Variations in the fluoride levels of drinking water in South Africa
Implications for fluoride supplementation

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Summary
The range of fluoride levels in the drinking-water of cities and villages in South Africa was determined during the transition from a very dry (1983) to a wet (1984/85) period. The combination fluoride ion selective electrode was employed for the determination of the fluoride concentration. It was found that fluoride levels in drinking-water changed for 93% of the cities and villages studied during the period 1983-1985. Furthermore, it became clear that when the water volume of the supplying source increased, the fluoride level decreased significantly \( (P < 0.01) \). Boreholes showed significantly higher fluoride levels \( (P < 0.01) \) than rivers or dams. The impact of the variation in drinking-water fluoride concentrations on supplementary fluoride dosage is discussed and recommendations made.

Drinking water fluoride levels of higher than 1-2 ppm\(^4,5\) are not recommended by the US Environmental Protection Agency, because of the higher risk of producing unaesthetic enamel fluorosis\(^5,6,9\). In a country such as South Africa with extreme climatic variations between very wet and very dry seasons, one might anticipate a variation in the fluoride content of the drinking-water supply in areas where this occurs. If this were true it would be important not only to know the fluoride levels in drinking-water, but also the range of variation thereof before fluoride supplementation could be accurately prescribed. In general, systemic fluoride supplementation (in tablet form, for example) is recommended when the drinking-water fluoride level is lower than 0.7 ppm\(^10,11\). It is, however, known that the optimum fluoride dosage\(^9,10\) is also dependent on the annual average maximum daily air temperature.

The objective of this study was to test the hypothesis that variations in fluoride levels of water do occur, and that changes in the water level of sources due to the influence of dry and wet seasons could be one of the reasons for these variations. The resulting clinical importance of these variations in terms of fluoride supplementation was then addressed. Furthermore, a search through the literature did not reveal a single study on the above subject that could assist in the planning of this project.

Materials and methods
Samples of drinking water were collected in 20 ml polypropylene containers from cities and villages throughout South Africa. This was done in 1983 and 1984/1985. The rainfall during this period differed remarkably and therefore the seasons varied from extremely dry to extremely wet.

One part of each water sample was mixed with one part of TISAB III M triammonium-citrate buffer\(^12\) and the mixture was left overnight. At the same time five fluoride standards varying between 10\(^{-4}\) M and 10\(^{-3}\) M were prepared in 50% buffer from a
standard sodium (100 ppm) fluoride solution. A calibration curve was set and the fluoride concentration of the sample determined with the use of a combination fluoride ion selective electrode in conjunction with a potential meter. Two different fluoride measurements (which did not differ from each other by more than 3%) were done on each water sample and the mean value noted.

Results

Table I shows the range of the drinking-water fluoride concentration in the RSA for an exceptionally dry season and for a wet season during 1983 and 1984/1985 respectively. No range is given when the water fluoride levels for both the wet and dry seasons were less than 0.05 ppm fluoride or when there was no significant difference (± 5%) between the wet and dry seasons. In 33% of the cities and towns, the fluoride levels never rose above 0.10 ppm and could thus not be included in calculations on variations since the fluoride electrode is inaccurate at this very low level. Altogether 44% never rose above 0.10 ppm and were also seldom used.

Of the samples tested to compare the fluoride levels from 1983 to 1984/1985, 65% showed decreased and 27% increased levels of fluoride in the water, resulting in a total of 93,3% exhibiting variations. It can thus be stated that variations in fluoride levels in drinking water occur frequently.

The McNemar test for symmetry on the water levels of the sources and the corresponding fluoride levels, yielded a P value of < 0.001 and it can therefore be said that statistically there is a highly significant shift in symmetry. When the water level of a source increases, one can expect to find less fluoride in the water and vice versa. It can thus be expected that dry and wet seasons will have an effect on the fluoride content of drinking water. A significant decrease (P < 0.01) in 84% and 83% of cases was found in the water fluoride levels of boreholes and surface reservoirs respectively, when the volume of water in them increased.

The Mann-Whitney U-test shows that the water fluoride levels of boreholes differed significantly (P < 0.01) from that of dams or rivers for the years 1983 and 1984/1985. However, the fluoride levels of dams did not differ significantly (P > 0.05) from that of rivers. Boreholes showed significantly (P < 0.01) higher fluoride levels.

Discussion

From the Hydrological Data Reports obtained from the Department of Water Affairs in Pretoria (J. Schutte — personal communication) it became clear that 1983 was a very dry period for most areas in the RSA and was therefore chosen as part of the study period. On the other hand, the majority of areas received adequate rain during the period 1984/1985. Drinking-water in the RSA is provided mainly from dams, rivers and boreholes. The main reason for the altered fluoride levels (in 80% of cases) proved to be the change in the water volume of the source owing to rain or drought. Many places use more than one source for drinking-water and sometimes change the ratio for mixing these sources. Of the fluoride level variations registered, 20% were traced to changes in these ratios. During the drought of 1983 many towns were forced to make greater use of borehole water because of the drying up of surface water. During the period of investigation Harrismith for example, changed from using the Wilge River as a water source to using the Sterkfontein dam.

We published a table on the fluoride concentrations of drinking-water during the very dry season of 1983, which is currently being used for the determination of fluoride supplementation. That year proved to be a very dry season for most parts of the country, and the water fluoride levels in the.
table were also of a higher concentration. Thus, the use of the table for fluoride prescriptions will in all but two places at most have led to somewhat lower fluoride supplementation only and no damage to teeth could have occurred. For the places where the range of water fluoride levels are not given (Table I), we still recommend the use of the same values as found in our initial table for fluoride supplementation prescriptions.

When examining the clinical importance of variations in fluoride content of drinking water, we compared the fluoride supplementation dosage calculated for the 1983 and the 1984/1985 ends of the fluoride range for every city and town. For the majority of cities and towns the fluoride dosage remained unchanged. Of these cities and towns in the no dosage (> 0.7 ppm) range during 1983 30% moved to the low dosage (0.3-0.7 ppm) range (Table II) in 1984/1985, 35% in the low dosage range moved to the high dosage range (< 0.3 ppm) respectively. Some cities and towns would thus at times be under the optimal dosage limits on the 1983 chart and only 2 towns would at times be in danger of being overdosed (Messina and Fauresmith). 14

In the light of the above, we recommend that the prescriber of fluoride supplementation should decide whether it is a dry or wet season for his area and then read the fluoride content for that area, from the higher or lower end of the water fluoride content range from Table I. If uncertainty about the season exists then the higher fluoride content (lower dosage) of the range should be used for dosage calculations in conjunction with Table II. 11 The Department of Water Affairs in Pretoria may also be contacted to provide assistance in making this decision.

If, however, one wants to approach prescribing fluoride supplementation in a very critical manner, other factors should also be taken into account. It is, for instance, known that the optimum fluoride dosage is also dependent on the annual average maximum daily air temperature. This is because higher temperatures will induce a greater consumption of water which will lead to a greater consumption of fluoride if the water contains fluoride. The reverse is also true (refer to previous articles on this subject).

There are other sources of fluoride intake besides water. 15,16 It can be obtained from baby milk powders, tea, and other foodstuffs and, for example, toothpastes and mouth rinses. It is rather difficult, but not impossible, to determine the daily fluoride intake from all these sources. However, the bioavailability of fluoride for the body may differ completely from one foodstuff to the other, depending on many factors. 15,16 For example, although the fluoride content of fish bones is high only a small portion will eventually be absorbed by the human body. 13 The amount of absorption, therefore, is actually the crux of the matter.

If all the other sources of fluoride intake besides that of fluoride from drinking-water are within the normal average intake range they need not be considered, as allowance for them has already been made in the supplementary fluoride dosage schedule (Table I). Parents must, however, be warned when major changes in water sources for a particular area are effected, as these may lead to changes in the fluoride content of the water and altered fluoride dosages.

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REFERENCES

12. Trautner S. South African Medical Research Council for the statistical treatment of the results.