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# *Analysis of Health Problems Caused by Fluoride in China and Its Response Policies*

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***Abstract:*** Excessive fluoride intake poses significant public health challenges in China, particularly concerning skeletal disorders. This study examines the health impacts of fluoride exposure through drinking water and industrial emissions, focusing on bone-related diseases such as osteosclerosis, reduced bone mineral density, and increased fracture risks. Utilizing epidemiological data from high-fluoride regions in China, including a case study on tea-drinking endemic fluorosis in Qinghai Province, the analysis reveals that prolonged exposure to elevated fluoride levels correlates with a 27–45% rise in fracture incidence and higher rates of osteoporosis. The economic burden of fluoride-related ailments is substantial, disproportionately affecting low-income households through medical expenditures and straining government budgets via healthcare subsidies and infrastructure investments. While policies like China's Safe Drinking Water Project and India's NPPCF demonstrate progress in mitigating fluoride contamination, gaps persist in remote areas due to inadequate monitoring and technology diffusion. The study advocates for strengthened regulatory frameworks, cost-effective water treatment technologies (e.g., reverse osmosis), and public health education to reduce exposure risks. Future research should prioritize longitudinal field studies and global data integration to enhance policy efficacy. This work underscores the urgency of interdisciplinary collaboration to address fluoride-induced health disparities and improve population well-being.

***Keywords:*** Fluoride exposure, skeletal fluorosis, public health policy.

## 1. Introduction

Fluoride intake, especially in China, has become one of the most important issues in global public health. Fluoride enters the human body mainly through drinking water, air pollution and industrial emissions. Some areas of China have high concentrations of fluoride in their water sources, and long-term exposure can lead to fluorosis, which affects dental and bone health and may even have a negative impact on children's brain development. To address this issue, the government has taken a number of measures, including water fluoride monitoring, improved water treatment technologies, regulation development, and public health education. Although some progress has been made, the problem of fluoride intake requires continued attention and management as industrialization accelerates.

This paper focuses on the effects of fluoride intake on bone health, especially its predisposing effect on skeletal disorders. Long-term exposure to high levels of fluoride may lead to health problems such as impaired bone development, decreased bone density, increased risk of fracture, and even

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fluorosis. Research addressing this issue is of great significance. From the perspective of protecting the health of the population, an in-depth analysis of the impact of fluoride on bones can help formulate a more scientific public health policy and reduce the health risks caused by fluorosis; from the perspective of reducing the burden of medical care, the timely adoption of effective preventive and control measures can reduce the cost of treatment of skeletal diseases caused by fluoride; from the perspective of improving the quality of life, controlling the intake of fluoride can help improve the health level of the population and the quality of life, and prevent potential chronic diseases. and quality of life, and prevent the potential burden of chronic diseases. Therefore, the research in this paper not only has academic value, but also has important significance in guiding the actual public health management and policy making.

## 2. Literature review

The issue of fluoride exposure and its associated health risks, particularly bone-related diseases, has drawn considerable attention in global public health research. Zhao et al. found a significant correlation between fluoride concentration in drinking water and bone density abnormalities in rural Chinese populations, leading to osteosclerosis and increased fracture risks in adults [1]. Fawell et al. highlighted that excessive fluoride intake can lead to skeletal fluorosis, with symptoms ranging from stiffness to severe pain, and stressed the need for better water quality management in high-fluoride regions [2]. Gong et al. concluded that prolonged exposure to elevated fluoride levels led to reduced bone mineral density and increased susceptibility to fractures [3]. In terms of public health policies, Cheng et al. noted that China made progress in reducing fluoride levels in rural water supplies, though gaps remained in remote areas [4]. Khan et al. found that while water fluoridation reduced dental caries, insufficient monitoring led to higher rates of skeletal fluorosis in some regions [5]. Ayoob & Gupta discussed successful defluoridation technologies in India, which helped prevent skeletal fluorosis by reducing fluoride levels in drinking water [6]. Technological interventions such as reverse osmosis systems were effective in reducing fluoride concentrations in rural India, as shown by Gupta et al. , leading to a decrease in skeletal fluorosis cases [7]. Sharma et al. found that public health education campaigns significantly reduced fluoride-related diseases by increasing awareness about fluoride risks [8]. This study synthesizes findings across these areas, offering an integrated perspective on fluoride exposure and highlighting the need for improved regulatory frameworks and technology-driven solutions, especially in remote areas.

## 3. Analysis and discussion

### 3.1. Fluoride and bone health

Extensive research has shown that excessive fluoride intake is a key factor leading to various health problems, especially posing serious threats to the bones, nervous system and cardiovascular health of children and adults. A large number of epidemiological studies have revealed a close connection between excessive fluoride intake and multiple health issues, particularly in bone health, where the effects are mainly manifested as osteoporosis, reduced bone density and increased risk of fractures. Studies have shown that individuals living in high-fluoride environments for a long time have a significantly higher fracture rate compared to the general population, especially in areas with high fluoride content.

#### 3.1.1. Incidence rate and inducing factors

Several studies have shown that the incidence of fluoride-related diseases is on the rise.According to data from the 2019 Epidemiological Survey of Tea-Drinking Endemic Fluorosis in Qinghai Province,

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the percentage of children with fluorosis in areas with high fluoride concentrations in drinking water was 18.2%, which was significantly higher than the 4.5% in low-fluoride areas. In addition, the incidence of fractures in the adult population chronically exposed to a high-fluoride environment increased by 27% compared with low-fluoride areas.

#### 3.1.2. Case in Qinghai province

According to an epidemiological investigation on endemic fluorosis caused by tea drinking conducted in Qinghai Province in 2019, it was found that the incidence of fractures among residents in high-fluoride areas, especially among adults who have long consumed fluoride-containing tea, was 45% higher than that in low-fluoride areas. Additionally, the incidence of bone density decline and osteoporosis in these areas also significantly increased. This study further supports the close association between excessive fluoride intake and bone health problems. These results indicate that excessive fluoride exposure has a wide range of negative impacts on bone health, and the risk of fractures and osteoporosis significantly increases with the increase in fluoride concentration.

### 3.2. The economic burden of fluoride-related health issues

Fluoride, while recognized for its dental health benefits in trace amounts, can become toxic at higher exposure levels. Chronic intake of excessive fluoride—especially through drinking water—has been linked to serious health conditions, including skeletal fluorosis, neurological disorders, and dental fluorosis. These conditions impose not only a public health challenge but also a considerable economic burden on individuals, governments, and research bodies. This section examines these burdens through three specific lenses: patient medical expenditures, government subsidies and interventions, and investments in scientific research and technological advancement.

#### 3.2.1. Patient medical expenditures

In regions with endemic fluorosis, such as parts of India and China, the cost of treating fluoride-related illnesses significantly affects low-income households. For example, in the Indian state of Rajasthan, where groundwater fluoride levels often exceed the WHO guideline of 1.5 mg/L, residents suffering from skeletal fluorosis require repeated orthopedic consultations, surgeries, and mobility aids. A 2016 study by Choubisa et al. found that the average cost of treatment for a fluorosis-affected household in Rajasthan was approximately ₹12,000–₹20,000 INR ($150–$250 USD) annually, which can exceed one-fourth of a family's yearly income in rural areas [9].

Dental fluorosis treatment, especially among children, also contributes to rising household healthcare costs. In the United States, the CDC reported that moderate to severe dental fluorosis affects about 2% of adolescents aged 12–15 [10]. Treatment costs for cosmetic correction—such as veneers or bleaching—can range from $500 to $2,500 per tooth, often not covered by dental insurance. These costs are particularly burdensome for low-income families and can affect children's psychological well-being and educational performance due to stigma and self-esteem issues.

#### 3.2.2. Research and technological development

Ongoing research into water treatment and fluorosis prevention remains vital. Reverse osmosis (RO) systems, activated alumina filters, and ion exchange methods have shown high efficacy in fluoride removal. In Kenya, for example, a 2020 pilot project in Baringo County successfully reduced groundwater fluoride levels from over 5 mg/L to under 1.0 mg/L using solar-powered RO units, with installation costs of approximately $12,000 per system [11]. Though effective, these technologies are

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capital-intensive and often inaccessible to remote or impoverished communities without government or NGO support.

In terms of academic research, the European Commission funded the FLURESP project (2017–2020), which investigated cost-effective strategies for reducing population fluoride exposure. The project concluded that investment in centralized water treatment was more cost-effective in the long run than individual household treatment systems, especially in regions with high fluoride prevalence.

Moreover, interdisciplinary efforts are improving the early detection of fluorosis and tracking its economic impact. Studies integrating geospatial mapping with socioeconomic surveys in Tanzania and Ethiopia have helped authorities prioritize resource allocation [12].

### 3.3. Major challenges and responses to fluoride-related health issues

Excessive fluoride exposure remains a pressing public health issue, despite growing global awareness and government action. Particularly in developing countries, weak environmental controls, limited public awareness, and inadequate healthcare systems continue to hinder effective prevention and treatment. This section highlights three major challenges and outlines corresponding response strategies.

#### 3.3.1. Difficulty in controlling fluoride pollution sources

Fluoride pollution stems not only from natural sources in drinking water but also from industrial emissions, fertilizers, and contaminated food. In regions with poor regulatory oversight, especially in developing countries, fluoride levels often exceed safe thresholds. For instance, in India's Andhra Pradesh, aluminum production has been linked to increased fluoride contamination and rising cases of skeletal fluorosis [13]. In parts of Africa, phosphate fertilizers contribute to fluoride buildup in crops, affecting food safety [14].

Response: Governments should strengthen environmental monitoring and enforce stricter regulations on industrial emissions and waste treatment. Targeted assessments in high-fluoride zones can help design localized interventions. Public-private partnerships may also support the adoption of cleaner technologies in affected industries.

#### 3.3.2. Lack of public awareness and health education

Many residents in fluoride-affected areas are unaware of the health risks, leading to prolonged exposure. In rural China, surveys showed that few people associated symptoms like joint pain or discolored teeth with fluoride-contaminated water [15]. Children are especially vulnerable due to limited access to preventive care and health information.

Response: Public education campaigns are essential. Schools, local clinics, and media should be used to raise awareness about fluoride risks, particularly targeting parents, children, and community leaders. Promoting safe alternatives like filtered water or low-fluoride foods can also help reduce intake.

#### 3.3.3. Inadequate healthcare resources in high-fluoride areas

Treating fluoride-related diseases such as skeletal fluorosis requires long-term medical care—often unavailable in rural areas. In Kenya's Baringo County, for example, local clinics lack diagnostic tools, delaying treatment and worsening patient outcomes [16]. Similarly, in Ethiopia's Rift Valley, distance and cost prevent many from seeking care [17]. Governments should increase healthcare investment in fluorosis-endemic regions, including mobile clinics, early screening programs, and

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specialized training for local medical staff. Strengthening community-based care and referral systems can help deliver timely treatment to those in need.

## 3.4. Countermeasures

### 3.4.1. Comparative analysis of China and India

Fluoride contamination in drinking water poses a significant public health challenge in both China and India, where large populations are affected by endemic fluorosis. In response, both countries have implemented public health interventions and infrastructure initiatives, albeit with differing strategies and scopes.

China's approach, embodied in the Safe Drinking Water Project, focused on long-term solutions through infrastructure development. Between 2015 and 2020, over ¥1 billion RMB (approximately $150 million USD) was invested in constructing defluoridation plants and distributing fluoride-safe bottled water to rural areas in severely affected provinces like Guizhou and Inner Mongolia. This infrastructure-based solution aimed to reduce fluoride exposure at its source, providing a sustainable remedy to the contamination problem. However, challenges remain, including high costs and logistical difficulties in reaching remote areas.

In contrast, India’s National Programme for Prevention and Control of Fluorosis (NPPCF), launched in 2008, primarily addresses the health impacts of fluorosis by offering diagnostic services and subsidized treatment. With an annual budget of ₹90 crore (approximately $11 million USD) in 2022, the program has expanded to over 100 districts. However, critics argue that the program's focus on treatment rather than prevention has limited its effectiveness. Despite the provision of medical care, there is insufficient emphasis on expanding access to fluoride-safe water or raising public awareness about the issue.

While both nations face financial constraints in addressing fluoride contamination, China's focus on infrastructure investment stands in contrast to India’s reliance on medical treatment. The disparity in funding and preventive efforts highlights the need for a more integrated approach that combines both infrastructure development and public health education to effectively combat fluoride-related health risks.

### 3.4.2. Specific countermeasures for China

Excessive fluoride intake remains a significant public health concern in China, particularly in rural and fluoride-affected regions. To address this issue, a comprehensive approach involving the government, healthcare institutions, and private sector is essential. This paper proposes several countermeasures aimed at reducing fluoride-related health risks.

First, the monitoring and evaluation system for fluoride exposure should be enhanced, with an emphasis on strict monitoring of water sources in high-risk areas. The government should implement advanced monitoring technologies and ensure transparency in data reporting, enabling timely interventions.

Second, research and development in fluoride removal technologies must be accelerated. Cost-effective and scalable water treatment solutions, such as household filtration systems, should be prioritized. Public-private partnerships can drive technological innovation and support the widespread adoption of these solutions in affected regions.

Third, public awareness campaigns are crucial in educating communities about the risks of fluoride contamination and the importance of preventive measures. Health campaigns should focus on safe drinking water, fluoride-free dental care, and the health effects of excessive fluoride consumption.

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Finally, legal frameworks need to be strengthened, with clearer regulations on fluoride levels in water and stricter enforcement at the local level. Local governments should be empowered to enforce these regulations, ensuring compliance and minimizing contamination risks.

In conclusion, a multi-faceted strategy involving enhanced monitoring, technological innovation, public education, and stronger regulatory enforcement is essential to mitigate fluoride exposure in China and protect public health.

## 4. Limitation and future outlook

Our empirical strategy involves combing through the statistics of diseases related to excessive fluoride intake in recent years, analyzing specific cases to determine the impact of fluorosis on bone health. Additionally, the study will also explore the economic burden brought about by fluoride-related bone health issues. These investigations provide us with information on health indicators such as incidence rates and triggering factors, as well as the economic pressure caused by fluorosis, thereby supporting the implementation of empirical strategy. Specifically, the primary sources of the data are epidemiological studies in high-fluoride areas of China and epidemiological investigations of fluorosis.

Although this paper analyzes the skeletal diseases caused by fluoride intake and the related response policies by reviewing the existing literature, there are still certain deficiencies. In terms of data review, the findings of some of the literature are limited, mainly focusing on specific regions or countries, and failing to comprehensively cover fluoride contamination in different parts of the globe. In addition, although existing studies reveal the potential health risks of fluoride, there is a lack of extensive field research data to verify the specific effects of fluoride exposure on the health of the population in different environments, especially in high-fluoride areas such as China, and the difficulty in obtaining data is also a major challenge. As for case studies, due to the complexity of the fluoride pollution problem, there are fewer relevant case studies, especially the lack of long-term evaluation studies on the effectiveness of response measures and technology application.

Looking forward to the future research direction, firstly, field research in different regions should be increased to obtain more representative and extensive data. Second, the optimization of fluoride removal technologies should be strengthened, especially low-cost and high-efficiency water treatment technologies. Meanwhile, future research can further focus on the health effects of long-term exposure to fluoride and the long-term mechanism for the implementation of related policies.

## 5. Conclusion

This study reviews the impacts of fluoride intake on skeletal disorders, discusses current response policies and practices, and suggests corresponding countermeasures. First, the study showed that long-term fluoride intake, especially in areas with high fluoride concentrations in water sources, poses significant risks to human bone health. Specifically, fluoride intake is strongly associated with changes in bone mineral density, increased risk of fracture, and the development of fluorosis, especially as high levels of fluoride exposure may lead to abnormal bone development and, in severe cases, bone deterioration and structural damage. Existing literature supports this conclusion, and studies have focused on China and some high-fluoride areas, providing preliminary data on bone health risks. Moreover, this paper analyzes existing public health policies to control fluoride exposure, and finds that although China and other countries have made some progress in reducing fluoride contamination, improving water treatment technologies, and promoting public health education, there are still deficiencies in policy implementation and technology diffusion, and the management and monitoring of fluoridated water sources, especially in remote areas, still face significant challenges.

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In summary, this study not only reveals the potential hazards of fluoride intake on bone health, but also proposes comprehensive countermeasures to address the inadequacy of existing policies and technologies, which provides a reference for future public health management and technology development.

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