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Fluoride levels in water and fish from Lake Magadi (Kenya)

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Abstract

Water entering Lake Magadi from a spring contained 73 mg fluoride (F) l^{-1}, while samples taken 100 and 400 m from the spring were estimated to contain 110 and 140 mg F l^{-1}. Evaporation apparently increased the F and salt concentrations to levels at which the common method of F analyses became unreliable, even after dilution. It is recommended to re-examine the very high F levels reported in the saline lakes of Rift Valley. The F levels of *Tilapia grahami* living in water with about 110 mg F l^{-1} averaged (mg F kg^{-1} dry weight): fillet 68, skin 819, gills 1,366 and bones 1,661. The variation was highest in fillet and skin. There was no positive correlation between tissue F levels and fish size (range 3–20 g). It remains uncertain whether the fish bone was saturated at this concentration of F or if some mechanism of elimination hindered higher F accumulation in the skeletal structures.

Introduction

The fluoride (F) levels are very high in some lakes of Africa's Great Rift Valley. Concentrations up to 2.8 g F l^{-1} ($1.5 \cdot 10^{-1}$ M F) have been reported (Manji & Kapila, 1984), which on a world wide basis seem to be the highest reported F-levels in water (Bell *et al.*, 1970). Several species of tilapia survive in the extreme conditions of salinity, pH and temperature of these lakes (Reite *et al.*, 1974).

Lake Magadi, located in the Kenyan part of Rift Valley, is inhabited by the species *Tilapia grahami* (Reite *et al.*, 1974). The lake has no river outlet and acts as an evaporating pan for inflowing water and hence salt production. A concentration of 1.48 g F l^{-1} ($7.8 \cdot 10^{-2}$ M F) has been reported in the lake (Kariuki *et al.*, 1984). Aquatic organisms living in high-F environments accumulate F, and their skeletal F levels have been correlated with the concentration of F in the environment (Sigler & Neuhold, 1972).

The present investigation aimed at studying tissue levels and accumulation of F in fish living in water with a very high F concentration.

Material and methods

Sampling

The water and fish samples were collected in November 1989. Water samples were collected in 500 ml polyethylene bottles directly from a spring entering the lake and at sites 3, 100 and 400 m

from the spring. A total of 118 fish with a mean weight of 12 g (range 3–20 g) were caught in finely mashed nets in a lagoon of the lake. Most fish weighed between 11 and 16 g. Fish of approximately the same weight were grouped together (9 groups) and brought to the laboratory where they were carefully dissected to separate fillet, skin, gills and bones. Tissues from the same group of fish were pooled together.

F Analyses

The levels of F were determined using a digital pH-mV meter (3020 Orion®, Cambridge Mass., USA) and a F specific ion electrode (Orion® 96-09). The calibration of the F electrode was repeatedly checked with appropriate standards during the measurements.

Water. Because of the high salinity and alkalinity (pH 10.0–10.2) of the water, it was anticipated that it could become difficult to complex interfering ions and adjust the pH to provide acceptable analytical conditions for the F determination. Measurements were done with both TISAB II (Orion® 94-09-07) and TISAB III (Orion® 94-09-11) as buffers. One ml TISAB II was added to 1.0 ml of the sample or standard; while 0.3 ml TISAB III was added to 3.0 ml of the sample. The buffers were added to the undiluted water samples and to the samples after dilution with deionized water: $^1/_{10}$, $^1/_{25}$, $^1/_{50}$, $^1/_{75}$, $^1/_{100}$, $^1/_{150}$ and $^1/_{200}$.

Fish. The total F levels of the tissues were assessed according to Birkeland (1970), slightly modified. In brief, after homogenization and drying for 24 h at 105 °C, 45 mg of the dry tissue sample was dissolved in a small polyethylene tube containing a mixture of 0.2 ml 11.6 N $HClO_4$ and 0.2 ml 14.3 N HNO_3 at 60 °C for 2 h. A double tube arrangement facilitated dissolution and buffering to pH 5.2–5.5 without opening the sealed outer tube and thus reduced loss of F from the strong acids (Fig. 1). When dissolved, the content of the inner tube was neutralized and buffered by

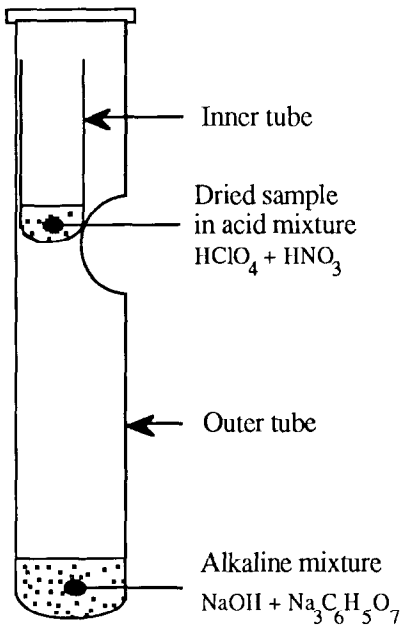

Fig. 1. Closed double tube arrangement used for reducing the loss of fluoride during dissolution of tissue samples.

an alkaline mixture (0.6 ml 7.8 N NaOH and 2.0 ml 1.0 N $Na_3C_6H_5O_7$) kept in the outer tube. Each tissue of the nine groups of fish was analyzed in duplicate. If the parallels differed by more than 20%, the sample was re-analyzed.

The accuracy of the method was checked in spiking and recovery experiments. The amounts of F added ranged from 0.5 to 30 µg F, i.e. equal to and up to 20 times the unspiked samples. The recoveries ranged as follows: fillet 77–93% ($n = 16$), skin 93–105% ($n = 12$), gills 93–118% ($n = 12$) and bones 102–118% ($n = 12$). In similar spiking experiments, this method yielded comparable recoveries from various other types of animal and vegetable foods (Opinya *et al.*, 1991).

Results

Water

The pH of the water samples ranged from 10.0 to 10.2. Addition of TISAB II or III in recommended quantities to undiluted water failed to lower the pH to 5.5. From dilution $^1/_{10}$ and up-

wards, both buffers brought the pH within the appropriate range for F determination (pH 5.0–5.5). The F-levels of the diluted and buffered samples were between 10^{-5} and 10^{-2} M F. At dilution $^{1}/_{75}$ and upwards, both the water collected from the spring and 3 m from the spring, reached a constant level of about $4 \cdot 10^{-3}$ M F, irrespective of the buffer (Fig. 2). With the water collected 100 and 400 m from the spring, however, no plateau levels were established, even at dilutions up to $^{1}/_{200}$. Accordingly, we are only able to give estimates of about $5.8 \cdot 10^{-3}$ M F 100 m from the spring and about $7.4 \cdot 10^{-3}$ M F 400 m from the spring.

Fish

The dissolved and buffered tissue samples contained between $5 \cdot 10^{-5}$ and 10^{-3} M F. Accordingly, the recorded values were in the F-range of the spiking experiments, and the lowest values exceeded the sensivity level of this method by about 10 times. There was no evidence of increased F concentration in any tissue at increased size of the fish (Fig. 3). On a dry weight basis, the F levels in the 118 fish were (mean ± S.E.M. mg F kg^{-1}, n = 9): fillet 68 ± 12, skin 819 ± 140, gills 1,366 ± 40 and bones 1,661 ± 49. On a wet

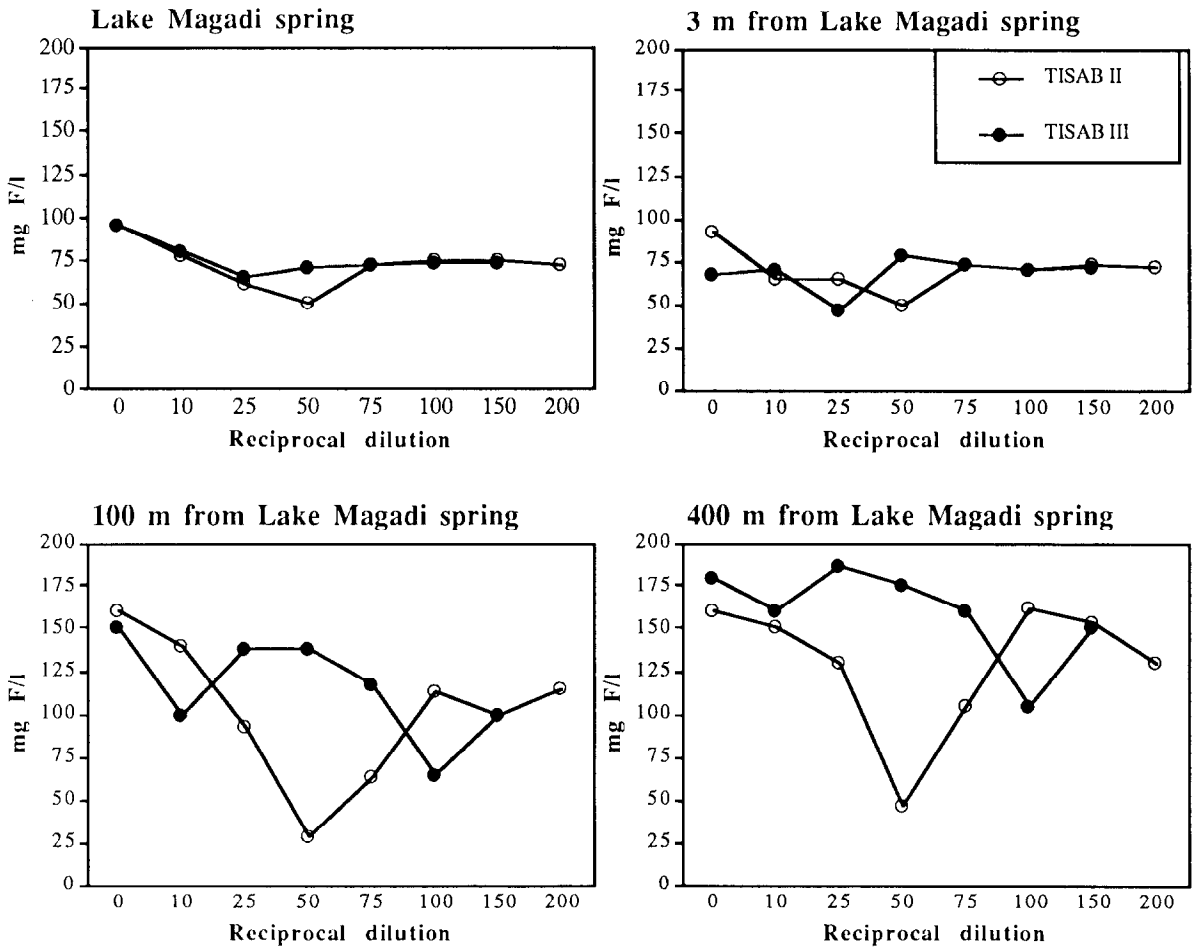

Fig. 2. Effect of dilution and buffering with TISAB II and TISAB III on fluoride (F) measurements of water from different sites of Lake Magadi.

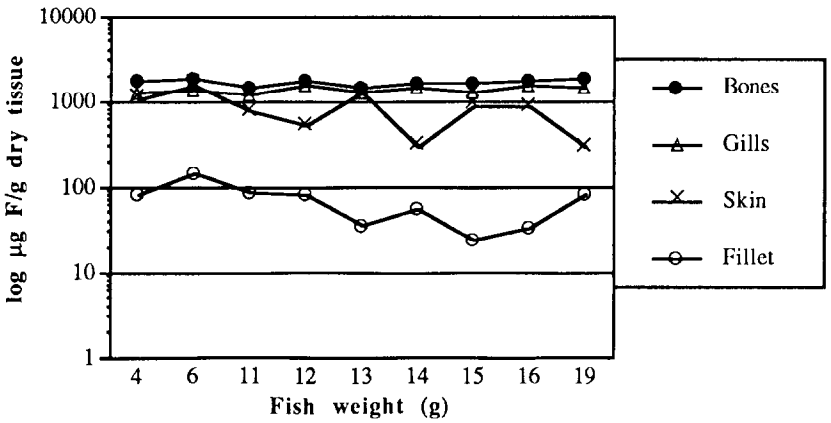

Fig. 3. Fluoride (F) levels in various tissues of *Tilapia grahami* from Lake Magadi.

weight basis the means were (mg F kg^{-1}): fillet 15, skin 266, gills 304 and bones 641.

Discussion

Water

The F concentrations reported in the lakes of Rift Valley show considerable variation, e.g. Lake Naivasha: 2–30 mg F l^{-1}, Lake Turkana 10–100 mg F l^{-1} and Lake Bogoria 1.0–2.8 g F l^{-1} (Williamson, 1953; Berg & Haug, 1971; Manji & Kapila, 1984; Kariuki *et al.*, 1984). The reported level of 1.48 g F l^{-1} in Lake Magadi (Kariuki *et al.*, 1984) exceeds our values by more than 10 times. There are several possible explanations for the differences; such as different sites of collection, seasonal variations in the degree of evaporation, different analytical methods, and errors caused by the extreme salt concentrations. We consider the value of 73 mg F l^{-1} in the water from the well and in the pond near to the well to be reliable, since a plateau level was reached. Further away from the well, evaporation had apparently increased the F and the general salt level to concentrations which affected the measurements even after dilution. Our findings indicate that it might be appropriate to reexamine the very high F levels reported in some of the saline lakes of Rift Valley.

Fish

The water in the lagoon where the tilapia was caught had an estimated level of about 110 mg F l^{-1} ($5.8 \cdot 10^{-3}$ M F). In a review on F intoxication of fish, Siegler & Neuhold (1972) stated that the response to moderate F concentrations (1.5 to 5.0 mg F l^{-1}) is species dependent and related to environmental acclimatization. They cited examples of trout able to live in water with 14 mg F l^{-1}, while trout populations reared in low F concentrations may succumb in 3 mg F l^{-1}. Neuhold & Sigler (1972) postulated that the survival of natural populations of fish at high F concentrations may partly depend on an excretion mechanism over the epithelial tissues. A variety of marine animals tolerate high F levels (Wright & Davison, 1975), but the F level at which the tilapia in Lake Magadi survive seems to be the highest so far reported.

Our spiking results indicated good recovery from all tissues and by the dissection of the tissues strong efforts were made to obtain clean samples. The F level within different tissues showed considerable variations. The coefficients of variation for analyses of skin and fillet were 5 to 6 times higher than for gills and bone. We have no explanation for the high variation of the F levels in skin and fillet.

Other studies have shown a positive correlation between fish size and bone F concentration

(Neuhold & Sigler, 1962; Christensen, 1987). We were unable to demonstrate a positive correlation between the fish size and the level of F in any tissue. The tilapia in Lake Magadi had a bone level of about 1.65 g F kg^{-1}, irrespective of size.

Acknowledgement

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References

Bell, M. E., E. J. Largent, T. G. Ludwig, J. C. Muhler & G. K. Stookey, 1970. The supply of fluorine to man. In Fluorides and Human Health. World Health Organization, Geneva: 17–74.

Berg, H. & J. Haug, 1970. The fluoride content and food value of Kenya lake fish. E. Afr. Agr. Forest. J. 36: 392–400.

Birkeland, J. M., 1970. Direct potentiometric determination of fluoride in soft tooth deposits. Caries Res. 4: 243–255.

Christensen, B., 1987. Uptake and release of fluoride in arctic char. Envir. Toxicol. Chem. 6: 529–533.

Kariuki, D. N., H. M. Thairu & L. W. Njenga, 1984. Dietary sources of fluoride in Kenya. In S. Likimani (ed.), Fluorosis Research Strategies. Afr. Med. Res. Found., Nairobi: 32–36.

Manji, F. & S. Kapila, 1984. Fluorides and fluorosis in Kenya – an overview. In S. Likimani (ed.), Fluorosis Research Strategies. Afr. Med. Res. Found., Nairobi: 11–21.

Neuhold, J. M. & W. F. Sigler, 1962. Chlorides affect the toxicity of fluorides to rainbow trout. Science 135: 732–733.

Opinya, G. N., N. Bwibo, J. Valderhaug, J. M. Birkeland & P. Lökken, 1991. Intake of fluoride and excretion in mothers' milk in a high fluoride (9 ppm) area in Kenya. Eur. J. Clin. Nutr. 45: 37–41.

Reite, O. B., G. M. O. Maloiy & B. Aasehaug, 1974. pH, salinity and temperature tolerance of Lake Magadi *Tilapia*. Nature 247: 315.

Sigler, W. F. & J. M. Neuhold, 1972. Fluoride intoxication in fish: A review. J. Wildlife Dis. 8: 252–254.

Williamson, M. M., 1953. Endemic dental fluorosis in Kenya: a preliminary report. E. Afr. Med. J. 30: 217–233.

Wright, D. A. & A. W. Davison, 1975. The accumulation of fluorides by marine and intertidal animals. Envir. Pollut. 8: 1–13.