THE OCCURRENCE OF FLUORIDE CONTAMINATED MAGADI (TRONA) IN KENYA AND TANZANIA

J M Nielsen* and E Dahi*

SUMMARY: The concentration of fluoride is measured in crystalline and scooped magadi originating from 5 alkaline lakes in Tanzania and Kenya and in scooped magadi from Northern Tanzania. The fluoride concentration is found to be comparable to what has been reported so far. The fluoride concentration varies from 0.12-17.9 mg/g magadi for crystalline magadi and from 0.10-5.09 mg/g for scooped magadi. The concentration is subject to considerable variation even for magadi originating from a given lake. The alkaline lakes, Lake Balangida, Lake Eyasi, Lake Magadi, Lake Manyara, and Lake Natron show fluoride concentrations of 0.13-17.9, 0.29-7.4, 0.12-8.7, 0.16-4.4, and 0.71-9.66 mg/g magadi respectively.

Key words: Magadi, food, alkaline lakes, fluoride, fluorosis

INTRODUCTION

The mineral trona, $Na_2CO_3 \cdot NaHCO_3 \cdot 2H_2O$, is an evaporite mineral which can be found at the alkaline lakes (crystalline) or as an efflorescent crust (scooped) on the earth's surface in the Rift Valley of East Africa. Trona, locally called magadi, is often contaminated with fluoride which is caused by the high fluoride content of the volcanic rocks enriched in alkalis in the rift zone.[1]

In East, West, and Central Africa magadi is used in food preparation as a tenderiser to speed up the cooking process for food such as beans, maize, and meat, as a flavouring agent, and as food preservative.[2-11]

It has been reported that in trona, fluoride is occurring as villiaumite, NaF, and as kogarkoïte, $Na_2SO_4 \cdot NaF$[12,13], and that the fluoride concentration in magadi varies between 0.2 and 14.9 mg F^-/g magadi.[5,8,12,14] Studies have shown that the use of magadi heavily contaminated with fluoride contributes to the high fluoride intake in fluorosis areas of East Africa. In fact, in some cases the fluoride uptake from magadi may be higher than that from water.[5]

This paper presents results of measurements of fluoride concentration in magadi originating from Tanzania and Kenya and the concentration's dependence on the form and origin of the magadi is elucidated.

MATERIALS AND METHODS

Magadi Samples, both scooped and crystalline, have been collected from Lake Balangida, Lake Eyasi, Lake Manyara, and Lake Natron in Tanzania (see location in Figure 1) and bought at different markets in Kenya and Tanzania. The origin of the magadi samples were determined according to the information given by the dealers. The amounts of magadi collected and bought were very different, therefore an available amount of magadi was crushed and homogenised in a mortar and 2.00 g was dissolved in 100.0 ml distilled water. Thereafter the fluoride concentration was measured in the solution.

* *Center for Developing Countries, Technical University of Denmark, 2800 Lyngby Denmark.*

Fluoride measurements: The fluoride concentrations were measured using a Radiometer F1052 fluoride electrode and a Metrohm Ag/AgCl reference electrode with a sleeve type diaphragm connected to a Metrohm potentiometer (692 pH/Ion Meter). A 10-ml sample of the solution was mixed with 10 ml CDTA-tisab and the fluoride concentration was measured using the calibration method, according to Standard Methods.[15]

RESULTS

The crystalline and scooped magadi from Kenya and Tanzania are very different in colour and form, ranging from crispy flakes mixed with light brown soil to long grey crystals shaped like needles of a length of 30 mm.

The fluoride concentration in the magadi reported by other researchers can be seen in Table 1.

In Figure 2 the fluoride concentration in magadi samples from this study, 94 in total, is plotted on logarithmic probability paper.

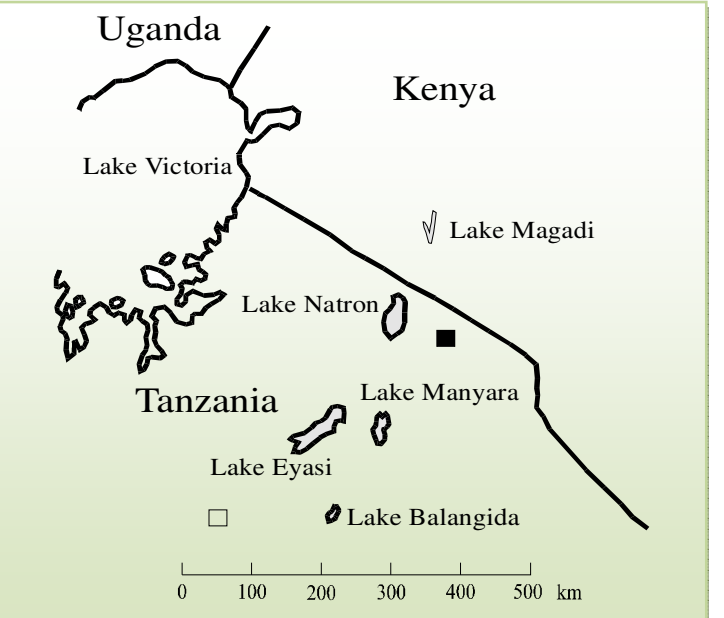

FIGURE 1. Map of the alkaline lakes in Northern Tanzania and Southern Kenya. See Table 1 for explanation of ■ and □.

TABLE 1. The fluoride concentration in magadi samples from Northern Tanzania and Lake Magadi, Kenya. For location see Figure 1.

Source (village/river/lake)	Fluoride (mg/g)	n	Reference	Location
Sepuka	0.036-0.18	22	Mabelya et al.[5]	□
Kiomboi	0.69-6.8	9	Mabelya et al.[5]	□
Engare Nanyuki River	0.20-6.0	11	Nanyaro et al.[14]	■
Kitefu	0.9-14.9	3	Mungure[8]	■
Kimandafu	2.80-7.4	3	Mungure[8]	■
Lerai	6.5-7.4	2	Mungure[8]	■
Kikatiti, near spring	0.80	1	Mungure[8]	■
Lake Natron	6.2	1	Adhia[16]	
Lake Magadi	4.0	1	Baker[12]	

In Figure 3 box plots of the fluoride concentration in crystalline and scooped magadi samples can be seen. The number of crystalline and scooped samples are 79 and 15 respectively. The ends of the box are the 25th and 75th percentiles, so that the length of the box is a measure of the spread; that gives the range covered by the middle half of the data. The line within the box is indicating the median value and the two lines (whiskers) outside the box extend to the smallest and the largest observation.

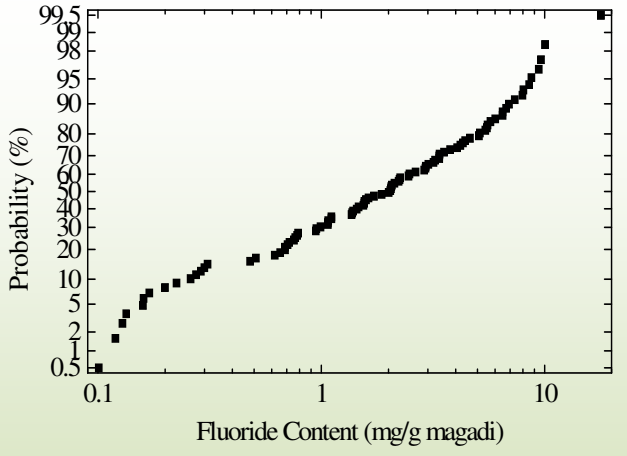

FIGURE 2. The fluoride concentration in magadi samples from this study plotted on logarithmic probability paper.

In Figure 4 box plots of the fluoride concentration in lake samples can be seen. The samples originate from Lake Balangida, Lake Eyasi, Lake Manyara, and Lake Natron, Tanzania and from Lake Magadi, Kenya and the number of samples from each lake are 18, 8, 11, 20, and 17 respectively.

this study plotted on logarithmic probability paper.

The box plots are worked out like in Figure 3, e.g. the ends of the whiskers are the smallest and the largest observation, the ends of the box represent the 25th and 75th percentile and the line within the box is the median value.

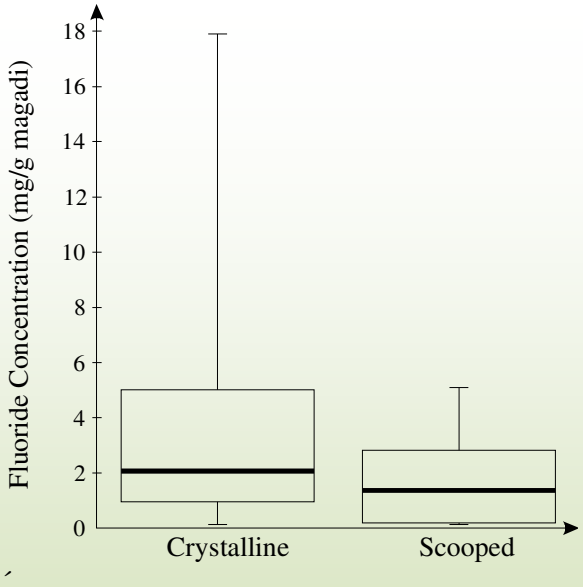

FIGURE 3. Box plot of the fluoride concentration in crystalline and scooped magadi samples. The box illustrates the 25th, 50th, and 75th percentiles, while the lines illustrate the lowest and highest measurements. results from this study and from Baker12 and Adhia16.

DISCUSSION

Looking at Figure 2 it can be observed that the fluoride concentration in the magadi samples is subject to considerable variation. The same tendency is observed from results reported by other researchers (see Table 1). The fluoride concentration in samples from Kitefu reported by Mungure[8] ranges from 0.9 mg/g to 14.9 mg/g and Nanyaro and coworkers[14] report fluoride concentrations between 0.2 and 6.0 mg/g in 11 different samples from the Engare Nanyuki River system.

In Figure 2 where all samples from this study are shown it can be seen that 50% of the samples have a fluoride concentration equal to or lower than 2.0 mg/g, and the 25th and 75th percentiles are 38% and 208% of the median respectively.

The cumulative frequency curve is not a straight line, thus the logarithmic fluoride concentration in the magadi samples is not normal distributed.

Some differences are observed when the samples are divided into 2 different groups representing their form, e.g. crystalline and scooped like seen in Figure 3. The variation, the length of the box, is bigger for crystalline samples than for scooped samples, even though the number of samples is higher, 79 compared to 15. The fluoride concentration is in general lower in scooped magadi than in crystalline, all scooped magadi samples have a fluoride concentration lower than 5.1 mg/g, whereas it is only 75% of the crystalline magadi samples.

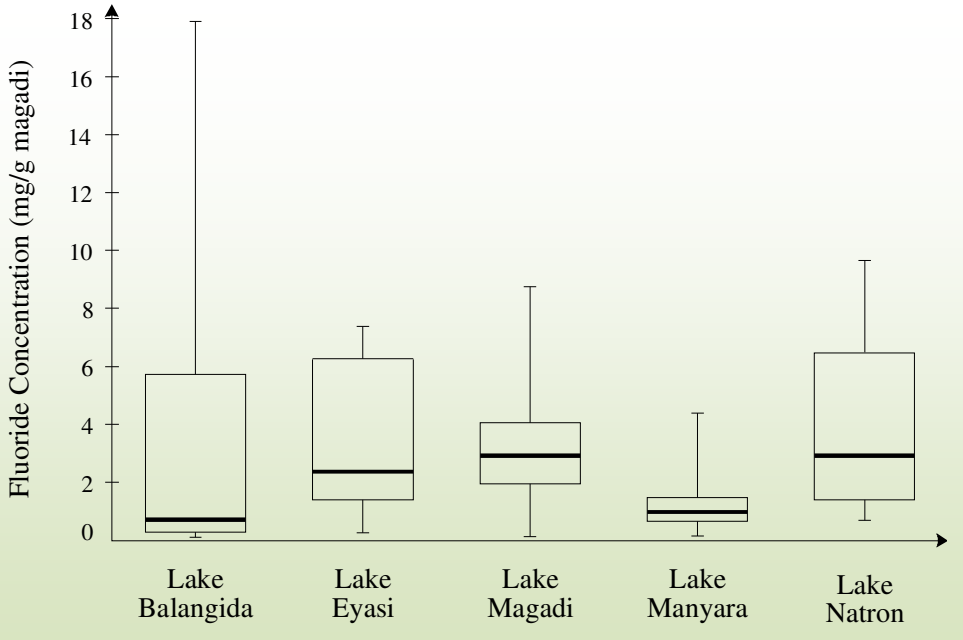

FIGURE 4. Box plot similar to Figure 3, for magadi samples divided into 5 groups representing the individual lakes. results from this study and from Baker[12] and Adhia[16].

The samples have also been divided into 5 groups representing their origin, Lake Balangida, Lake Eyasi, Lake Manyara, and Lake Natron from Tanzania and Lake

Magadi from Kenya (see Figure 4). The median fluoride concentrations in magadi from Lake Balangida, Lake Eyasi, Lake Magadi, Lake Manyara, and Lake Natron are 0.73. 2.39, 3.19, 0.99, and 2.94 mg/g respectively, and the variations, the length of the boxes are high, especially for Lake Balangida, Lake Eyasi, and Lake Natron. The upper quartile of the fluoride concentration for these three lakes are equal to 5.7-6.5 mg/g compared to 4.1 mg/g for Lake Magadi and 1.5 mg/g for Lake Manyara. The fluoride concentration in magadi from Lake Manyara is in general lower than in magadi from the other lakes.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the financial support from Danida through the Enreca Program (Grant no. 104.Dan.8.L/902).

REFERENCES

1. Gerasimovskiy VI, Savinova YN. Fluorine Content of Volcanic Rocks in the Rift Zone of East Africa. Geochemistry International 6 1124-1128 1969.
2. Ankrah E K, Dovlo FE. The properties of Trona Known as Kawe and Its Effect on the Cooking Time of Cowpeas. Journal of Science of Food and Agriculture 29 950-952 1978.
3. Hill MF. Magadi. The story of the Magadi Soda Company. Kynoch Press, England 1964. 199 pp.
4. Kisanga P, Lyamuya V. The Prevalence of Dental and Skeletal Flurosis and the Role of Diet and Nutritional Status in Determining Its Development: The Case of Kitefu Village, Maji ya Chai, Arusha. In: Proceedings of the 6th Annual Scientific Conference: Maternal and child health, family planning - monitoring and evaluation. Morogoro, Tanzania Public Health Association 1987 176-190.
5. Mabelya L, König KG, van Palenstein Helderman WH. Dental Fluorosis, Altitude, and Associated Dietary Factors. Caries Research 26, 65-67 1992.
6. Makanjuola AA, Beetlestone JG. Some Chemical and Mineralogical Notes on Kaun (Trona). Journal of Mining Geology 10 31-41 1975.
7. Malentlema TN. The likely increase of fluoride uptake due to type of diet of the people in Tanzania. In: Report on Workshop on Domestic Water Health Standard with Emphasis on Fluoride. 21-23 June 1982. Arusha, Ministry of Water and Energy, 118-122.
8. Mungure JS. Incidences of Fluorosis and Possible Fluoride Sources in Maji ya Chai Ward of Arumeru District. In: Proceedings of the Second Workshop on Domestic Water Health Standards with Emphasis on Fluoride. (Edited by F. Gumbo, Ministry of Water, United Republic of Tanzania) Arusha 1987 33-41.
9. Sodipo OA. How Safe Is the Consumption of Trona? [letter]. American Journal of Public Health 83 1181 1993.
10. Uzogara SG, Morton ID, Daniel JW, Emery PW. Use of Kanwa-cooked Cowpea (Vigna unguiculate) in Infant Food Formulation: Effect on Protein Utilization and Digestibility [letter]. Journal of Tropical Pediatrics 36 207-208 1990.

11. World Health Organization. Fluorides and Oral Health. Report 846, 40p. WHO Technical Report Series. Report of a WHO Expert Committee on Oral Health Status and Fluoride Use, 1994 Geneva, Switzerland.
12. Baker BH. Geology of the Magadi Area. Report 42. Geological Survey of Kenya, Nairobi, Kenya 1958. 81pp.
13. Darragi F, Gueddari M, Fritz B. Presence of Kogarkoïte (Na3SO4F) in the Salt Paragenesis of Lake Natron in Tanzania. (in French). Comptes Rendus de l'Academie de Sciences Serie II 297 141-144 1983.
14. Nanyaro JT, Aswathanarayana U, Mungure JS, Lahermo PW. A Geochemical Model for the Abnormal Fluoride Concentrations in Water in Northern Parts of Tanzania. Journal of African Earth Sciences 2:2 129-140 1984.
15. Standard Methods. Standard Methods for the Examination of Water and Wastewater. AP Health Association, 18th ed., Washington 1992, ISBN 0-87553-207-1.
16. Adhia JD. Techno-economic Study. A Small Scale Soda Ash Production Plant near Lake Natron. United Nations Industrial Development Organisation. 1983.