

Relation of Dental Fluorosis to Ground Water Fluoride In South Africa

E J Ncube^{a,c} and C F Schutte^b
Republic of South Africa

SUMMARY: Two sets of data, one of the occurrence of fluoride in ground water and the other of the occurrence of dental fluorosis in South African regions are surveyed and mapped. The percentage morbidity of dental fluorosis varies from province to province, district to district and village to village. Most affected are the Limpopo, Northern Cape, North-West and KwaZulu Natal provinces. The results reveal that most of the local people in these areas suffer from dental fluorosis at varying degrees.

It is shown that dental fluorosis occurs in areas where the fluoride levels in ground water are higher than those recommended for drinking water. The degree and severity of mottling in the subjects studied corresponds with the level of fluoride in drinking water.

It is concluded that fluorosis constitutes a health problem in South Africa and that the problem is related to the occurrence of fluoride in the ground water.

Key words: Dental fluorosis, fluoride, fluoride ion concentration; groundwater, health, morbidity of dental fluorosis, occurrence, South Africa, water quality

INTRODUCTION

The beneficial attributes of fluorides to human health have been known for many years ¹. The fluoride ion is a very important dietary substance. When ingested at specific doses, the fluoride ion is beneficial to both bone and dental development in human beings. At correct intake levels it plays a very important role in the formation of the teeth ². Too low fluoride intake levels during childhood may give rise to the occurrence of preventable dental caries in later years. Dental caries is a disease caused by specific bacteria harboured in dental plaque, fermenting carbohydrates to produce acids that can demineralise tooth enamel ³. If this demineralisation is allowed to continue, the enamel is penetrated permitting bacterial invasion and eventual loss of the tooth by decay in the absence of restorative dental care.

Too high fluoride intake normally gives rise to teeth mottling (dental fluorosis) and related problems. Endemic fluorosis is a condition which is caused by an excess of fluoride in drinking water and which affects the calcification of the teeth, resulting in what is commonly known as dental fluorosis. Maughan-Brown in 1935 and Raubenheimer in 1938 first reported a study of the occurrence of mottled enamel in South Africa.¹

In 1941, Ockerse produced three reports on human fluorosis in various regions of the former Union of South Africa. At that time 805 areas in which dental fluorosis occurred were known ⁴. The majority of the dental fluorosis affected in South Africa

^a Rand Water Board, 522 Impala Rd, Glenvista, 2000, South Africa.

^b Department of Chemical Engineering, University of Pretoria, Pretoria, 0002; South Africa.

^c For correspondence: Rand Water, P.O. Box 1127, Johannesburg, 2000, South Africa. E-mail: encube@randwater.co.za

are the black people living in rural areas. Different studies have shown that the occurrence of dental fluorosis in the majority of cases in South Africa are related to the fluoride content of groundwater used for drinking purposes ^{5,6}.

The awareness of excess fluoride consumption through water has however been increasing countrywide ^{7,8}. The issue of whether and at what levels of concentration, to manage the fluoride ion concentrations in South Africa's public water supplies is a contentious one. The Department of Water Affairs and Forestry (DWAF) as the custodian of the country's water resources, manages the fluoride levels through the criteria set in its guidelines⁹. The guidelines are used by DWAF as a decision support tool to judge the fitness of water for different use. The current target water quality range, (TWQR) which is the concentration range in water necessary to meet requirements for a healthy tooth structure is 0-10 mgF/L. This is a function of daily water intake and varies with the annual maximum daily air temperature. For South African conditions, a concentration of approximately 0.75 mgF/L corresponds to a maximum daily temperature of approximately 26-28°C. The DWAF works closely with the South African Bureau of Standards (SABS) that is the standard setting body in South Africa. According to the SABS specifications ¹⁰ the ideal concentration of fluoride in water that is suitable for lifelong consumption is 0.7 mg/L. In September 2000, the Department of Health proposed compulsory fluoridation of public water supplies ¹¹ to an optimum concentration of fluoride not more than 0.7mg/L.

The main problem is the lack of adequate information on the environmental and health impacts of fluoride. There is also a lack of accurate information about the current status of fluoride in the country's groundwater resources. This paper addresses these gaps by assessing the groundwater fluoride data for the period 1996-2000 in order to establish the current distribution of fluoride ion concentration levels in groundwater sources and the impact of dietary fluoride on dental health. Areas with fluoride ion concentrations lower or higher than those recommended for drinking water are delineated. The occurrence of dental fluorosis in selected provinces is shown. The degree of the severity of dental fluorosis is shown in terms of the percentage morbidity of dental fluorosis. This is overlain on a water quality map in order to assess the relationship between the occurrence of fluoride in groundwater and the incidences of dental fluorosis. Relevant recommendations based on the results of this study are also made. A detailed analysis of the factors that affect the occurrence of fluoride in groundwater and distribution of fluoride in groundwater is beyond the scope of this paper.

MATERIALS AND METHODS

The fluoride data was extracted from the DWAF's Water Management System (WMS) database housed at the Institute for Water Quality Studies (IWQS). This constituted of 14,509 groundwater samples. This included boreholes and springs. The data was screened for errors incorrect reference codes, incorrect coordinates and

number of fluoride ion concentrations reported for the station. A statistical package, STATISTICA, which calculated a fluoride median value for each unique groundwater source was used to process the data. This resulted in a summarized data set comprising of 6042 values. Plotting this data on a map assessed the current status of fluoride ion distribution in the country, cf. Figure 1. The dental fluorosis data was obtained from the National Department of Health (NDOH). These data were processed according to Wang, *et al.*, 1999¹², Table 1, in order to obtain the % morbidity of dental fluorosis. The results for the selected provinces are as shown in Tables 2-5. The results are based on the degree of mottling of the teeth as observed during the dental examinations. A comparison was made between the % morbidity of dental fluorosis and the drinking water quality in selected provinces. The results are shown in Figures 2-5.

RESULTS AND DISCUSSION

The current status of fluoride ion distribution in South African groundwater is provided in Figure 1. The figure shows that the problems of high fluoride ion concentrations are currently being experienced in the Limpopo, Northern Cape, North-West and KwaZulu Natal provinces. A few cases were recorded in other parts of the country. The current situation of the fluoride distribution in the country is such that no clear demarcation can be made of areas deficient in fluoride since some areas have groundwater sources in which the fluoride ion concentrations are higher than the recommended limits for drinking water. This is an indication that the occurrence of low fluoride ion concentrations in groundwater is currently not a national problem. Many sources in the Limpopo, North-West, Northern Cape, Western Cape and KwaZulu Natal provinces are in need of partial de-fluoridation. This must receive serious consideration if the water from those sources is being used for drinking purposes.

The results of the general investigations of fluorosis obtained from the data received from the DOH are as presented in Tables 2-5. The criteria used to interpret the results are as presented in Table 1, adopted from Wang, *et al.*, 1999¹². The information on the dependency of communities on groundwater for use as drinking water is presented in Table 6. This information was obtained in order to confirm the link between high fluoride levels in groundwater, the consumption of this fluoride contaminated water and the occurrence of dental fluorosis in the same areas. It should be noted that in a province where the communities depend largely on groundwater for drinking water purposes like the North-West Province, the morbidity of dental fluorosis is high.

TABLE 1: Criteria used for the interpretation of Dental fluorosis results.

% Morbidity of dental fluorosis = (B + C)

Class	Dental Fluorosis symptoms
A-Normal	No apparent abnormality
B-Slight (Questionable, Very mild, Mild)	Yellowish teeth with slight erosion
C-Heavy (Moderate and Severe)	Extended erosion or mottling or heavy damage to teeth.

TABLE 2: Dental Fluorosis by level of Severity in the Free State (FS) Province

(Age group 12)

Name of Place	Class A	Class B	Class C	B + C	% Morbidity
FS-Region A	34.5%	62.2%	2.5%	64.7%	64.70
FS-Region B	35.6%	62.3%	1.3%	63.6%	63.60
FS-Region C	66.1%	29.1%	3.0%	32.1%	32.10
FS-Region D	66.1%	31.5%	1.7%	33.2%	33.20
FS-Region E	66.5%	29.7%	1.7%	31.4%	31.40
FS-Region F	42.4%	51.4%	4.8%	56.2%	56.20

TABLE 3: Dental Fluorosis by level of Severity in the Western Cape (WC) Province

(Age group 12)

Name of Place	Class A	Class B	Class C	B + C	% Morbidity
WC-Boland –Overberg Region	86.0%	13.3%	0 %	13.3%	13.30
WC- Metro	54.5%	42.1%	2.2%	44.3%	44.30
WC- South Cape –Karoo	46.5%	39.2%	10.7%	48.7%	48.70
WC-West-Coast	69.4%	26.5%	1.4%	27.9%	27.90

TABLE 4: Dental Fluorosis by level of Severity in the KwaZulu Natal (KZN) Province

(Age group 12)

Name of Place	Class A	Class B	Class C	B + C	% Morbidity
Durban	79.6%	10.9%	1.4%	12.3%	12.30
Jozini	50.7%	34.7%	2.5%	37.2%	37.20
Ladysmith	41.7%	50.8%	7.0%	57.8%	57.80
Newcastle	86.4%	7.6%	3.3%	10.9%	10.90
Pietermaritzburg	72.2%	23.1%	2.1%	25.2%	25.20
Port Shepstone	77.1%	17.5%	1.8%	19.3%	19.30
Ulundi	57.8%	38.2%	1.9%	40.10%	40.10

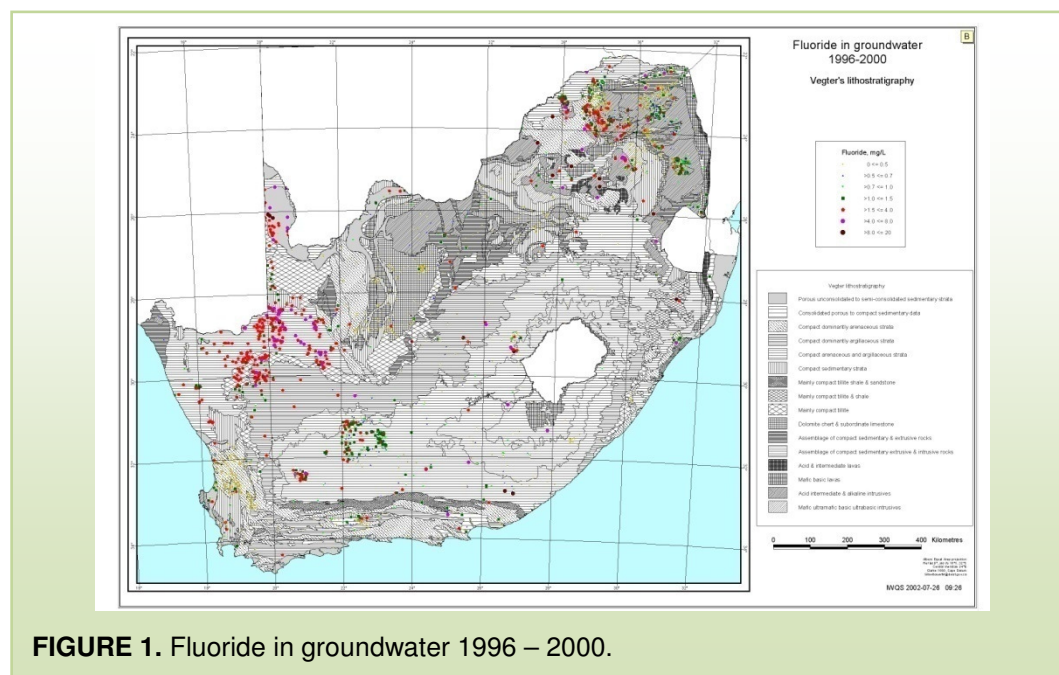
TABLE 5: Dental Fluorosis by level of Severity in the North-West (NW) Province (Age group 12)

Name of Place	Class A	Class B	Class C	B + C	% Morbidity
NW-Brits	32.8%	61.7%	5.6%	67.3%	67.30
NW-Delareyville	80.7%	5.8%	0%	5.8%	5.80
NW-Mafikeng	97.7%	0.9%	0%	0.9%	0.90
NW-Mogwase	6.7%	93.4%	0%	93.4%	93.40
NW-Moretele	25.6%	35.3%	39.1%	74.4%	74.40
NW-Potchefstroom	82.8%	17.2%	0%	17.2%	17.20
NW-Rustenburg	81.9%	5.8%	0%	5.8%	5.80
NW-Ganyesa	26.7%	54.9%	18.4%	73.3%	73.30
NW-Klerksdorp	82.7%	13.5%	1.8%	15.3%	15.30
NW-Kuruman	42.3%	57.7%	0%	57.7%	57.70
NW-Lichtenburg	86.6%	12.8%	0.5%	13.3%	13.30
NW-Schweizer	71.7%	26.6%	1.6%	28.2%	28.20
NW-Taung	31.6%	60.7%	7.1%	67.8%	67.80
NW-Ventersdorp	73.3%	20%	6.7%	26.7%	26.70
NW-Vryburg	49.7%	43.6%	6.7%	50.3%	50.30
NW-Zeerust	47.8%	48.6%	2.1%	50.7%	50.70
NW-Wolmaranstad	61.1%	33.4%	5.6%	39%	39.00

The distribution of dental fluorosis in selected provinces is shown in the maps in figures 2-5. The maps show the spatial distribution of the current % morbidity of dental fluorosis for the Western Cape, North-West and KwaZulu Natal provinces. The fluoride data is overlain on each provincial map in order to correlate the level of the morbidity of dental fluorosis and fluoride levels in drinking water. It should be noted that there exist differences in the morbidity of dental fluorosis among the investigated and this is true for the fluoride levels in groundwater sources. It was difficult to present the Free State province data using the same format as the dental fluorosis data was reported in regions whose digital data was not present at the time of writing this dissertation.

TABLE 6: Dependency of the communities, Com., on water sources and the water supply potential.

Province	North-West		Free State		KwaZulu Natal	
Source type:	Com.	People	Com.	People	Com.	People
Groundwater	1063	1,411,707	72	122,161	807	2,416,721
Surface Water	221	2,099,461	149	3,097,252	75	212,698
Combined Sour.	13	108,593	30	139,452	48	149,685
None	-	-				
Unknown	-	-			1,563	5,624,304
Total	1297	3,619,761	251	3340,865	2,493	8,403,408
Supply Potential						
Poor	160	48,733	-	-	-	-
Low	207	330,061	24	83,380	-	-
Moderate	341	1,220,101	99	905,112	996	2,590,125
High	266	1,620,011	124	2,271,450	558	1,529,404
Very High	323	400,855	4	80,923	939	4,283,879
Total	1297	3,619,761	251	3,340,865	2,493	8,403,408

**FIGURE 1.** Fluoride in groundwater 1996 – 2000.

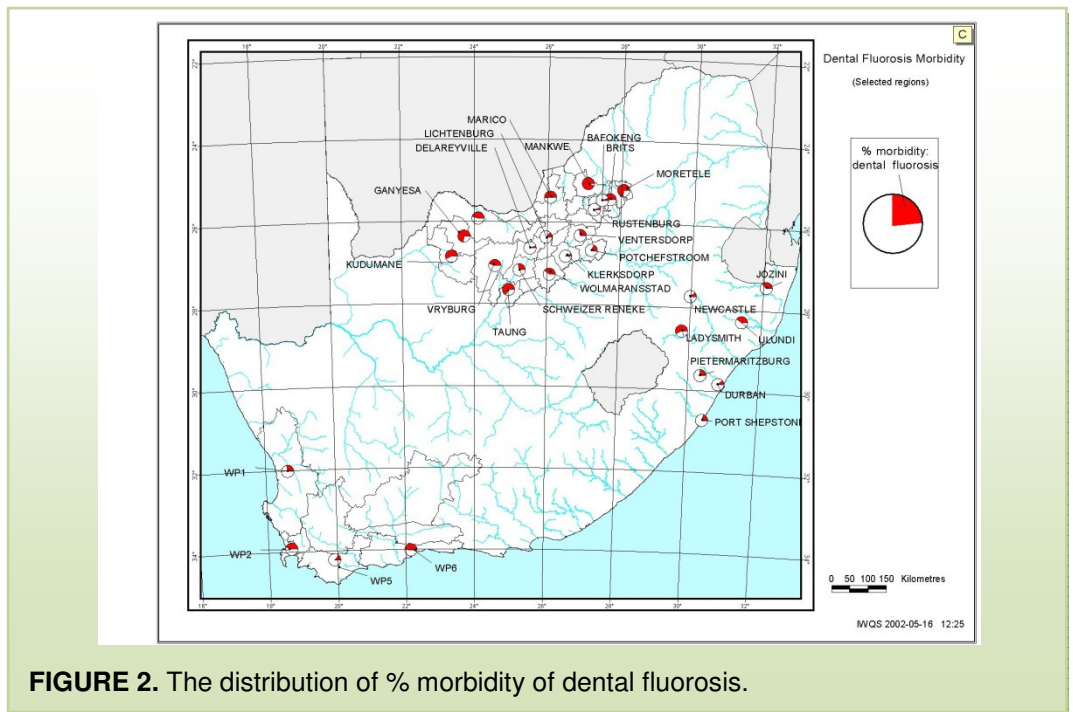


FIGURE 2. The distribution of % morbidity of dental fluorosis.

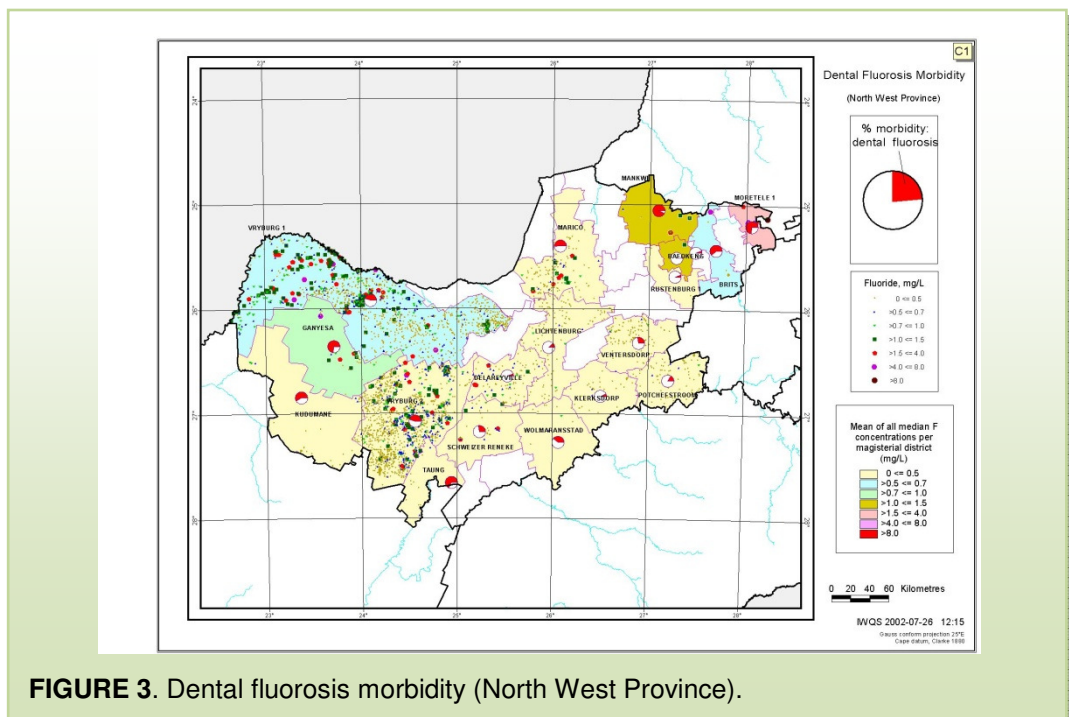


FIGURE 3. Dental fluorosis morbidity (North West Province).

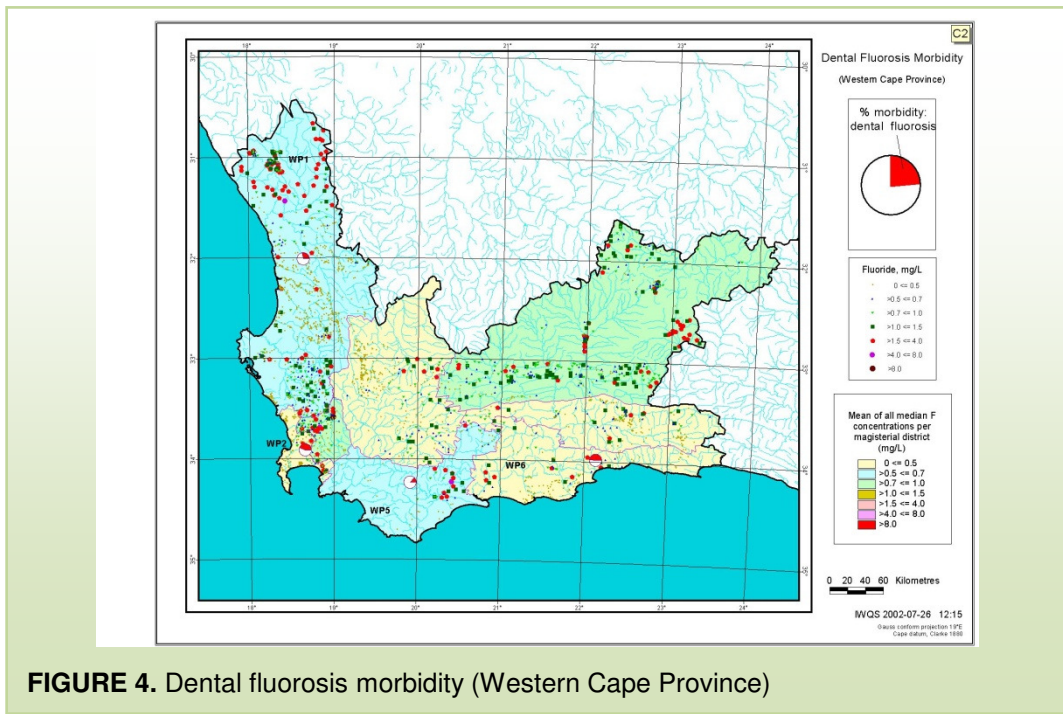


FIGURE 4. Dental fluorosis morbidity (Western Cape Province)

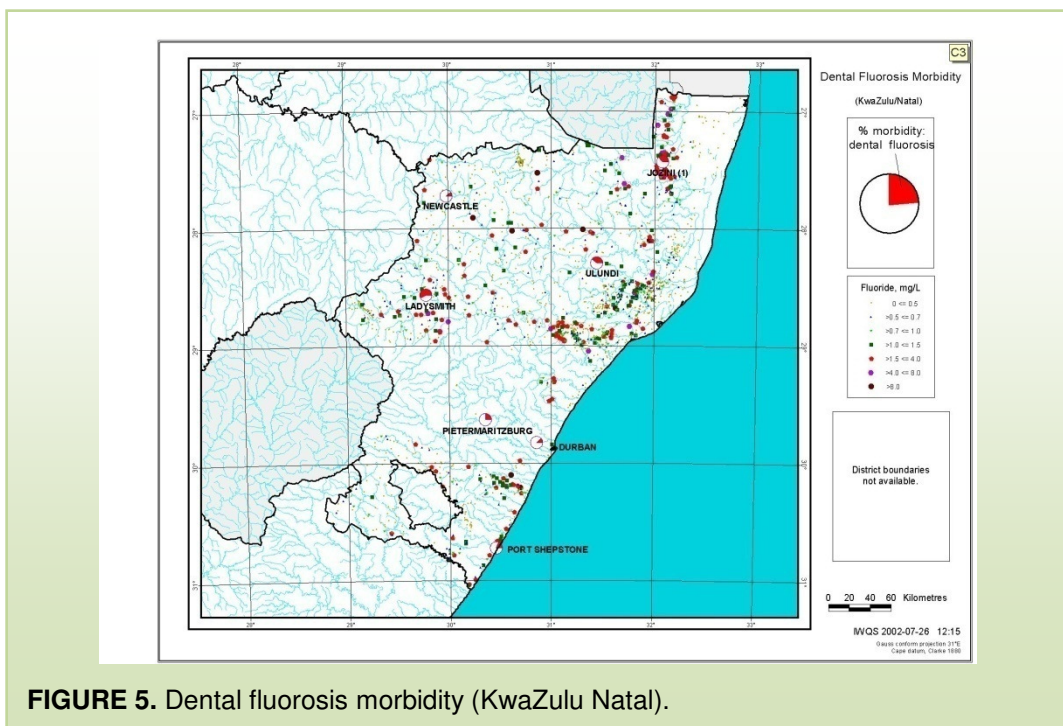


FIGURE 5. Dental fluorosis morbidity (KwaZulu Natal).

From the results, a percentage morbidity of dental fluorosis as high as 97 % was recorded in the North-West province. In comparing the distribution of the % morbidity of fluorosis with that of fluoride concentration in groundwater sources (Figures 2-5), it is apparent that high morbidity of fluorosis occurs in areas where fluoride concentrations are extremely high and in most cases exceeding the limits for drinking water. In towns and villages where the water quality problem in terms of fluoride ion concentration is less serious, the morbidity of fluorosis is comparatively low. It is evident from the maps that the occurrence of dental fluorosis and its morbidity correspond to the levels of fluoride ion concentrations in drinking water. The size of the shaded part (% morbidity of dental fluorosis) in each area gives the idea of the general quality of drinking water consumed by the examined subjects.

CONCLUSION

Areas with high fluoride ion concentrations in their groundwater supplies and high percentage morbidity of dental fluorosis have been identified. Many of these sources require partial de-fluoridation if they are currently being used for drinking water purposes. Proper research needs to be initiated in order to develop cheap and technologically simple processes for small-scale removal of fluoride from fluoride-rich groundwater or developing alternative sources of supply in areas where there is such a problem especially in rural areas.

This study shows that the low fluoride concentration in groundwater is not a national problem. Experiences from other countries where the water fluoride is similarly “low” while the oral health is very advanced, without any fluoridation of water or any medium apart from toothpaste should be considered and much research is needed to test their relevance and feasibility in the South African context.

ACKNOWLEDGEMENTS

Mike Silberbauer and his team have provided unconditional assistance with data extraction, quality control of the data and GIS expertise. Dr Kroon and colleagues at the Department of Health have given the authority to access the dental fluorosis data.

REFERENCES

26. WRC. Distribution of fluoride-rich groundwater in the Eastern and Mogwase regions of the Northern and North-West province South Africa. WRC Report No.526/1/01 2001; 1.1 - 9.85
27. Pontius FW. Fluoride regulation and water fluoridation. Journal American Water Works Association. 1991;83(11): 20-22,96.
28. Hammer, MJ. Need for fluoridation of desalinated water supplies. Aqua London UK. 1986;4:179-182.
29. Ockerse, T. Endemic fluorosis in South Africa a PHD Thesis submitted to the University of Witwatersrand. 1947
30. Du Plessis JB. What would be the maximum concentration of fluoride in water that would not cause dental fluorosis? Fluoride and Fluorosis. The status of South African Research, Pilanesberg National Park, North West Province. 1995; 4.
31. M^ccaffrey, LP, Willis JP. Distribution of fluoride-rich groundwater in the eastern parts of Bophuthatswana, relationship to bedrock and soils and constraints on drinking water supplies: a preliminary report, Africa Needs Ground Water. An International Ground Water convention. 1993; 1:1-8
32. Fayazi, M. Regional groundwater investigation on the Northern Springbok flats. Department of Water Affairs and Forestry. Geohydrology, GH Report no. 3684. 1994;108-155.
33. Rudolph, MJ, Molefe, M, Chikte, OME. Dental fluorosis with varying levels of fluoride in drinking water. J Dental Research. 1995;74:1012.
34. DWAF. South African Water Quality Guidelines for domestic use. 1st Edition. 1996.
35. SABS Fluoride standard for drinking water. SABS 241.5th edition. 2001.
36. Anonymous. Notice R797 of 12 June 1998. Regulations under the Health act, 1977 (Act No. 53 of 1977). Schedule: Regulations of fluoridating public water supplies. Republic of South Africa Government *Gazette*. 396, Issue 18960: 1998;7-14.
37. Wang, XC, Kawahara, K, Guo XJ. Fluoride contamination of groundwater and its impacts on human health in Inner Mongolia area, China, *Aqua*. 1999; 48 (4):146-153.