

Fluoride in Drinking Water and its Effects on Human Health and Nutrition in Selected Towns of the Northern Cape Province, South Africa

Report to the
WATER RESEARCH COMMISSION

by

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EXECUTIVE SUMMARY

Water is a scarce resource in South Africa and many parts of the country have limited access to water either from natural rainfall, rivers, dams and localised boreholes. The Northern Cape depends on water supply from the Vaal and Orange Rivers as well as groundwater resources. The borehole water supply has several constraints in that it is limited in supply, often very brackish and hard and many times very high in mineral contents like fluoride.

The aim of the project was to determine the fluoride in drinking water and its effects on human health and nutrition. The objectives of the project were to determine: a) the levels of fluoride in the groundwater supply used for human consumption in the Northern Cape; b) the nutritional status of the selected samples of children in terms of outcomes related to high and low fluoride levels; c) fluoride toxicity as measured by the teeth using the TF Index, and d) to initiate a pilot project with appropriate and inexpensive technology for safe and sustainable drinking water supply in the Northern Cape.

Samples of drinking water were collected for the analysis of free fluoride ions from 81 towns in the Northern Cape. Specific samples were collected from different school sites in Diamond fields (Kimberley and peri-urban area), De Aar, Leliefontein and Kamassies.

A total number of 954 school children were examined for nutritional status (height & weight), caries and fluorosis in the Kimberley, De Aar, Leliefontein and Kamassies areas of the Northern Cape. A stratified sample of schools was selected for true representation of the province.

The fluoride levels for Northern Cape ranged from <0.05 to 8.2 ppm. (The average fluoride levels of major towns with centralised water supply were 0.31 to 0.35 ppm). De Aar, with borehole water supply, had a fluoride level of 0.71 ppm. The fluoride levels of two rural areas with borehole water supply were 0.2-2.5 ppm for Leliefontein and 2.4-8.2 ppm for Kamassies.

The percentage of caries-free children for 3-5 years old ranged from 25% in De Aar to 45% in Kimberley. The results of the decayed, missing and filled permanent teeth showed very low prevalence of dental caries (DMFT=0.49-1.31) in the 11-13 years of age in the whole Northern Cape Province.

There was no difference in nutritional status of the sample population in Diamond fields (Kimberley and peri-urban areas) and De Aar. According to WHO criteria, approximately 21.5% in Diamond fields and 20% in De Aar showed malnourishment or stunting (i.e. HAZ > -2.0).

Mild-to-severe fluorosis was seen in different parts of the province. Peri-urban areas in the Diamond field, Kamassies and Leliefontein areas showed higher percentage of TF Index scores of 1-4.

In conclusion, the study indicates that fluoride levels of 0.3 ppm have a beneficial effect on permanent teeth with little effect on primary teeth of children 3-5 years. Furthermore some 20.21% of children suffer from malnutrition or stunting.

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CHAPTER 1: NORTHERN CAPE

1.1- INTRODUCTION

The Northern Cape is one of the nine provinces of South Africa. It is the largest province in the country, with a land area of 361 830 km², covering almost a third of the total national territory (29.7%) (Figure 1.1).



Figure 1.1: Provincial map of South Africa¹

The old administrative boundaries comprised six district councils (Diamond Fields, Lower Orange, Kalahari, Hantam, Upper Karoo, and Namaqualand), twenty-six magisterial districts, and sixty-eight local authorities. The new demarcation divides the province into five district councils (the same as the old ones except for Namaqualand and Hantam, which are combined into one district council) and thirty-one municipalities and district management areas (Figure 1.2). After this study the District Municipalities were reformulated into Namakwa, Pixley ka Seme, Siyanda, Frances Baard and Kgalagadi.

¹ Southern Africa Places CC. http://www.places.co.za/maps/south_africa_map.html (access January, 2008).



Figure 1.2: Regions of Northern Cape

1.2- CLIMATE DATA

The climatological information is the normal values based on monthly averages for the 30-year period 1961-1990 (Table 1.1).

Area	Temperature (°C)				Precipitation (mm)		
	Highest Recorded	Average Daily Maximum	Average Daily Minimum	Lowest Recorded	Average Monthly	Average Number of days with $\geq 1\text{mm}$	Highest 24 Hour Rainfall
Kimberley	40	26	11	-8	414	71	88
De Aar	40	25	9	-8	336	55	135
Upington	43	29	13	-7	189	37	59

1.3- POPULATION

The Northern Cape population is reported to be 822 727 people (2001 Census²) and has the lowest population in the country. Of these, around 412 000 are male and 427 000 are female.

An estimated 33% of the Northern Cape's population are African/ Black, 52% are Coloured, 0.3% are Indian/Asian and 13% are White. The province's Coloured population is the largest after that of the Western Cape. Figure 1.3 shows the population by age and sex distribution of the population.

- 33 % of the population is below 15 years of age an equal distribution of male and females.
- 5% of the population is above 65 years of age.
- This compares similarly to the general population of South Africa with
- 36% below the age of 15 years and
- 4% above the age of 65 years.
- Indication of lower proportion of children below 5 years (+/- 11%)
- 22% children between 5-14 years of age

The age distribution of the population is typical of an industrialized country, relatively few young children and high proportion of persons 65 and above (>20%) (Figure 1.4).

² The 1996 census data are used. More recent information can be found in the 2001 Census Database and the 2007 Community Survey.

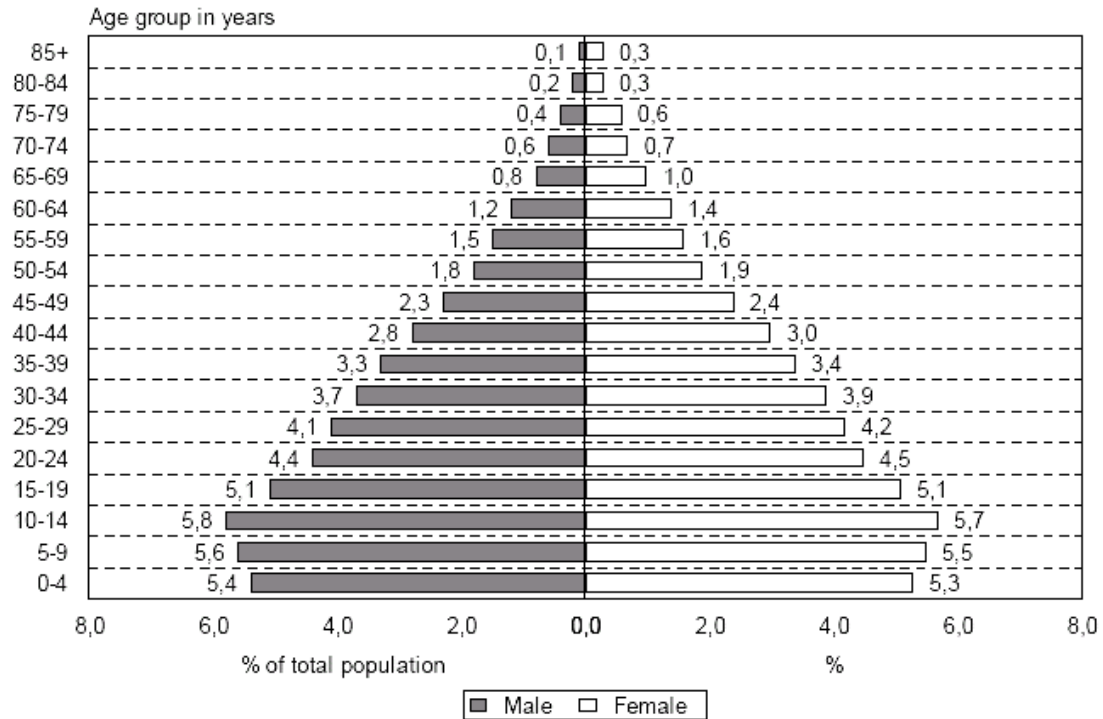


Figure 1.3: Population by age group and sex, Northern Cape
Source: Stats SA, Population census 1996

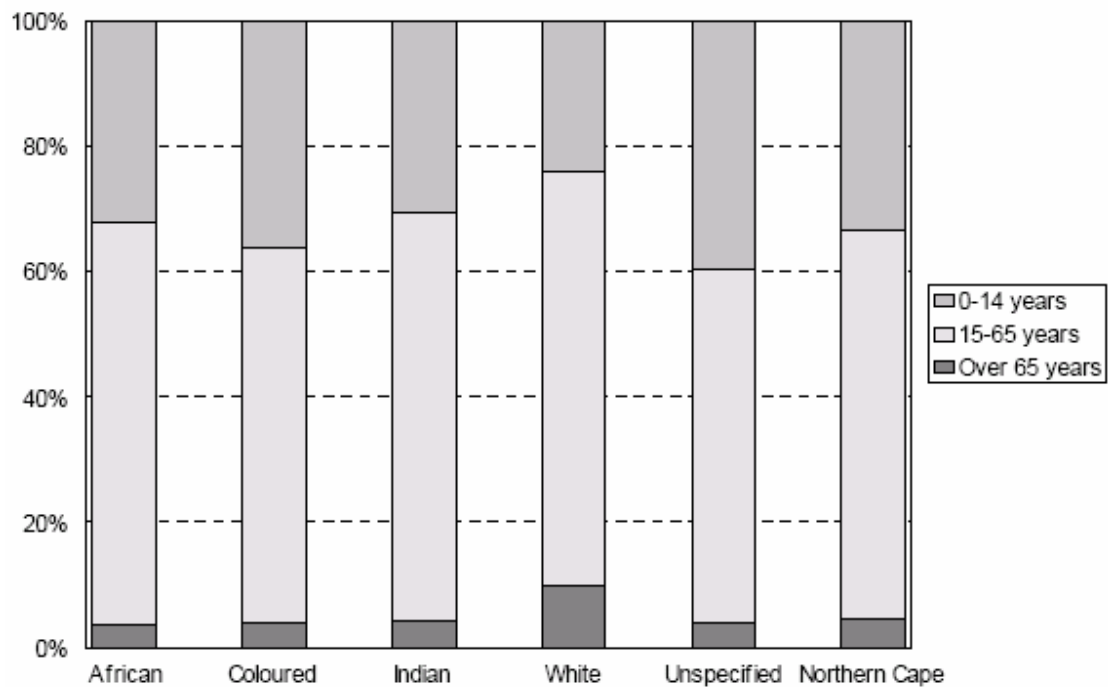


Figure1.4: Population by age and population group, Northern Cape
Source: Stats SA, Population census 1996

Figure 1.4 shows that:

The coloured (36.0%) and African (31.8%) population in the province had the highest proportion of children.

A larger share of the white population than of other population groups (65.3%) fell in the working-age group (15-65 years).

The white population had a far higher proportion of elderly people (10.7%) than the other population groups (5.0% for Africans, 4.7% for coloureds, and 4.5% for Indians).

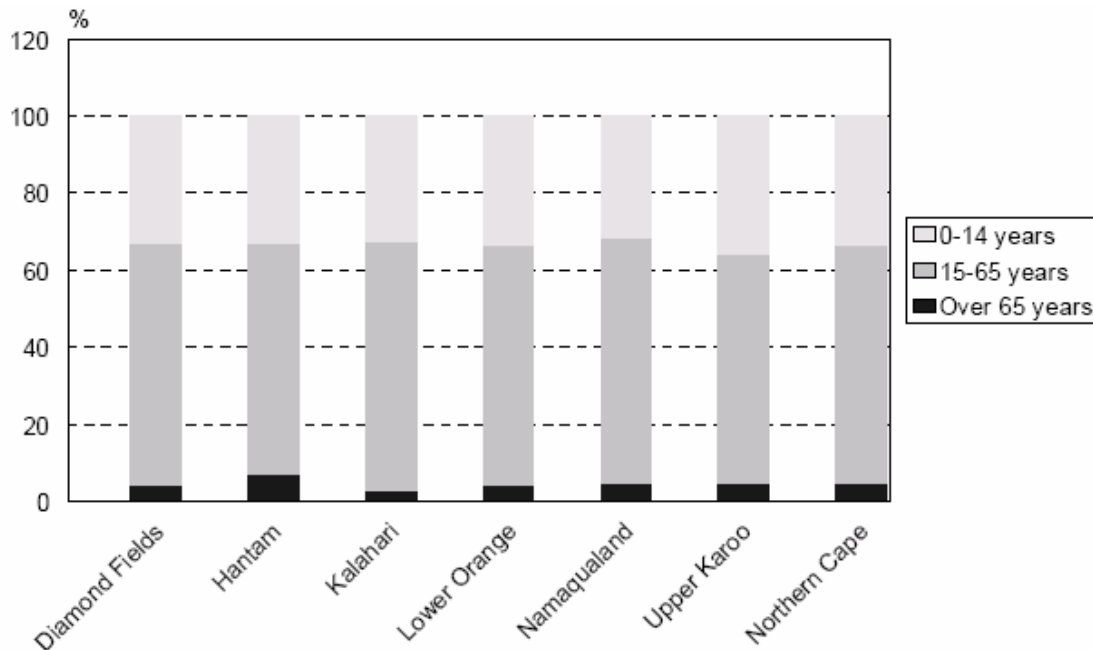


Figure 1.5: Population by age and district council area, Northern Cape

Source: Stats SA, Population census 1996

Figure 1.5 indicates that:

The percentage of children (below 15 years) was almost identical in all district councils with a slightly higher percentage in Upper Karoo (35.9%).

Namakwa district council had the highest proportion of elderly (7.3%).

Kalahari and Namaqualand districts had slightly higher proportions of working-age people (64.3% and 63.7%, respectively).

1.4- SOCIO ECONOMIC INDICATORS OF THE PROVINCE

1.4.1- Education:

- The education levels in the Northern Cape are expectedly low.
- Estimated 79% of the entire Adult Population age > 20 years and older did not have 12 years of schooling in 1996 (non-matriculates).

- Of these 93% were Coloured and African Population Groups.
- This is some 8% higher than the national figures with 12 years of education.
- One in four of the adult population of Coloureds and Africans had no formal education with equal proportions of male and females in either group.
- Very small proportion of Coloured and African population has tertiary education compared to the White group.

1.4.2- Employment

In 1996, 43% of the population were not economically active.

Of the 208000 who said that they were economically active some 73% were gainfully employed.

Unemployment tends to be higher in the non-urban areas for age groups greater than 20 years (13%).

- 22.6% are found in agriculture
- 18.4% work in the personal services
- 12.4% in private households
- 10.7% in trade, wholesale and retail
- 8.6% in the mining and quarrying sector

Table 1.2: Employed (15-65 years) by highest level of education and district council area, Northern Cape 1996

Education level	Diamond Fields	Hantam	Kalahari	Lower Orange	Namaqua- land	Upper Karoo	Northern Cape N	%
No schooling	15 786	3 217	6 095	7 068	848	7 405	40 419	18,8
Some primary (Gr 0-6)	13 533	2 586	3 941	10 941	3 305	6 337	40 643	18,9
Primary (Grade 7)	5 398	934	1 573	4 090	2 275	2 214	16 484	7,6
Some secondary (Gr 8-11)	22 684	2 226	5 605	10 685	7 769	5 960	54 929	25,5
Less than matric & certificate/diploma	1 832	144	815	618	750	392	4 551	2,1
Matric only	13 185	1 431	3 784	5 294	3 260	3 449	30 403	14,1
Matric & other	9 396	959	3 119	3 515	2 210	2 852	22 051	10,2
Unspecified	2 423	207	1 384	861	447	720	6 042	2,8
Total	84 237	11 704	26 316	43 072	20 864	29 329	215 522	100,0

Source: Stats SA, Population census 1996

Table 1.2 shows that:

In October 1996, 37.7% of the employed population in the Northern Cape had not completed primary school education. Countrywide, the same category accounted for 29.3% of the employed.

Above a quarter (25.5%) of the total employed population had completed some secondary schooling (without matriculation). An additional 24.3% had higher qualifications (14.1% with matric only and 10.2% with matric and other qualifications).

Nationally, the employed with matriculation or higher qualification represented 31.4% (19.0% with matric only and 12.4% with matric and other qualifications).

1.4.3- Income distribution

Figure 1.6 represents the distribution of the employed population (in percentages) per income category in 1996.

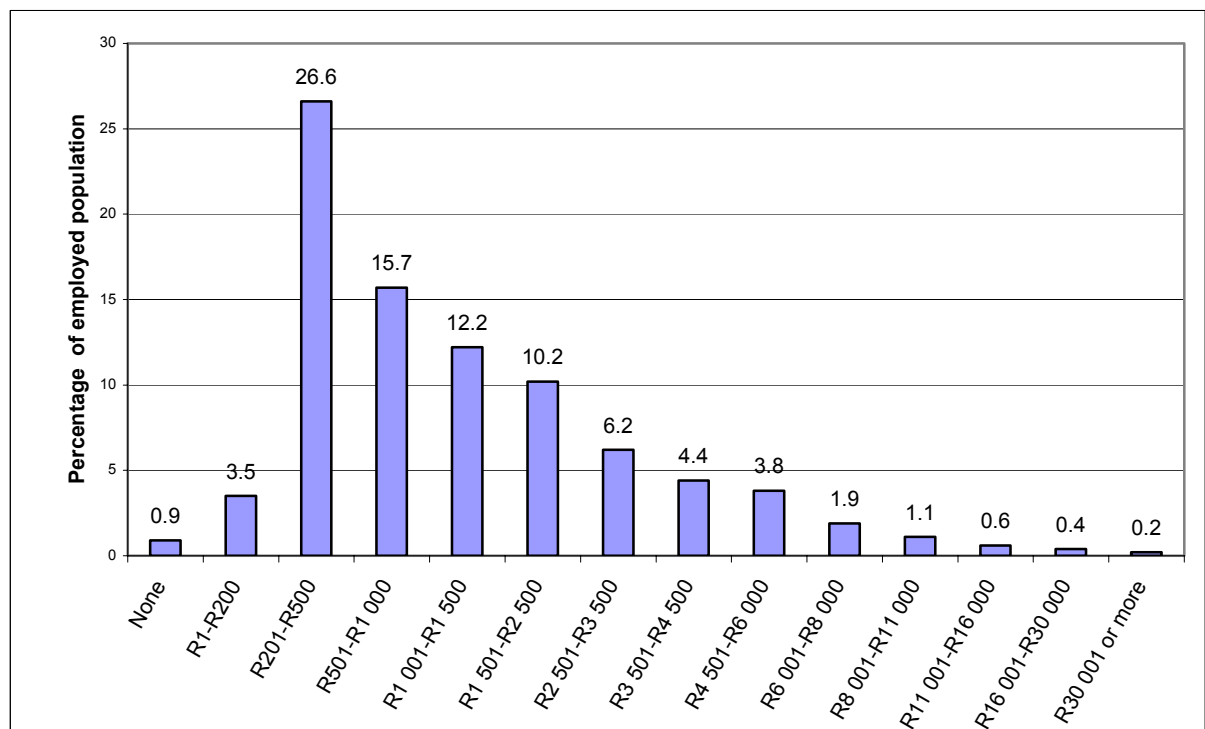


Figure 1.6: Employed by individual monthly income category, Northern Cape
Source Stats South Africa Population Census 1996

The above figure reveals that:

The largest proportion of the employed (26.6%) earned between R201 and R500 per month.

The income distribution is skewed to the right, suggesting that a large proportion of workers were concentrated in the lower income categories and that a small proportion were in the higher. Countrywide, those earning between R201 and R500 accounted for 16.5% of the total employed.

The modal income category for South Africa was R501-R1 000, which represented 18.7% of the total employed (closely followed by the income category R1 001-R1 500 with 17.5% of the total employed). Therefore Northern Cape is worse off than South Africa as a whole.

1.4.4- Measurement of Income Inequality

Two measures of income inequality, namely the Lorenz curve and the Gini coefficient, show the extent of income disparities in the Northern Cape.

The Lorenz curve is defined as the relationship between the cumulative proportion of income units and the cumulative proportion of income received when units are arranged in ascending order of their income. The cumulative percentage of the population, arranged from lowest to highest earner (0% to 100%), has been plotted on the horizontal axis while the cumulative percentage of income, arranged from lowest to highest (0% to 100%), has been indicated on the vertical axis. The distance between the Lorenz curve and the diagonal indicates the degree of income inequality. The further the Lorenz curve is from the diagonal, the more unequal is the income distribution. When there is perfect equality, all earners get the same share and the curve coincides with the diagonal.

The Gini index/coefficient measures the degree of income inequality. It is closely related to and determined from the Lorenz curve. It is equal to 0 in the case of perfect equality (when the Lorenz curve coincides with the diagonal) and 1 in the case of absolute inequality.

Figure 1.7 shows one half of the Lorenz curve in the lower triangle of the square delimited by the horizontal and vertical axes. The second half lies in the upper triangle and is symmetric to the first one according to the first diagonal. Thus, the Gini coefficient is given by twice the area under the diagonal and above the Lorenz curve. The area inside the square is equal to 1.

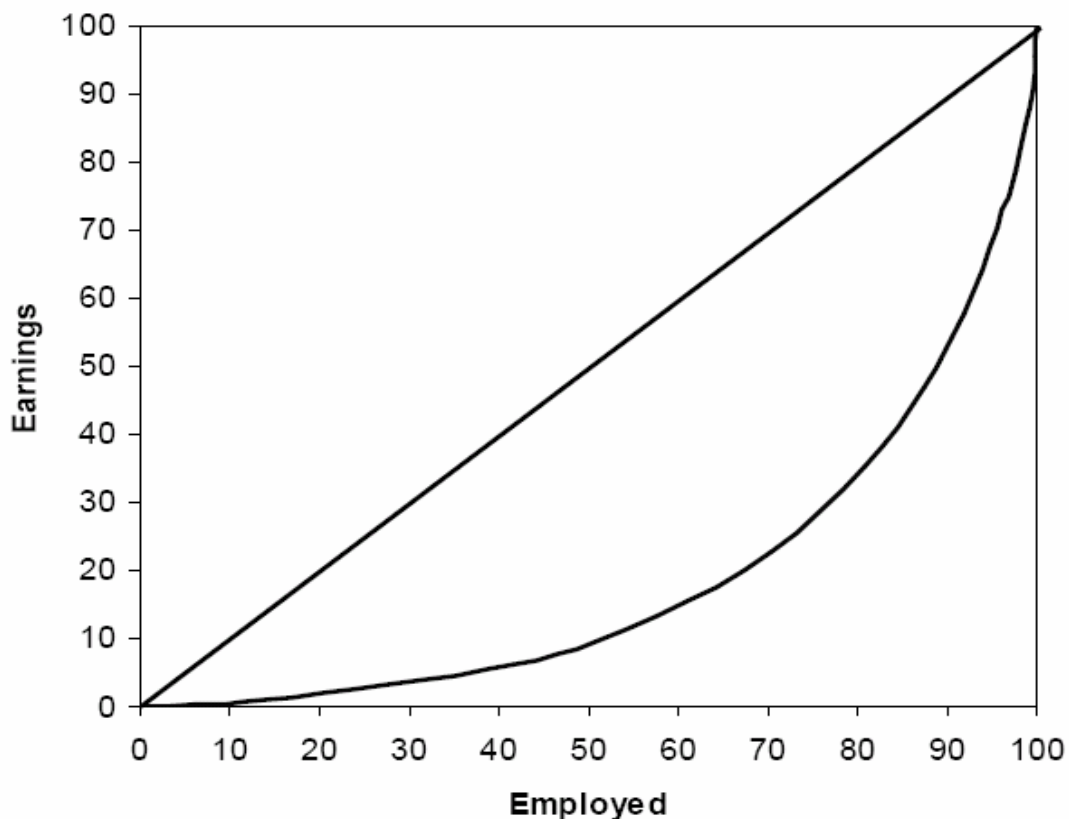


Figure 1.7: Lorenz Curve for Northern Cape
Source: Stats SA, Population census 1996

Figure 1.7 indicates that:

- Approximately one-fifth of total earnings accrued to two-thirds of the earners.
- A little more than half of all earnings were shared by 90% of the employed.
- The Gini coefficient for the Northern Cape was found to be 0.62. This figure shows that income distribution is highly unequal amongst the employed in the Northern Cape.

1.5- Water

In the Northern Cape, about half of the households (49,9%) had access to piped water inside their dwellings, based on the 1996 census data. A third of all households (33,0%) had piped water on site. Households with access to water from a public tap accounted for 8.6% for Northern Cape.

In every district council, about 80% of all households had access to piped water either inside the dwelling or on site.

Households relying on a public tap as the main water supply were mostly encountered in the Diamond Fields and Upper Karoo district councils (11.1% of all households in each of the two districts).

Households relying on other sources of water such as wells or tanks, rainwater, boreholes, dams and rivers were predominantly found in the Lower Orange, Namaqualand, and Hantam districts (13.7%, 11.0%, and 10.5%, respectively).

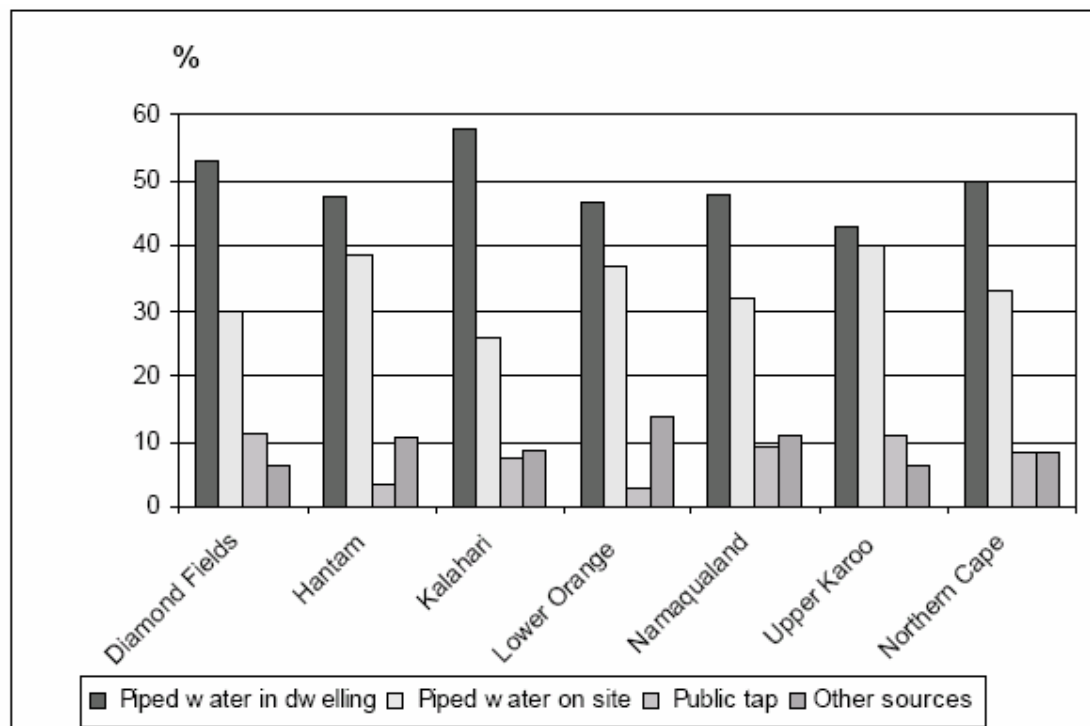


Figure 1.8: Households by water supply and district council area, Northern Cape
Source: Stats SA, Population census 1996

CHAPTER 2: AIM AND OBJECTIVES OF THE PROJECT

Aim: The aim of the project is to determine the fluoride in drinking water and its effects on human health and nutrition in the Northern Cape.

Objectives: The Objectives of the project were:

- 1- To contribute to a sustainable and safe drinking water supply in the Northern Cape with particular reference to groundwater supply in areas where there is the greatest need.
- 2- To determine the levels of fluoride in the groundwater supply used for human consumption.
- 3- To use the Geographic Information System to map the following parameters:
 - fluoride levels of the drinking water
 - population distribution and water utilisation
 - socio-economic status of the population
- 4- To determine the nutritional status of selected samples of children in terms of outcomes related to high and low fluoride levels and the quality of the drinking water to the following:
 - nutritional status
 - fluoride toxicity as measured by the teeth using the TF index (Thylstrup & Fejerskov, 1978)
 - health status of children under 5-years and history of mortality and morbidity related to water outcomes
- 5- To initiate a pilot project with appropriate and inexpensive technology for safe and sustainable drinking water supply in households related to outcomes for:
 - Defluoridation of excessive fluoride in the drinking water
 - Improving the quality of drinking water applying simple measures

CHAPTER 3: METHODS AND RESULTS

PART 1- ANALYSIS OF FLUORIDE LEVELS IN THE DRINKING WATER

3.1- INTRODUCTION

In the last 8 years there have been at least four systematic reviews on fluoride in the drinking water. The main reasons for the reviews were due to the debate on the efficacy of water fluoridation in the reduction of dental decay and its efficacy in good oral health. Many of the arguments are based on the use of fluoride and its perceived harmful effect on general health. The proponents of natural water are opposed to water fluoridation and have argued on the toxic effects on the various human organs and the safety of such a system.

These reviews, which have been requested by different governmental agencies in different countries, have systematically reviewed the current practice and reviews of the literature in Canada, Australia, United Kingdom and United States of America.

It is therefore appropriate to summarize the main findings of the Systematic Reviews of all these reports so that the main issues are viewed in relationship to the situation in the Northern Cape and in South Africa.

The National Oral Health Policy in South Africa recommends the fluoridation of water supplies to reduce the dental decay in the population (Moola, 1995). The policy argues the recommendation on the basis of equity and beneficial effects to the whole population.

However, where there is excessive fluoride in the drinking water it is proposed that defluoridation of the water be considered.

The analysis of the drinking water in the Northern Cape was undertaken to measure the fluoride levels in the different modalities of water and further to examine the effect of dental decay, health nutrition and toxicity on teeth.

3.2- SYSTEMATIC REVIEWS UNDERTAKEN 1996-2003

1- Benefits and Risks of water fluoridation.

An update of the 1996 Federal Provinces Sub Report submitted by Dr David Locker, Community Dental Health Services Research Unit Faculty of Dentistry, university of Toronto. November 15, 1999.

2- A Systematic Review of Public Water Fluoridation.

NHS Centre for Reviews and Dissemination University of York
September 2000

3- Review of Water Fluoridation and Fluoride Intake from discretionary Fluoride Supplements.

Review NHMRC. Australia, Melbourne, 1999.

4- Fluoride in Drinking Water: A scientific Review of the Environmental Policy Agency Standards USA.

The National Sciences of USA, March 2006.

5- Evidence Based Dentistry: Systematic Review of Fluoridation: Vol 3, 2002; Journal of Evidence based Dentistry.

3.3- SUMMARY OF THE KEY FEATURES OF THE 5 PUBLICATIONS

1- That water is safe and healthy at levels used for water fluoridation or naturally occurring fluoride in water in the range 0.7 – 1.2 mg/l.

2- Community water fluoridation is safe and effective for preventing tooth decay.

The balance of evidence suggests that rates of dental decay are lower in fluoridated than non-fluoridated communities,

The effect tends to be more pronounced in the deciduous teeth.

3- Communities living in areas with natural fluoride at 2 mg/l or greater put children 8 years old and younger at increased risk of severe enamel fluorosis. A condition that causes staining and pitting of enamel surface of teeth.

The enamel fluorosis is confined to the “very mild” and “mild” categories of the conditions.

“They are of concern insofar as they are discernible to the lay population and may impact on those so affected.” (Canadian Review, Locker, 1999).

A significant “dose response relationship was identified through a regression analysis” (NHS Review, 2002). It is theoretically estimated that with low levels of fluoride ranging from 0.4 ppm to 1 ppm at least one quarter will have aesthetic concern.

4- Communities living in areas where fluoride levels greater than 4 mg/l with a lifetime exposure to fluoride is likely to increase fracture rates in the population, particularly in some demographic subgroups that are prone to accumulate fluoride into their bones (e.g. people with renal disease) (EPA recommendation 2006).

5- There is some evidence that water fluoridation reduces the inequalities in the dental health across social classes in 5 and 12 year olds using dmft/DMFT measure.

6- This effect was not seen in the proportion of caries free children among 5 years old (NHS Study 2002).

7- There is no clear association between water fluoridation and incidence or mortality of bone cancer, thyroid cancer or all cancers found.

This study is in three separate parts:

1. Analysis of Water in the Northern Cape.
2. Clinical Examination of Children to measure the effects on teeth and nutritional status in varying levels of fluoride in the drinking water.
3. Assessment of defluoridation of Water in levels > 2 mg/l.

3.4- DESIGN OF THE STUDY

3.4.1- Introduction

Water is a scarce resource in South Africa and many parts of the country have limited access to water either from natural rainfall, rivers, dams and localised boreholes.

The Northern Cape is not endowed with good rainfall and depends on the supply from the Vaal and Orange Rivers and borehole water.

The borehole water supply has several constraints in that it is limited in supply, often very brackish and hard, many times very high in mineral contents like fluoride.

This part of the study was to determine the levels of fluoride in the Northern Cape. Based on the outcome levels of fluoride, a hypothesis was framed to test some of the recommendations of the Systematic Reviews discussed previously.

3.4.2- Sources of fluoride

Fluorine is the thirteenth most abundant element in the Earth's crust. It rarely occurs as the element but normally is found as the fluoride ion or as a variety of inorganic and organic fluoride. It occurs in varying concentrations in rocks, soils, water, air, plants and animals both naturally and as a consequence of human activity such as agriculture or industrial processes. Human exposure may be through any or all of these sources.

This study is limited to consideration of fluoride, which is occurring either naturally or artificially in water, which is consumed as part of safe water human consumption, or in the diet.

3.4.3- PAST/PREVIOUS (PURPOSE OF THIS) STUDY

The purpose of this part of the study was to identify the sources of fluoride in water and human consumption either through centralized or reticulated water or from boreholes.

In South Africa, the natural fluoride concentrations in water have been studied from as early as 1935 (Maughan, 1935) and Ockerse (1941).

Subsequently selected studies were done to determine the fluoride concentration by various authors.

Table 3.1: Studies undertaken in South Africa

Author	Year	Title
Maughan Brown, H	1935	Our Land, Is the population Satisfactory
Ockerse, T.	1941	Endemic Fluorosis in the Kenhardt and Gordonia District
Ockerse, T	1947	Dental Caries: Clinical & Experimental Investigations
Retief, DH; Bradley, EL et al.	1979	Kenhardt Revisited
Dreyer, G & Grobler, S	1984	Die fluoriedgehalte in die drinkwater van S.A. & SWA
Grobler, SR et al.	1991	Die fluoriedkonsentrasie in die drinkwater van kleiner dorpe in the Kaapprovinsie
Janse van Rensburg SD et al.	1991	Fluoriedstatus van gemeenskap met "n lae fluoriedkonsentrasies in the drinkwater.
Grobler, SR et al.	1994	The fluoride concentration in the drinking water of towns in the Transvaal, Orange, Free State and Natal
Grobler, SR, Chikte, UME et al.	2007	Fluoride concentration of drinking water in South Africa.

3.4.4- Naturally occurring fluoride

Naturally fluoridated waters contain the fluoride ion derived from sparingly soluble minerals such as fluoro-apatites or fluorite. The usual range of concentrations found varies from 0.05-8.2 ppm, with most values falling between 0.1 – 2 ppm. The fluoride levels in naturally fluoridated South African waters ranges from <0.1 – 8 ppm. In areas such as the Northern Cape and Pilanesberg regions of North West Province concentrations range from 0.1 to 8.2 ppm.

In many countries there is a paucity of information on fluoride content of drinking water. However, in recent years there has been an active effort to measure the fluoride concentration of natural water in many parts of the world. In the USA, there is a concerted effort to measure fluoride content in natural water supplies and some of the most classical epidemiological studies since 1944 have been undertaken in USA, Canada, Australia and parts of South East Asia. There is vast documentation in the USA, Canada and Northern Europe.

In India and parts of Africa, the measurement of naturally occurring fluoride has been reported since 1970.

Table 3.2: Selected areas of naturally occurring fluoride in India and Africa

City/District	Country	Fluoride Level	Source
Lahore (Punjab)	Pakistan	0.5 - 2.01	Wells & Tap
Kellampalli (Andra Pradesh)	India	5.7 - 33.5	Wells
Nagpur	India	4.1 - 4.8	Wells
Magadi	Uganda	2.8 - 17.1	Salt Pans
Arusha	Tanzania	3.8	Tap
Moshi	Tanzania	0.4	Tap
Rift Valley	Ethopia	>1.5	Country
Rift Valley	Ethopia	2.0 - 5	Lakes/Hot springs

3.5- METHODOLOGY

3.5.1- Collection of Samples from Water Supplies

The Diamond District (Kimberley and peri-Urban areas) has a radius of 80 kilometres and a population concentration of 346672 out of 840321 (i.e. 41 % of the total population of the Northern Cape). The samples of drinking water were collected for analysis of free fluoride ions at the different school sites from tap water (central supply shown in Table 3.3). The analysis of fluoride ions would be expressed as parts per million (ppm) or mg/l and was measured to an accuracy of two decimal points.

Table 3.3: School sites

Kimberley (Diamond fields) School Sites	
Urban	Peri-urban
Floor Noord	Simbamba
HF Verwoerd	Aalwyn
Isago	Vaal-Oranje
Little Flower	Twee-Rivier
	Kammaland
	LSW
	Francis Mohapanele
	Arthrudes
	Barkley West

For De Aar the collection of water was from the school and residences. However, the water supply is from a central source through the taps, the origin of the total water supply in De Aar is from groundwater abstracted using boreholes.

For the Leliefontein and Kamassies the collection of water was from the school and residencies. The water supply is also groundwater.

3.5.2- Analysis of Fluoride Levels in Drinking Water

The water samples were collected and analysed for free fluoride. The obtained water samples were filtered through a 0.45 µm membrane filter. One part of each water sample was mixed with one part TISAB/CDTA reference buffer. At the same time five fluoride standards varying between 10^{-1}M and 10^{-7}M were prepared in 50% TISAB/CDTA buffer and a calibration curve was set from where the fluoride concentration of the sample was determined with the use of a combination fluoride ion selective electrode (Orion). Three different fluoride dilutions were made from each water sample, the fluoride concentrations in each determined (which should not differ from each other by more than 3%) and the values noted.

3.6- RESULTS

3.6.1- Diamond Fields

Table 3.4 shows free fluoride levels for the Kimberley and peri-urban areas. The mean level for Kimberley was 0.35 ppm and 0.31 ppm for peri-urban areas. The fluoride levels for Kimberley ranged from 0.34 – 0.36 ppm.

Table 3.4: Fluoride levels for Kimberley and peri-urban areas

Kimberley (Tap water)	School	Fluoride Levels (ppm)	Average
Urban	Floor Noord	0.36	0.35
	HF Verwoerd	0.35	
	Isago	0.34	
	Little Flower	0.34	
Peri-Urban	Simbamba	0.45	0.31
	Aalwyn	0.34	
	Vaal-Oranje	0.15	
	Twee-Rivier	0.19	
	Kammaland	0.34	
	LSW	0.34	
	Francis Mohapanele	0.45	
	Arthrudes	0.15	
	Barkley West	0.34	

In the peri-Urban areas of the Diamond Fields district the fluoride levels ranged from 0.15 to 0.45 ppm.

3.6.2- De Aar

Table 3.5: Free fluoride levels in De Aar

Area	Fluoride Level (ppm)
De Aar (borehole)	0.71

The fluoride levels in De Aar were 0.71 ppm.

3.6.3- Leliefontein and Kamassies

Table 3.6: Free fluoride levels of Leliefontein and Kamassies

Area	Fluoride Level (ppm)			
Kamassies (Rural)	5.7	8.2	2.7	2.4
Lieliefontein (Rural)	2.5	0.2	1.1	0.2

Five sets of water samples were collected from different boreholes in Kamassies and Leliefontein. These two areas are in the Garies district with small rural and pastoral villages. The levels of fluoride ranged from 0.2 to 8.2 ppm.

3.6.4- Fluoride levels in other areas of Northern Cape

As part of the whole study, it was necessary to analyse as many sites in the Northern Cape for the fluoride levels of drinking and potable water supply commonly used by the population.

Two 100 ml samples per town were collected and then transferred to Cape Town. The samples were analysed using the same methods as described previously. The results of the samples of water per town/district are enumerated below.

From the results it can be ascertained that the fluoride levels ranged from <0.05 to 8.2 ppm (<0.05 mg/l to 8.2 mg/l). The higher levels are from borehole water supplies. Table 3.7 shows the fluoride distribution in the Northern Cape

Table 3.7: Fluoride levels of other towns in Northern Cape

Area	F (ppm)	Area	F (ppm)	Area	F (ppm)
Noenieput	1.2	Griekwastad, etc	0.17	Norvalspont	0.13
Kenhardt	3	Philipstown	0.62	Noupoort	0.68
Riemvasmaak	4	Bergsig	0.15	Hartswater	0.3
Keimoes	0.16	Matjieskloof	0.17	Jan Kempdorp	0.34
Lennertsville	0.16	Springbok	0.18	Pampierstad	0.3
Kakamas	0.17	Nababeep	0.17	Ganspan	0.74
Loubos	0.94	Bulletrap	2.22	Barkley-West	0.24
Olifantshoek	0.29	Garies	0.6	Delporthoop	0.3
Philandersbron	1.04	Leliefontein	1.81	Deben	0.26
Soverby	0.18	Kamieskroon	1.6	Warrenton	0.24
Mata Mata	2.22	Loeriesfontein	1.04	Karoo hoogland - Williston	0.32
Lime Acres	2.96	Pella, Aggeneys, Defender	0.23	De Aar	0.76
Kanoneiland	0.16	Sutherland	0.64	Calvinia/3 Boreholes	1.96
Nossol	0.48	Onseepkans	0.18	Loeriesfontein	0.94
Upington / Kalahari weg	0.19	Steinkopf	0.28	Niewoudtville	0.32
Twee Rivieren	4.6	Gladkop	1.36	Brandvlei	0.12
Groot Mier/Klein Mier	2.2	Eyams	0.12	Ritchie	0.11
Vredesvallei	0.16	Henkries, etc	0.2	Kakamas	0.16
Danielskuil	0.14	Goodhouse	0.23	Vanzylsrus	0.2
Postmasburg	0.14	Hopetown Mun. Aard	0.14	Kuruman	<0.1
Groblershoop	0.12	Sanddrift	0.18	Kogung	0.1
Ashlam	0.12	Kuboes	0.48	Seoding	<0.1
Niekerkshoop	0.64	Douglas, etc	0.15	Banknara	<0.1
Strydenburg	0.46	Kimberley	0.26	Rietfontein	0.66
Prieska	0.18	Colesberg	0.12	Springbok dorp	0.17
Marydale	1.22			Namaqualand DC	0.24
Van der Kloof / Petrusville	0.14			Concordia	0.2
Campbell	0.28			Komaggas	0.7

The fluoride levels in the Northern Cape ranged from < 0.1 in Kuruman to 4.6 ppm in Twee Rivieren.

There is variation in the results of fluoride levels in those areas multiple samples were taken from multiple sites in some towns. However, the differences are marginal and not significant. The real concern was the high levels obtained from boreholes in the Garies district.

The analysis of fluoride in the Northern Cape gave some indication of setting up the three hypotheses to test the various conclusions and recommendations from the Systematic Reviews from different parts of the world.

The population distribution of Northern Cape in the six new districts is centred around the towns of Kimberly, De Aar, Upington and Springbok.

The Diamond Fields district has 41% of the population with a fluoride range of 0.19 to 0.45 ppm. The urbanization of the population and concentration in the area allowed for the sampling frame to be designed to draw most of the children from this district.

De Aar was selected as a strategic railway junction town and had a mixed settled population. One unique feature of De Aar was that its water supply is from groundwater. The difference in the water source gave the opportunity to test the hypothesis of groundwater fluoride against water from other sources such as rivers and dams.

Kamassies and Leliefontein were chosen as the rural areas with borehole water supply. There was marked variation in the fluoride levels within each of the two rural sites. Fluoride levels in the water from each of the five boreholes in each of the two villages varied from 0.2 to 8.2 ppm. This variation of the fluoride levels and poor status of the communities allowed us to set the hypothesis for severity of fluorosis with varying degrees of fluoride as a marker for dysfunction in mineralization of teeth.

PART 2- EXAMINATION OF POPULATION

Testing of Hypotheses

Hypothesis 1:

There is no difference in dental caries prevalence in children living in the Kimberley, Diamond fields' district with fluoride levels ranging from 0.3 to 0.4 ppm and the children living in De Aar with fluoride levels of 0.71 to 0.73 ppm.

Hypothesis 2:

There is no difference in the prevalence of fluorosis experience between the children who reside in Kimberley area with the varying degrees of fluoride levels.

Sub hypothesis that there is no difference in fluorosis using the TF Index in the different fluoride areas.

Hypothesis 3:

There is no difference in the prevalence of dental decay in deciduous teeth in both areas in children between the ages of 5-6 years.

Hypothesis 4:

There is no difference in the nutritional status of children living in the Kimberly Diamond Fields Area and De Aar.

3.7- METHODOLOGY

3.7.1- Sampling

1- Diamond fields

A list of all the schools was obtained from the Department of Education and the necessary permission granted through the Departments of Education and Health in the Northern Cape through the assistance of the then Superintend-General of Health of the Northern Cape.

A stratified sample of schools was selected for the Kimberley and peri-urban areas. The principals of the schools were contacted prior to our visit, informed about the purpose of our visit, and permission subsequently obtained. The consent from each participant was obtained through the Principals office from the parents. Special schools were excluded in the sampling frame.

The Children in the age range 3-12 years were then randomly selected. A total of 700 children were selected for the different schools stratified for age and gender. A total of 691 were examined of the selected sample. Learners absent during the examination were not repeated or replaced.



Some of the children examined in Diamond fields area



More children examined in Diamond fields area

2- De Aar:

De Aar was selected as an examination site because the water supply is from a centralised borehole. This would give a better representation of the sample of children drinking water from a centralised source defined as borehole. De Aar has centralised water supply from taps but the water is sourced from a borehole. The level of fluoride in the water ranged from 0.71 to 0.76 ppm both in winter and summer.

A stratified multistage sample of schools (similar to the Diamond fields) was done and children aged 5-6 and 11-13 years was selected in De Aar, Northern Cape.

A total of 137 children were selected for the examination for age and gender, but only 128 were examined.



Some of the children examined in the De Aar area

3- Leliefontein and Kamassies

The sample was selected from preschools, schools and adult population in Leliefontein and Kamassies areas of Northern Cape. The sample selection was not on the same framework as De Aar and Diamond Fields. This was because of the nature of the population distribution in the rural areas in the northwestern area of the district of Namaqualand and Grater Karoo that was very different from those of Diamond fields and De Aar.

All the children aged 3-5 years and school going children in Leliefontein and Kamassies were examined on the particular day of visit.

It was further decided to examine as many of the adults in the two villages. The anomaly of the sample was that the adult population was made up largely of elderly people and mostly females in each of the households. Male adults were a rarity as most of them were working in towns like Springbok and O'Kiep.

3.8- PHYSICAL EXAMINATION

3.8.1- Height

Each child was measured for height, in centimetres, to the accuracy of one decimal point, by means of a standardized meter rule. Each child was positioned with their heels up against the t-bar of the measuring stand, their shoulders, and heads

positioned with occipital part of the skull, up against the post of the measuring stand (Figures 3.1).



Figure 3.1: Height measurement using standardized meter

Ten percent (10%) of the children were re-measured for height (as part of inter/intra-examiner validity). Any impediment to a standardised reading of height was removed e.g. caps, females with hairstyles that were tied high up, were asked to lower their hair.

3.8.2- Weight

Each child was weighed, in kilograms, to the accuracy of one decimal point, by means of an electronic scale (Figure 3.2). 10% of the children were re-weighed, so as to validate readings.



Figure 3.2: Weight measurement using electronic scale

Children were measured for height and weight without shoes on. Children were allowed to wear basic uniforms or the equivalent in casual clothing.

By means of an anthropometrics software package (Epi Info 6), these values of height and weight were used for anthropometric calculations: WHZ (weight-for-height), WAZ (weight-for-age) and HAZ (height-for-age).

3.8.3- Dental Examination

The dental evaluation involved the examination of teeth for fluorosis (Figure 3.3), using TF index proposed by Thylstrup and Fejerskov (1978). A photographic record was made of the children that manifested TF scores greater than and equal to 5 (Figures 3.4 to 3.12).



Figure 3.3: Dental examination of a child

Kimberley



Figure 3.4 & 3.5: Fluorosis in Kimberley area

De Aar

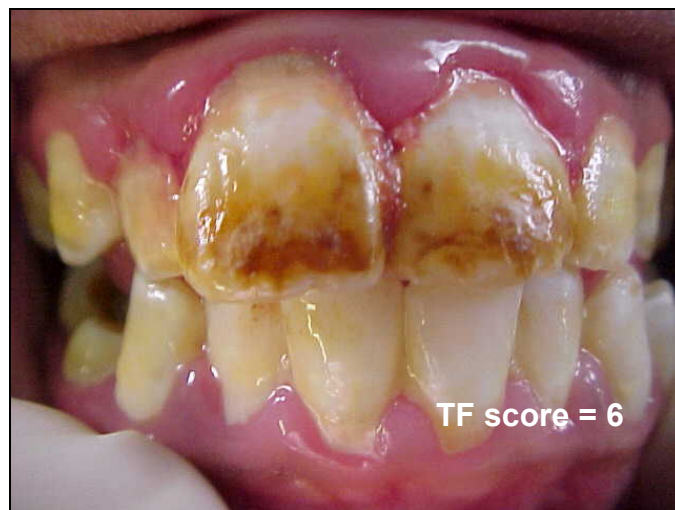


Figure 3.6, 3.7 & 3.8: Fluorosis in De Aar

Leliefontein and Kamassies

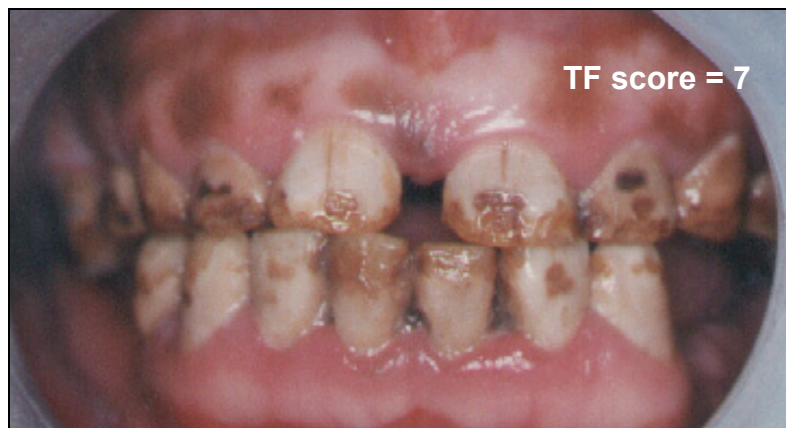


Figure 3.9, 3.10, 3.11 & 3.12: Fluorosis in Leliefontein and Kamassies

The clinical examination also recorded the dental caries prevalence of the population using the modified BASCD index (Figure 3.13). 10% of oral examinations were repeated to check inter-examiner and intra-examiner variability. An 80% consistency was determined.



Figure 3.13: Dental examination of population

Table 3.8: The modified Thylstrup-Fejerskov classification, TF-index of fluorosis.

Score	Clinical Appearance
0	The normal translucency of the glossy creamy-white enamel remains after wiping and drying of the surface.
1	Thin white opaque lines are seen running across the tooth surface. Such lines are found on all parts of the surface. The lines correspond to the position of the perikymata. In some cases, a slight “snowcapping” of cusps/incisal edges may also be seen.
2	The opaque white lines are more pronounced and frequently merge to form small cloudy areas scattered over the whole surface. “Snowcapping” of incisal edges and cusp tips is common.
3	Merging of the white lines occurs, and cloudy areas of opacity spread over many parts of the surface. In between cloudy areas white line can also be seen.
4	The entire surface exhibits a marked opacity, or appears chalky white. Parts of the surface exposed to attrition or wear may appear to be less affected.
5	The entire surface is opaque, and there are round pits (focal loss of outermost enamel) that are less than 2 mm in diameter.
6	The small pits may frequently be seen merging in the opaque enamel to form bands that are less than 2 mm in vertical height. In this class are included also surfaces where the cuspal rim of facial enamel has been chipped off, and the vertical dimension of the resulting damage is less than 2 mm.
7	There is a loss of the outmost enamel in irregular areas, and less than half the surface is so involved. The remaining intact enamel is opaque.
8	The loss of the outmost enamel involves more than half the enamel. The remaining intact enamel is opaque.
9	The loss of the major part of the outer enamel results in change of the anatomical shape of the surface/tooth. A cervical rim of opaque enamel is often noted.

3.9- RESULTS

Table 3.9 shows the total number of sample examined at different District areas of the Northern Cape Province.

Table 3.9: Total number of sample

Area	Number
Kimberley and peri-urban areas (Diamond Fields)	691
De Aar	128
Leliefontein and Kamassies	135
Total	954

3.9.1- Diamond Fields

Age Distribution of the Sample

Table 3.10 shows the age distribution of the 691 children who were examined in the Kimberley and peri-urban areas. In the Kimberley area, more children in the lower age groups were examined. A greater percentage of children in the higher age groups were examined in the peri-urban areas.

Table 3.10: Age distribution of sample

Total number of children examined				
Kimberley			Peri-urban	
Age (years)	Frequency	Percentage	Frequency	Percentage
3-5	40	13.5	24	6.1
6-7	84	28.3	88	22.4
8-10	94	31.6	163	41.6
11-13	49	16.5	100	25.5
Total*	267	89.9	375	95.5

*The total percentage does not add to 100% because children aged 61-71 months were excluded. This was implemented so as to ensure that the 3-5 year age group would have a purely primary dentition.

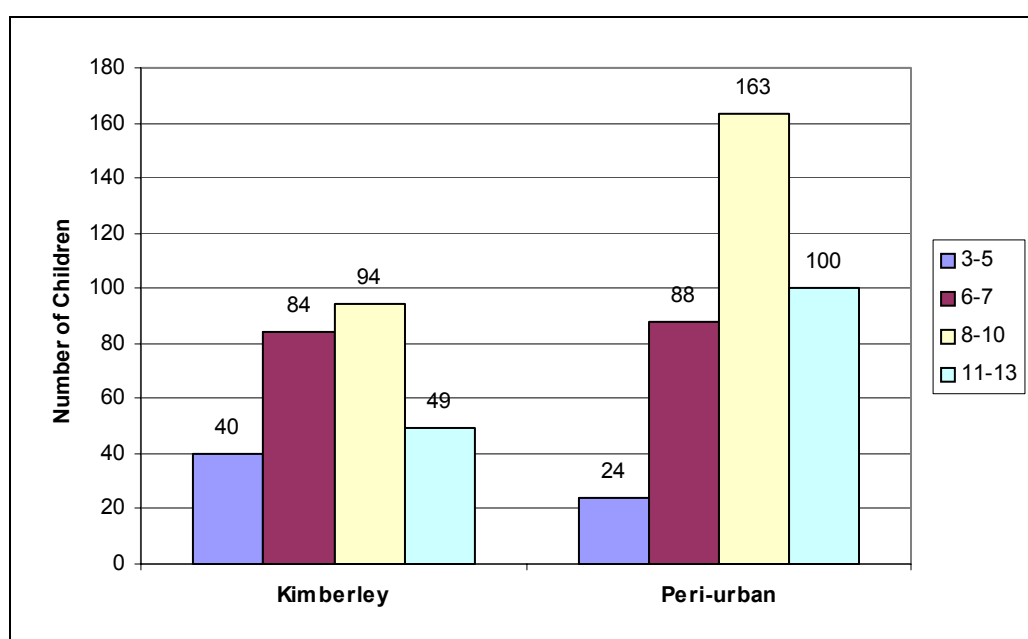


Figure 3.14: Frequency of sample in Diamond fields

Results of Nutritional Status

Table 3.11: Mean z-values for the Kimberley and peri-urban areas

	Mean scores (std. dev.)					
	Kimberley			Peri-urban		
Age (years)	WHZ	WAZ	HAZ	WHZ	WAZ	HAZ
3-5	0.11(1.37)	-0.23 (1.24)	-0.43 (0.83)	-0.37 (2.09)	-0.67 (1.86)	-0.53 (1.06)
6-7	-0.66 (0.97)	-0.83 (1.05)	-0.62 (1.04)	-0.90 (1.270)	-1.12 (1.30)	-0.83 (1.06)
8-10	-0.71 (1.04)	-1.16 (0.95)	-0.99 (1.21)	-0.90 (1.17)	-1.25 (1.08)	-1.07 (1.10)
11-13	0.18 (0.99)	-1.11 (0.79)	-1.23 (0.96)	-0.60(0.90)	-1.11 (0.97)	-1.25 (1.19)

There were no significant differences between the WHZ, WAZ, and HAZ values for the Kimberley and peri-urban areas. There were also no significant differences between these values for that percentage of the sample population who were below -2.0 in the anthropometric analysis (i.e. those who were wasted, underweight or stunted). For this sub-population, there were also no significant differences between WHZ, WAZ, HAZ and dmf(t), DMF(T) and fluorosis.

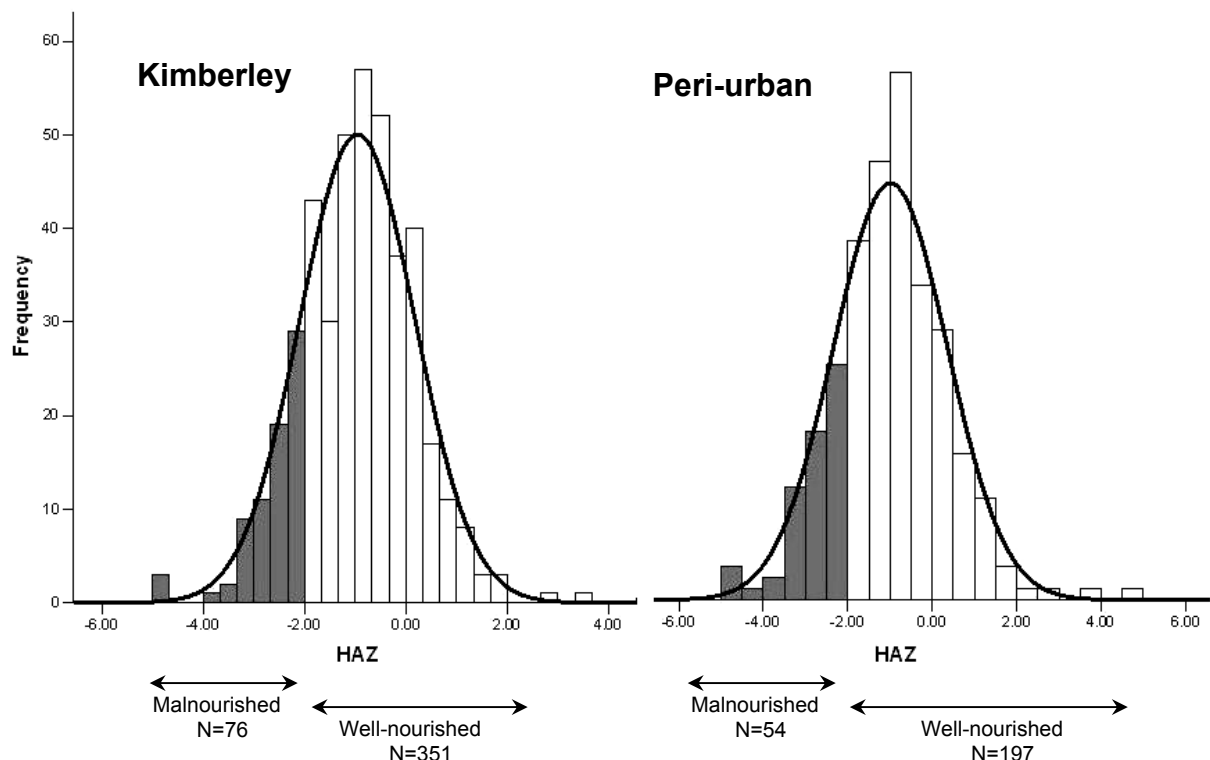


Figure 3.15: Height for age for Kimberley and peri-urban

Though there is no significant difference between the above parameters in the Kimberly/Diamond Fields area, some 21.5 to 21.6% of the children were malnourished (i.e. z-score > -2 for HAZ).

GROWTH CHARTS FOR KIMBERLEY

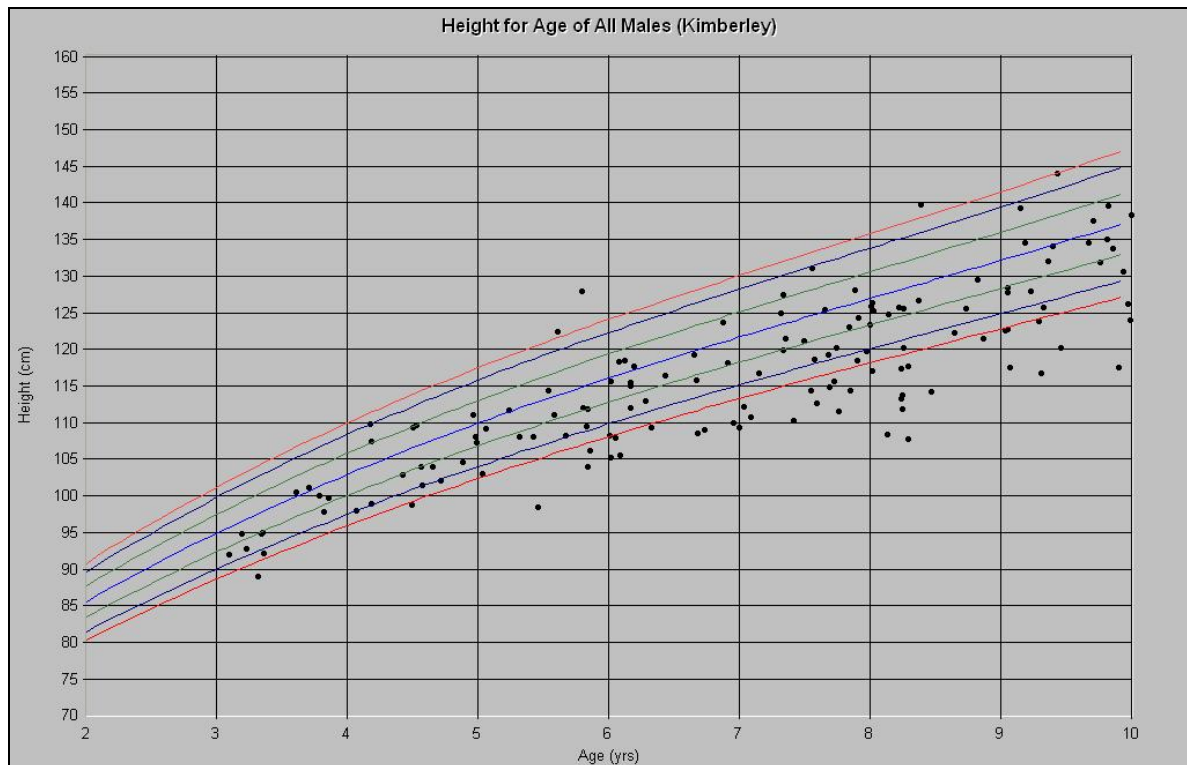


Figure 3.16: Height for age of all males in Kimberley area

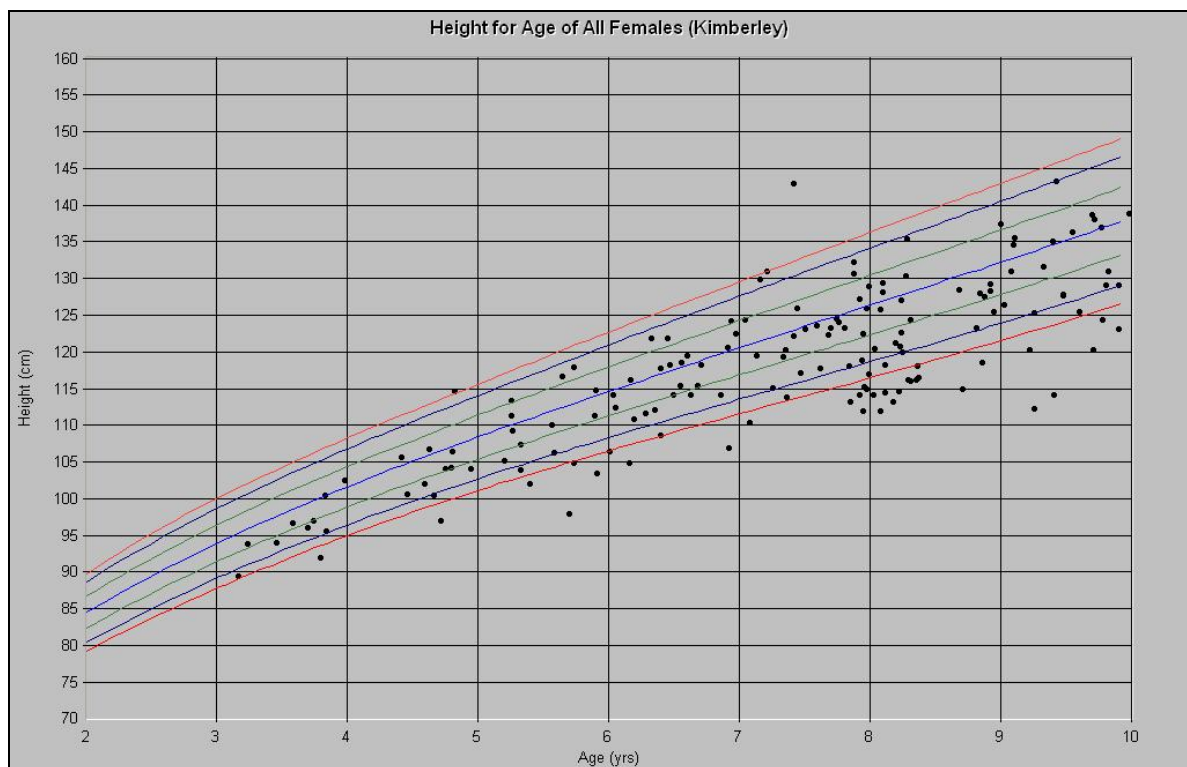


Figure 3.17: Height for age of all females in Kimberley area

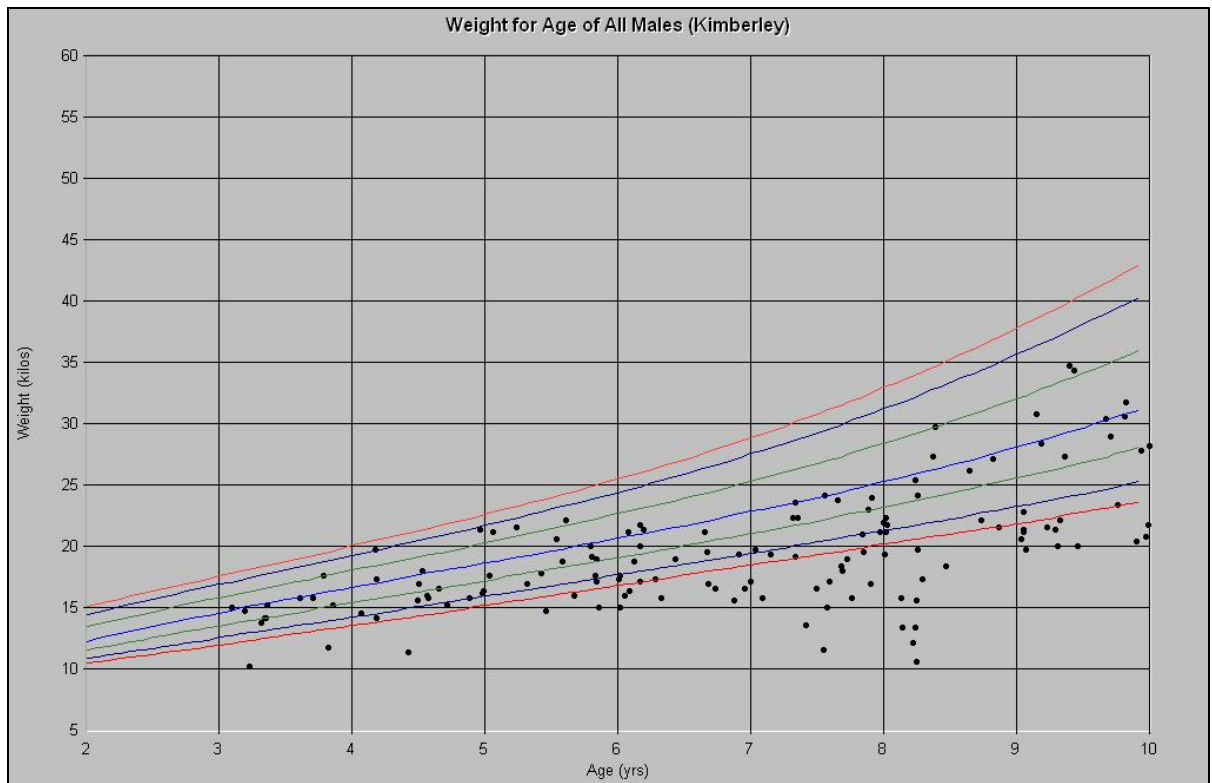


Figure 3.18: Weight for age of all males in Kimberley area

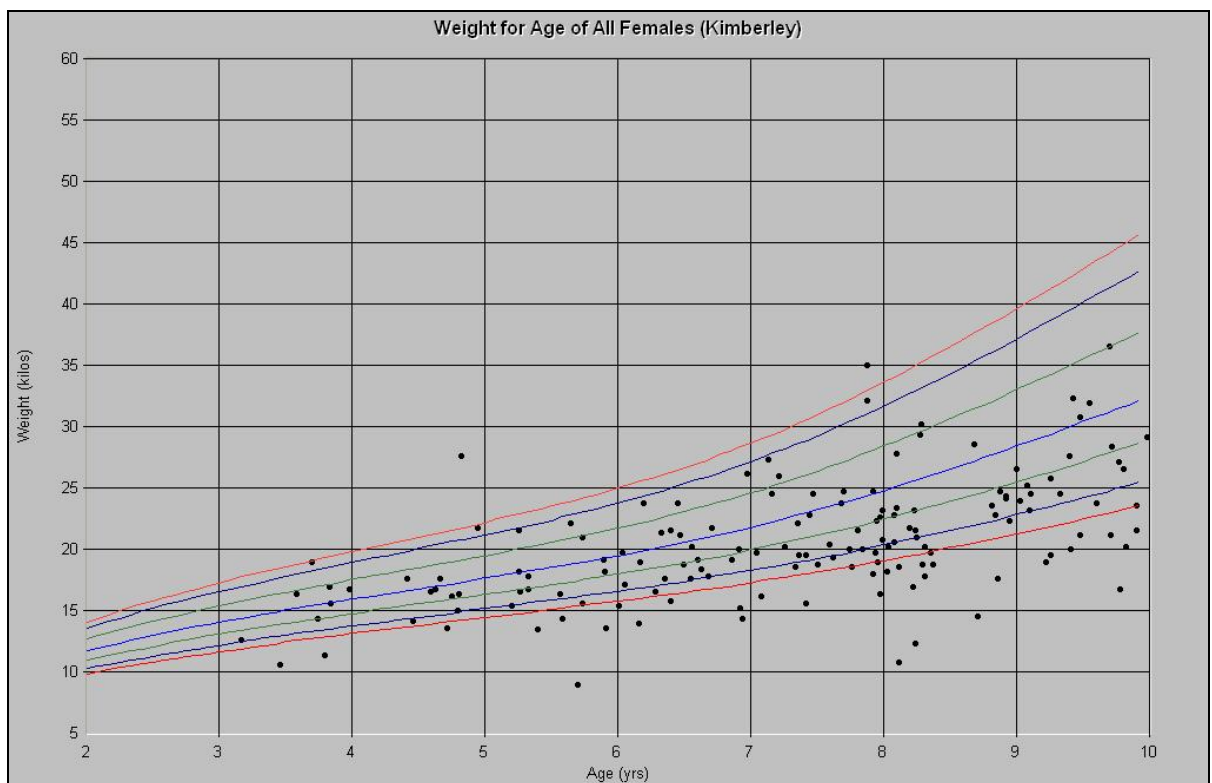


Figure 3.19: Weight for age of all females in Kimberley area

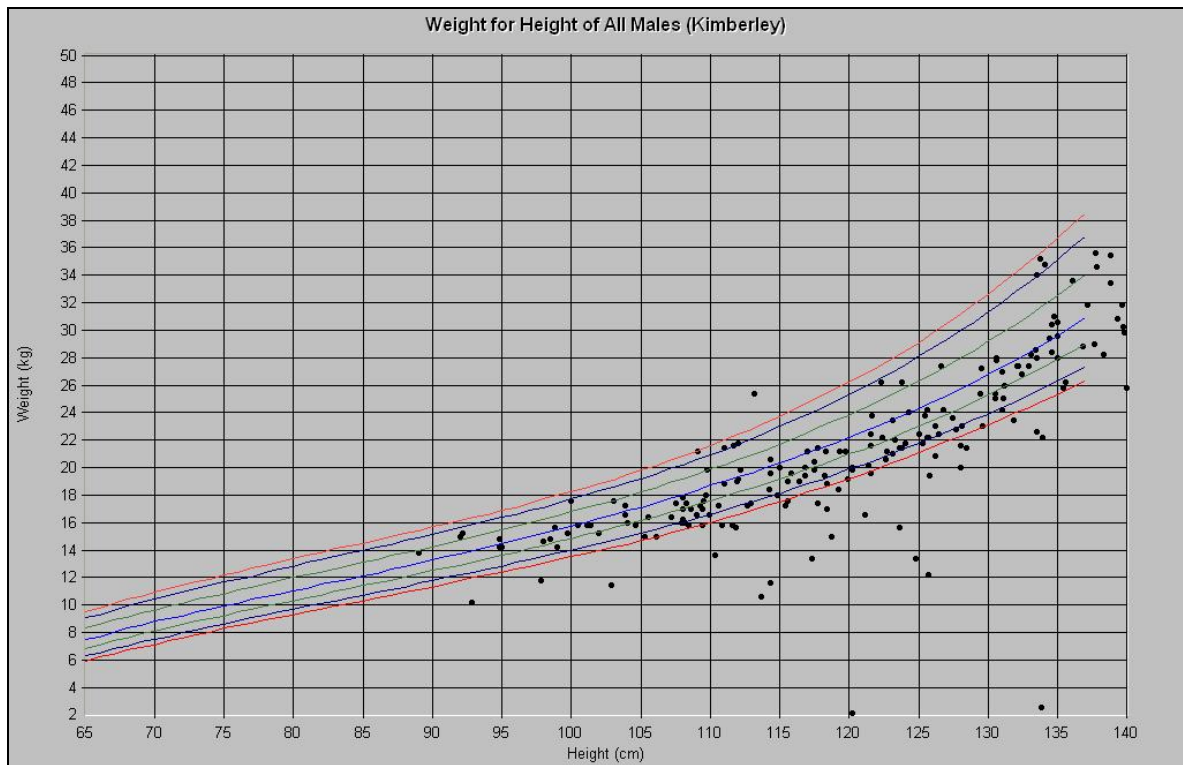


Figure 3.20: Weight for height of all males in Kimberley area

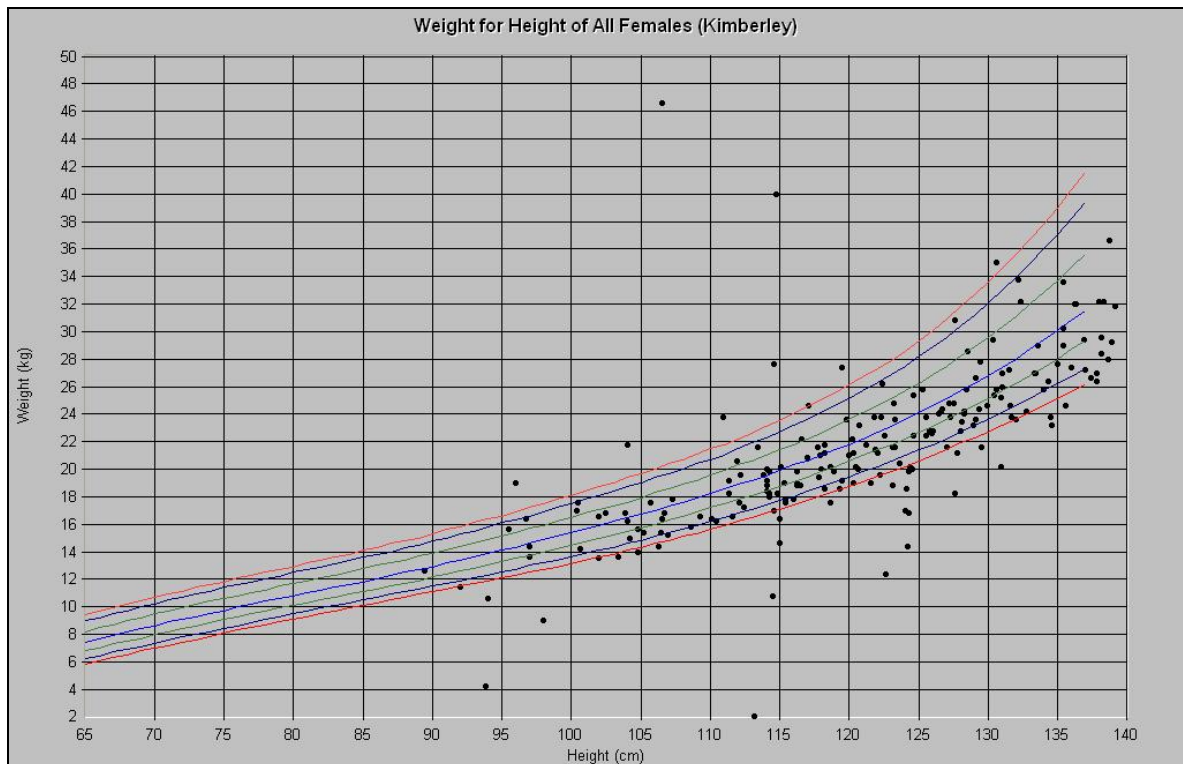


Figure 3.21: Weight for height of all females in Kimberley area

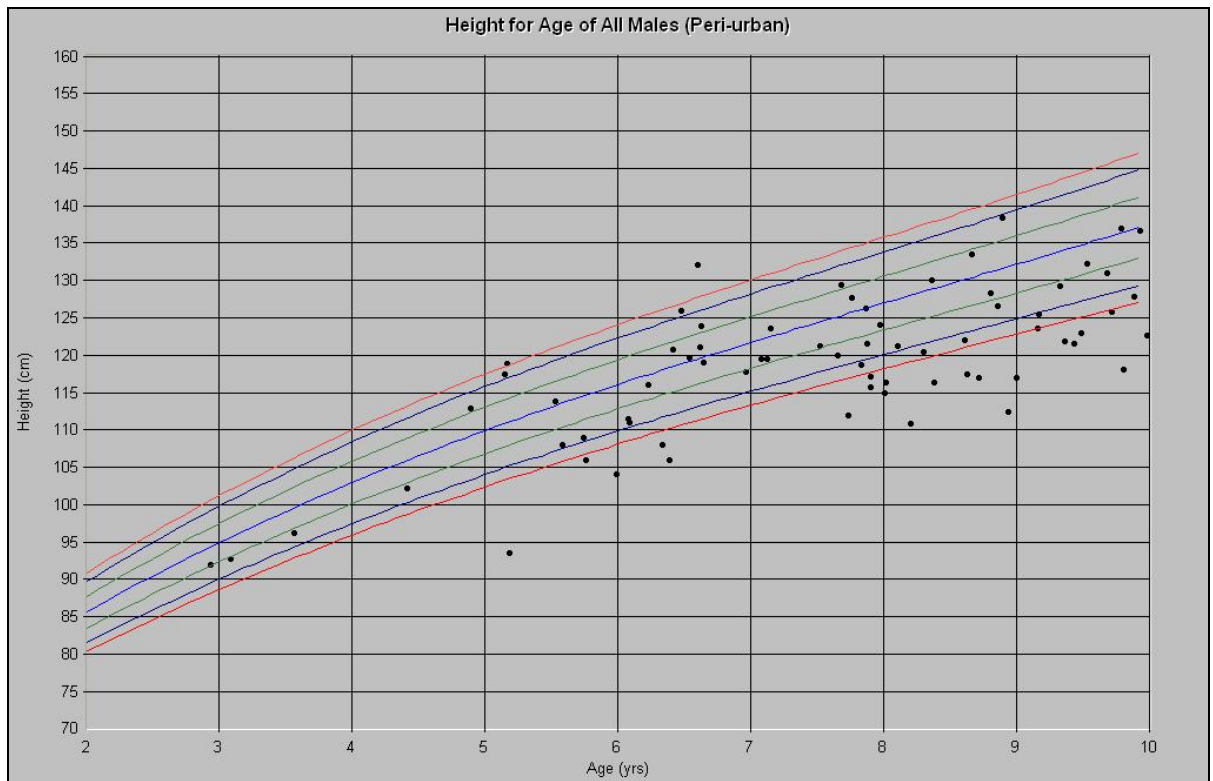


Figure 3.22: Height for age of all males in peri-urban area

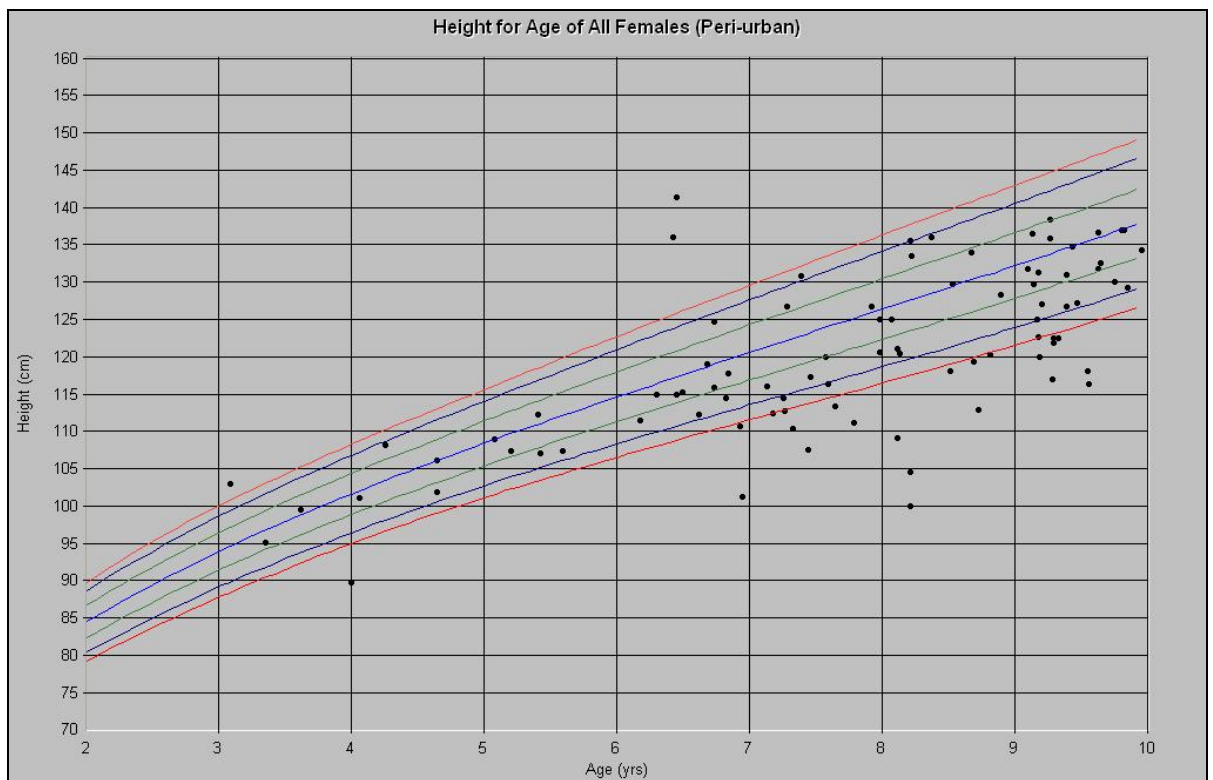


Figure 3.23: Height for age of all females in peri-urban area

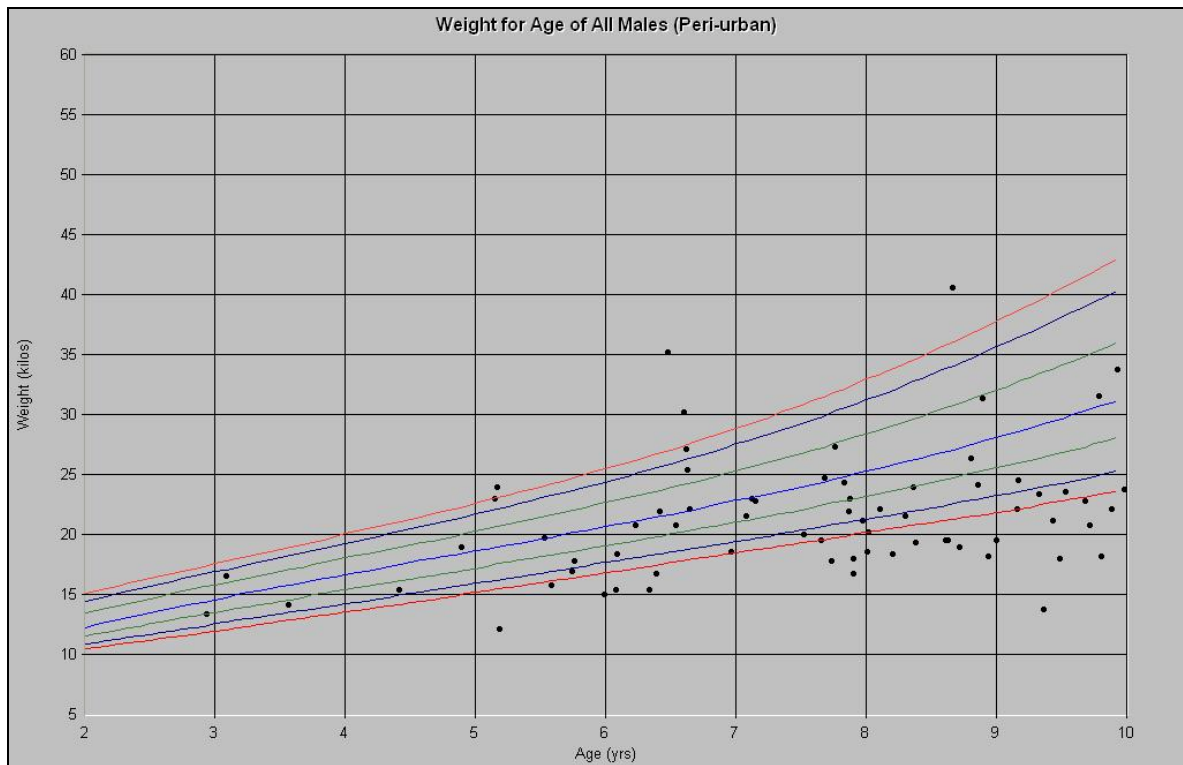


Figure 3.24: Weight for age of all males in peri-urban area

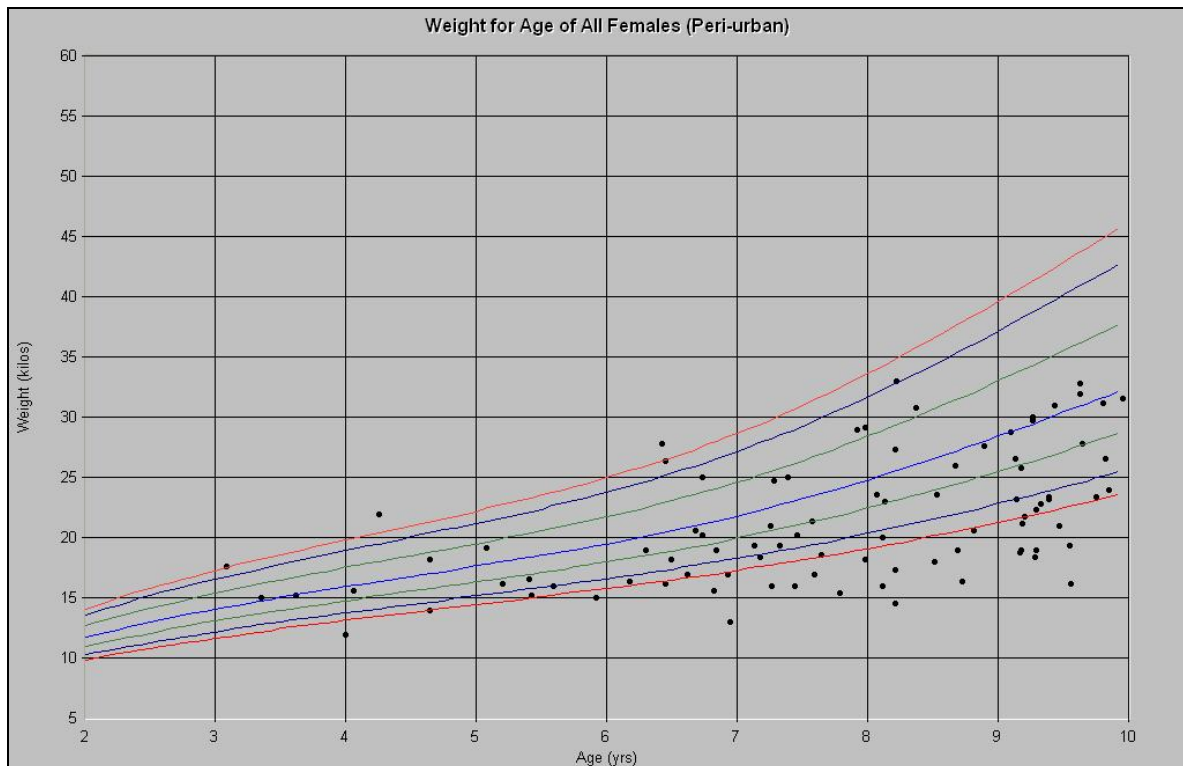


Figure 3.25: Weight for age of all females in peri-urban area

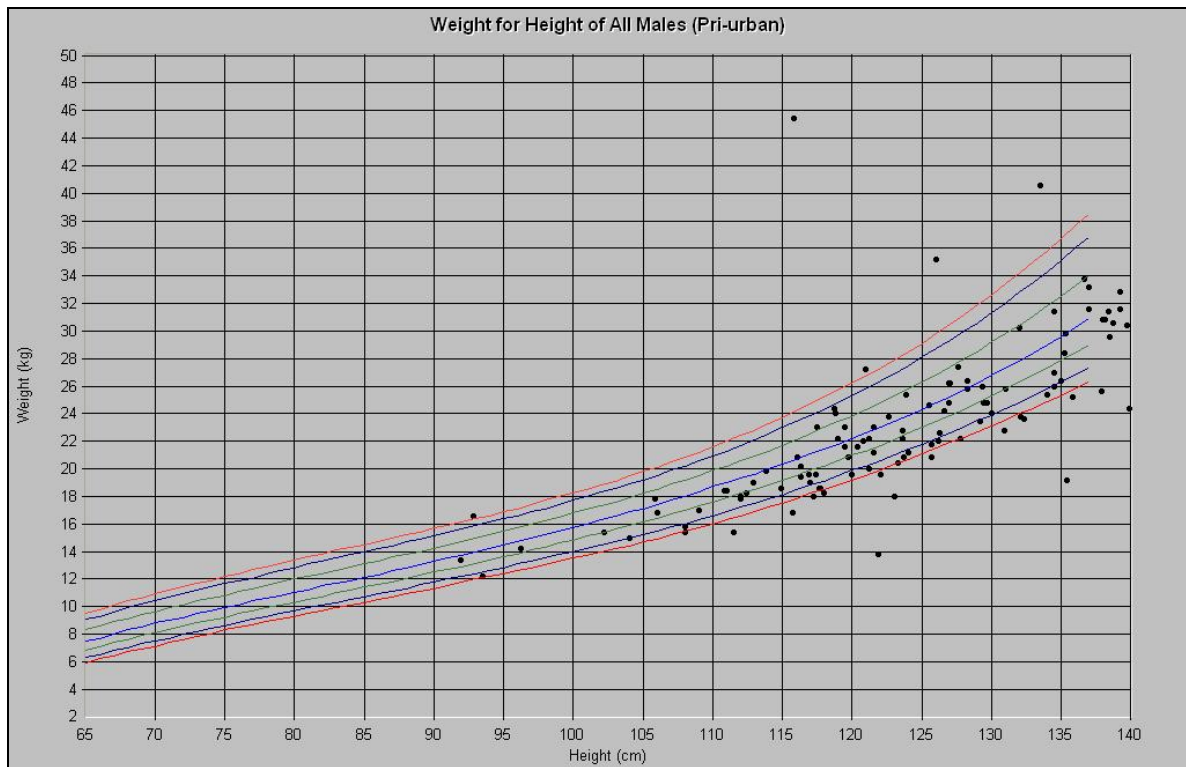


Figure 3.26: Weight for height of all males in peri-urban area

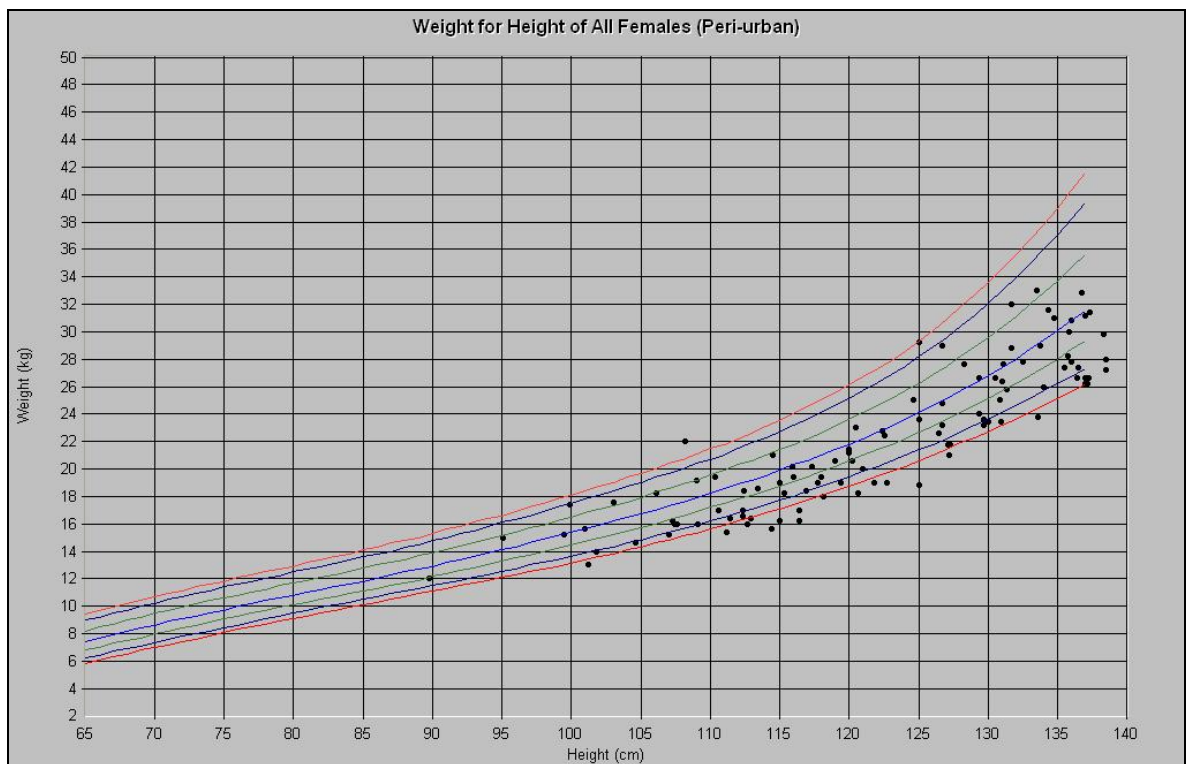


Figure 3.27: Weight for height of all females in peri-urban area

Results of the caries determination

Table 3.12 shows the mean values of the dmft and DMFT scores for the Kimberley and peri-urban areas, for the respective age groups. There is a significant difference between: the dmft of the 6-7 year age group in the Kimberley and peri-urban areas (p-value = 0.0001), the dmft and DMFT of the 8-10 year age group (p-value = 0.0019 and 0.0038, respectively), DMFT of the 11-13 year age group (p-value = 0.0093). Although other differences were not statistically significant, a clinical difference was noted.

Table 3.12: Mean dmft and DMFT Scores

Mean Scores (sd.)								
	Age (years)							
	Kimberley				Peri-urban			
	3-5	6-7	8-10	11-13	3-5	6-7	8-10	11-13
dmft	3.63(4.4)	4.42(3.6)	2.67(2.9)	0.74(1.6)	1.33(1.5)	2.15(2.3)	1.54(2.0)	1.05(1.2)
DMFT		0.24(0.9)	0.68(1.2)	1.31(1.9)		0.12(0.4)	0.28(0.7)	0.49(0.9)

Results of the Fluorosis in the Kimberley and peri-urban areas

Table 3.13 shows the fluorosis scores in the Kimberley and peri-urban areas. There is a statistical difference between the frequency of the fluorosis scores in the Kimberley and peri-urban areas (p-value = 0.001).

Table 3.13: Fluorosis Score

Fluorosis Score	Kimberley		Peri-urban	
	Frequency	Percentage	Frequency	Percentage
0	121	40.7	114	29.2
1-4	99	33.3	208	53.2
5-9	77	25.9	69	17.7

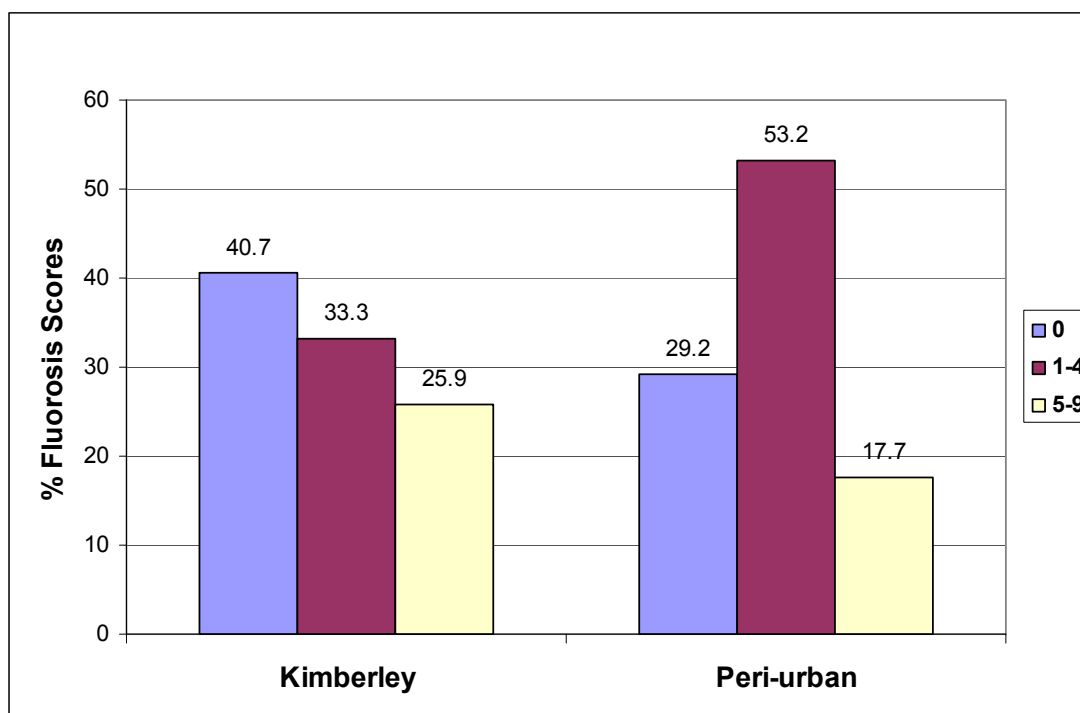


Figure 3.28: TF scores for Kimberley and peri-urban areas

Table 3.14: Mean values for all variables considered, for the Kimberley and peri-urban areas

Variable	Mean Value
Fluorosis	2.07
Fluorosis 0	17.12
Fluorosis 1-4	5.17
Fluorosis 5-9	0.59
WAZ	-1.03
HAZ	-0.93
WHZ	-0.67
Fluoride level (ppm)	0.33
dmf(t)	2.46
DMF(T)	0.43

3.9.2- De Aar

Age Distribution of the Sample

Table 3.15 shows the age distribution of the 128 children who were examined in the De Aar Area of the Northern Cape.

Table 3.15: Age distribution of the sample

Total number of children examined		
De Aar		
Age (years)	Frequency	Percentage
3-5	8	6.3
6-7	52	40.6
8-10	14	10.9
11-13	33	25.8
>13	21	16.4
Total	128	100

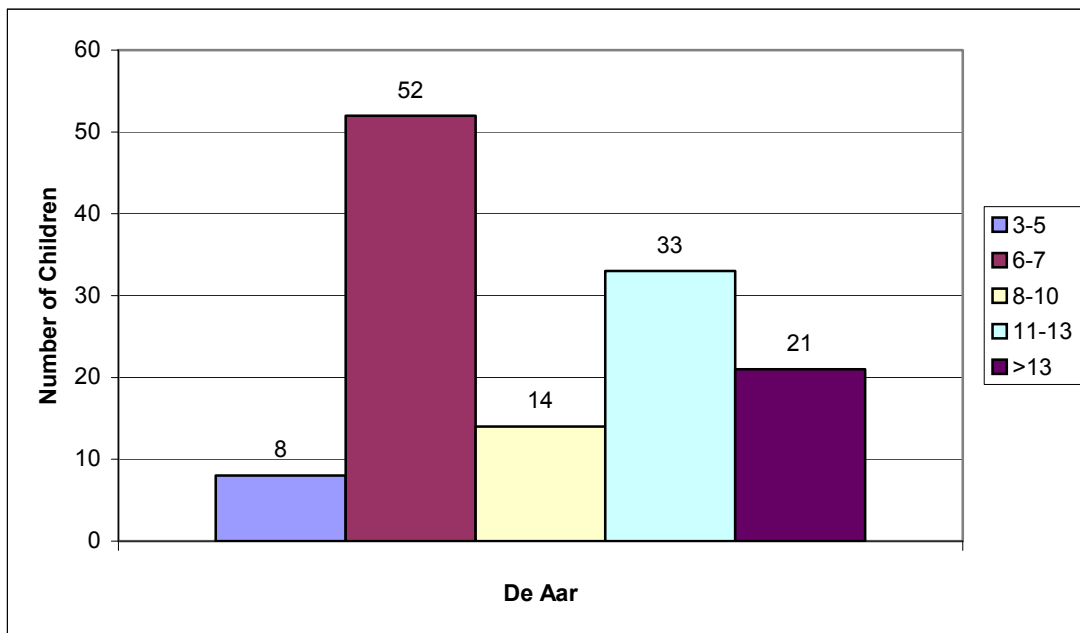


Figure 3.29: Frequency of sample in De Aar

Results of Nutritional Status

Table 3.16: Mean z-values for De Aar

	Mean Scores (std. dev.)		
Age (years)	WHZ	WAZ	HAZ
3-5	-0.50(0.75)	-1.20(0.96)	-1.26(0.94)
6-7	-0.45(1.08)	-0.97(1.03)	-1.07(1.0)
8-10	-0.64(0.54)	-1.04(1.02)	-1.07(1.2)
11-13	-0.89(0.83)	-1.21(0.94)	-1.19(1.09)

The z-scores for nutritional status are shifted to the left. The figures indicate stunting and delayed growth.

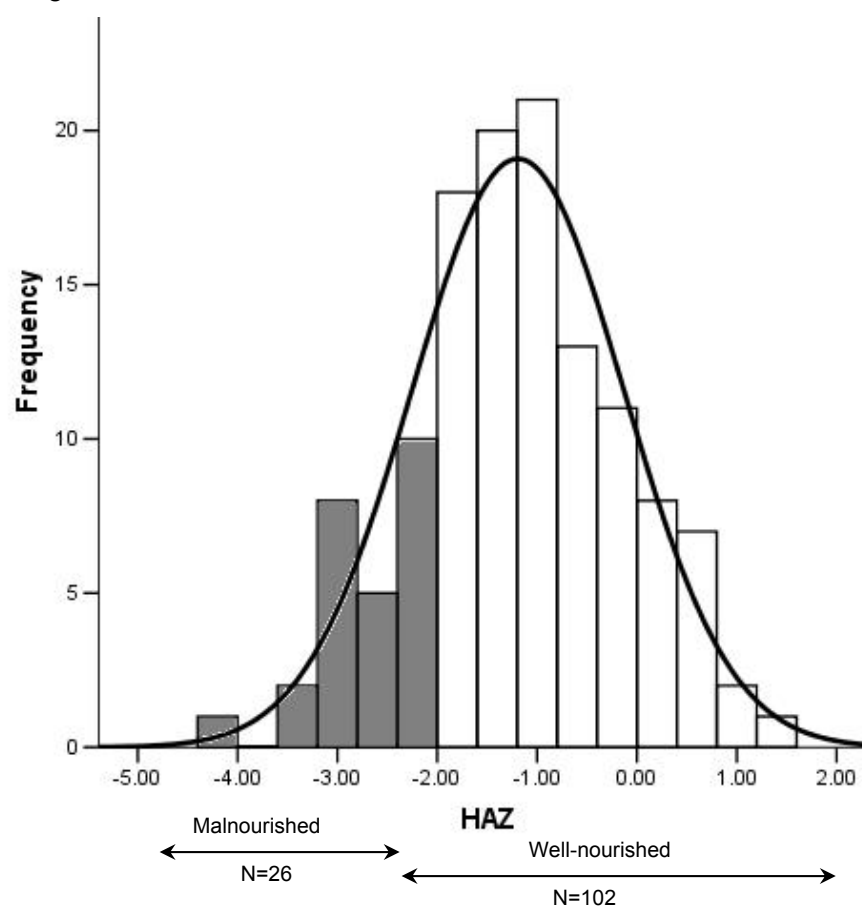


Figure 3.30: Height for age graph for De Aar

About 20% of school population showed malnourishment with stunting, HAZ (-2 to -4.5).

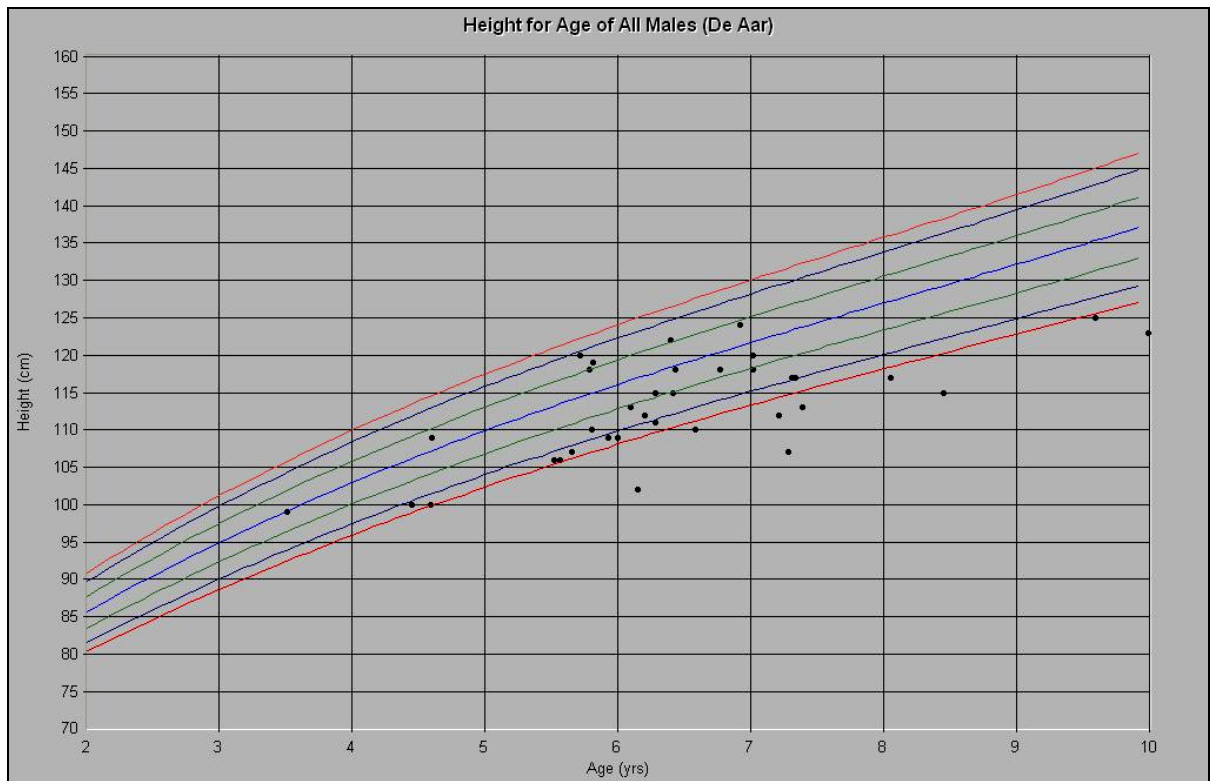


Figure 3.31: Height for age of all males in De Aar

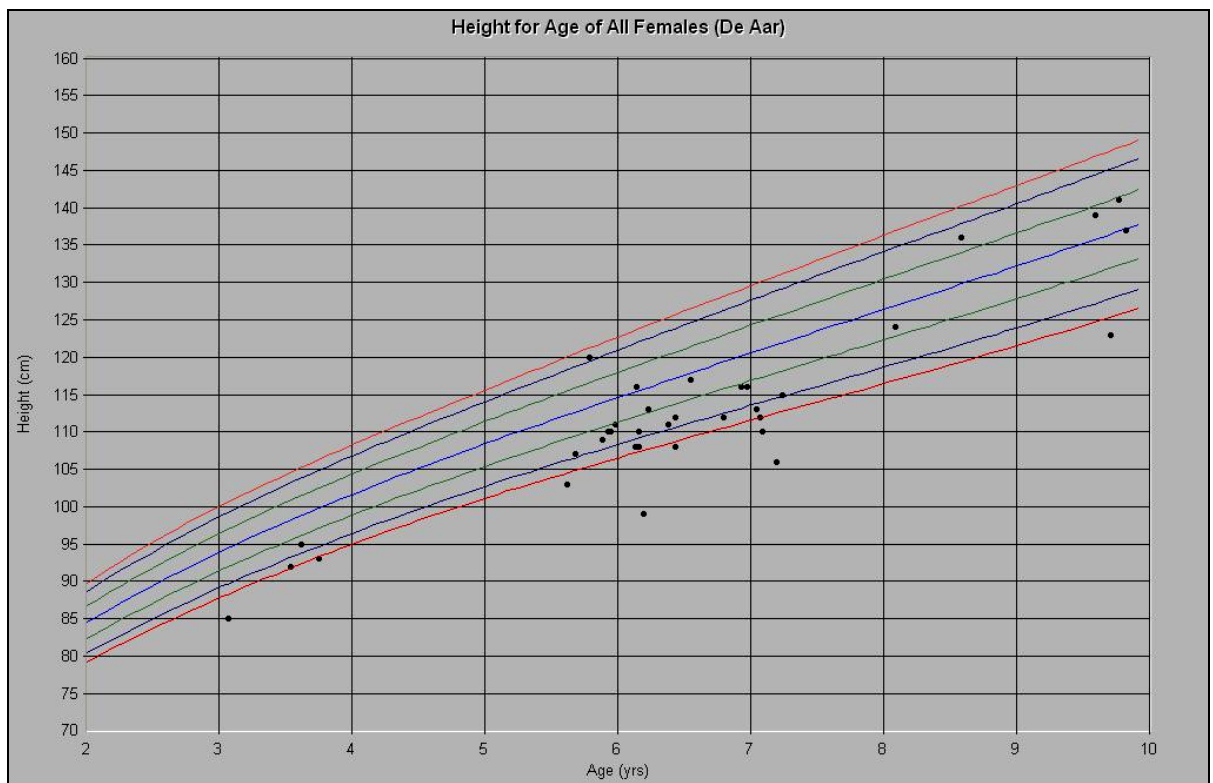


Figure 3.32: Height for age of all females in De Aar

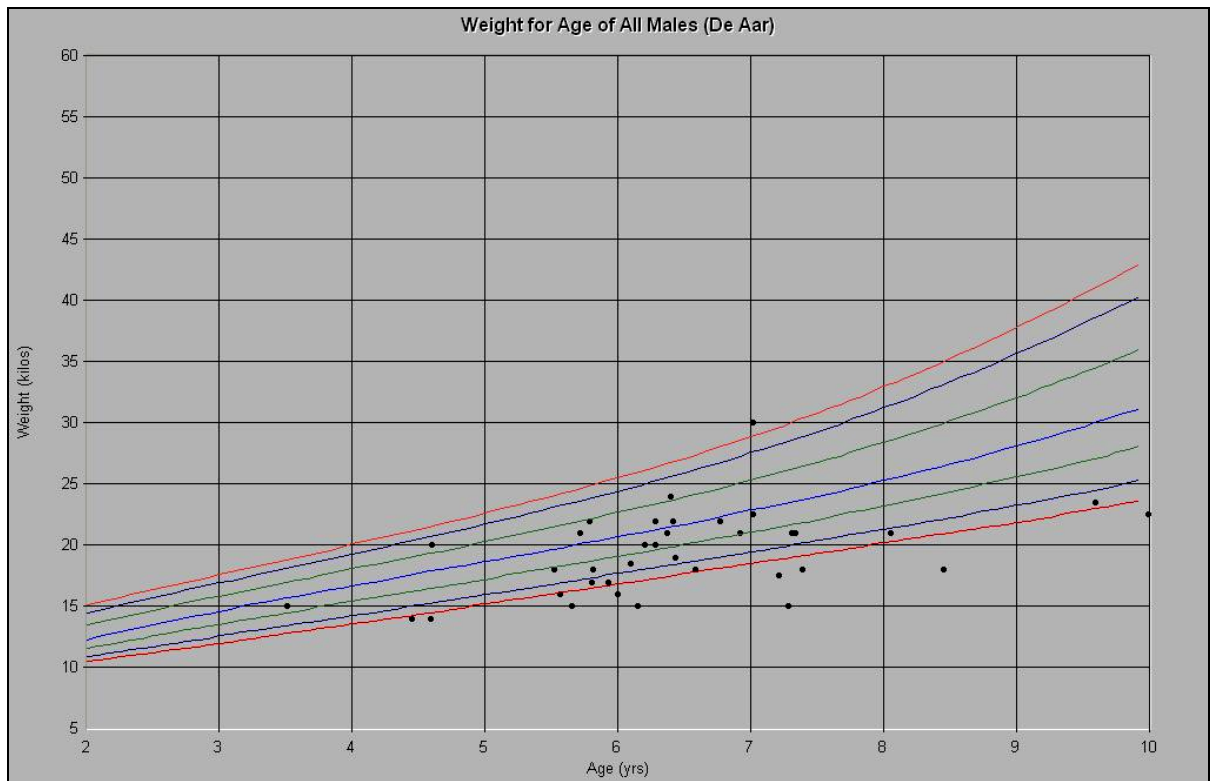


Figure 3.33: Weight for age of all males in De Aar

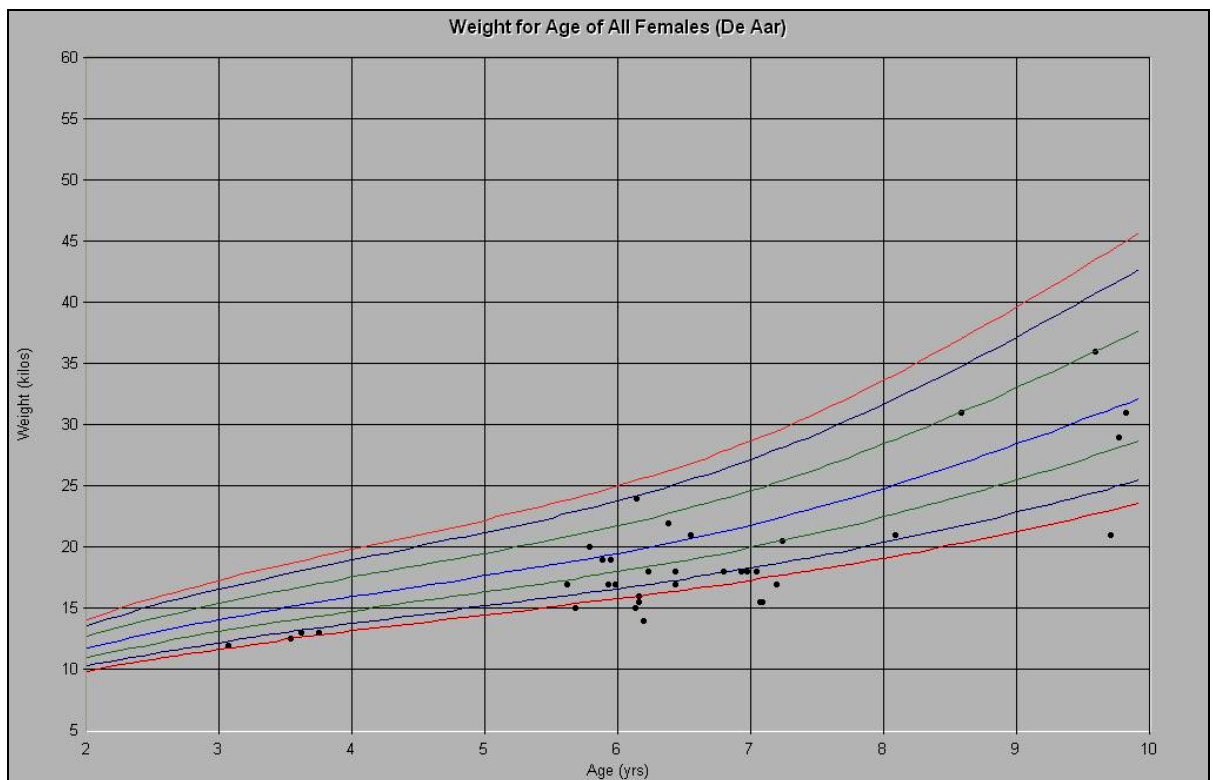


Figure 3.34: Weight for age of all females in De Aar

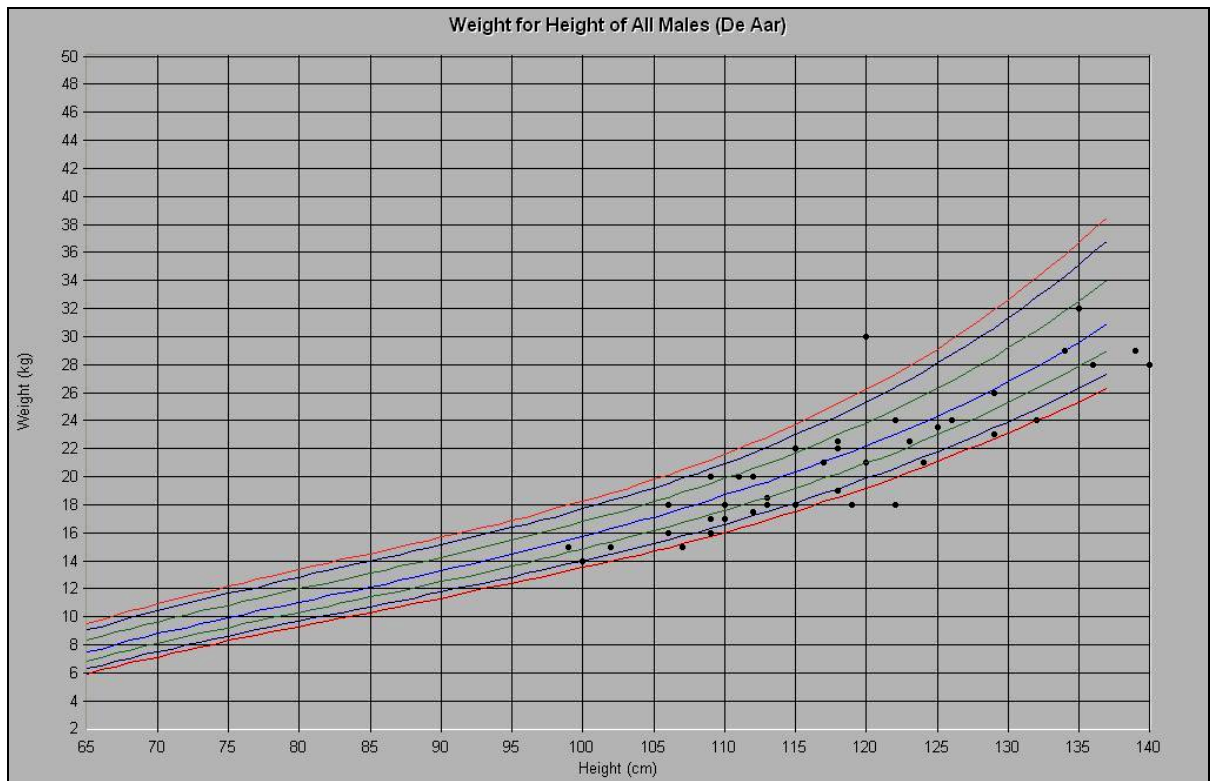


Figure 3.35: Weight for height of all males in De Aar

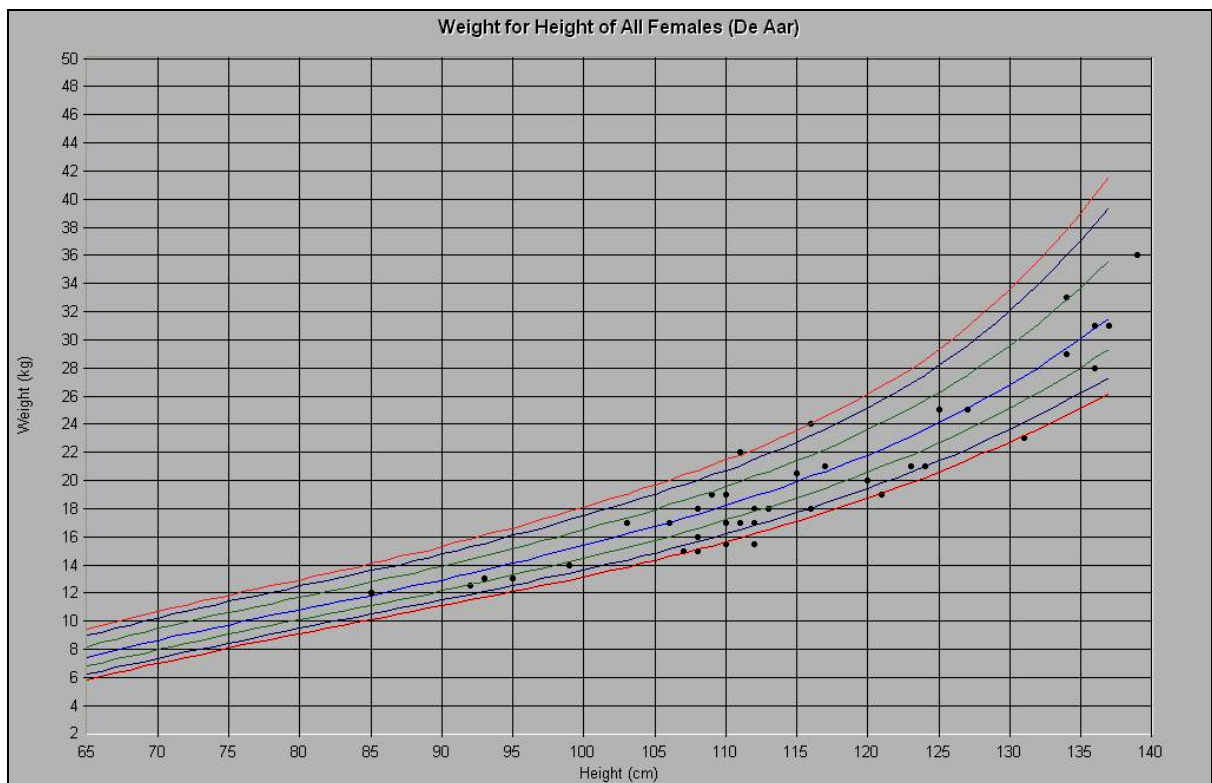


Figure 3.36: Weight for height of all females in De Aar

Results of the caries determination

Table 3.17: Mean dmft(t) and DMF(T) Scores

	Mean Scores (sd)				
Age (years)	dmft	dmfs	DMFT	DMFS	% CF
3-5	3.25(2.5)	6.38(8.5)	0	0	25
6-7	5.42(3.87)	12.98(10.12)	0.12(0.62)	0.42(2.78)	5.8
8-10	2.78(2.72)	8.93(9.28)	0.5(0.76)	1.28(2.40)	35.7
11-13	0.73(1.15)	1.94(3.47)	0.67(1.02)	1.76(3.32)	66.7

In 3-5 years old children, the mean dmft(t) for De Aar 3.25 (2.5) is almost equal to those in the Diamond fields area. But the fluoride level is double (Kimberley = 0.36 ppm, De Aar = 0.71 ppm). In the 11-13 the DMF(T) is 50% (half) of those in Kimberley.

3.9.3- Leliefontein and Kamassies

Results of the caries determination

Table 3.18: Caries prevalence in sample

Age	DMFT(dmft)	DMFS(dmfs)	%CF
2-5	(4.8)	(16.9)	25
6-7	(5.4)	(14.3)	16.7
12	0.31	0.3	69
>35	16		

This study showed that the caries prevalence amongst the preschool children is low but there is significant difference in the dt & ds between the two districts of Leliefontein (F level 0.1-2.4 ppm) and Kamassies (F levels 2.4-8.2, Table 3.19). The % caries free children were four times higher in Kamassies than in Leliefontein.

The 6 and 12 year olds from the area have very low caries compared to the Western Cape or other parts of South Africa.

The adult sample, which was biased due to availability of only elderly people and females, had 50% who were edentulous.

Table 3.19: Caries prevalence in preschool children

Area	F1-level	dt	ds	dmft	dmfs	%Cf
Kamassies	2.4-8.2	2.5	3.4	2.5	3.4	41.7
Leliefontein	0.2-2.5	4.1	8.4	4.8	11.9	12.5

Results of the Fluorosis**Table 3.20: Frequency of TF Index Score**

Score	0	1	2	3	4	5	6	7	8	9
Kamassies<5	25	8	5	11	34	8	6	5	2	-
Leliefontein<5	56	6	9	17	8	4	-	0	-	-
Grade 1	57	22	12	5	-	5	1	-	-	-
Grade 7,8	26	20	17	15	18	6	-	-	-	-
Adults	15	10	1	3	34	24	4	9	1	3

The TF index (Table 3.20) showed that > 50% of the population had a score greater than 1 with 76% of the adult dentate having a score > 6.

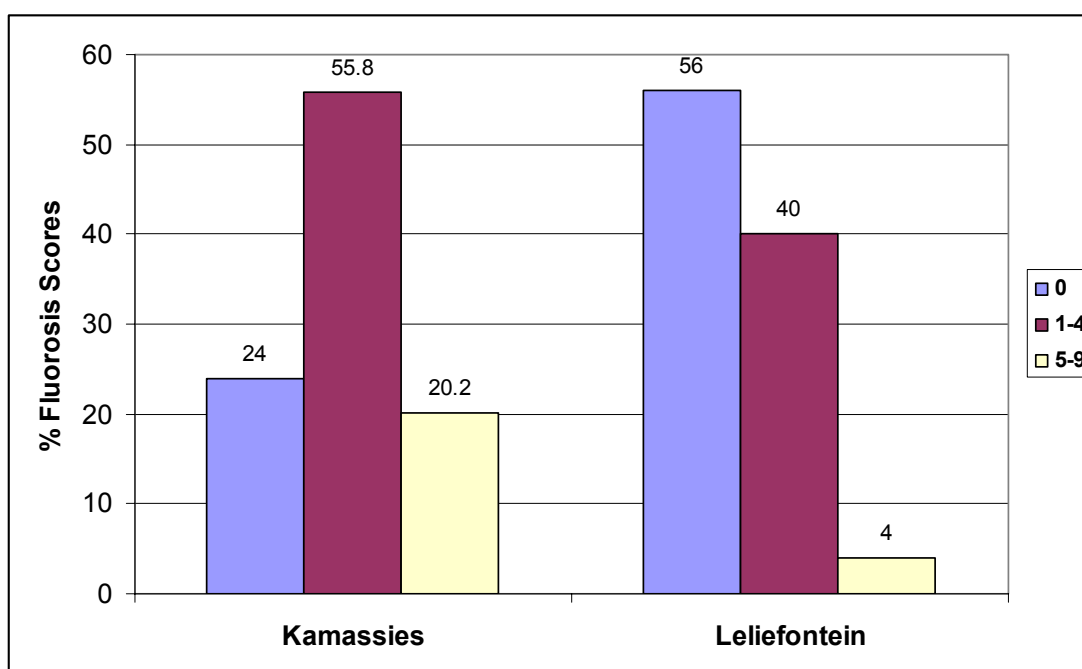


Figure 3.37: TF Index scores for Kamassies and Leliefontein

3.10- DISCUSSION

3.10.1- Children with Primary Dentition

Table 3.21: Caries distribution in primary dentition for all sites examined in the Northern Cape

Town	Age	Fluoride Level	dmft	%CF
Leliefontein	2-5	2.5	4.8	25
Kamassies	3-5	0.2-8.2	2.5	41.7
Kimberley	3-5	0.34	3.63(4.4)	35.1
Peri-Urban	3-5	0.36	1.33(1.5)	45
De Aar	3-5	0.71	3.25	25

Hypothesis 1 is to test the efficacy of fluoride in primary teeth and the percentage caries free.

The lowest dt is in the peri-urban area 1.33(1.5) with 45% of the sample caries free. The mean fluoride levels in the peri-urban area of the Diamond Fields were 0.36.

De Aar with fluoride level of 0.71 had only 25% caries free in this age group. One possible reason for the low percentage is that the sample size was very small and may not reflect the true distribution in the De Aar population.

Overall, though the difference may be clinically significant, statistically there is no significance within the different fluoride levels and the mean dmft score in the primary dentition.

The whole area has naturally occurring fluoride and it was expected that there would be a greater % of children who were caries free and with lower dmft. Only two of the sites, Kamassies and peri-urban areas showed these expected results.

It is not possible to compare these results in this age group with the National Oral Health Study of 2002 as the survey did not examine children 3-5 year olds in the Northern Cape.

Cleaton Jones (1982) reported that in the district of Kenhardt with fluoride levels varying between 2 – 4 ppm the mean dmft ranged between 0.6 – 1.4. These results are somewhat similar to the peri-urban areas (dmft = 1.3) and Kamassies (dmft = 2.5). The % caries free children between 1-5 years were 82%. These unexpected high caries free children can be explained by sample which has ages 1 & 2 years of age when all the primary teeth are still not present or erupting.

In the low fluoride area (0.2 ppm Kamassies) there were only 8% caries free children at five years of age which is much lower than the results obtained in De Aar and Kimberley.

From these samples with varying degrees of fluoride levels and without considering the confounding factors it is difficult to explain the low % of caries free children between the ages 3-5. One possible explanation is that the groundwater containing fluoride does not allow for free fluoride ions such that little amounts are available for the preventive action.

3.10.2- Children with permanent dentition

Table 3.22: Mean DMFT for children aged 11-13 in the Northern Cape

Town	Age	Fluoride level	DMFT	% Caries Free
Kimberley	11-13	0.34	1.31(1.9)	80.4%
Peri-Urban	11-13	0.45	0.49(0.9)	77.3%
De Aar	11-13	0.71	0.62(0.88)	66.67%
Kamassies	12	5.7	0.31	69%
Leliefontein	-	-	-	

These results of the decayed, missing and filled permanent teeth show very low prevalence of dental caries in the 11-13 years of age in the whole Northern Cape Province.

The percentage caries free children range from 66.7% in De Aar to 80.4% in Kimberley.

The lower caries free children with optimum fluoride may be due to the design of the study where there was not sufficient number of children examined in this age group through sampling problem. However, De Aar with the optimum fluoride level of 0.71 ppm showed a mean DMFT of 0.62 (sd 0.88), which is much lower than Kimberley by 50 %. From this data it is assumed that in Kimberley fewer children (19.6%) have dental decay in the 11-13 years of age but those who have decay have at least 1-2

permanent teeth decayed. Kimberley has almost double the number of teeth decayed compared to the peri-urban area and De Aar.

The results of these studies with other fluoride studies in South Africa for this age group show that the percentage caries free children in the Northern Cape in this age group is much higher than those reported by Grobler (2001) in Kuboes (57%) in the Northern Cape. Likewise the mean DMFT was much lower in the peri-urban and De Aar area compared to Kuboes (1.54 [0.24]). The mean DMFT of Kimberley and Kuboes are very similar.

The National Children's Oral Health Survey in South Africa (1999-2002) reported a weighted mean DMFT for 12 year old in the Northern Cape as 1.33. This is similar the DMFT obtained for the 11-13 years in Kimberley. As this is a weighted mean the variations obtained in the other sites in Northern Cape show a very low prevalence compared to the National Survey.

3.10.3- TF Index scores

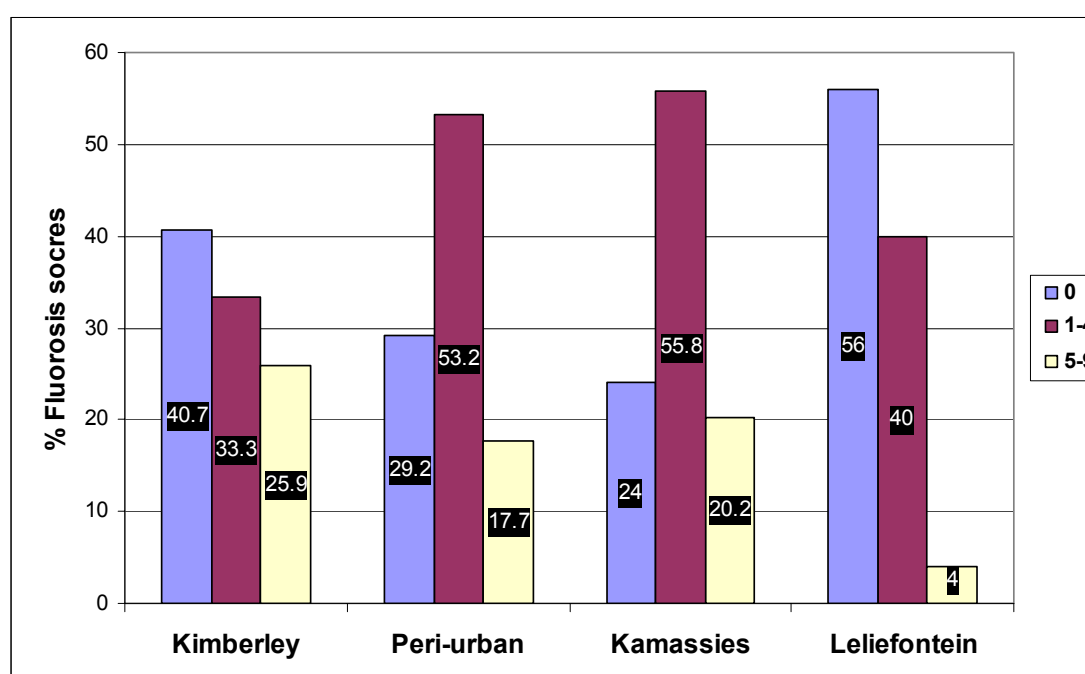


Figure 3.38: TF Index scores for Diamond field and Kamassies and Leliefontein

Fluorosis was assessed using the TF index of Thylstrup and Fejerskov (1978). They studied fluorosis histologically and clinically and described a new index overcoming some of the shortcomings of the Fluorosis Index. In the TF Index, fluorosis is categorised on a 10-point ordinal scale on the basis of the clinical appearance of dried enamel. Teeth are classified by comparison of the appearance of enamel with given; descriptive criteria (Table 3.8) where score 0 represents no fluorosis and score 9 represents severe fluorosis with changes in the anatomical shape of the tooth. The TF Index is easy to use, sensitive, correlates well with subsurface enamel porosity and has shown good reliability (Fejerskov, 1988; Thylstrup and Fejerskov, 1978). The categories have been validated by comparison with the histological appearance of the enamel, giving the index a biological validity.

In this project, fluorosis estimations were based on the appearance of multiple teeth. Findings were presented as distributions in the various groups of participants by TF Index scores. Figure (3.38) shows a general distribution of fluorosis scores in Diamond fields, Kamassies and Leliefontein.

In spite of low fluoride levels in Kimberley and peri-urban areas (approx 0.34 ppm), they showed mild fluorosis i.e. approximately 34% in Kimberley and 54% in peri-urban areas with fluorosis scores of 1-4. The reason for this might be fluoride in drinking water and use of supplementary fluoride in form of toothpastes, milk, etc.

Peri-urban and Kamassies areas showed approximately similar distribution of fluorosis with highest percentages of fluorosis scores ranging from 1-4.

In spite of high fluoride levels (2.5 ppm) in Leliefontein, it showed highest numbers of 0 fluorosis scores. This might be due to a small sample size and presence of adult population in the sample.

3.11- CONCLUSION

Hypothesis 1:

There is no difference in dental caries prevalence in children living in the Kimberley, Diamond fields' district with fluoride levels ranging from 0.3 to 0.4 ppm and the children living in De Aar with fluoride levels of 0.71 to 0.73 ppm.

Results

A- There is a difference ranging from 25% (De Aar) to 45% (peri-urban) for % caries free children in the 3-5 year old.

B- There is a statistically significant difference between % caries free in Kamassies/Kimberley/peri-urban areas. The range of % caries free children is 35.1-45%.

C- The % caries free is similar between Leliefontein and De Aar where the fluoride levels are 2.5 ppm (Leliefontein) and 0.71 ppm (De Aar) respectively.

D- (1) In the 11-13 year old in Kimberley, peri-urban and De Aar, there is no significant difference in the number of caries free children.

(2) The DMFT is twice as high in Kimberley (1.31) as compared to De Aar (0.62). But difference between Kimberley (1.31) and peri-urban area (0.49) is significant.

Hypothesis 2:

There is no difference in the prevalence of fluorosis experience between the children who reside in Kimberley area with the varying degrees of fluoride levels.

Sub hypothesis that there is no difference in fluorosis using the TF Index in the different fluoride areas.

Results:

A- There is 10.5% difference in the score 0 between Kimberley (0.34 ppm) and peri-urban (0.45 ppm).

The lower the fluoride level the greater the score 0 (i.e. enamel is normally translucent after drying).

B- Score 1-4 is consistently higher in children residing in peri-urban (53.2%), Kamassies (55.8%) and Leliefontein (40%) that have higher fluoride levels than Kimberley (33.3%).

C- There is an anomaly in the group score 5-9. The distribution of score 5-9 is in the range of 17.7% (peri-urban) to 25.9% in Kimberley.

The expected results should have been lower. The possible reasons for this might be:

- 1- Migration of families from rural and pastoral land to Urban (Kimberley) and peri-urban (Diamond fields).
- 2- There might have been earlier exposure of high fluoride levels before migration.
- 3- There may be the “halo” effect of fluoride due to fluoride in water, beverages and supplementary exposures.

Hypothesis 3:

There is no difference in the prevalence of dental decay in deciduous teeth in both areas in children between the ages 5-6 years of age.

Results

The caries free children (67.32%) in 5-6 year olds is much higher than those in similar age group in South Africa (Moola, 1997).

There is no significant difference in the dmft/dmfs compared to children in low fluoride levels.

Hypothesis 4:

There is no difference in the nutritional status of children living in the Kimberly Diamond Fields Area and De Aar.

Results

There were no significant differences between the WHZ, WAZ, and HAZ values for the Kimberley and peri-urban areas. There were also no significant differences between these values for that percentage of the sample population who were below -2.0 in the anthropometric analysis (i.e. those who were wasted, underweight or stunted).

Some 21.5 to 21.6% of the children were malnourished (i.e. z-score > -2 for HAZ) in Kimberly/Diamond Fields area and about 20% of school population showed malnourishment with stunting, HAZ (-2 to -4.5) in De Aar.

PART 3- DEFLUORIDATION OF DRINKING WATER

3.12- Introduction

In recent years environmental protection has attracted great attention yet there has not been enough concern with human health. Water supply problems have received little emphasis and have frequently been ignored. Drinking water supply standards were established to protect the health of the individual. The first concern was the bacterial quality; the second, the chemical quality. There was also concern for physical parameters such as turbidity, colour and odour that are primarily aesthetic problems. These standards are updated periodically and additional elements or compounds are added as necessary. One such chemical constituent in drinking water is fluorine.

Fluoride is an essential micronutrient for both human and animal depending on the total amount ingested. Consumption of drinking water provides more than 60% of fluoride required by the body. According to WHO, the optimum fluoride level in drinking water is considered between 0.5 to 1.5 mg/L (WHO, 1984). Concentrations higher than this cause multidimensional health problems including mottling of teeth, dental and skeletal fluorosis and several neurological damages in severe cases (Yadav *et al.*, 2005; Das *et al.*, 2005).

3.12.1-Definition of Defluoridation

The removal of excessive fluoride from drinking or potable water for human consumption is known as defluoridation.

3.12.2-Types or Methods of Defluoridation

Defluoridation of drinking water needs to be practiced, if fluoride levels of groundwater sources are beyond the recommended limit. Excess fluoride in drinking water occurs in many countries including South Africa, Tanzania and India that affects millions of people. Several methods of defluoridation have been developed and can be divided broadly into two categories, namely precipitation and adsorption.

The precipitation process is based on the addition of chemicals to the raw water and removal of insoluble compounds as precipitates.

In adsorption method, fluoride of raw water is retained on the adsorbent due to physical, chemical or ion exchange interactions. Activated alumina, coconut shells, carbon, chemically activated carbon, bone charcoal, natural zeolites and burnt clay are different types of adsorbents commonly used for defluoridation (Yadav *et al.*, 2005; Venkobachar *et al.*, 1997).

Development of new and cost effective fluoride sorbents using several synthetic, natural and waste materials has been the prime research focus in recent years. Clays, soils, bleaching earth, zeolites, red mud and alum sludge have shown potential to fluoride adsorption from drinking water but their safety and feasibility for wide spread use still need to be tested (Das *et al.*, 2005).

A: Chemical Methods of Defluoridation

- Defluoridation of drinking water by Tricalcium Phosphate
- Defluoridation of water by Magnesite
- Defluoridation of water by activated alumina
- Defluoridation of drinking water using the Nalgonda Technique

B: Defluoridation Methods using Bone Char

- Charcoal packed furnace for low-tech charring of bone
- Bone char based bucket defluoridator for household use
- The Applied ICOH Defluoridator.
- Defluoridation using fishbone charcoal columns

C: Isothermal methods of Defluoridation

- Sorption Isotherms of fluoride on flocculated Alumina
- Fluoride sorption isotherm in fired clay

D: Defluoridation of drinking water by use of Clay/Soil

- Use of activated clay for defluoridation of water

E: Other Methods of defluoridation

- Reverse Osmosis (RO) Membrane Process
- Electro-dialysis (ED) Membrane Process
- Membrane Filtration Nanofiltration (NF)

1- Defluoridation of drinking water using Nalgonda Technique

The Nalgonda Technique was developed in India in 1975 (Nawlakhe *et al.*, 1975). It has been introduced in Indian villages and studied at pilot scale in countries such as Kenya, Senegal and Tanzania. The most recommended defluoridation method is the Nalgonda Technique because its low cost and ease of handling.

The Nalgonda technique is normally adopted when the area under consideration has the following characteristic features:

1. Absence of acceptable alternate low fluoride source within transportable distance.
2. Total dissolved solids below 1500 mg/l; desalination may be necessary when the total dissolved solids exceed 1500 mg/l.
3. Total hardness is below 600 mg/l.
4. Hardness >200 mg/l and <600 mg/l require precipitation softening, and > 600 mg/l becomes a cause for rejection or adoption of desalination.
5. Alkalinity of the water to be treated must be sufficient to ensure complete hydrolysis of alum added to it and to retain a minimum residual alkalinity of 1 to 2 mg/l in the treated water to achieve pH of 6.5 to 8.5 in treated water.

6. Raw water fluorides ranging from 1.5 to 20 mg/l.

Large Scale Water Defluoridation Plant

Nalgonda Technique involves addition of alum (aluminium sulphate or potassium aluminium sulphate), lime and bleaching powder followed by rapid mixing, flocculation, sedimentation, filtration and disinfection. Aluminium salt is only responsible for removal of fluoride from water. The dose of aluminium salt increases with an increase in the fluoride and alkalinity levels of the raw water. The selection of either aluminium sulphate or aluminium chloride also depends on sulphate and chloride contents of the raw water to avoid them exceeding their permissible limits. The dose of lime is empirically 1/20th that of the dose of aluminium salt. Lime facilitates forming dense flocs for rapid settling. Bleaching powder is added to the raw water at the rate of 3 mg/l for disinfection. Approximate doses of alum required to obtain water with acceptable limit of fluoride (<1.0 mg/l) at various fluoride and alkalinity levels in raw water are given below (Table 3.23):

Table 3.23: Approximate alum dose (mg/l) required to obtain acceptable quality (fluoride <1 mg/l) of drinking water from raw water at various alkalinity and fluoride levels.

Test water Fluorides (mg /l)	Alkalinity (ppm)							
	125	200	300	400	500	600	800	1000
2	145	220	275	310	350	405	470	520
3	220	300	350	405	510	520	585	765
4	*	400	415	470	560	600	690	935
5	*	*	510	600	690	715	885	1010
6	*	*	610	715	780	935	1065	1210
8	*	*	*	*	990	1120	1300	1430
10	*	*	*	*	*	*	1510	1690

* To be treated after increasing the alkalinity with lime or sodium carbonate.

MECHANISM

The Nalgonda Technique is a combination of several processes incorporating rapid mixing, chemical interaction, flocculation, filtration, disinfection and sludge concentration to recover water and aluminum salts.

Rapid Mixing

Provides thorough mixing of alkali, aluminum salts and bleaching powder with the water. The chemicals are added just when the water enters the system.

Flocculation

Flocculators subsequently provide gentle agitation before entry to the sedimentation tank. The flocculation period permits close contact between the fluoride in water and polyaluminic species formed in the system. The interaction between fluoride and aluminium species attains equilibrium.

The chemical reaction involving fluorides and aluminium species is complex. It is a combination of polyhydroxy aluminium species complexation with fluorides and their adsorption on polymeric aluminium hydroxides (floc). Turbidity, colour, odour, pesticides and organics are also removed. The bacterial load is also reduced significantly. All these are achieved by adsorption on the floc.

Lime or sodium carbonate ensures adequate alkalinity for effective hydrolysis of aluminium salts, so that residual aluminium does not remain in the treated water.

Simultaneous disinfection is achieved with bleaching powder, which also keeps the system free from undesirable biological growths.

Sedimentation

Permits settleable floc loaded with fluorides, turbidity, bacteria, and other impurities to be deposited and thus reduces concentration of suspended solids that must be removed by filters.

Filtration

Rapid gravity sand filters are suggested to receive coagulated and settled water. In these filters unsettled gelatinous floc is retained. Residual fluorides and bacteria are absorbed on the gelatinous floc retained on the filter bed.

Disinfection and Distribution

The filtered water collected in the storage water tank is re-chlorinated with bleaching powder before distribution.

Domestic Defluoridation

Defluoridation at domestic level can be carried out in a container (bucket) of 60 litre capacity with a tap 3-5 cm above the bottom of the container for the withdrawal of water after precipitation and settling. The raw water in the container is mixed with adequate amount of alum (aluminium sulphate solution), lime or sodium carbonate and bleaching powder depending upon its alkalinity and fluoride content. Alum solution is added first and mixed rapidly with contaminated water. Lime or sodium carbonate solution is then added and the water stirred slowly for 20 minutes inducing "cotton-wool" like flocs (aluminium hydroxides) that are allowed to settle for one hour. The supernatant, which contains permissible amount of fluoride, is withdrawn through the tap for consumption. The settled sludge is discarded. Approximate volumes of alum solutions for defluoridation of 40 litre of water are given in Table 3.24.

Table 3.24: Domestic defluoridation: Approximate volume of alum solution (ml) required to be added in 40 litres of test water to obtain acceptable limit (~1.0 mg/l) of fluoride in water at various alkalinity and fluoride levels.

Test water fluoride (mg/l)	Test water alkalinity, (CaCO ₃ mg/l)							
	125	200	300	400	500	600	800	1000
2	60	90	110	125	140	160	190	210
3	90	120	140	160	205	210	235	310
4		160	165	190	225	240	275	375
5			205	240	275	290	355	405
6			245	285	315	375	425	485
8					395	450	520	570
10							605	675

2- Household defluoridation of drinking water using activated alumina

The household defluoridation unit consists of basically two chambers made mainly of stainless steel and copolymer plastic. The upper chamber is fitted with microfilter with a hole at the bottom to give a flow rate of 12 L/h (Figure 3.39). The chamber is filled with 3 kg of activated alumina. A perforated stainless steel plate is placed on the top of activated alumina bed to facilitate uniform distribution of raw water containing fluoride onto the bed. The upper chamber is covered with a lid. Lower chamber contains a tap at the bottom to withdraw treated water. In rural areas, lower chamber can be replaced with earthen pot, which not only lowers initial cost but also provides cold water in summer (Venkobachar *et al.*, 1997).

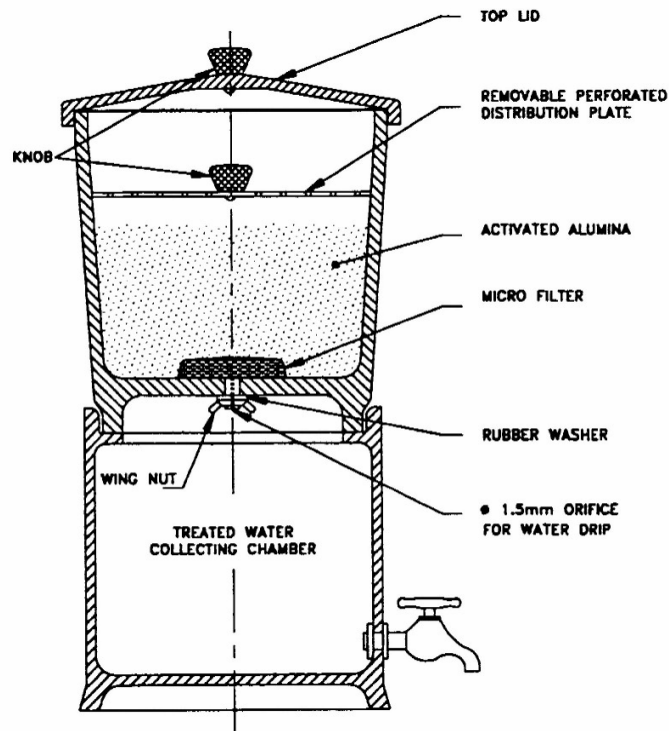


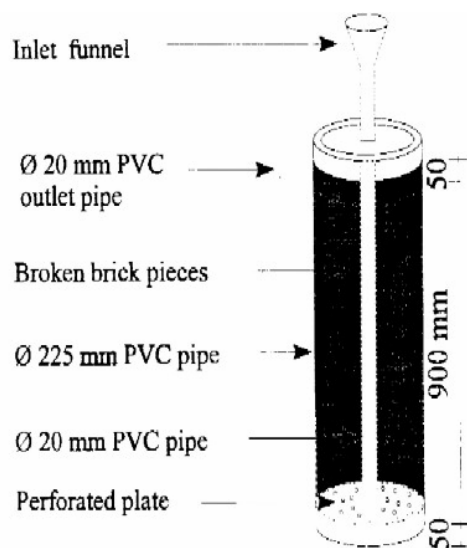
Figure 3.39: Domestic defluoridation unit (Venkobachar, 1997).

3- Defluoridation of groundwater using brick powder as an adsorbent

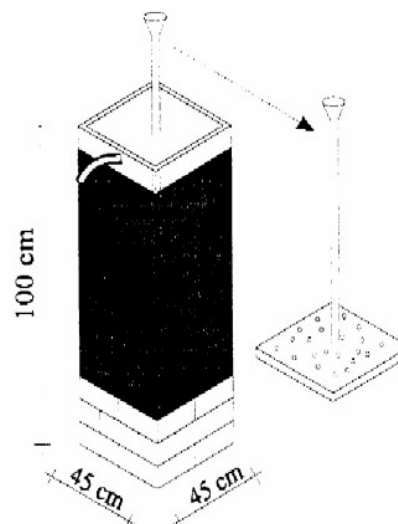
Two types of defluoridator (PVC-defluoridator and brick/cement defluoridator) are used for drinking water defluoridation.

PVC-defluoridator: This household defluoridator is made of a PVC pipe, 100 cm in length and 20 cm in diameter. The inner diameter is 2 cm. The filter has a circular perforated plate fixed at 5 cm from the bottom. The outlet is fixed at 5 cm below the top of the filter. The filter unit is packed up to height of 75 cm with broken pieces of freshly burnt bricks, grain size 8-16 mm. The filter medium used for the removal of fluoride is low temperature burnt clay pieces. The fluoride rich water is fed through a funnel like inlet pipe at the top (Figures 3.40, 3.41).

Before using the filter unit, it is filled with fluoride rich water and left for 12 hours. When later fresh fluoride water is passed through the inlet pipe, an equal amount of defluoridated water comes out through the outlet.



Padmasiri (1997)



Padmasiri (1997)

Figure 3.40: Low cost defluoridator

Figure 3.41: Defluoridator made of cements and bricks

The Applied ICOH Defluoridator

It has been accepted as appropriate technology. It uses charred bone meal that is prepared by burning fresh bovine bone, bought from the market, outdoor until it turns black. After cooling the bone is crushed into small pieces of approximately 0.5 cm in diameter. The details of the defluoridator are shown in Figure 3.42.

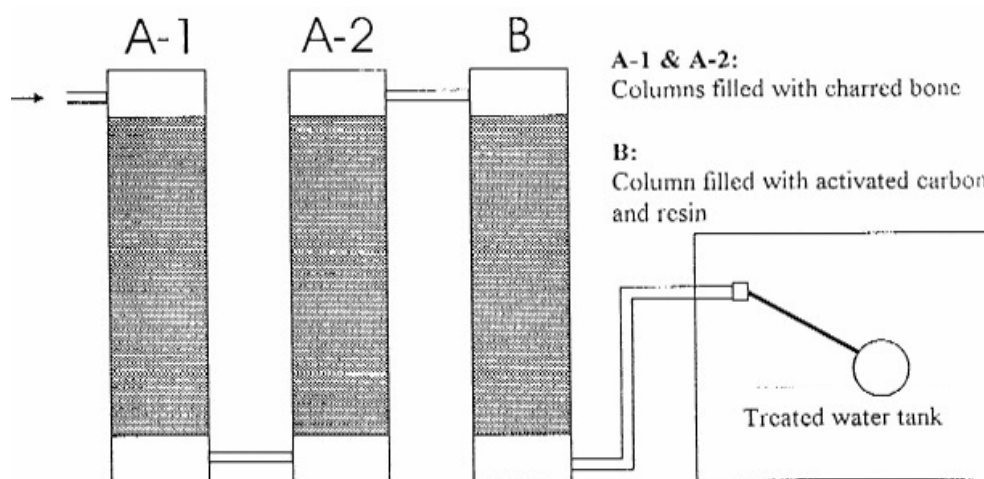


Figure 3.42: Schematic presentation of the applied ICOH defluoridator (Rajchagool, 1995).

Cylinder A1 and 2 are filled with 10 litres of black bone char. Cylinder B is filled with 4 litres of resin and 4 litres of activated carbon. The flow rate of 6 L/h gives adequate reduction in the fluoride concentration of the water. After treatment water has no smell and is suitable for drinking. Figure 3.43 shows the original ICOH water defluoridator.

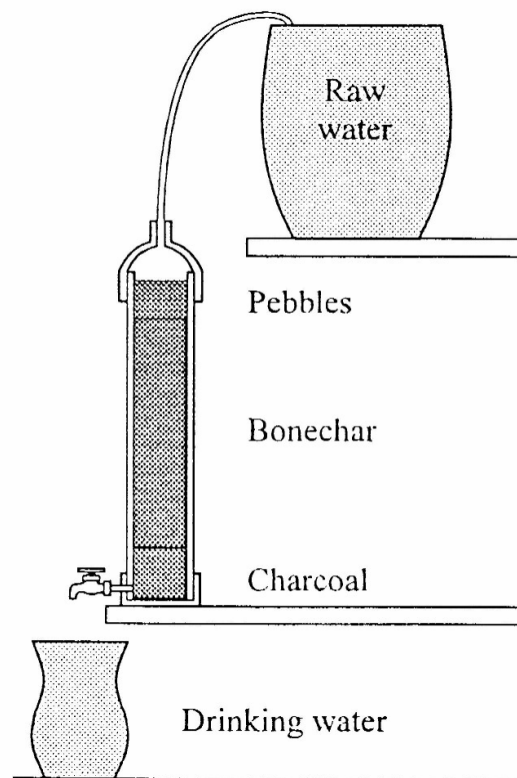


Figure 3.43: The original ICOH water defluoridator (Rajchagool, 1995).

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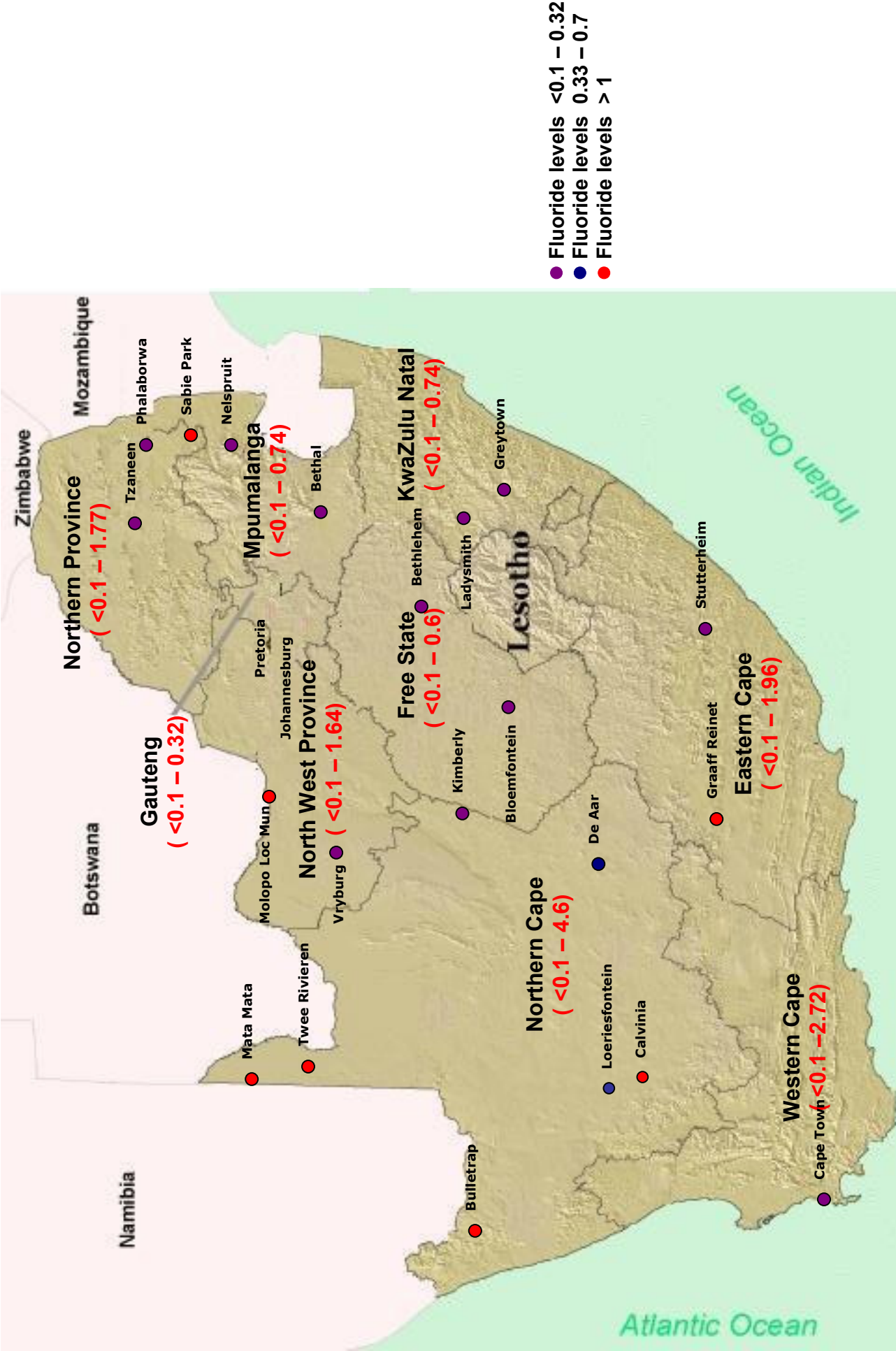
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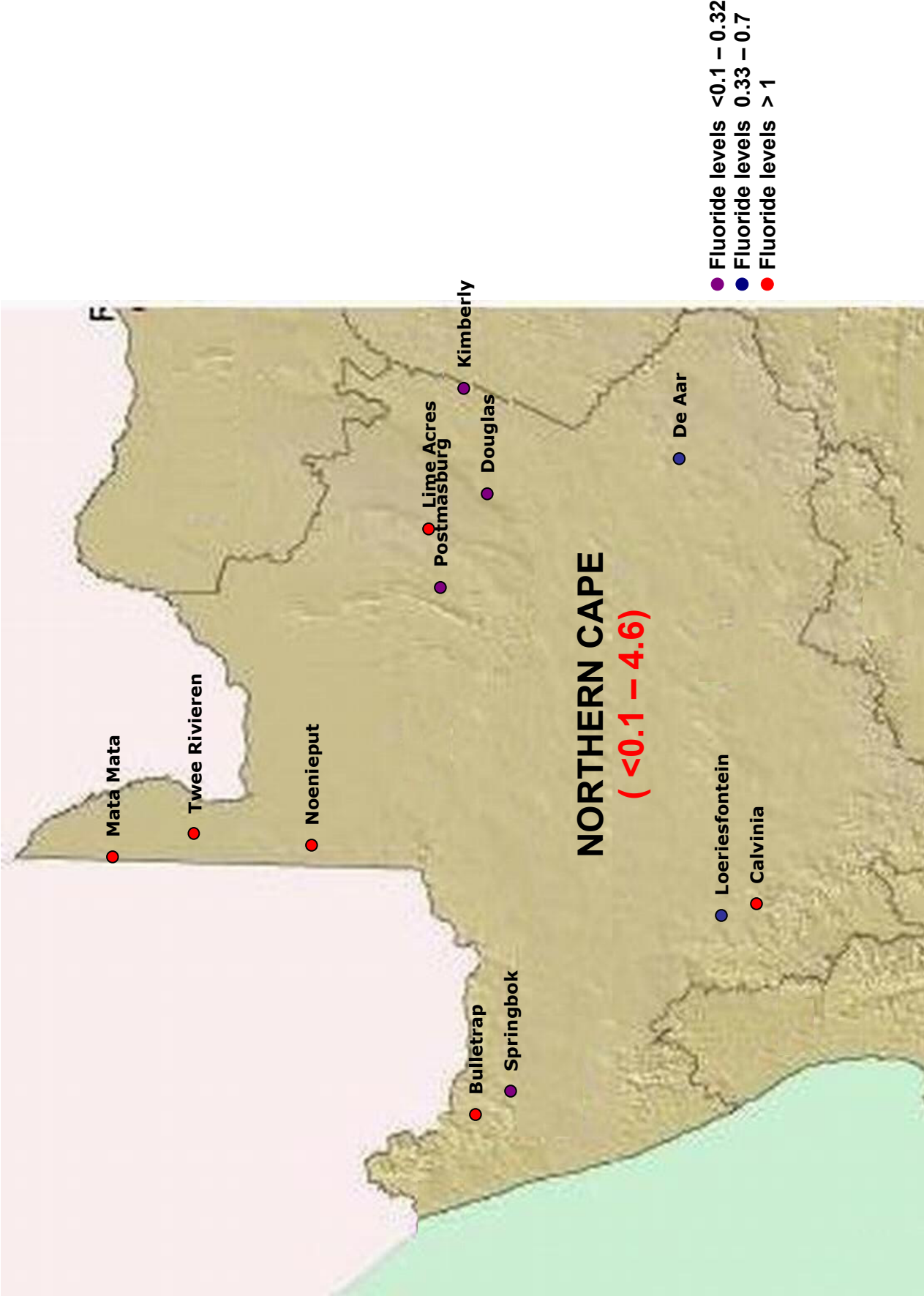
Appendix I



Fluoride levels in different areas of South Africa

[Base Map: Southern Africa Places CC. http://www.places.co.za/maps/south_africa_map.html (access January, 2008).]

Appendix II



Fluoride levels in different areas of Northern Cape

[Base Map: Southern Africa Places CC. http://www.places.co.za/maps/south_africa_map.html (access January, 2008).]