



How widespread is fluoride contamination of Ghana's groundwater?

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Cover – A hand-dug well in northern Ghana. Source: CIFOR


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 English



Fluoride occurrence in groundwater is mainly driven by climatic and geological factors.



Excessive consumption of fluoride in the long run can lead to severe health conditions associated with teeth and bones.



Spatial modelling through machine learning methods can help predict fluoride occurrence in data-scarce contexts such as Ghana where we estimate 920,000 people to be at risk of fluoride contamination.



Fluoride is a naturally occurring chemical element that is often added to [drinking water supplies](#) and dental hygiene products to improve dental health. However, when fluoride levels exceed drinking water guidelines, the health impacts can be serious. Excessive fluoride consumption can affect bone formation and density, leading to conditions such as [dental fluorosis](#), [crippling skeletal fluorosis](#) and [tendon calcification](#).

In Ghana, groundwater is the predominant source of drinking water for many communities, particularly in [rural](#) and [peri-urban](#) regions where water infrastructure is substantially less developed compared to metropolitan regions. Ghana is also a fluorosis endemic nation. [A study of 200 children from Bongo district](#) in northern Ghana revealed that 63% of children were affected by dental fluorosis. However, data on fluorosis and other fluoride-associated health impacts remain scattered and are [not readily available](#). Our study, [recently published in a leading journal, Water Research](#), addresses this knowledge gap by predicting populations at risk across Ghana.

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The presence of fluoride in groundwater is attributed to fluoride-bearing [minerals from soil and rocks, climatic conditions and topography](#). According to World Health Organisation (WHO) standards, the concentration of [fluoride in drinking water should not exceed 1.5 mg/L](#), assuming that the average water intake is 2 L per day for adults. In regions with warmer climates, such as northern Ghana, drinking water consumption could be as high as 3-4 L per day, increasing health risks. Children aged between 0-9 years, [comprising 25% of Ghana's population](#), are particularly vulnerable and can develop permanent teeth issues from excessive fluoride consumption.

Groundwater use is largely unregulated in Ghana - consumers often access groundwater from [private boreholes, hand-dug wells](#) and through informal water vendors. Limited regulation and sporadic testing of groundwater is a constraint to protecting communities exposed to contaminated water.

In the absence of extensive data, environmental and socioeconomic variables can be used to predict the occurrence of, and exposure to fluoride using spatial models with machine-learning. The machine-learning method we applied in our study uses existing data on fluoride contamination to observe the complex relationship between contamination and different environmental factors such as geology, terrain and soil conditions. The observations are then used to predict the probability of fluoride occurrence above or below the threshold of 1.0 mg/L in regions with limited data.

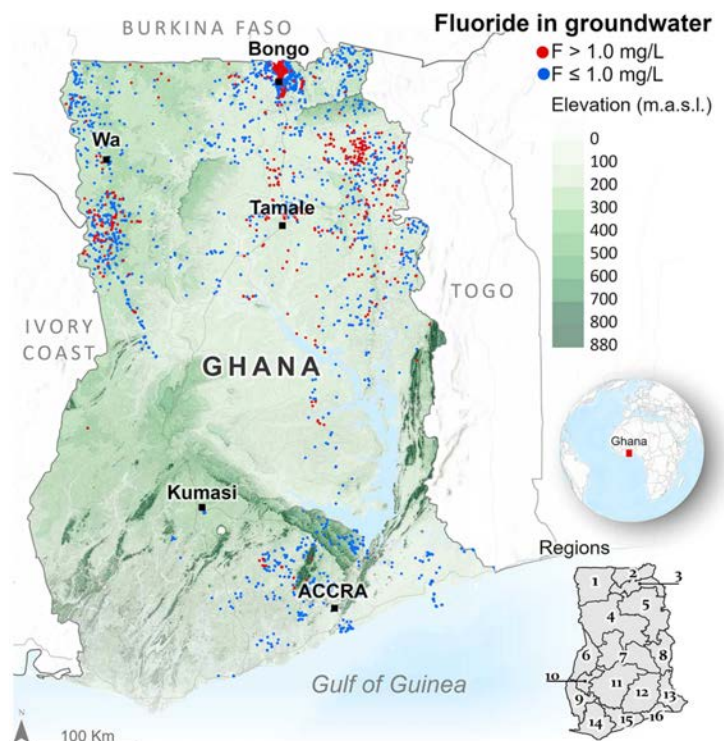
To build a comprehensive assessment of groundwater fluoride contamination for Ghana, we modelled the probability of fluoride occurrence. We used innovative spatial methods to create a hazard map superimposed over data on population and the use of untreated groundwater to estimate the number of adults and children exposed to fluoride contamination. A total of 3,234 groundwater quality measurements from across Ghana were categorised into two classes based on fluoride concentration (Fig.1). The spatial model uses these water quality measurements and 19 geospatial predictor variables of geology, climate, soil and topography. We also used advanced methods to cross-validate the data and to reduce machine-learning biases.

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References
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Regions: 1. Upper West, 2. Upper East, 3. North East, 4. Savannah, 5. Northern, 6. Bono, 7. Bono East, 8. Oti, 9. Western North, 10. Ahafo, 11. Ashanti, 12. Eastern, 13. Volta, 14. Western, 15. Central, 16. Greater Accra

Figure 1 – Fluoride concentrations in groundwater greater than and less than 1.0 mg/L – 3234 samples plotted on a topographic map of Ghana. (Source: authors)

Our model predicts fluoride contamination to be very high in northern Ghana (Fig.2), where districts are predominantly rural and highly dependent on groundwater for drinking. We estimate that about 920,000 people (680,000 adults and 240,000 children) are exposed to contamination across Ghana, with the highest population of children at risk in districts around Tamale, northern Ghana's largest urban centre (Fig.3).

We also found that among the multiple drivers of fluoride occurrence, some variables, such as geology and climate, play a greater role than others. Regions with specific rock types, high temperatures and evapotranspiration are prone to higher fluoride occurrence, particularly in the dry season.

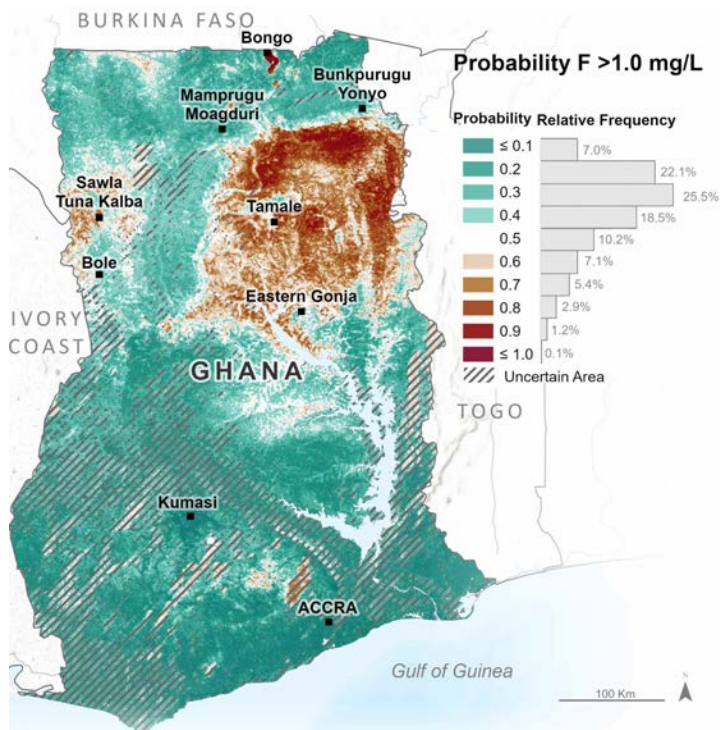


Figure 2 – Hazard (probability) map of fluoride exceeding 1.0 mg/L in groundwater (This map can be viewed in high resolution on the GIS-based Groundwater Assessment Platform (GAP)). Areas hatched grey are regions with uncertain prediction of contamination levels. (Source: authors)

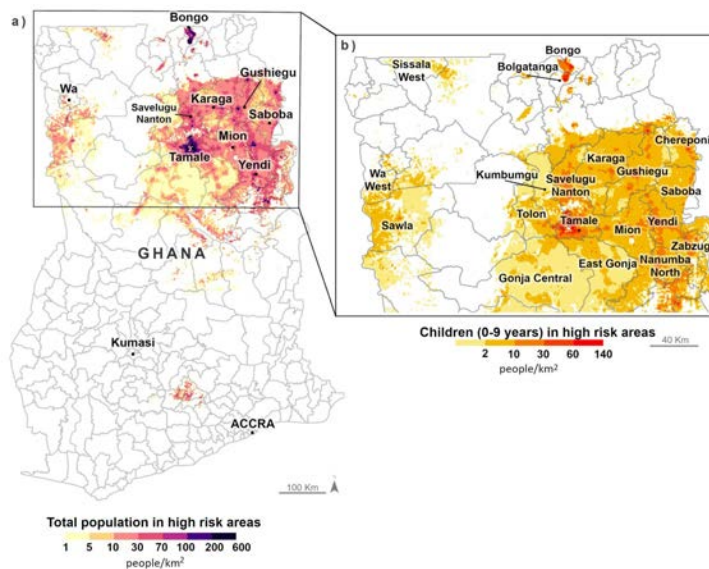


Figure 3 – a) Total population density and b) children population density in the areas at risk of consuming groundwater of high fluoride concentration (>1.0 mg/L). (Source: authors)

The results of our study have the potential to inform water and health policy to mitigate risks and prioritise further research in vulnerable regions in Ghana, including seasonal substitution of water supply in areas with particularly high concentrations of fluoride. More generally, our methodology is highly relevant to predicting risk in other regions that

experience elevated fluoride levels in drinking water and lack the data necessary to respond with effective policies.

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