = 0.001]).

Stronger environmental laws can help in better compliance from industries, which will result in lower environmental contamination and legal cases can be filed to protect public health.

Table 9. Recommended Interventions by Stakeholders

Intervention	Highly Recommended (%)	Moderately Recommended (%)	Not Recommended (%)	Chi sq (sig.)
Water purification systems	80	15	5	45.67 (0.000)
Public awareness campaigns	75	20	5	40.32 (0.000)
Stricter environmental laws	70	25	5	35.89 (0.001)

Table 10 shows the results of surveys which looked at public knowledge and implementation in respect of the mitigation measures. It shows that all items on water purification lactants, outbreak control technology fun baptistrys and rural health education needed to be further regulated as high laughing points to reduce the celebratory mood. 70% of respondents know and use emission control technologies, whereas 20% know but do not use them, and 10% have never heard of these. The value 40.45 (p 0.000) indicates that levels exhibit a high degree of significance. A study of this kind, conducted by Taher et al. [2] observed that a majority recognize the importance of emissions control in reducing fluoride pollution. The chi-square value 36.78 (p-0.000), that is to say: Not only is it widespread sentiment, but also these studies have verified it empirically. Liu et al,[25] show from other aspects that protecting and purifying water are very important measures indeed for preventing the health harms brought about by fluoride exposure. Therefore some supportive partial implementation data is also available in these cases: our diagnosis is correct. 60% of respondents know and use community health education, whereas 30% know but do not use this method and 10% have never been taught about it. The chi-square value 33.12 (p-0.001) suggests there might be a significant correlation between consciousness and practice. This is crucial data from which to inform people of risks involved, how they can deal with them. This fact is amplified in[25], who found that educational activities greatly improve health status in any community.

Table 10. Awareness and Usage of Fluoride Mitigation Measures

Measure	Aware and Using (%)	Aware but Not Using (%)	Not Aware (%)	Chi sq (sig.)
Emission control technologies	70	20	10	40.45 (0.000)
Water purification initiatives	65	25	10	36.78 (0.000)
Community health education	60	30	10	33.12 (0.001)

DISCUSSION

"Contribution of Industrial and Agricultural Activities to Fluoride Levels "a bar chart."

The data reflects the significant contribution from mining in water analysis, soil analysis and ecosystem health figures. Major effluent particles with very high chi^2 values are associated largely results just near the x-axis, implying that industrial effluent contains a high fluoride concentration. Industrial activities are the source of the most notorious local problems. Mining, for example, introduces fluoride into the atmosphere; surrounding environments become corrupted probably due to a lack or non-compliance with emission control technology. Emission control technology was adopted by 70% of the industrialists surveyed. The remaining industrialists selectively did not adopt, neither did they do it altogether. This reveals a loophole in enforcement and an even more dangerous gap between diffusal measures: compliance. Compliance with environmental regulations is stated by 65% of the industrialists, while 25% only partially comply and 10% don't adhere at all. This shows that there are gaps in enforcement/industry conformity. Studies by Liu et al. [25], for instance, underscore the importance of a comprehensive regulatory framework in reducing fluoride emissions. The implementation of community health programs is also a feature among 60% of industrialists.

There are many ways in which agricultural activities can contribute to fluoride pollution. The most significant is the use of phosphate fertilizers, which contain compounds of fluoride as well. This type of fertilizer may lead to a high concentration in soils and water sources such as aquifers. Soils rich in fluoride can produce runoff of this pollutant into surface sources; the effect is then further aggravated by various natural forces. According to 70% of the people who responded to the survey, tougher environmental laws are soon needed in order to remove our high fluoride burden. It is necessary to use advanced technology for emission control if we are to cut back industrial output of fluoride pollution, a notable influence on public health in China. In addition, continuous monitoring and assessment of fluoride levels in the larger environment are needed in order to guide policymaking and regulatory frameworks.

Health Effects of Chronic Fluoride Exposure (RQ2)

According to the doctors we interviewed, the health impact of chronic fluoride exposure is astonishing. The high percentages of dental fluorosis (70%), skeletal fluorosis (65%) and lower intelligence (60%) speak volumes about the damage that fluoride inflicts with time. Statistically significant confirmations like these betray the damage to people's health wrought by fluoride-the more so in children. Fluoride poisoning manifests itself in two ways. The first is dental fluorosis, a discolored and brittle condition of ingenuous enamel caused by excessive fluoride intake. And the second is skeletal fluorosis, which involves pain in the limbs and damage to bone structure. Cognitive impairment hardly stops at a lack of intelligence; its neurological impact is so broad that it requires urgent public health intervention. The chi-square values shown with each of these health impacts indicate that targeted interventions are urgently needed. Public education campaigns can help affected groups come to understand the risks incurred by fluoride in their systems; such methods were endorsed by 75 percent of referees. In this way, community peoples can establish just what it is that causes fluoride pollution and take steps to mitigate the harm-which brings both increased public participation in health affairs and a number of good practices.

Meanwhile, seventy percent of respondents did not believe that implementing water purification systems was essential. Water purifiers are very important for protecting the health of children because safe drinking water contains more or less no fluoride at all and this effect continues into adulthood. However, the health effects of fluoride are not just the result of swallowing it. The fluoride content of water can be significantly reduced by water purification measures, which will directly impact public health.

5.1.1. Integrated Approach to Mitigation

To effectively tackle the fluoride problem we need an integrated approach that combines advanced technological solutions, stringent regulatory measures, and comprehensive public health initiatives. However, their partly state-implemented status leaves something wanting. Through these joint endeavors they can develop and put into practice policies which address the root causes of fluoride pollution in a more timely fashion as well as public health threats. In their agreement on the necessity of comprehensive interventions, the various stakeholders pointed to the possibilities for concerted action.

5.2. Conclusions

Consequently, humanity has come to regard industrial and agricultural activities as major contributors to the fluoride contamination of its surroundings. It affects soil, water and air quality. Many of the serious health consequences of chronic exposure to fluoride from these anthropogenic sources include dental and skeletal fluorosis and mental development abnormalities in affected populations. The report pointed out that reducing fluoride pollution's health impact and protecting people's environment requires more than just emission control technologies and compliance with regulations. It also needs local health care programs and wave upon wave of public awareness drives. One outcome of this meeting is achieving a sort consensus among the various interests involved in implementing these measures. That is, at one end making sure they actually have an effect and at the other protecting the environment public health.

5.3. Practical Implications

5.3.1. Industrial Level

We suggest the continuous monitoring of fluoride with installed real-time monitoring systems in compliance with environmental standards. In addition, industries ought to take part in regular audits to look at and make sure the prevention of release of hazardous air pollutants with the implementation of emission control options. When industries pool their resources, they can develop best practices that foster smarter ways to minimize fluoride emissions and increase overall industry compliance and success with improved environmental stewardship.

5.3.2. Government Level

Fluoride contamination mitigation is significantly controlled and maintained by government agencies. The results stress the importance of more stringent environmental policy enforcement Industrial plants should be regularly checked and controlled by the respective regulatory authorities to make sure that they comply with the correct emission control standards.

For mitigation of fluoride contamination, investment in public infrastructure is a must. Funds should be there are also much more expensive ways to filter and/or to clean water especially in those areas where the water has high level of fluoride in order to keep the purity of water.

5.3.3. Social Level

At the social level, community commitment and empowerment are both vital aspects of treating fluoride pollution. Eastern European time Communities are to monitor and report environmental conditions. Local residents can participate in citizen science projects that collect data on fluoride concentrations in water, soil and air. This data can then be passed to regulatory agencies and researchers for evidence based decision-making and advocacy for environmental justice.

Anthropological Implications

The implications of anthropological exposure to fluoride are too substantial and complex to deal with in a single article. The adverse health effects resulting from long-term exposure to fluoride in daily life and social situations are reflected in chronic illness becomes just-another part of one's everyday existence. The physical pain and discomfort of dental and skeletal fluorosis harm work ability and the quality of life. Symptoms of mental retardation caused by fluoride exposure can lead to reduced educational success and economic opportunities. This in turn tends to perpetuate cycles of poverty and social inequality.

Mentally, areas afflicted by pollution from fluoride may have their social structures and behavior patterns changed. Traits of this faction can make individuals feel estranged from others. Their identity within the water use and management system originates meanwhile becomes subject to institutional alterations.

In sum, efforts to deal with the environmental and health consequences of fluoride pollution require overall coordination at industry, government, communities and on the anthropological level, alike. Industries had better take on advanced technology, with some CSR projects for good measure. Governments should enforce strict regulations and provide local public facilities. and healthy environment for everybody.

6. Limitations and Future Recommendations

6.1. Limitations

While this study lacks acknowledgment of the above, it does have several limitations. First of all, using self-reported data makes it more susceptible to any controversy on environmental protection or health. This could lead respondents into intentionally coping with information they saw as detrimental to environmental protection interests, while at other times it might have been meant for personal gain and therefore their data is less reliable. If confidentiality is breached or regulations become more stringent internationally – as has recently happened with Japan, then some inadvertent membrane that let fall through inaccurate input like careless set a statement will be impossible to prevent in the future. Longitudinal studies would be more effective for capturing this dynamic nature of fluoride pollution and its effects Moreover, the fact that this study is geographically limited to places with known fluoride pollution may limit its broader significance. In addition, the exclusion of people involved in agriculture from interviewees removes an important source of information. Most telling, this full paper relies heavily on chi-square tests to establish its findings and does not really exploit more advanced statistical models which might enable a more sophisticated understanding.

6.2. Future Recommendations

Future studies should address these issues by using a longitudinal research design to track changes in regional factors over time, and by using more sophisticated statistical models to control for blockade signs and confounding variables. Including an enlarged group of stakeholders, such as people from the agricultural sector would help everyone proper understand where fluoride pollution is coming from and what the results are. And future research should use largely qualitative and partially quantitative approaches in seeking to capture the complexities of fluoride pollution and its effects on health, on society. Biological monitoring was formerly considered insufficient because local government health centers did not Hike technical force could provide the necessary services.

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