Research Article

Increased risk of fluorosis and methemoglobinemia diseases from climate change: evidence from groundwater quality in Mayo Tsanaga River Basin, Cameroon.

Wilson Y. Fantong[1*], Alain F. Takounjou[1], Emilia Bi. Fantong[2], Hycinth S. Banseka[3], Cletus D. Gwanfogbe[4], Samuel. N. Ayonghe[5], and Gregory .Z. Tanyileke[1]

1 Institute of Geological and Mining Research (IRGM), Box 4110, Yaounde, Cameroon
2 Graduate School of Science and Engineering, University of Toyama, 3190 Gofuku, Toyama 930-8555, Japan
3 Global Water Patnership, Central Africa, Box 5506, Yaounde, Cameroon
4 Regional Delegation of Public Health, Far North Region, Box 620, Maroua, Cameroon
5 Department of Geology and Environmental Science, University of Buea, Box 63, Buea, Cameroon
*Corresponding author email: fyetoh@yahoo.com

Abstract

Current assessments of the impacts of climate variability and change on water resources commonly exclude groundwater. Thus, the identification of actual and potential health threatening elements in the groundwater, and linking up to climate variation and change at hydrologic catchment scale is an important ingredient for identifying feasible local-scaled adaptation strategies. Against these backdrops the focus of this paper was to assess the implications of climate change on groundwater-derived methemoglobinemia, and fluorosis which have been identified in Mayo Tsanaga River Basin (MTRB), North Cameroon. The basic approach of the study involved collection and analyses of previously published reports and articles that are related to the impact of climate change on water resources in Cameroon. Moreover in addition to groundwater samples that were collected from hand dug wells and boreholes in the dry season, streams, rivers, springs, and dams were sampled in the rainy season. In-situ measurements, and determination of electrical conductivity, pH, water temperature, atmospheric temperature, and alkalinity, respectively, were done. Laboratory analysis of potassium, sodium, calcium, magnesium, chloride, sulfate, nitrate, and fluoride was done by ion chromatography. The succinct results showed that atmospheric averaged annual temperature has increased from 28ºC to 29ºC over the past 40 years. Projected temperature for the year 2030 is 30ºC. Twenty seven percent of the sampled drinking water sources were contaminated by fluoride, which is causing fluorosis. The variation in nitrate suggests that during the dry season water in rivers, springs, dams, boreholes, and shallow wells contained nitrate below the WHO upper limit of 45 mg/l, while in the rainy season some shallow wells were polluted by nitrate. In contrast to the relationship of fluoride with groundwater age and depth, nitrate concentrations increased with decreasing age and depth of the groundwater. Based on the premises that a complex nexus exists between climate change, groundwater quality and health in the study area, adaptation and mitigation strategies were identified, and summarized with the accronym "ADAPT" for: Avoid untreated groundwater from deeper aquifers, Drink water from rain, rivers, and springs, Adopt local drinking water norms, Prohibit shallow well water in the rainy season and Treat young groundwater for nitrate and old groundwater for fluoride before drinking.

Keywords: Climate change. Groundwater quality. Fluorosis. Methemoglobinemia. Adaptation strategies. Mayo Tsanaga River Basin.

Resumé

Les évaluations actuelles des impacts de la variabilité et du changement climatique sur les ressources en eau excluent généralement les eaux souterraines. Ainsi, l'identification des menaces actuelles et potentielles venant de l'eau souterraine et liées aux changements climatiques à l'échelle du bassin hydrologique est un ingrédient important pour identifier les stratégies d'adaptation à l'échelle locale. L'objectif de cet article est d'évaluer les répercussions du changement climatique sur la prévalence de la méthémoglobinémie et de la fluorose lié à la consommation des eaux souterraines qui a été identifié dans bassin versant du Mayo Tsanaga au Cameroun. Ainsi, une étude et analyse des travaux publiés sur l'impact des changements climatiques sur les ressources en eau souterraines au Cameroun a été préalablement réalisée pour mieux orienter les approches. Par ailleurs, des échantillons d'eau souterraine ont été prélevés dans quelques puits d'approvisionnement en eau sélectionnés au hasard. Des mesures in situ concernant la détermination de la conductivité électrique, le pH, température de l'eau, température atmosphérique, et l'alcalinité ont été réalisées. L'analyse en laboratoire des éléments majeurs (potassium, sodium, calcium, magnésium, chlorure, sulfate, nitrate, fluorure) a été réalisée par chromatographie ionique. Les résultats ont montré une augmentation de la température atmosphérique, passant de 28 º C à 29 º C au cours des 40 dernières années ; avec une prévision de 30 º C pour l'année 2030. 27% des sources échantillonnées sont contaminées par le fluorure, qui est à l'origine des fluoroses. Les résultats montrent que, pendant la saison sèche les eaux de rivières, sources, forages et puits peu profonds contiennent une concentration en nitrate inférieure à la limite supérieure de l'OMS qui est de 45 mg/l, alors que pendant la saison des pluies certains puits peu profonds sont pollués par les nitrates. Contrairement à la relation de fluorure avec l'âge des eaux souterraines et de la profondeur de prélèvement, les concentrations en nitrates augmentent avec l'âge et diminuent avec la profondeur de la nappe phréatique. Basé sur l'hypothèse d'une relation complexe entre les changements climatiques, la qualité des eaux souterraines et la santé dans la zone d'étude, cinq stratégies d'adaptation et de mitigation sont présentées.

Mots-clés: Changement climatique, Qualité des eaux souterraines, Fluorose.Méthémoglobinémie, Stratégies d'adaptation, Mayo Tsanaga.

Introduction

Current assessments of the impacts of climate variability and change on water resources commonly exclude groundwater. This omission is of particular concern in the semi-arid zone of Africa where the current usage of water and future adaptations in response to climate variability and change, together with rapid population growth, place considerable reliance upon groundwater to meet domestic, agricultural, and industrial water demands. In a bid to fill up this gap, the first conference that focused on groundwater and climate in Africa was held from 24-28 June 2008, in Kampala, Uganda (IAHS 2008). The key policy-relevant outcomes were summarized in The Kampala Statement, and selected articles were published by IAHS (2009) which among others declared that episodic deterioration in groundwater quality and the risk of waterborne diseases are expected to increase as a result of climate change. It was accordingly recommended that waterborne diseases from contaminated and polluted groundwater be identified to ensure preventive measures, which are less costly than remediation that is often neither feasible nor affordable. In response to this recommendation several research works have been conducted on groundwater and health in Sub-Saharan Africa and reviewed by Adelana et al. (2011). However, none of those findings attempted to show how climate change may impact groundwater-borne diseases such as methemoglobinemia which is caused by nitrate pollution (Hem 1985), and fluorosis which manifests as pitted teeth with white horizontal striations, pitted brown teeth, and un-pitted teeth with black, brown, and chalky coats. Against these backdrops the focus of this paper was to assess the implications of climate change on groundwater-derived fluorosis, which has been identified (Fantong et al., 2010), in Mayo Tsanaga River Basin (MTRB) of Cameroon.

The MTRB is located in the semi-arid Sahel climatic zone of Cameroon (Fig. 1). It experiences a mean annual rainfall of 700 mm, mean annual evapotranspiration of 4118mm, mean annual temperature of about 29°C, mean relative humidity of about 45 %, and has a population of about 500,000 inhabitants who rely entirely on groundwater for household use. Thus, the identification of actual and potential health threatening elements in the groundwater, and linking these to climate variation and change at hydrologic catchment scale is an important ingredient for identifying feasible local-scaled adaptation strategies.

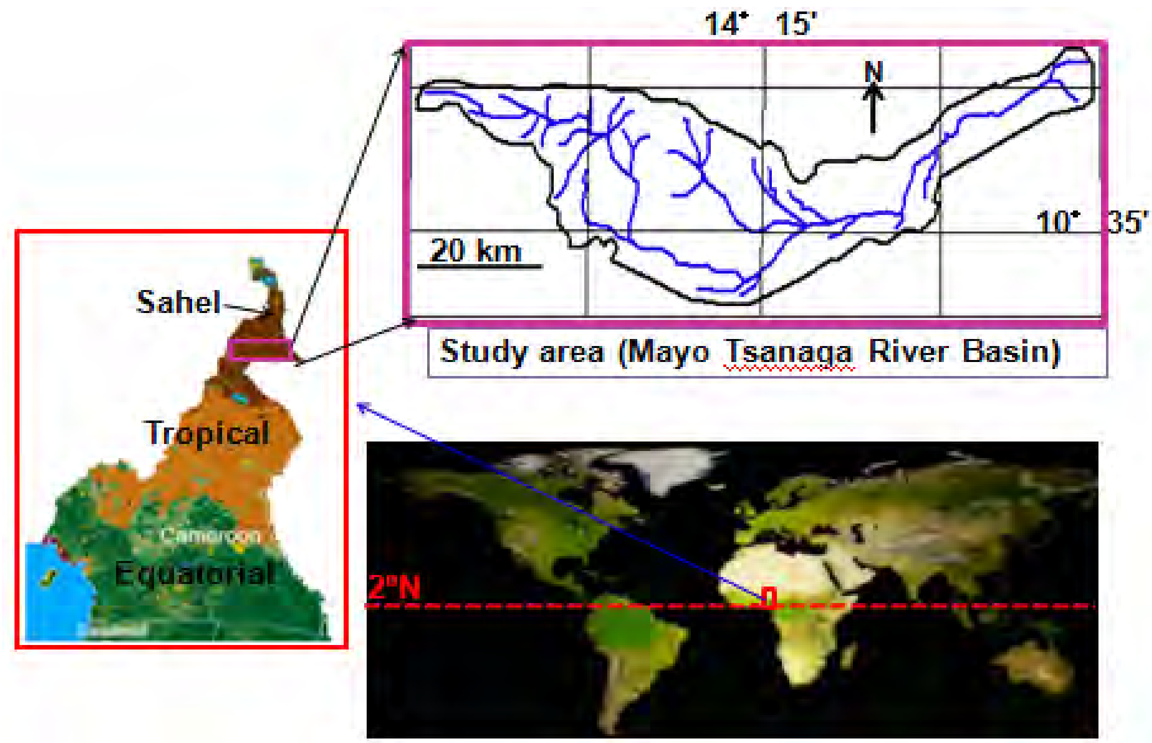

Fig. 1: Location of study area

Method of study

The basic approach of the study involved collecting and analyzing previously published reports and articles that are related to the impact of climate change on water resources in Cameroon. Data were also obtained from official statistics provided by various water stakeholders such as the Global Water Partnership, Ministry of Water and Energy, Ministry of Environment Nature Protection and Sustainable Development, Ministry of Scientific Research and Innovation, Ministry of Higher Education (State Universities), National Institute of Statistics, Meteorological stations, the Climate Change Unit of the United Nations Development Program (PACC)

Moreover, a groundwater sampling campaign was conducted and 101 water samples were collected. The samples were taken from existing water supply wells that were selected randomly, but in a manner that the hydrologic catchment was represented. In-situ measurements, and determination of electrical conductivity, pH, water temperature, atmospheric temperature, and alkalinity, respectively, were done. Laboratory analysis for potassium, sodium, calcium, magnesium, chloride, sulfate, nitrate, and fluoride was done by ion chromatography at the University of Toyama, Japan. Details on the water sampling procedures, freighting of samples, laboratory analyses, and data treatment are presented in Fantong et al. (2009). Investigation of clinical evidence of fluorosis in children was done in the study area by medical doctors who were co-opted during the water sampling campaign and severe cases were diagnosed as shown in Figure 2.

Fig. 2. Diagnosed incidence of groundwater-borne disease (fluorosis) in children of Meri village in MTRB.

Results and discussions

From 1963 to 1990, average annual temperature in the study area has increased from 28ºC to 29ºC with an increase of about 1º C (Fig. 3).

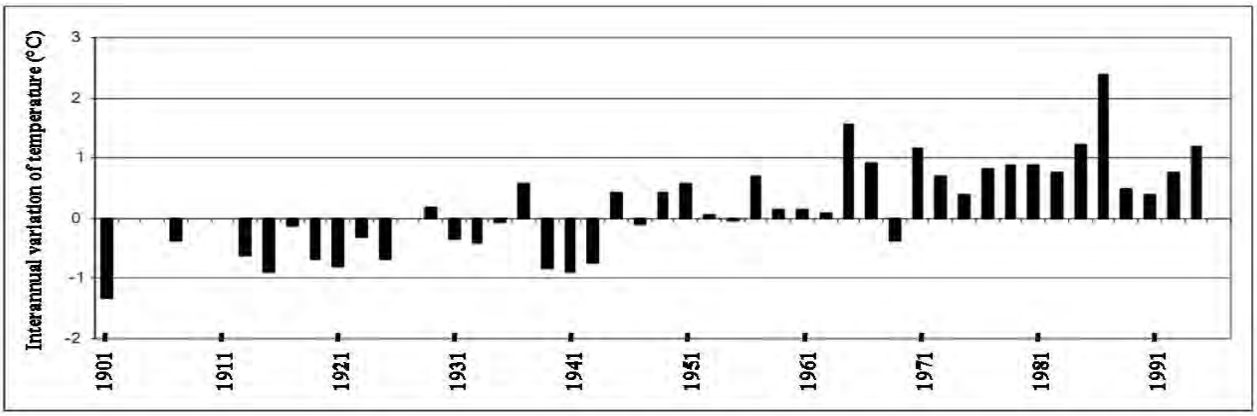

Fig. 3. Variability of inter-annual average temperature in Sahel (study area inclusive)

The projected average annual temperature computed from trend line equations for the year 2030 is 30°C. The variability of rainfall amount (mm) showed a drop from about 900 mm/year in 1950 to about 700 mm/year in 2000 (Fig.4a&b).

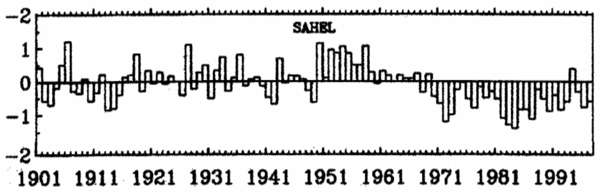

Fig. 4a. Variability of rainfall in Sahel (Study area inclusive)

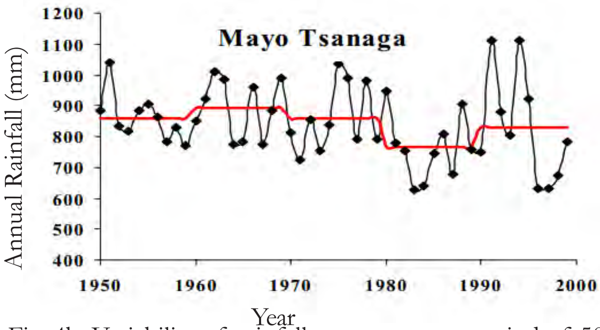

Fig. 4b. Variability of rainfall amount over a period of 50 years in MTRB, showed that annual rainfall dropped from 900 mm to about 850 mm.

The increase in temperature and the decrease of rainfall as a function of time is a succinct indication that climate change is a real phenomenon in the study area. This phenomenon has caused the channels of the Tsanaga river to be void of water for about eight out of twelve months in a year, thus limiting the availability of rainfall and surface water for the livelihood of the ever growing population. Such a limitation of surface water leaves the inhabitants with no other choice than to exploit groundwater for drinking and for various day-to-day activities. The groundwater quality with respect to fluoride concentration (Fig. 5), showed that about 27 % of the sampled sources was contaminated by containing high concentrations of fluoride which is above the WHO (1994) upper limit of 1.5 mg/l. According to Fantong et al. (2010), minerals in granitic rocks are the sources of the fluoride whose concentration tends to increase as a function of increasing groundwater age and depth. The variation in nitrate concentration in the observed water sources is shown in Figure 6, which suggests that during the dry season water in rivers, springs, dams, boreholes, and shallow wells contained nitrate below the WHO upper limit of 45 mg/l (WHO 1984), while in the rainy season some shallow wells were polluted by nitrate. Such a seasonal control of nitrate content in the different water sources could be explained by flushing of municipal waste by rainwater into shallow groundwater at the beginning of the rainy season. Then as the rain water during the rainy season continues flushing, the municipal waste is rid of the nitrate precursors, such that at the beginning of the dry season most of the water resources must have been subjected to either de-nitrification or dilution-processes that require further investigation in the study area. A spatial variation of nitrate concentration as a function of season is shown in Figure 7. In contrast to the relationship of fluoride with groundwater age and depth, nitrate concentrations increased with decreasing age and depth of the groundwater.

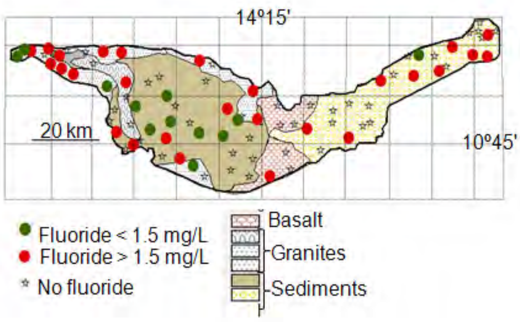

Fig. 5. Spatial distribution of fluoride concentration in groundwater of MTRB

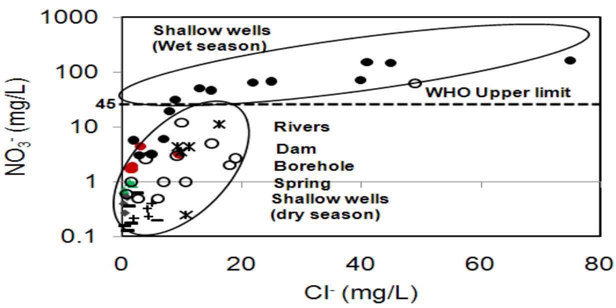

Fig. 6. Nitrate versus Chloride concentrations in water sources in MTRB

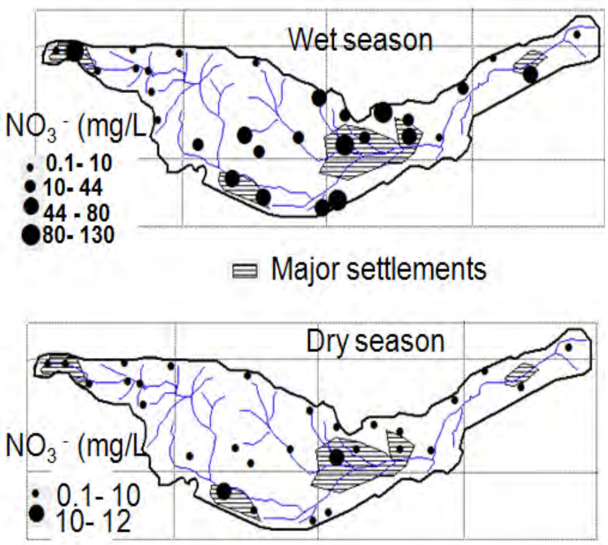

Fig. 7. Seasonal variation of nitrate in groundwater of MTRB

Adaptation and mitigation strategies were identified based on the premises that:

- Groundwater is and shall remain the main source of drinking water in the study area;
- The consumption of the groundwater is causing the incidence of fluorosis;
- The gravity of fluorosis is based on the volume of fluoridated groundwater that is drunk per day;
- The volume of water that is consumed per day is a function of atmospheric temperature;
- Atmospheric temperature that is on a rise in the study area is an index of climate change;
- Nitrate pollution (which causes methamoglobinemia) of the groundwater is a function of season (climate);

Adaptation and mitigation strategies

1) The Gallagan and Vermillion (1957) equation considered an ambient temperature of 16ºC to set the WHO fluoride norms of 1.5 mg/l. Given that in the phase of climate change the average annual ambient temperature in the study area is 29ºC and is projected to increase to 30ºC by the year 2030, the norm of fluoride in drinking water within the catchment should be recalculated and readjusted as a function of the ever changing temperature. Based on this argument, Fantong et al. (2010), proposed that to locally adapt to the present climatic scenario viz-a-viz drinking water quality, the fluoride norm can be readjusted to 0.7 mg/l due to high consumption rate of groundwater especially during drier periods.

2) Before supplying older and deeper groundwater sources in granitic aquifers there-in, it should be controlled for fluoride concentration.

3) Groundwater in shallow aquifers should be avoided for drinking during the rainy season, because it is enriched in nitrate that causes methemoglobinemia.

4) Groundwater in shallow aquifers can be supplied for drinking during the dry season, because it is depleted in nitrate

5) Rainwater and springs should be captured for drinking because they are free of nitrate and fluoride.

6) Strategies to adapt and mitigate to this climate change related diseases can be summarized with the acronym "ADAPT". Where,

A is Avoid the use of untreated groundwater from deeper aquifers,

D is Drink water from rain, rivers, and springs,

A is Adopt local drinking water norms,

P is Prohibit shallow well water in the rainy season, and

T is Treat young groundwater for nitrate and old groundwater for fluoride before drinking.

Conclusions

In the study area, inter-annual variation in average temperature has increased by about 2º C over the past 6 decades, while rainfall has experienced negative anomaly of about -1.5 over the past 4 decades. These climatic trends have caused the population to consume more of the fluoride-rich groundwater which they rely on for household needs such as drinking. The reliance on the groundwater has increased the incidence and severity of fluorosis, and probability of methamoglobinemia.

Acknowledgements

Access to information at the regional office of Global Water Partnership-Yaounde, the Climate Change Laboratory in the University of Buea, and the Climate Change Unit of UNDP-Yaounde, is gratefully acknowledged. Financial and logistical support from Prof. Hiroshi SATAKE (RIP) of the University of Toyama, Japan, and the Grant-in-Aid for scientific Research No: 20-626 from the Sasagawa foundation, Japan are gratefully acknowledged.

Role of authors: Fantong Wilson Yetoh (FWY), conceived the research theme, planned sampling, analyzed the samples and drafted this write up. Alain Fouepe Takoundjou (AFT), Emilia Bi Fantonng (EBF) assisted during sampling and analyses of the water samples, Banseka Hycinth Sunjo (BHS), Ayonghe Samuel Ndonwi (ASN), and Tanyileke Z Gregory (TZG) helped in information gathering and in reorganization of the results. Gwanfogbe Cletus Dinga (GCD) is the medical practitioner who diagnosed the incidence of fluorosis during field work.

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Received: 21/04/13
Accepted: 29/07/13