

OXIDATION PHENOMENON OF FERROUS TO FERRIC IRON IN WATER SOURCES OF BUI DIVISION, NORTH WEST REGION OF CAMEROON

(Case study of Mbiame water catchment)

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Abstract: Oxidation is accompanied by addition of oxygen or a loss of electron by a species. Aluminium and iron were dominant heavy metals in Bui water bodies. Iron has two oxidation states (Fe^{2+} and Fe^{3+}). Fe^{3+} is more stable, accounted for by the stability of electrons in its atomic orbitals, whereas the unstable state converts to the more stable form. Oxidation was observed in Bui water sources, very pronounced at Mbiame catchment in Mbven subdivision. The consequence of this oxidation phenomenon was the predominance of a reddish-brownish colouration. This was glaring as water samples changed colour from greenish to reddish on exposure in a beaker few minutes after sampling indicating intense aerial oxidation. This phenomenon is characteristic of transition metals with variable oxidation states and produce coloured solutions. The process expressed in this article does not compromise water quality. The concentrations Al and Fe remained within suitable limits for water consumption, stipulated in norms such as the World Health Organisation (WHO, 2004, 2008). A paradigm shift is made from the assertion wherein coloured water was generally considered unsuitable for human consumption particularly drinking.

Keywords: water colouration, ferrous and ferric iron, transition metals.

1. INTRODUCTION

It is universally acknowledged that one criterion for acceptability of water quality for drinking is that it should be colourless. Nonetheless there are numerous water bodies that possess some colour and are still acceptable for drinking within norms stipulated by some organizations. Amongst the coloured water bodies in Bui division, North West Region of Cameroon the particular case of water from a catchment in Mbiame, Mbven subdivision is at the centre of this article. Colloidal reddish precipitates were encountered conspicuously at the water source and colourless water samples collected changed to a reddish/yellowish colouration on exposure to the atmosphere. This phenomenon was suggested to be controlled by the iron rich rocks within the vicinity of the water catchment. The role played by iron in determination of this colour forms the centre of this research article

2. LOCATION OF MBVEN SUBDIVISION (MBIAME WATER CATCHMENT)

Mbiame water catchment at height of 2110m above sea level (a.s.l) with geographical coordinates at sampling point; Longitude E010° 48' 37.2" East of the Greenwich Meridian and 06° 13' 04.6" North of the Equator, is shown in Fig 1; a, b and c. Fig 1 (a) indicates the North West Region in Cameroon, Fig 1 (b) Bui division in the North West region and Fig (c) Mbven subdivision of Bui division. Mbven subdivision has boundaries, with the West Region of Cameroon, Jakiri, Nkum, and Kumbo subdivisions of Bui division

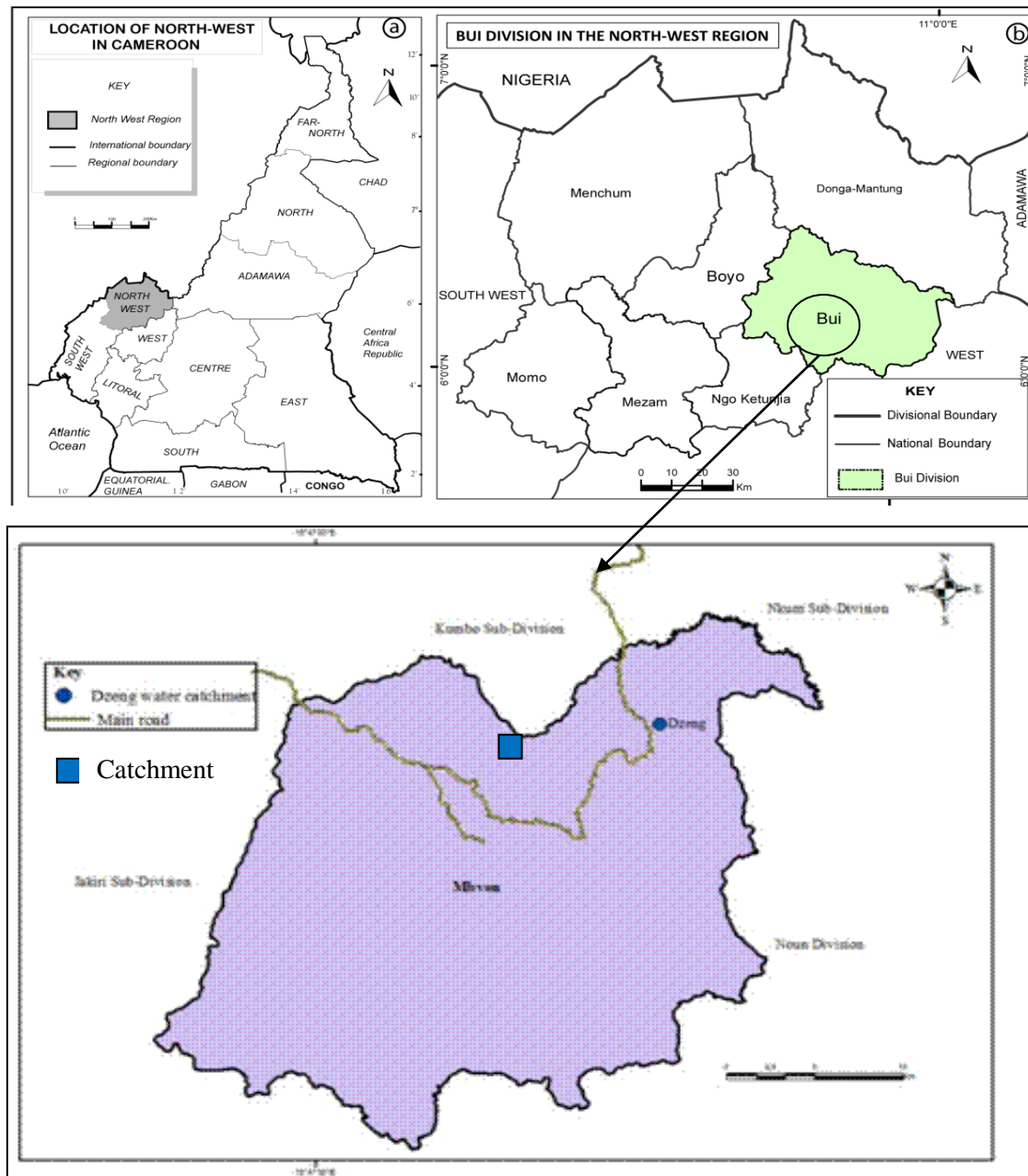


Fig 1: Position of the study site (a) The North West region in Cameroon (b) Bui in the N.W region (c) Mbven division (Landsat, 2015).

3. THE GEOLOGICAL CONTEXT OF THE CATCHMENT

3.1 Rocks in Mbven subdivision (Basaltic lava; mafic, Trachytic lava; felsic)

Mbven subdivision in Bui division is part of the Bamenda highlands, a northward extension of the Bambouto Mountain part of the continental Cameroon Volcanic Line (C.V.L). The dominant geologic formations are basalts and trachytes similar to those of the Bambouto Mountain as revealed in works of (Gountie 2004, 2011; Youmen 1994, 2005; Tabue 2000; and Kagou *et al.*, 2010). A synthetic review of the geological setting of the Bambouto Mountain, proposed by (Kagou *et al.*, 2010) indicated that, the first stage 21 million years ago corresponded to the building of an initial basaltic shield volcano. The second stage from 18.5 to 15.3 million years ago was marked by the collapse of the caldera linked to the pouring out of ignimbrites, rhyolites and trachytes. The third stage from 15 to 4.5 million years ago renewed with basaltic effusive activity together with post-caldera extrusions of trachytes and phonolites. In these works, the Bambouto

Mountain was proven to be of volcanic origin which is same with its northern extension the Bamenda highlands in which Mbiambe water catchment our study area is found. These observations strongly agreed with the field realities. Field observations proof that trachytes, and basalts are the dominant rocktypes. To the trachytes are often associated phonolites, rhyolites and ignimbrites.

Trachytes are formed from felsic lava that constitutes rocks like, phonolite, rhyolite and ignimbrite. The trachytes have as minerals, alkaline feldspars, plagioclase, clinopyroxene, biotite and oxides. Basalts are aphyric (aphanitic) and porphyric (porphyritic) in texture. Aphyric basalts were found within the locality of the water catchment. The basalts are mafic lava, generally dark grey to black massive and compact. Mineralogically, basalts contain olivine, pyroxene, plagioclase, calcite and oxides of major elements. The minerals present in the rocks were summarized in Table 1

Table 1: Minerals and Chemical composition (Whitten et al., 1978)

SITE	ROCKTYPE	MINERALS	CHEMICAL COMPOSITION
Mbiambe	Basalts/Trachytes/Phonolites	Olivine Calcite Pyroxene (augite) Apatite	Mg_2SiO_4 Fe_2SiO_4 $CaCO_3$ $(Ca, Mg, Fe, Al)_2(Al, Si)_2O_6$ $Ca_2Cl_5(PO_4)_3$

Weathered rock samples and the dominant basaltic rock within the vicinity of the water catchments were presented in Fig 2.



(a) Weathered rock

(b) Basalt

Fig 2: Mbiambe water catchment

4. METHODOLOGY; CHEMICAL ANALYSIS (LABORATORY WORK)

This was done using HI 83200 Multiparameter Bench Photometer produced by Hanna instruments Inc in the Highland industrial park of the United States of America. It was an instrument that measures 44 different parameters using specific reagents. The amount of reagent was precisely dosed to ensure maximum reproducibility. This was done by scrupulously respecting the prescribed quantities as stipulated for each method for the particular parameter. Heavy metals including transition metals with a characteristic of rendering coloured solutions were of interest in this article and a result of the tested metals were presented in Table 2.

5. RESULTS AND DISCUSSION

Al, Fe, Cu, Ni, Mn, and Zn were the heavy metals evaluated in the water samples. Aluminium (Al^{3+}) had a calculated average concentration of 0.62 mg/l with 0.21 mg/l of Iron in the water samples, which agrees with the fact that they are respectively third and fourth most abundant elements in the earth's crust. In Mbven subdivision of Bui division, Iron was found present in the water indicating a prevalence of iron rich rocks within the vicinity of the water sources. The reason for the low concentration of these elements was because of their immobility and tendency to form precipitates, due to their high charge. The other heavy metals, Cu, Zn, and Mn were not identified in the water sources whereas concentration of

0.01 for Ni was considered negligible. Rain water as it infiltrates the soil and underlying geologic formations dissolves iron carrying it deep into the aquifers that serve as sources of groundwater. Concentrations of some heavy metals in Mbiame water catchment were presented in Table 2.

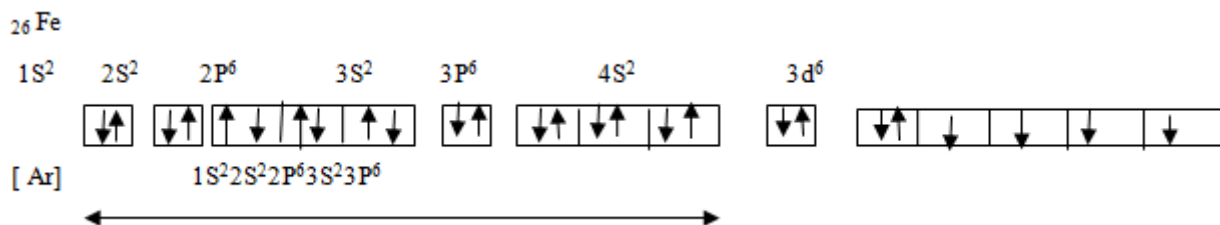
Table 2: The concentrations of some heavy metals in the Mbiame water catchment

SITE	DATE	Fe ³⁺	Al ³⁺	Zn ²⁺	Mn ²⁺	Cr ³⁺	Ni ⁺	Cu ²⁺
Mbiame	12-02-16	0.18	0.17	0.00	0.00	0.00	0.01	0.00
	31-05-16	0.29	0.16	0.00	0.00	0.00	0.00	0.00
	06-08-16	0.19	0.14	0.00	0.00	0.00	0.00	0.00
	18-11-16	0.33	0.15	0.00	0.00	0.00	0.00	0.00
	20-03-17	0.18	0.20	0.00	0.00	0.00	0.00	0.00
	15-09-17	0.21	0.23	0.00	0.00	0.00	0.00	0.00

5.1. Role of iron in colouration

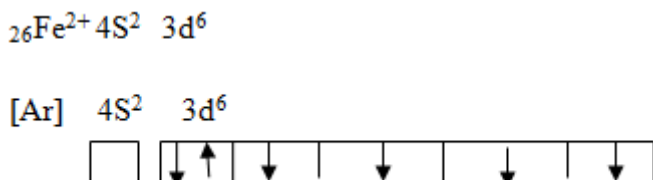
Though present in drinking water it is seldom found with concentrations > 10mg/l (Freiberg *et al.*, 1979; Alloway *et al.*, 1997; Ingersoll *et al.*, 2000). However as little as 0.3mg/l it can cause water to turn reddish brown in colour a phenomenon observed in Mbiame (MBI) where clear water samples turned reddish to brown a short while after exposure to air. Iron is mainly present soluble in the Fe²⁺ state while insoluble in the Fe³⁺ state. Water with Fe²⁺ is slightly clear (with faint greenish colour) but on exposure to air the water turns reddish brown because the Fe²⁺ state is oxidized to the more stable Fe³⁺. The collected samples were immediately firmly corked and this oxidation reaction was prevented. The stability of the Fe³⁺ with respect to Fe²⁺ is explained from their electronic distribution in the atomic orbitals.

Iron with atomic number 26 has its electronic configuration and the distribution of electrons in atomic orbitals as expressed using electron in box representation.

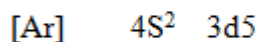
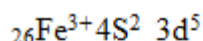


Oxidation (loss of electrons involves only the outer shell with 4S and 3d atomic orbitals. The 4S has one atomic orbital and can contain a maximum of 2 electrons where as the 3d has 5 atomic orbitals and can contain a maximum of 10 electrons when completely filled.

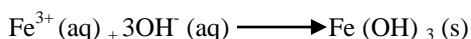
The formation of Fe²⁺ involves a loss of two electrons from the 4S² atomic orbital in Fe to produce an electron in box arrangement illustrated below.



Stability of electrons in shells of an atom is when atomic orbitals are filled with two electrons or half filled with a single electron, while instability is encountered when the orbitals are partially filled. Fe²⁺ with a partially filled atomic orbitals in 3d⁶ will readily loss one electron to provide single filled atomic orbitals (3d⁵) to which stability is associated. Consequently, Fe³⁺ is the most stable oxidation state and responsible for the dominantly reddish- brownish colouration in the water sources.



The high charge of +3 in Fe³⁺ causes this ion to combine with OH⁻ to form reddish precipitates responsible for the colloidal deposits in the water sources.



The low concentrations for the other heavy metals were negligible and their interference with respect to their colours equally of no significance. The relative high concentrations of Al and Fe as compared to the other metals agree with their abundance in the earth's crust with Al being most abundant followed by Fe.

6. CONCLUSION

A paradigm shift could be made from the allusion that all coloured water is considered as unsuitable for consumption. The view expressed in this article wherein colour is linked to inherent chemical properties dominated by incidence of iron in its Fe³⁺ stable form. Nonetheless, coloured water should be put in question as the colour source could be from the presence of pollutants that render the water unsuitable for diverse purposes. The dominantly coloured water samples and colloidal precipitates observed at Mbiame water catchment and other water bodies were accounted for by the phenomenon of oxidation.

ACKNOWLEDGEMENTS

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REFERENCES

- [1] **Alloway, B.J and Ayres D.C (1997).** Chemical principles of environmental pollution. Blcakie Academic Professional, an imprint of Chapman and Hall, London, 394pp.
- [2] **Freiberg, L., Norberg, G.F., Vouk, B.(1979).** Handbook on the toxicology of metals. Elsevier/ North Holland Biomedical Press, Amsterdam, New York, Oxford.
- [3] **Gountie, D.M. (2004).** Séquence lithologique et étude géologique du versant Sud des monts Bambouto.Mem. DEA.Univ, Yde.I. 56p
- [4] **Ingersoll, C.G., MacDonald, D.D., WANG, N., Severen C., et Smorong, D.E. (2000).** Prediction of sediment toxicity using consensus- based freshwater sediment quality guidelines U.S. Environmental Protection Agenc (USEPA), Chicago.
- [5] **Kagou,D.,Nkoathio,D.,Pouclet,A.,Bardintzeff,J.M.,Wandji,K.,Nono,A., Katri Ots and Malle Mandre. (2011).** Monitoring of heavy metals uptake and allocation in Pinus sylvestris organs in alkalized soil. Environ Mont Assess DOI 10.1007/s 1066- 011- 2247- 8.

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- [6] **Tabue, J. G. (2000).**Influence de la nature lithologique sur la qualité des eaux de sources: Casde Fokamezoung – Doumbouo. Mem. Maît. Univ.Dschang.
- [7] **Whitten, D.G.A. and Brooks, J.R.V. (1978).** A Dictionary of Geology. Penguin books, pp 494- 511.
- [8] **W.H.O. (2004).** Guidelines for drinking-water quality (3rd edition) Geneva, Switzerland.
- [9] **W.H.O. (2008).** Guidelines for drinking- water quality. Third edition, Volume I.
- [10] **Youmen, D. (1994).** Evolution volcanique pétrographique et temporelle de la caldeira des Monts Bambouto (Cameroun). Thèse Kiel, 273 p.