Chapter 1

A national survey of the quality of groundwater used by poultry producers in South Africa.

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Introduction

Knowledge regarding water quality is important for poultry production as it provides the producer with managerial information to prevent the potential adverse consequences of specific concentrations of water constituents. These typically pertain to health and production parameters, the quality of the livestock product and the watering systems of intensive poultry production systems. Meyer, Casey and Coetzee (1998 e) reported that there was no national database on the water quality constituent profile of water sources used for livestock production. They suggested that a water quality monitoring system be formulated in which the relevant water constituents for the specific areas and production systems be identified. The system should be based primarily on the constituent's potential to cause adverse effects and their occurrence in the natural aquatic environment. Existing information lacked the analyses of critical constituents at specific sites, required to formulate a risk assessment. Analyses are often not standardised and information on constituents that may affect the usability of the water source may be left out.

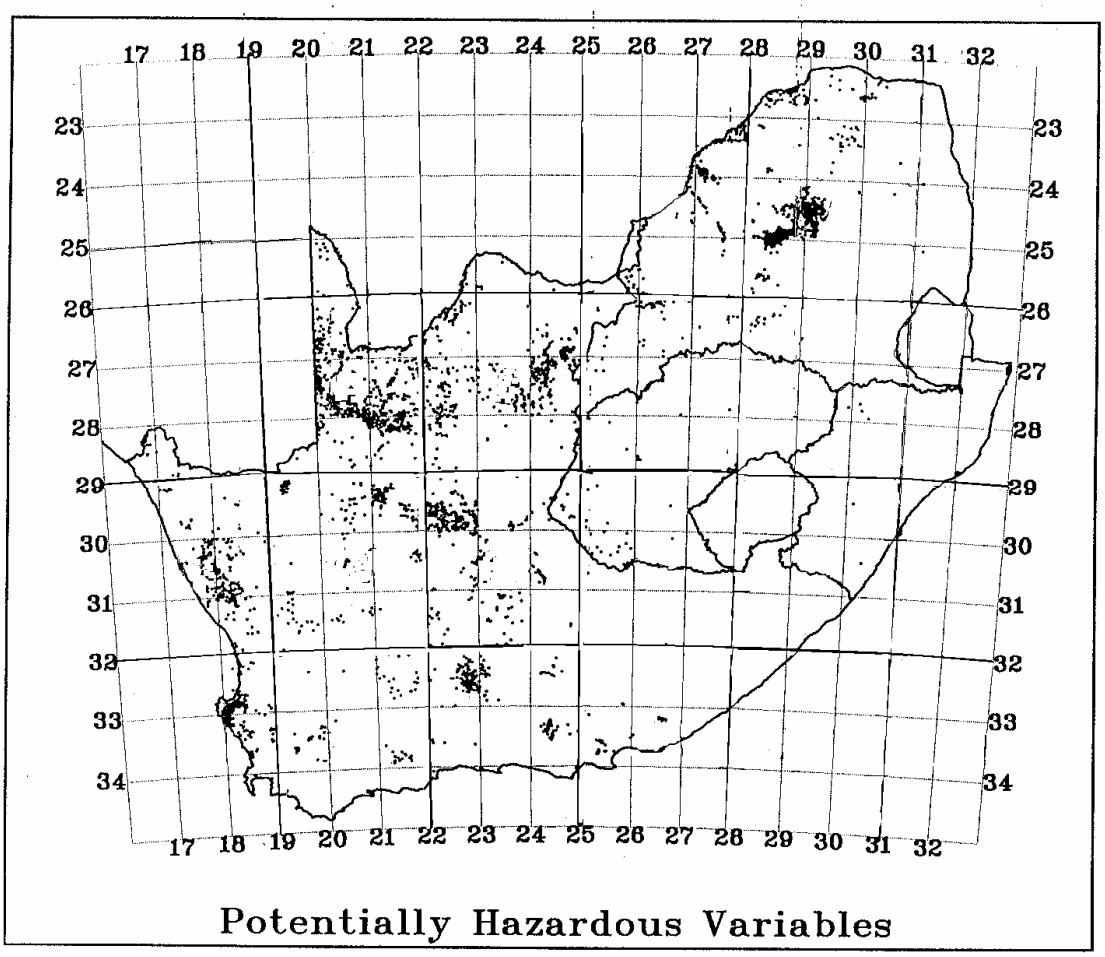
This chapter reports on the quality of water used by poultry producers in South Africa. It refers to and uses the PHC (Potentially Hazardous Constituent) and COC (Constituent of Concern) quantification system described by Meyer, 1998 and Meyer et al., 1997 but with specific reference to poultry. The objective was to identify PHCs (constituents in excess of the recommended guidelines) and COC (constituents within 10% of the recommended upper limit), to establish the validity of water quality guidelines currently in use for poultry, and to identify constituents at specific sites that require further investigation as potential hazards.

Materials and Methods

1. Borehole Selection:

A map (Map 1.1) was obtained from the Atomic Energy Corporation showing the occurrence of potentially hazardous constituent levels for livestock watering in southern Africa (Map 1.1). A large number of poultry producers in provinces with potentially hazardous water sources were contacted and those that use ground water were visited on site and the boreholes in use sampled. In the Western Cape 35 boreholes were sampled; in the North Western Province 9, in Gauteng 9, in the Freestate 17 and in the Eastern Cape, 3 boreholes.

Map 1.1: **Potentially hazardous levels for livestock watering occurring in South African ground water.**



Source: Atomic Energy Corporation 1997

2. Sample collection:

The sampling bottles were left in a solution of 1 ml concentrated nitric acid per litre of water for 24 hours. Bottles were rinsed with distilled water and dried. The borehole pump was allowed to run for at least 30 minutes. A tap near the borehole was located and allowed to run for at least 1 minute to purge the plumbing. More or less 1 litre of water was collected in a clean bucket from the running tap at 1 minute intervals for at least 5 minutes. This sample was stirred and 500 ml and 100 ml of water respectively was collected in acid treated plastic containers. The 500 ml sample was analysed for mineral content and the 100 ml sample for metal content. The 100 ml sample was acidified with nitric acid to a 0,001% solution, to keep the metals in suspension and the samples were kept at less than 5°C and returned to water quality laboratory within a week of the sampling time (Goan et al., 1992).

Laboratory Analyses:

The water samples were analysed for mineral content and a semi-quantitative metal scan was done by the Institute for Soil, Climate and Water at the ARC in Pretoria, making use of the United States Environmental Protection Agency's (EPA) Standard Operating Procedure for the determination of metals and minerals. See Tables 1.2 (mg/l) and 1.3 (µg/l) for lists of the constituents analysed.

Statistical evaluation:

Means, standard deviations, minimum and maximum levels of constituents in water sources were determined using Proc Means (PC – SAS Version 6.08).

2. Results of water analysis:

Results of water analyses of boreholes are presented in Tables 1.2 – 1.16., with a summary in Tables 1.17 – 1.18. The results of the survey are presented with a list of probable or possible adverse effects linked to the relevant constituents. Note the huge differences between minimum and maximum levels of the different minerals and metals observed within the same province. This accentuated the need for a water quality index system.

The Western Cape:

Map 1.2. The Western Cape region where the water samples were taken

Source: http://www.places.co.za/html

The Western Cape region west of the Hottentot's Holland mountain range is highly urbanised and industrialised and is farmed intensively. The farms include some of the country's biggest poultry units, which collectively deliver 24.5% of the gross egg production and 27.1% of the gross broiler production (Liebenberg et al., 1996) of South Africa. The physiography is a dominance of fold mountains, which affect the spatial distribution of rainfall and results in a high runoff. The potentially precarious water supply and the high demand for water for the urban areas, industry and agriculture, has forced many producers to rely on or supplement water from subterranean sources. The characteristics of this water may vary substantially (Hem, 1979), due to the occurrence of fractured aquifers (Parsons and Tredoux, 1993).

No complete reference to all the constituents adverse to poultry was found in the literature. Many different sources were used to compile a complete list of constituents involved in poultry water quality and often these sources used different methods to indicate guidelines. Tables 1.2 and 1.3 show the means of constituents present in the samples analysed. Highest recorded levels of constituents are presented in Table 1.4. Bicarbonates, chlorides, fluoride, nitrates, phosphates, sodium, cadmium, iron, lanthanum, lead, mercury, titanium and zirconium were identified as potentially hazardous constituents (PHC) in some areas. The mean levels of chlorides, bicarbonates, sodium and lead, found in all the boreholes samples were higher than the maximum levels allowed by the authors mentioned in Table 1.4. The rest of the constituents identified as potentially hazardous were isolated cases of levels exceeding the allowed maximum levels (Table 1.2 and 1.3).

Table 1.2. Water Quality Constituents (mg/l), pH and electrical conductivity (mS/m) of borehole water from selected poultry farms in the Western Cape (n = 35).

Measured variable	Mean	SD	Minimum	Maximum	MAX PHC	COC	Adverse effects of excess #
Bicarbonate	108.249	43.208	18.3	216.6	98	88.2	Non-toxic.
Boron	0	0	0	0	5	4.5	Not a priority pollutant
Calcium	33.391	15.39	9.3	68.5	600	540	Non-toxic, clogs up pipes.
Carbonate	0	0	0	0	500	450	Lower egg production.
Chloride	326.937	182.132	82.7	703.5	250	225	May cause metabolic problems.
Fluoride	0.934	1.521	0	7.2	6	5.4	Lower feed intakes and growth rates.
Magnesium	24.471	12.398	6.7	53.7	125	112.5	Laxative effect.
Nitrate	8.271	8.886	0	48.5	10	9	Reduced growth, increased mortality rate.
Nitrite	0	0	0	0	1	0.9	Thyroid enlargement methaemoglobinaemia
Phosphate	0.5	2.233	0	5.2	5	4.5	Indicator of sewage contamination.
Potassium	5.129	3.696	1.6	20.7	2000	1800	Acts as a laxative
Sodium	153.543	87.555	42.4	357	50	45	Diuretic, reduced egg production and growth.
Sulphate	27.36	25.413	4.9	87	250	225	Laxative effect, reduced egg production.
TDS	634.629	296.569	201.4	1216	3000	2700	Indication of excessive mineral content.
Hardness	87.2	33.73	15	151	-	-	Blocks water systems, scale formation.
pH	7.602	0.389	6.8	8.22	6-9	6-9	Acid - corrosive to pipes, lower performance, lower egg production.
pHs	8.082	0.381	7.7	9.24	-	-	Stability pH
NAV	4.822	2.259	2.24	9.75	-	-	-
Electrical conductivity	109.171	49.666	37	208	1980	1782	Related to ions in water, no influence on poultry production.

#Kempster et al., (1981); Waggoner et al. (1994); Vohra (1980); Zimmerman (1995); Carter (1985); Phillips et al. (1935); Ralph (1989), Puls 1994 and Coetzee (1994)

Table 1.3. Water quality constituents (µg/l) of borehole water from selected poultry farms in the Western Cape (n = 35).

Measured variable	Mean	SD	Minimum	Maximum	MAX PHC	COC	Adverse effects of excess #
Antimony	0.42	0.707	0.108	4.223	6	5.4	Emetic and a cardio-toxin.
Arsenic	1.332	2.181	0	9.812	50	45	Toxic substance.
Barium	69.371	67.776	9.795	252.1	2000	1800	Cardio-toxin.
Bismuth	0.066	0.033	0.015	0.149	500	450	Neuro-toxin.
Bromine	56.442	30.594	20.103	123.33	3000	2700	Reduced growth rate.
Cadmium	1.371	2.604	0	12.694	5	4.5	Excess has severe health effects.
Caesium	4.517	8.849	0	32.918	50000	45000	Cyanosis and convulsions.
Chromium	35.69	4.108	25.484	47.17	100	90	May contribute to hardness of water, low toxicity, Essential nutrient; absence causes diabetes.
Cobalt	4.043	6.706	0.557	27.166	1000	900	Essential nutrient, toxic in excess.
Copper	25.609	35.602	5.082	194.99	1300	1170	Bitter, causes liver damage.
I odine	110.942	82.558	43.131	485.47	1000	900	Thyroid-related effects.
Iron	3.731	7.858	0	37.19	6	5.4	Causes odour, bad taste & precipitate.
Lead	40.288	36.9	112.432	202.8	20	18	Toxic element
Manganese	649.986	661.358	27.157	2204.7	4600	4140	May contribute to hardness and turbidity, deposits in pipes and bitterness of water.
Mercury	0.956	1.214	0	4.182	2	1.8	A toxic element with no beneficial physiological function.
Molybdenum	0.781	1.639	0	8.148	100	90	Reduced growth, highly toxic.
Nickel	41.755	21.399	19.342	109.96	1000	900	Reduced growth.
Platinum	0.236	0.154	0.005	0.568	-	-	Allergenic.
Rubidium	7.895	7.435	0.486	27.463	5000	4500	Non-toxic.
Selenium	0.076	0.447	0	2.645	50	45	Reduced growth.
Strontium	289.913	274.323	36.206	1328.4	10000	9000	May contribute to hardness of water.
Tin	0.565	0.677	0.07	3.281	200	180	Essential nutrient, low toxicity.
Titanium	173.348	108.758	26.457	430.68	100	90	Soluble salts potentially toxic.
Tungsten	0.546	0.597	0.046	2.072	500	450	Only soluble salts potentially toxic.
Uranium	26.924	96.931	0.014	423.42	4000	3600	Low Toxicity
Vanadium	0.454	1.293	0	6.131	100	90	Nutritionally essential.
Zinc	256.827	388.63	50.319	1661.8	1500	1350	Astringent taste, may contribute to hardness.
Zirconium	0.731	0.577	0.237	2.916	1	0.9	Low toxicity.

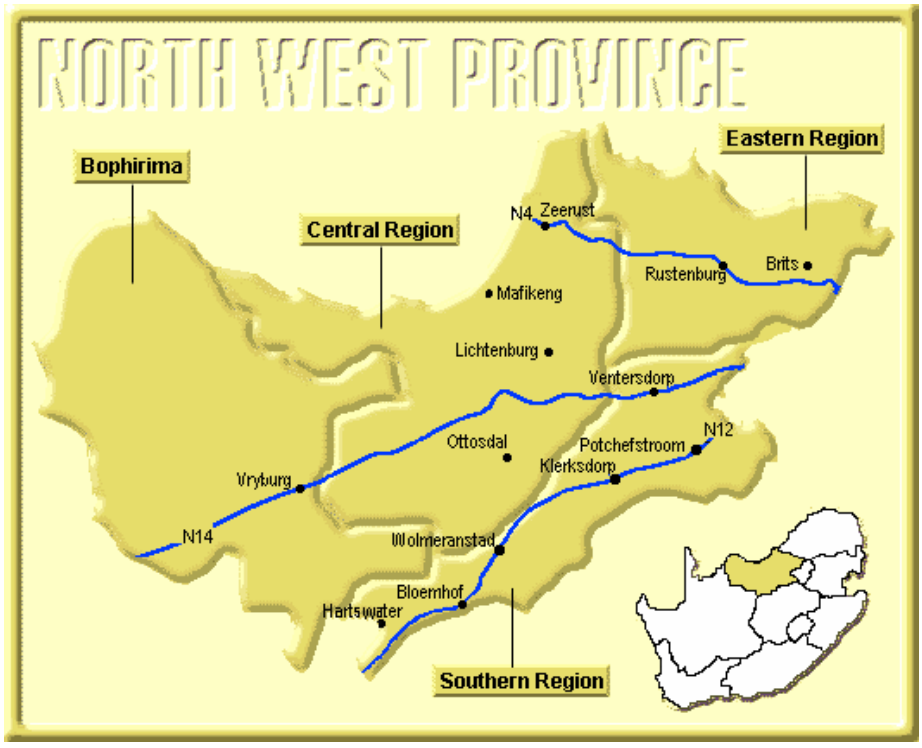
Kempster et al., (1981); Waggoner *et al.* (1994); Vohra (1980); Zimmerman (1995); Carter (1985); Phillips *et al*. (1935); Ralph (1989) and *Puls (1994)*

Table 1.4. Highest recorded levels of constituents in the Western Cape

Constituents	Highest recorded level	Recommended maximum levels	Source
Bicarbonates	216.6 mg/l	98.0 mg/l	Kempster *et al.*, 1981
Chlorides	703.5 mg/l	250.0 mg/l	Waggoner *et al.*, 1994
Fluoride	7.2 mg/l	2.0 mg/l	Kempster *et al.*, 1981
Nitrates	48.5 mg/l	10.0 mg/l	Waggoner *et al.*, 1994
Phosphates	5.2 mg/l	5.0 mg/l	Kempster *et al.*, 1981
Sodium	357.0 mg/l	50.0 mg/l	Waggoner *et al.*, 1994
Cadmium	12.694	5.0 µg/l	Zimmerman, 1995
Iron	37.190 mg/l	6.0 mg/l	Keshavarz, 1987
Lanthanum	2.304 µg/l	1.0 µg/l	Vohra, 1980
Lead	202.8 µg/l	20 µg/l	Schwarz, 1994
Mercury	4.182 µg/l	2.0 µg/l	Zimmerman, 1995
Titanium	430.68 µg/l	100.0 µg/l	Kempster *et al.*, 1981
Zirconium	2.916 µg/l	1.0 µg/l	Vohra, 1980

The North West Province

Map 1.3. The North West Province where the water samples were taken.



Source: http://www.places.co.za/html

Much of the province consists of flat areas of scattered trees and grassland (Map 1.3). The Magaliesberg mountain range in the northeast extends about 130 km (about 80 miles) from Pretoria to Rustenburg. The Vaal River flows along the southern border of the province. Temperatures range from 17° to 31° C (62° to 88° F) in the summer and from 3° to 21° C (37° to 70° F) in the winter. Annual rainfall totals about 360 mm (about 14 inches), with almost all of it falling during the summer months, between October and April.

Tables 1.5 and 1.6 show the means of constituents present in the samples analysed. The PHCs observed in the North Western Province were, bicarbonates, nitrates, sodium, lanthanum and titanium. The highest recorded levels of these constituents are shown in Table 1.7. No COCs were observed.

Table 1.5. Water quality constituents (mg/l), pH and electrical conductivity (mS/m) of borehole water from selected poultry farms in the North West Province (n = 9).

Measured variable	Mean	SD	Minimum	Maximum	MAX PHC	COC	Adverse effects of excess #
Bicarbonate	311.789	118.162	91.5	515.5	98	88.2	Non-toxic.
Boron	0	0	0	0	5	4.5	Not a priority pollutant
Calcium	46.233	26.189	19.9	93.8	600	540	Non-toxic, clogs up pipes.
Carbonate	3.5	3.824	0	10.5	500	450	Lower egg production.
Chloride	30.456	23.055	4	79	250	225	May cause metabolic problems.
Fluoride	0.018	0.038	0	0.11	6	5.4	Lower feed intakes and growth rates.
Magnesium	34.122	11.345	16.5	54.6	125	112.5	Laxative effect.
Nitrate	66.167	37.897	10.1	133.5	10	9	Reduced growth, increased mortality rate.
Nitrite	0	0	0	0	1	0.9	Thyroid enlargement methaemoglobinaemia
Phosphate	0	0	0	0	5	4.5	Indicator of sewage contamination.
Potassium	2.289	2.599	0.1	7.9	2000	1800	Acts as a laxative
Sodium	33.244	31.428	2.6	104.3	50	45	Diuretic, reduced egg production and growth.
Sulphate	14.233	6.788	1.3	24.7	250	225	Laxative effect, reduced egg production.
TDS	386.189	135.857	235.9	632.7	3000	2700	Indication of excessive mineral content.
Hardness	241.222	80.298	75	331	-	-	Blocks water systems, scale formation.
pH	8.356	0.314	7.87	8.74	6-9	6-9	Acid - corrosive to pipes, lower performance, lower egg production.
PHs	7.463	0.419	6.96	8.19	-	-	Stability pH
NAV	0.899	0.79	0.07	2.51	-	-	-
Electrical conductivity	55.333	17.081	35	87	1980	1782	Related to ions in water, no influence on poultry production.

#Kempster et al., (1981); Waggoner et al. (1994); Vohra (1980); Zimmerman (1995); Carter (1985); Phillips et al. (1935); Ralph (1989), Puls 1994 and Coetzee (1994)

Table 1.6. Water quality constituents (µg/l) of borehole water from selected poultry farms in the North West Province (n = 9).

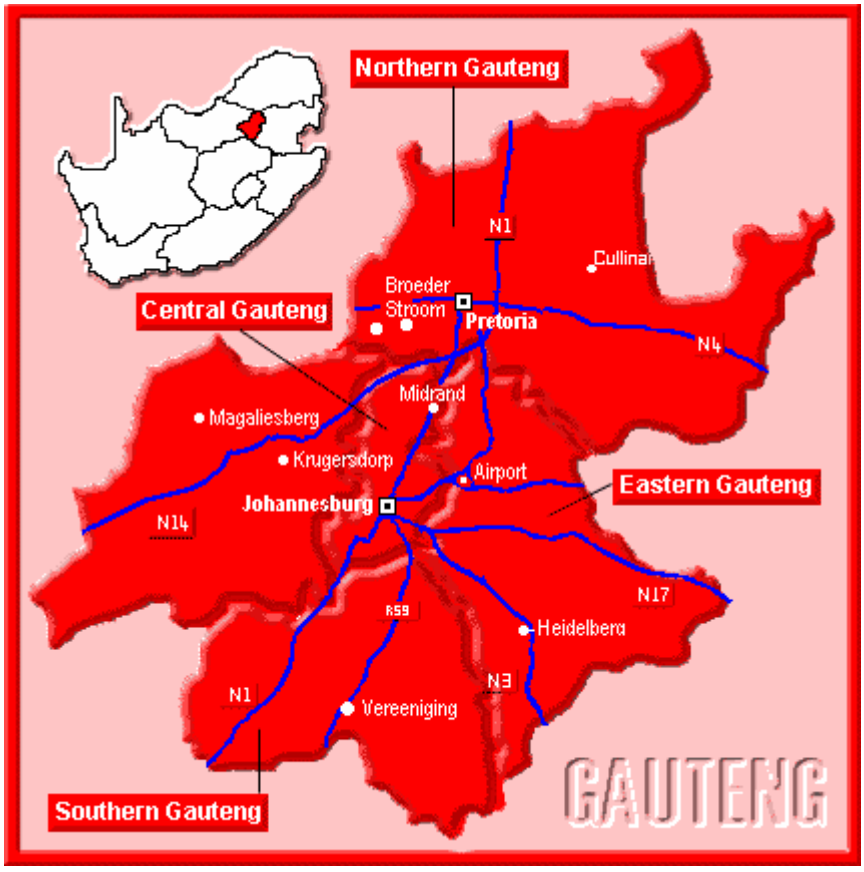
Measured variable	Mean	SD	Minimum	Maximum	MAX PHC	COC	Adverse effects of excess #
Antimony	0.018	0.029	0	0.081	6	5.4	Emetic and a cardio-toxin.
Arsenic	0.006	0.018	0	0.055	50	45	Toxic substance.
Barium	77.113	67.297	8.958	202.98	2000	1800	Cardio-toxin.
Bismuth	0.028	0.056	0	0.166	500	450	Neuro-toxin.
Bromine	0	0	0	0	3000	2700	Reduced growth rate
Cadmium	0.021	0.061	0	0.183	5	4.5	Excess has severe health effects.
Caesium	0.008	0.022	0	0.066	50000	45000	Cyanosis and convulsions.
Chromium	46.428	3.688	39.237	50.432	100	90	May contribute to hardness of water, low toxicity. Essential nutrient; absence causes diabetes.
Cobalt	0.02	0.059	0	0.176	1000	900	Nutritionally essential, toxic in excess.
Iron	0	0	0	0	6	5.4	Causes odour, bad taste & precipitate.
Lanthanum	5.077	9.827	0.021	27.429	1	0.9	Low to moderate acute toxicity rating.
Lead	0.786	0.465	0.167	1.417	20	18	Toxic element
Manganese	0	0	0	0	4600	4140	May contribute to hardness and turbidity, deposits in pipes and bitterness of water.
Mercury	0	0	0	0	2	1.8	A toxic element with no beneficial physiological function.
Molybdenum	0	0	0	0	100	90	Reduced growth, highly toxic.
Nickel	30.177	4.127	24.33	35.965	1000	900	Reduced growth.
Platinum	0.074	0.107	0	0.285	-	-	Allergenic.
Rubidium	0	0	0	0	5000	4500	Non-toxic.
Selenium	7.123	7.788	0	19.624	50	45	Reduced growth.
Strontium	269.467	145.397	30.846	416.09	10000	9000	May contribute to hardness of water.
Tin	0	0	0	0	200	180	Essential nutrient; low toxicity.
Titanium	377.359	216.745	145.1	773.68	100	90	Soluble salts potentially toxic.
Tungsten	0.031	0.037	0	0.144	500	450	Only soluble salts potentially toxic.
Uranium	0.36	0.226	0.005	0.777	4000	3600	Low Toxicity
Vanadium	14.894	11.747	2.313	38.802	100	90	Essential nutrient.
Zinc	319.309	418.698	0	1207	1500	1530	Astringent taste, may contribute to hardness.
Zirconium	0	0	0	0	1	0.9	Low toxicity.

Kempster et al., (1981); Waggoner *et al.* (1994); Vohra (1980); Zimmerman (1995); Carter (1985); Phillips *et al*. (1935); Ralph 1989)and*Puls(1994)*

Table 1.7. Highest recorded levels of constituents in the North West Province

Constituents	Highest recorded level	Recommended maximum levels	Source
Bicarbonates	515.500 mg/l	98.0 mg/l	Kempster *et al.*, 1981
Nitrates	133.5 mg/l	10.0 mg/l	Waggoner *et al.*, 1994
Sodium	104.300 mg/l	50.0 mg/l	Waggoner *et al.*, 1994
Lanthanum	27.429 µg/l	1.0 µg/l	Vohra, 1980
Titanium	773.680 µg/l	100.0 µg/l	Kempster *et al.*, 1981

Gauteng
Map 1.4. The province of Gauteng where the water samples were taken.



Source: http://www.places.co.za/html

Most of the province lies in the High Veld, a plateau of grassy plains that covers much of central South Africa. The Witwatersrand, (which is Afrikaans for "ridge of white waters") is a rocky ridge that extends for about 80 km (about 50 miles) down the middle of Gauteng and is famous for its rich gold deposits. Average temperatures in Gauteng range from 16° to 32° C (60° to 90° F) in the summer (October to April), and from 6° to 17° C (43° to 63° F) in the winter. Annual rainfall totals 510 mm (20 inches), with most of the rain falling in the summer months (Map 1.4).

Tables 1.8 and 1.9 show the means of constituents present in the samples analysed.

The PHCs observed in Gauteng were bicarbonates, nitrates, manganese, mercury and titanium. The highest recorded levels of these constituents are shown in Table 1.10. No COCs were observed.

Table 1.8. Water quality constituents (mg/l), pH and electrical conductivity (mS/m) of borehole water from selected poultry farms in Gauteng (n = 9).

Measured variable	Mean	SD	Minimum	Maximum	MAX PHC	COC	Adverse effects of excess #
Bicarbonate	35.144	39.802	0	131.2	98	88.2	Non-toxic.
Boron	0.011	0.033	0	0.1	5	4.5	Not a priority pollutant.
Calcium	9.256	5.577	1.9	19.6	600	540	Non-toxic, clogs up pipes.
Carbonate	0.333	1	0	3	500	450	Lower egg production.
Chloride	11.033	12.415	0.9	32.3	250	225	May cause metabolic problems.
Fluoride	0.058	0.082	0	0.24	6	5.4	Lower feed intakes and growth rates.
Magnesium	5.3	4.082	0.3	11.4	125	112.5	Laxative effect.
Nitrate	34.611	46.416	2.5	116.6	10	9	Reduced growth, increased mortality rate.
Nitrite	0	0	0	0	1	0.9	Thyroid enlargement methaemoglobinaemia
Phosphate	0.189	0.567	0	1.7	5	4.5	Indicator of sewage contamination.
Potassium	4.922	4.373	2	16.3	2000	1800	Acts as a laxative.
Sodium							
Sulphate	0.777	0.521	0.1	1.5	250	225	Laxative effect, reduced egg production.
TDS	92.178	59.672	28.2	187	3000	2700	Indication of excessive mineral content.
Hardness	24.222	24.939	0	80.000	-	-	Blocks water systems, scale formation.
pH	6.619	1.697	3.79	8.54	6-9	6-9	Acid - corrosive to pipes. Lower performance, lower egg production.
PHs	9.347	0.737	8.05	10.28	-	-	Stability pH
NAV	5.552	14.433	0.14	44	-	-	-
Electrical conductivity	16.222	11.065	4	34	1980	1782	Related to ions in water, no influence on poultry production.

#Kempster et al., (1981); Waggoner et al. (1994); Vohra (1980); Zimmerman (1995); Carter (1985); Phillips et al. (1935); Ralph (1989), Puls 1994 and Coetzee (1994)

Table 1.9. Water quality constituents (µg/l) of borehole water from selected poultry farms in Gauteng (n = 9).

Measured variable	Mean	SD	Minimum	Maximum	MAX PHC	COC	Adverse effects of excess #
Antimony	719	0.475	0.074	1.38	6	54	Emetic and a cardio-toxin.
Arsenic	4.077	2.174	0.196	7.03	50	45	Toxic substance.
Barium	125.262	86.41	30.77	270.14	2000	1800	Cardio-toxin.
Bismuth	0.268	0.202	0.025	0.704	500	450	Neuro-toxin.
Bromine	0	0	0	0	3000	2700	Reduce growth rate
Cadmium	1.39	0.947	0	2.414	5	4.5	Excess has severe health effects.
Caesium	0	0	0	0	50000	45000	Cyanosis and convulsions.
Chromium	45.841	14.18	22.628	59.016	100	90	May contribute to hardness of water, low toxicity. Essential nutrient, absence causes diabetes.
Cobalt	7.601	12.332	0.646	30.321	1000	900	Nutritionally essential, toxic in excess.
Copper	39.078	39.034	2.881	111.38	1300	1170	Bitter, causes liver damage.
Iron	0	0	0	0.001	6	5.4	Causes odour, bad taste & precipitate.
Lanthanum	0	0	0	0	1	0.9	Low to moderate acute toxicity rating.
Lead	5.901	3.757	1.095	12.141	20	18	Toxic element
Manganese	11130.32	17685.53	96.326	4420.9	4600	4140	May contribute to hardness and turbidity, deposits in pipes and bitterness of water.
Mercury	17.743	14.127	0	34.434	2	1.8	A toxic element with no beneficial physiological function.
Molybdenum	1.445	0.824	0	2.48	100	90	Reduced growth, highly toxic.
Nickel	53.043	25.508	0	89.544	1000	900	Reduced growth.
Platinum	0.514	0.533	0	1.169	-	-	Allergenic.
Rubidium	0	0	0	0	5000	4500	Non-toxic.
Selenium	21.979	16.969	0	41.789	50	45	Reduced growth.
Strontium	44.965	29.035	3.029	90.717	10000	9000	May contribute to hardness of water.
Tin	1.633	1.149	0	2.921	200	180	Essential nutrient, low toxicity.
Titanium	69.197	47.077	27.265	181	100	90	Soluble salts potentially toxic.
Tungsten	2.89	0.194	0	0.602	500	450	Only soluble salts potentially toxic.
Uranium	1.411	1.871	0.12	5.236	4000	3600	Low Toxicity
Vanadium	32.724	20.996	4.839	62.898	100	90	Essential nutrient.
Zinc	344.254	686.62	10.11	2127.4	1500	1350	Astringent taste, may contribute to hardness.
Zirconium	0	0	0	0	1	0.9	Low toxicity.

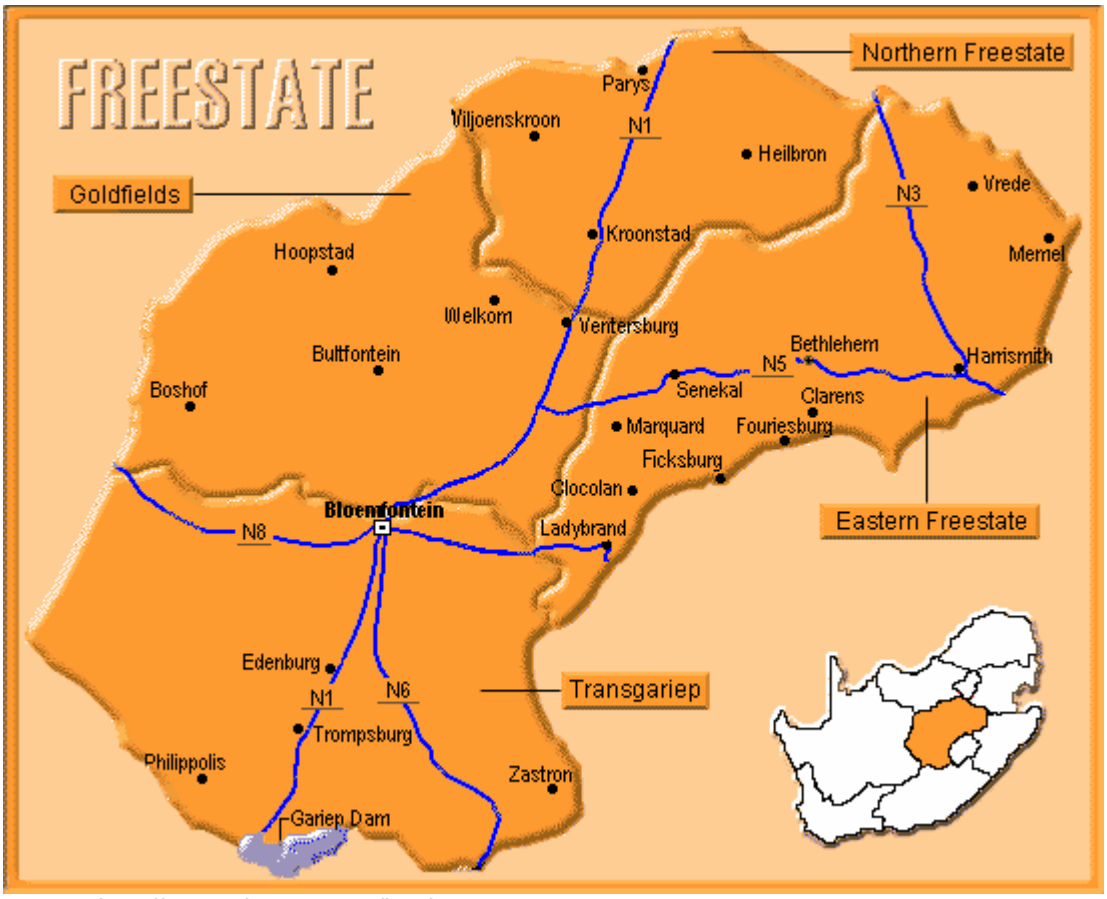
Kempster et al., (1981); Waggoner *et al.* (1994); Vohra (1980); Zimmerman (1995); Carter (1985); Phillips *et al*. (1935); Ralph (1989) and *Puls (1994)*

Table 1.10. Highest recorded levels of constituents in Gauteng

Constituents	Highest recorded level	Recommended maximum levels	Source
Bicarbonates	131.2 mg/l	98.0 mg/l	Kempster *et al.*, 1981
Nitrates	116.6 mg/l	10.0 mg/l	Waggoner *et al.*, 1994
Manganese	4420.9 µg/l	4600.0 µg/l	Kempster *et al.*, 1981
Mercury	34.434 µg/l	2.0 µg/l	Kempster *et al.*, 1981
Titanium	181.000 µg/l	100.0 µg/l	Kempster *et al.*, 1981

The Freestate

Map 1.5. The Freestate Province where the water samples were taken.



Source: http://www.places.co.za/html

The Free State is located on the High Veld, the large plateau that covers much of the central region of South Africa. The far western part of the province is flat and sparsely vegetated, while in the far east the land rises to the Drakensberg Mountains. The rest of the province consists of rolling plains. Average temperatures range from 16° to 31° C (60° to 88° F) in the summer and from 1° to 18° C (34° to 64° F) in the winter. Average annual rainfall totals 360 mm (14 inches) with most of the rain falling in the warmer months, from October to April. The eastern part of the province receives considerably more rain than the western region (Map 1.5).

Tables 1.11 and 1.12 show the means of constituents present in the samples analysed.

The PHCs observed in the Freestate were bicarbonates chlorides, phosphates, bromine, chromium, lanthanum, mercury, selenium, titanium and zirconium. The highest recorded levels of these constituents are shown in Table 1.13. No COCs were observed.

Table 1.11. Water quality constituents (mg/l), pH and electrical conductivity of borehole water from selected poultry farms in the Free State (n =17).

Measured variable	Mean	SD	Minimum	Maximum	MAX PHC	COC	Adverse effects of excess #
Bicarbonate	293.262	195.264	4.9	555.1	98	88.2	Non-toxic.
Boron	0.247	0.56	0	2.4	5	4.5	Not a priority pollutant.
Calcium	121.076	117.952	3.8	291	600	540	Non-toxic, clogs up pipes.
Carbonate	0.356	1.455	0	6	500	450	Lower egg production.
Chloride	222.752	280.581	3.5	907.1	250	225	May cause metabolic problems.
Fluoride	0.025	0.087	0	0.36	6	5.4	Lower feed intakes and growth rates.
Magnesium	22.653	19.915	0.05	60.5	125	112.5	Laxative effect.
Nitrate	0	0	0	0	10	9	Reduced growth, increased mortality rate.
Nitrite	0	0	0	0	1	0.9	Thyroid enlargement methaemoglobinaemia
Phosphate	13.847	11.379	0.2	31.9	5	4.5	Indicator of sewage contamination.
Potassium	192.371	177.662	6.5	786	2000	1800	Acts as a laxative.
Sodium	224.426	218.816	0.55	520.5	50	45	Diuretic, reduced egg production and growth.
Sulphate	41.324	0.521	0.1	1.5	250	225	Laxative effect, reduced egg production.
TDS	1082.91	769.28	72.1	2501.3	3000	2700	Indication of excessive mineral content.
Hardness	199.941	113.942	4	305	-	-	Blocks water systems, scale formation.
pH	7.339	1.136	4.37	8.53	6-9	6-9	Acid - corrosive to pipes. Lower performance, lower egg production.
PHs	7.431	1.04	6.57	9.74	-	-	Stability pH
NAV	8.342	13.327	0.41	53.61	-	-	-
Electrical conductivity	165.529	111.168	13	385	1980	1782	Related to ions in water, no influence on poultry production.

#Kempster et al., (1981); Waggoner et al. (1994); Vohra (1980); Zimmerman (1995); Carter (1985); Phillips et al. (1935); Ralph (1989), Puls 1994 and Coetzee (1994)

Table 1.12. Water quality constituents (µg/l) of borehole water from selected poultry farms in the Free State (n =17).

Measured variable	Mean	SD	Minimum	Maximum	MAX PHC	COC	Adverse effects of excess #
Antimony	0.184	0.135	0.063	0.686	6	5.4	Emetic and a cardio-toxin.
Arsenic	9.881	2.627	6.739	15.753	50	45	Toxic substance.
Barium	76.616	29.233	25.5	113.11	2000	1800	Cardio-toxin.
Bismuth	0.082	0.031	0.024	0.129	500	450	Neuro-toxin.
Bromine	16917.47	11096.88	4045.3	43697	3000	2700	Reduced growth rate
Cadmium	0.797	0.415	0.41	2.079	5	4.5	Excess has severe health effects.
Caesium	0.077	0.096	0.019	0.356	50000	45000	Cyanosis and convulsions.
Chromium	54.134	17.902	20.3	112.81	100	90	May contribute to hardness of water .Essential nutrient; absence causes diabetes, low toxicity.
Cobalt	165.565	229.312	0.631	528.93	1000	900	Essential nutrient, toxic in excess.
Copper	18.366	12.278	5.993	141.27	1300	1170	Bitter, causes liver damage.
Iron	0	0	0	0	6	5.4	Causes odour, bad taste & precipitate.
Lanthanum	2.327	3.295	0.534	12.758	1	0.9	Low to moderate acute toxicity rating.
Lead	2.072	0.804	1.095	4.387	20	18	Toxic element
Manganese	110.306	133.633	23.976	383.73	4600	4140	May contribute to hardness and turbidity, deposits in pipes and bitterness of water.
Mercury	10.358	3.565	6.08	16.338	2	1.8	A toxic element with no beneficial physiological function.
Molybdenum	2.844	2.564	1.061	11.718	100	90	Reduced growth, highly toxic.
Nickel	35.478	5.9518	26.672	47.25	1000	900	Reduced growth.
Platinum	0.346	0.212	0.053	0.814	-	-	Allergenic.
Rubidium	0	0	0	0	5000	4500	Non-toxic.
Selenium	67.957	13.797	50.772	94.996	50	45	Reduced growth.
Strontium	2549.83	2165.42	104.66	5749.4	10000	9000	May contribute to hardness of water.
Tin	0.821	0.368	0.539	2.086	200	180	Essential nutrient, low toxicity.
Titanium	884.182	854.179	56.6	2427.1	100	90	Soluble salts potentially toxic.
Tungsten	0.143	0.057	0.028	0.238	500	450	Only soluble salts potentially toxic.
Uranium	4.045	2.868	0.16	8.892	4000	3600	Low Toxicity
Vanadium	4.81	3.847	0.91	16.051	100	90	Nutritionally essential.
Zinc	171.056	240.236	42.075	1066.8	1500	1350	Astringent taste, may contribute to hardness.
Zirconium	0.923	0.767	0.449	3.586	1	0.9	Low toxicity.

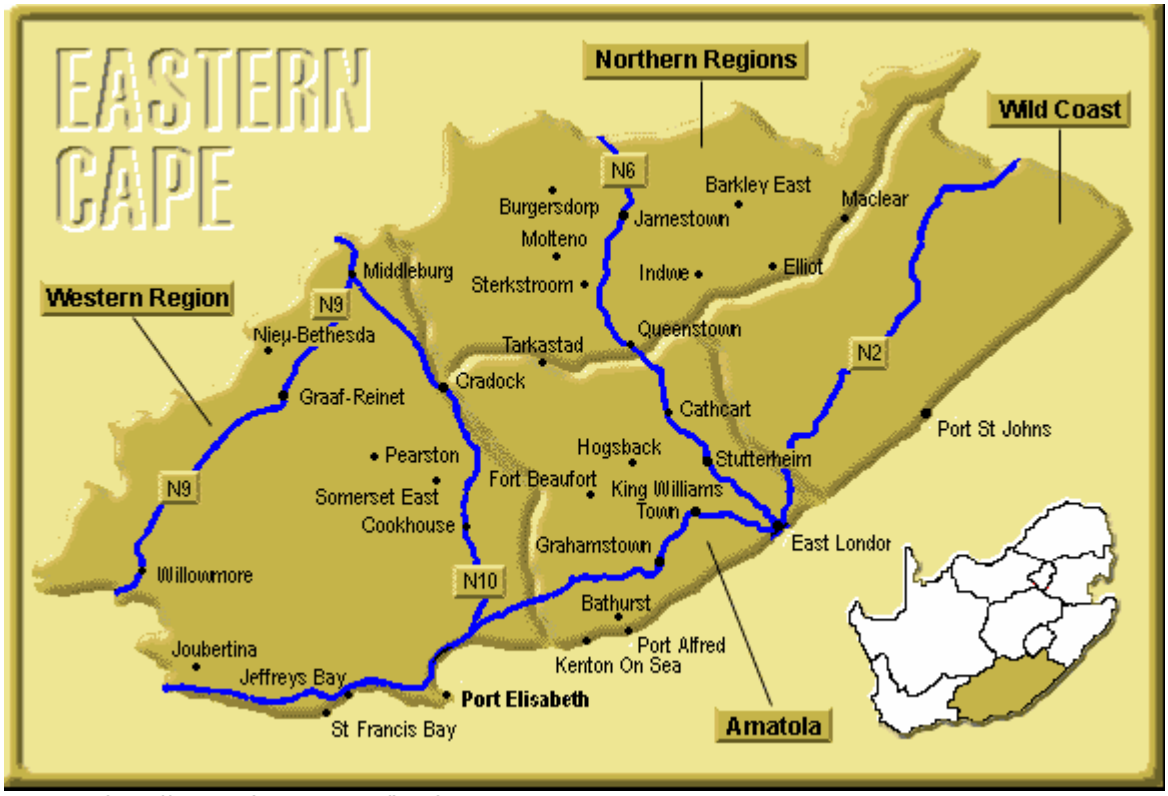
Kempster et al., (1981); Waggoner *et al.* (1994); Vohra (1980); Zimmerman (1995); Carter (1985); Phillips *et al*. (1935); Ralph (1989) and *Puls (1994)*

Table 1.13. Highest recorded levels of constituents in the Freestate

Constituents	Highest recorded level	Recommended maximum levels	Source
Bicarbonates	555.1 mg/l	98.0 mg/l	Kempster *et al.*, 1981
Chlorides	907.1 mg/l	250.0 mg/l	Waggoner *et al.*, 1994
Phosphates	31.9 mg/l	5.0 mg/l	Kempster *et al.*, 1981
Sodium	520.5 mg/l	50.0 mg/l	Waggoner *et al.*, 1994
Bromine	43697 µg/l	3000 µg/l	Vohra, 1980
Chromium	112.810 µg/l	100.0 µg/l	Kempster *et al.*, 1981
Lanthanum	12.758 µg/l	1.0 µg/l	Vohra, 1980
Mercury	16.338 µg/l	2.0 µg/l	Kempster *et al.*, 1981
Selenium	94.996 µg/l	50 µg/l	Kempster *et al.*, 1981
Titanium	2427.1 µg/l	100.0 µg/l	Kempster *et al.*, 1981
Zirconium	3.586 µg/l	1.0 µg/l	Vohra, 1980

The Eastern Cape

Map 1.6. The Eastern Cape Province where the water samples were taken.



Source: http://www.places.co.za/html

The Eastern Cape has a varied topography and climate. Much of the province consists of rolling grasslands, but the northwest section is part of the sparsely vegetated Great Karoo, a large, arid plateau (see Karoo). Extensive forests cover the southern section of the province. A series of mountain ranges runs through the center of Eastern Cape, and the Witteberge Mountains and the Drakensberg Mountains rim the province's northeastern boundary. The Great Fish, the Keiskamma, and the Kei rivers flow through the region. Eastern Cape's coastal area receives abundant rainfall, but the interior is much drier and has had chronic drought problems. The city of East London, located on the coast, receives an average annual rainfall of 900 mm (36 inches), while Cradock, in the interior, receives an average annual rainfall of 310 mm (10 inches). Most rain falls during the warmer months of October through April. Average temperatures in Eastern Cape range from 18° to 27° C (from 64° to 80° F) in the summer and from 8° to 20° C (46° to 68° F) in the winter (Map 1.6).
Tables 1.14 and 1.15 show the means of constituents present in the samples analysed.

The PHCs observed in the Eastern Cape were, bicarbonate, nitrates, sodium, mercury, selenium and titanium. Zirconium was present as a COC. The highest recorded levels of these constituents are shown in Table 1.16.

Table 1.14. Water quality constituents (mg/l), pH and electrical conductivity (mS/m) of borehole water from selected poultry farms in the Eastern Cape (n = 3).

Measured variable	Mean	SD	Minimum	Maximum	MAX PHC	COC	Adverse effects of excess #
Bicarbonate	287.967	33.405	256.9	323.3	98	88.2	Non-toxic.
Boron	0.033	0.058	0	0.1	5	4.5	Not a priority pollutant.
Calcium	26.8	12.093	16.7	40.2	600	540	Non-toxic, clogs up pipes.
Carbonate	0	0	0	0	500	450	Lower egg production.
Chloride	6.867	2.754	4.2	9.7	250	225	May cause metabolic problems.
Fluoride	0.007	0.012	0	0.02	6	5.4	Lower feed intakes and growth rates.
Magnesium	10.967	7.753	3.1	18.6	125	112.5	Laxative effect.
Nitrate	6.267	5.062	2.1	11.9	10	9	Reduced growth, increased mortality rate.
Nitrite	0	0	0	0	1	0.9	Thyroid enlargement methaemoglobinaemia
Phosphate	0	0	0	0	5	4.5	Indicator of sewage contamination.
Potassium	0.933	0.651	0.3	1.6	2000	1800	Acts as a laxative.
Sodium	68.567	34.755	29.1	94.6	50	45	Diuretic, reduced egg production and growth.
Sulphate	12.967	5.636	8.9	19.4	250	225	Laxative effect, reduced egg production.
TDS	294	29.099	360.5	313	3000	2700	Indication of excessive mineral content.
Hardness	113	61.798	55	178	-	-	Blocks water systems, scale formation.
pH	7.963	0.307	7.62	8.21	06-Sep	06-Sep	Acid - corrosive to pipes, lower performance, lower egg production.
PHs	7.617	0.166	7.46	7.79	-	-	Stability pH
NAV	3.333	2.313	0.95	5.57	-	-	-
Electrical conductivity	50.667	3.215	47	53	1980	1782	Related to ions in water, no influence on poultry production.

#Kempster et al., (1981); Waggoner et al. (1994); Vohra (1980); Zimmerman (1995); Carter (1985); Phillips et al. (1935); Ralph (1989), Puls 1994 and Coetzee (1994)

Table 1.15. Water quality constituents (µg/l) of borehole water from selected farms in the Eastern Cape (n = 3).

Measured variable	Mean	SD	Minimum	Maximum	MAX PHC	COC	Adverse effects of excess #
Antimony	0.163	0.083	0.073	0.237	6	5.4	Emetic and a cardio-toxin.
Arsenic	11.41	1.478	9.703	12.281	50	45	Toxic substance.
Barium	94.36	34.917	60.136	129.93	2000	1800	Cardio-toxin.
Bismuth	0.083	0.024	0.065	0.11	500	450	Neuro-toxin.
Bromine	5068.8	335.51	4719	5387.9	3000	2700	Reduced growth rate.
Cadmium	0.655	0.066	0.587	0.718	5	4.5	Excess has severe health effects.
Caesium	0.051	0.011	0.04	0.061	50000	45000	Cyanosis and convulsions.
Chromium	55.188	5.496	49.267	60.126	100	90	May contribute to hardness of water. Essential nutrient; absence causes diabetes, low toxicity.
Cobalt	43.968	72.635	0.91	127.83	1000	900	Essential nutrient, toxic in excess.
Copper	14.026	8.905	7.434	24.157	1300	1170	Bitter, causes liver damage.
Iron	0	0	0	0	6	5.4	Causes odour, bad taste & precipitate.
Lanthanum	0.865	0.234	0.66	1.12	1	0.9	Low to moderate acute toxicity rating.
Lead	7.049	7.359	1.871	15.473	20	18	Toxic element
Manganese	196.903	271.532	31.781	510.29	4600	4140	May contribute to hardness and turbidity, deposits in pipes and bitterness of water.
Mercury	7.553	0.9	6.555	8.305	2	1.8	A toxic element with no beneficial physiological function.
Molybdenum	2.751	1.259	1.86	4.191	100	90	Reduced growth, highly toxic.
Nickel	38.592	4.654	33.946	43.254	1000	900	Reduced growth.
Platinum	0.247	0.134	0.12	0.388	-	-	Allergenic.
Rubidium	0	0	0	0	5000	4500	Non-toxic.
Selenium	67.366	10.143	57.425	77.7	50	45	Reduced growth.
Strontium	693.763	281.415	514.31	1018.1	10000	9000	May contribute to hardness of water.
Tin	0.778	0.128	0.668	0.919	200	180	Essential nutrient, low toxicity.
Titanium	211.85	81.1809	152.64	304.39	100	90	Soluble salts potentially toxic.
Tungsten	0.124	0.018	0.107	0.141	500	450	Only soluble salts potentially toxic.
Uranium	2.669	2.622	0.663	5.636	4000	3600	Low Toxicity
Vanadium	5.125	2.283	3.562	7.746	100	90	Essential nutrient.
Zinc	407.905	397.067	102.59	856.82	1500	1350	Astringent taste, may contribute to hardness.
Zirconium	0.788	0.164	0.67	0.975	1	0.9	Low toxicity.

 # Kempster et al., (1981); Waggoner et al. (1994); Vohra (1980); Zimmerman (1995); Carter (1985); Phillips et al. (1935); Ralph (1989) and Puls (1994)

Table 1.16. Highest recorded levels of constituents in the Eastern Cape Province

Constituents	Highest recorded level	Recommended maximum levels	Source
Bicarbonates	323.3 mg/l	98.0 mg/l	Kempster *et al.,* 1981
Nitrates	11.9 mg/l	10.0 mg/l	Waggoner *et al.,* 1994
Sodium	94.6 mg/l	50.0 mg/l	Waggoner *et al.,* 1994
Mercury	8.305 µg/l	2.0 µg/l	Kempster *et al.,* 1981
Selenium	77.7µg/l	50 µg/l	Kempster *et al.,* 1981
Titanium	304.39 µg/l	100.0 µg/l	Kempster *et al.,* 1981
Zirconium	0.975 µg/l	1.0 µg/l	Vohra, 1980

Table 2.17. Water quality constituents (mg/l) of boreholes from selected poultry farms in the Western Cape, North West, Gauteng, Free State and Eastern Cape Provinces

Variable	PHC	COC	Western Cape		North West		Gauteng		Free State		Eastern Cape		
	>	= / <	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Adverse effects of excess #
Bicarbonate	98	88.2	108.249	43.208	311.789	118.162	35.144	39.802	293.262	195.264	287.967	33.405	Non-toxic.
Boron	5	4.5	0	0	0	0	0.011	0.033	0.247	0.56	0.033	0.058	Not a priority pollutant.
Calcium	600	540	33.391	15.39	46.233	26.189	9.256	5.577	121.076	117.952	26.8	12.093	Non-toxic, clogs up pipes.
Carbonate	500	450	0	0	3.5	3.824	0.333	1	0.356	1.455	0	0	Lower egg production.
Chloride	250	225	326.937	182.132	30.456	23.055	11.033	12.415	222.752	280.581	6.867	2.754	May cause metabolic problems.
Fluoride	6	5.4	0.934	1.521	0.018	0.038	0.058	0.082	0.025	0.087	0.007	0.012	Lower feed intakes and growth rates.
Magnesium	125	112.5	24.471	12.398	34.122	11.345	5.3	4.082	22.653	19.915	10.967	7.753	Laxative effect.
Nitrate	10	9	8.271	8.886	66.167	37.897	34.611	46.416	0	0	6.267	5.062	Reduced growth, increased mortality rate.
Nitrite	1	0.9	0	0	0	0	0	0	0	0	0	0	Thyroid enlargement methaemoglobinaemia.
Phosphate	5	4.5	0.5	2.233	0	0	0.189	0.567	13.847	11.379	0	0	Indicator of sewage contamination.
Potassium	2000	1800	5.129	3.696	2.289	2.599	4.922	4.373	192.371	177.662	0.933	0.651	Acts as a laxative.
Sodium	50	45	153.543	87.555	33.244	31.428	8.111	3.541	224.426	218.816	68.567	34.755	Diuretic, reduced egg production and growth.
Sulphate	250	225	27.36	25.413	14.233	6.788	0.777	0.521	41.324	0.521	12.967	5.636	Laxative effect, reduced egg production.
TDS	3000	2700	634.629	296.569	386.189	135.857	92.178	59.672	1082.91	769.28	294	29.099	Indication of excessive mineral content.
Hardness	-	-	87.2	33.73	241.222	80.298	24.222	24.939	199.941	113.942	113	61.798	Blocks water systems, scale formation.
PH	6-9	6-9	7.602	0.389	8.356	0.314	6.619	1.697	7.339	1.136	7.963	0.307	Acid - corrosive to pipes, lower performance, lower egg production.
PHs	-	-	8.082	0.381	7.463	0.419	9.347	0.737	7.431	1.04	7.617	0.166	Stability pH
NAV	-	-	4.822	2.259	0.899	0.79	5.552	14.433	8.342	13.327	3.333	2.313	-
Electrical conductivity	1980	1782	109.171	49.666	55.333	17.081	16.222	11.065	165.529	111.168	50.667	3.215	Related to ions in water, no influence on poultry production.

Table 2.18. Water quality constituents (µg/l) of boreholes from selected poultry farms in the Western Cape, North West, Gauteng, Free State and Eastern Cape Provinces

Chapter 5 ariable	PHC	COC	Western Cape		North West		Gauteng		Free State		Eastern Cape		
Chapter 6	>	= / <	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Adverse effects of excess #
Antimony	6	5.4	0.420	0.707	0.018	0.029	0719	0.475	0.184	0.135	0.163	0.083	Emetic and a cardio-toxin.
Arsenic	50	45	1.332	2.181	0.006	0.018	4.077	2.174	9.881	2.627	11.410	1.478	Toxic substance.
Barium	2000	1800	69.371	67.776	77.113	67.297	125.262	86.410	76.616	29.233	94.360	34.917	Cardio-toxin.
Bismuth	500	450	0.066	0.033	0.028	0.056	0.268	0.202	0.082	0.031	0.083	0.024	Neuro-toxin.
Bromine	3000	2700	56.442	30.594	0	0	0	0	16917.47	11096.88	5068.800	335.510	Reduced growth rate.
Cadmium	5	4.5	1.371	2.604	0.021	0.061	1.390	0.947	0.797	0.415	0.655	0.066	Excess has severe health effects.
Caesium	50000	45000	4.517	8.849	0.008	0.022	0	0	0.077	0.096	0.051	0.011	Cyanosis and convulsions.
Chromium	100	90	35.690	4.108	46.428	3.688	45.841	14.180	54.134	17.902	55.188	5.496	Contributes to hardness. Essential nutrient; absence causes diabetes,low toxicity.
Cobalt	1000	900	4.043	6.706	0.020	0.059	7.601	12.332	165.565	229.312	43.968	72.635	Essential nutrient, toxic in excess.
Copper	1300	1170	25.609	35.602	4.319	8.646	39.078	39.034	18.366	12.278	14.026	8.905	Bitter, causes liver damage.
Iodine	1000	900	110.942	82.558	0	0	0	0	0	0	0	0	Thyroid-related effects.
Iron	6	5.4	3.731	7.858	5.077	9.827	0	0	2.327	3.295	0.865	0.234	Causes odour, bad taste & precipitate.
Lanthanum	1	0.9	0.946	0.393	0.786	0.465	5.901	3.757	2.072	0.804	7.049	7.359	Low to moderate acute toxicity rating.
Lead	20	18	40.288	36.900	0.018	0.029	0719	0.475	0.184	0.135	0.163	0.083	A toxic element
Manganese	4600	4140	649.986	661.358	0	0	11130.32	17685.53	110.306	133.633	196.903	271.532	Contributes to hardness and turbidity, deposits in pipes and bitterness of water.
Mercury	2	1.8	0.956	1.214	0	0	17.743	14.127	10.358	3.565	7.553	0.900	A toxic element with no beneficial physiological function.
Molybdenum	100	90	0.781	1.639	0	0	1.445	0.824	2.844	2.564	2.751	1.259	Reduced growth, highly toxic.
Nickel	1000	900	41.755	21.399	30.177	4.127	53.043	25.508	35.478	5.9518	38.592	4.654	Reduced growth.
Platinum	-	-	0.236	0.154	0.074	0.107	0.514	0.533	0.346	0.212	0.247	0.134	Allergenic.
Rubidium	5000	4500	7.895	7.435	0	0	0	0	0	0	0	0	Non-toxic.
Selenium	50	45	0.076	0.447	7.123	7.788	21.979	16.969	67.957	13.797	67.366	10.143	Reduced growth.
Strontium	10000	9000	289.913	274.323	269.467	145.397	44.965	29.035	2549.830	2165.420	693.763	281.415	May contribute to hardness of water.
Tin	200	180	0.565	0.677	0	0	1.633	1.149	0.821	0.368	0.778	0.128	Essential nutrient, low toxicity.

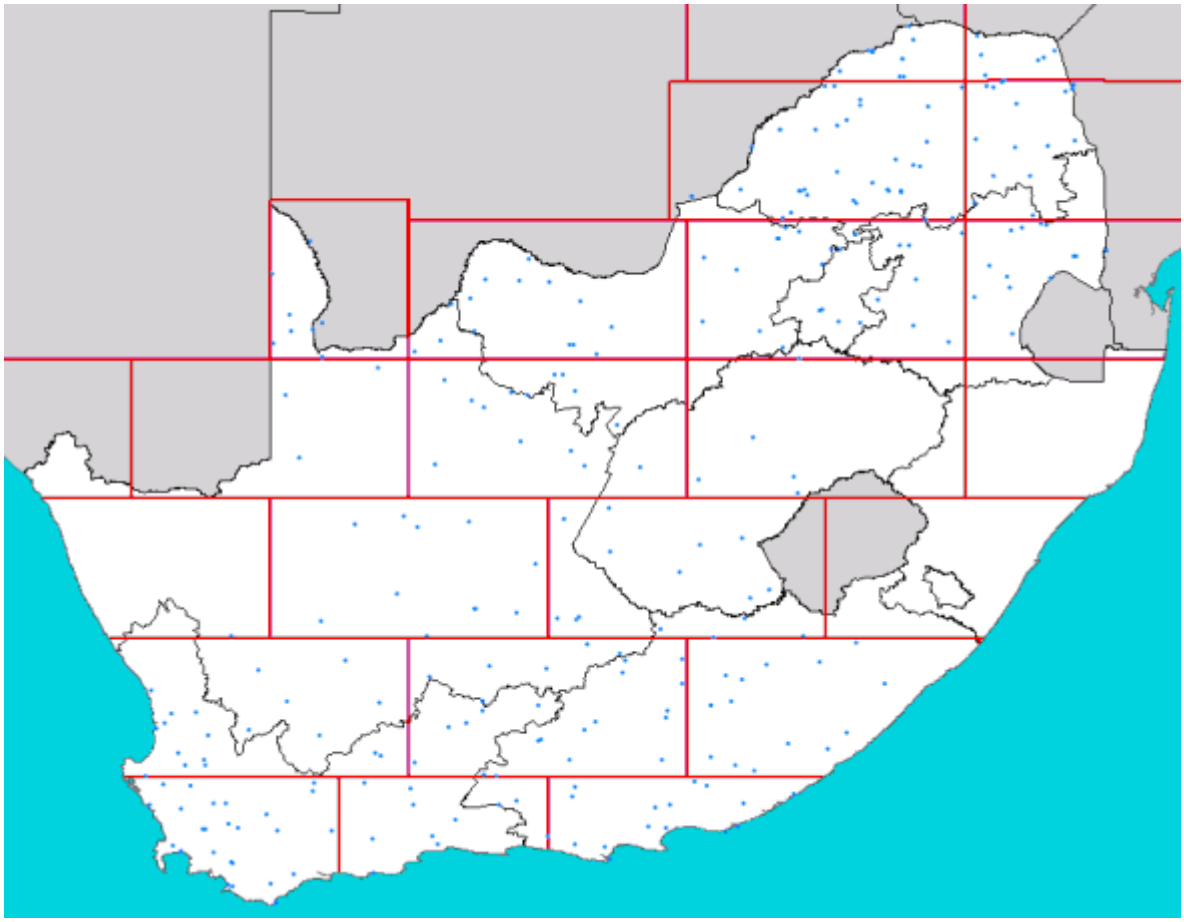
Titanium	100	90	173.348	108.758	377.359	216.745	69.197	47.077	884.182	854.179	211.850	81.1809	Soluble salts potentially toxic.
Tungsten	500	450	0.546	0.597	0.031	0.037	2.890	0.194	0.143	0.057	0.124	0.018	Only soluble salts potentially toxic.
Uranium	4000	3600	26.924	96.931	0.360	0.226	1.411	1.871	4.045	2.868	2.669	2.622	Low Toxicity.
Vanadium	100	90	0.454	1.293	14.894	11.747	32.724	20.996	4.810	3.847	5.125	2.283	Essential nutrient.
Zinc	1500	1350	256.827	388.63	319.309	418.698	344.254	686.62	171.056	240.236	407.905	397.067	Astringent taste, may contribute to hardness.
Zirconium	1	0.9	0.731	0.577	0	0	0	0	0.923	0.767	0.788	0.164	Low toxicity.

Kempster et al., (1981); Waggoner *et al.* (1994); Vohra (1980); Zimmerman (1995); Carter (1985); Phillips *et al*. (1935); Ralph (1989) and *Puls (1994)*

Department of Water Affairs and Forestry sampling results (1996 – 2001)

A project was launched by the Directorate of Geohydrology to ascertain the influence of rainfall on the groundwater quality and to determine the groundwater quality on a national scale. Currently 376 monitoring points are being sampled twice a year. Qualified personnel of the Department of Water Affairs and Forestry undertake the sampling itself. During the sampling procedure personell gather as much information on the monitoring point as possible and that is later stored in the National Groundwater Database. Map 1.7 show the area monitored.

Map 1.7. Monitoring points of the National Groundwater Quality Monitoring Project of South Africa.

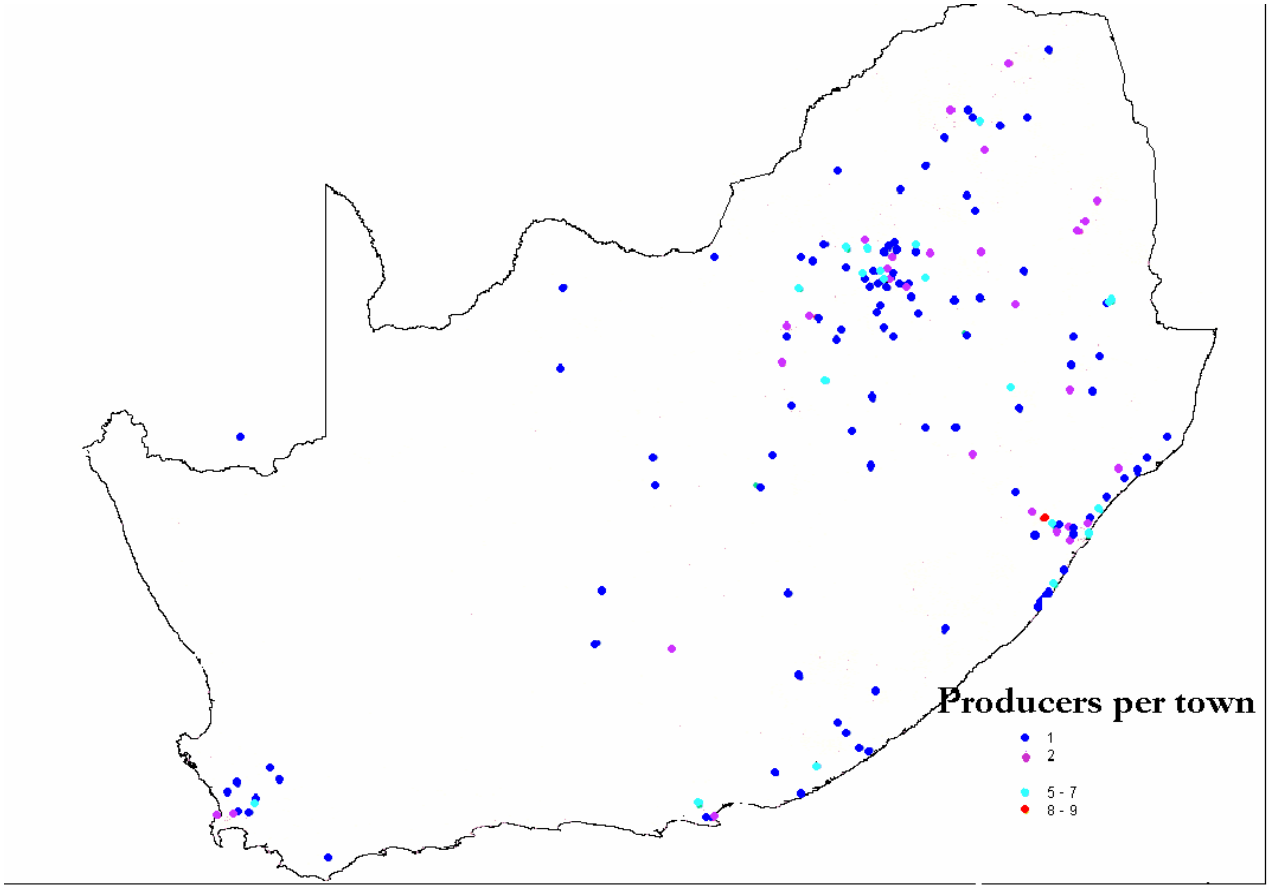


Data and maps of the distribution of groundwater sampling points where water constituent levels exceeded the recommended maximum over the last five years, were obtained from the Directorate: Geohydrology of the Department of Water Affairs and Forestry (DWAF). Following the results of analyses of borehole water at poultry production units across South Africa, it was decided to investigate the effect of magnesium, chlorides, sulphates, sodium, calcium, nitrates and fluoride more closely.

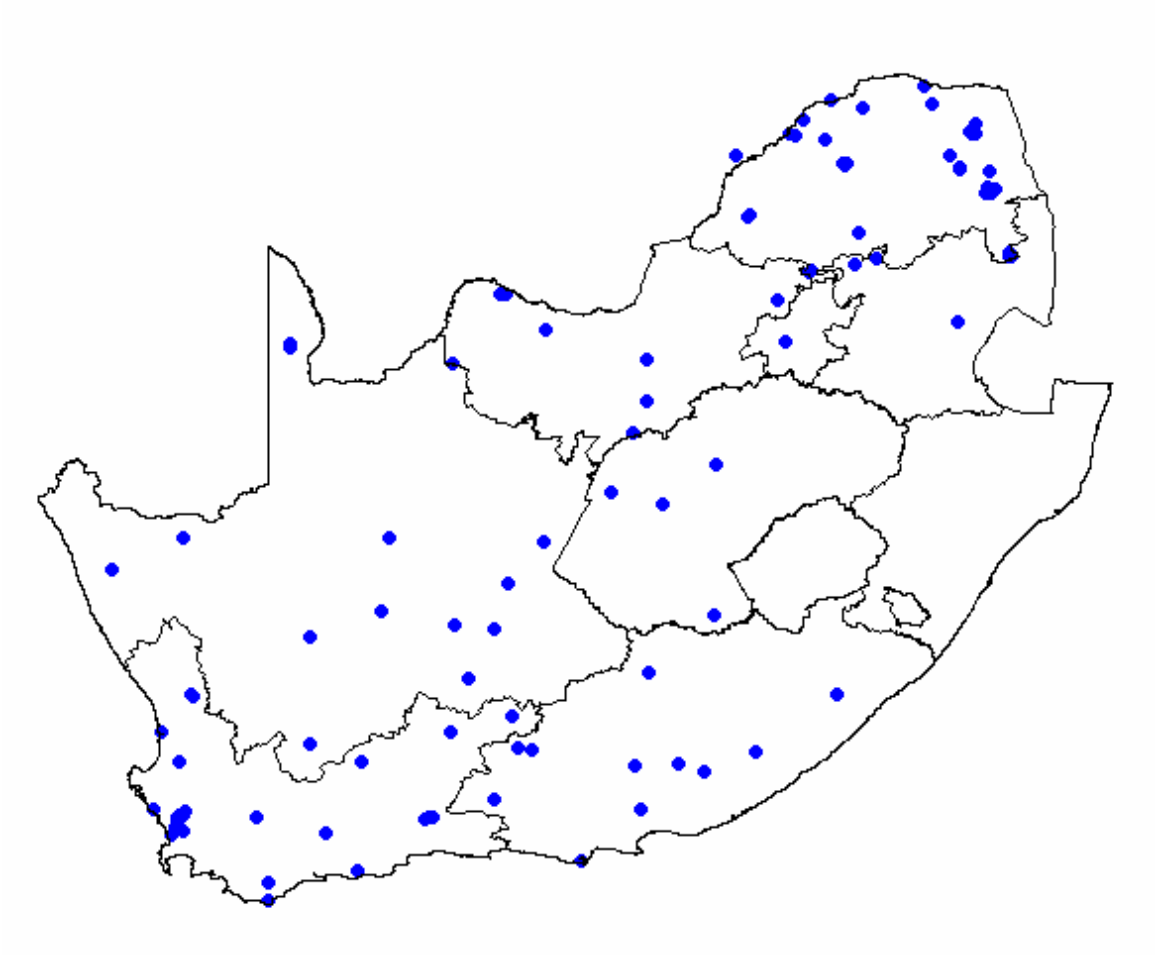
Super-imposing a map showing the distribution of poultry producers with a capacity of more than 20 000 birds (Map 1.8) onto the distribution of mineral sampling points where high levels of

minerals were measured over the last five years, shows that South African Poultry producers are forced to use water with elevated levels of the minerals mentioned above (Maps 1.9 - 1.15). The effect of this on poultry production will be addressed in Chapters 2 - 4.

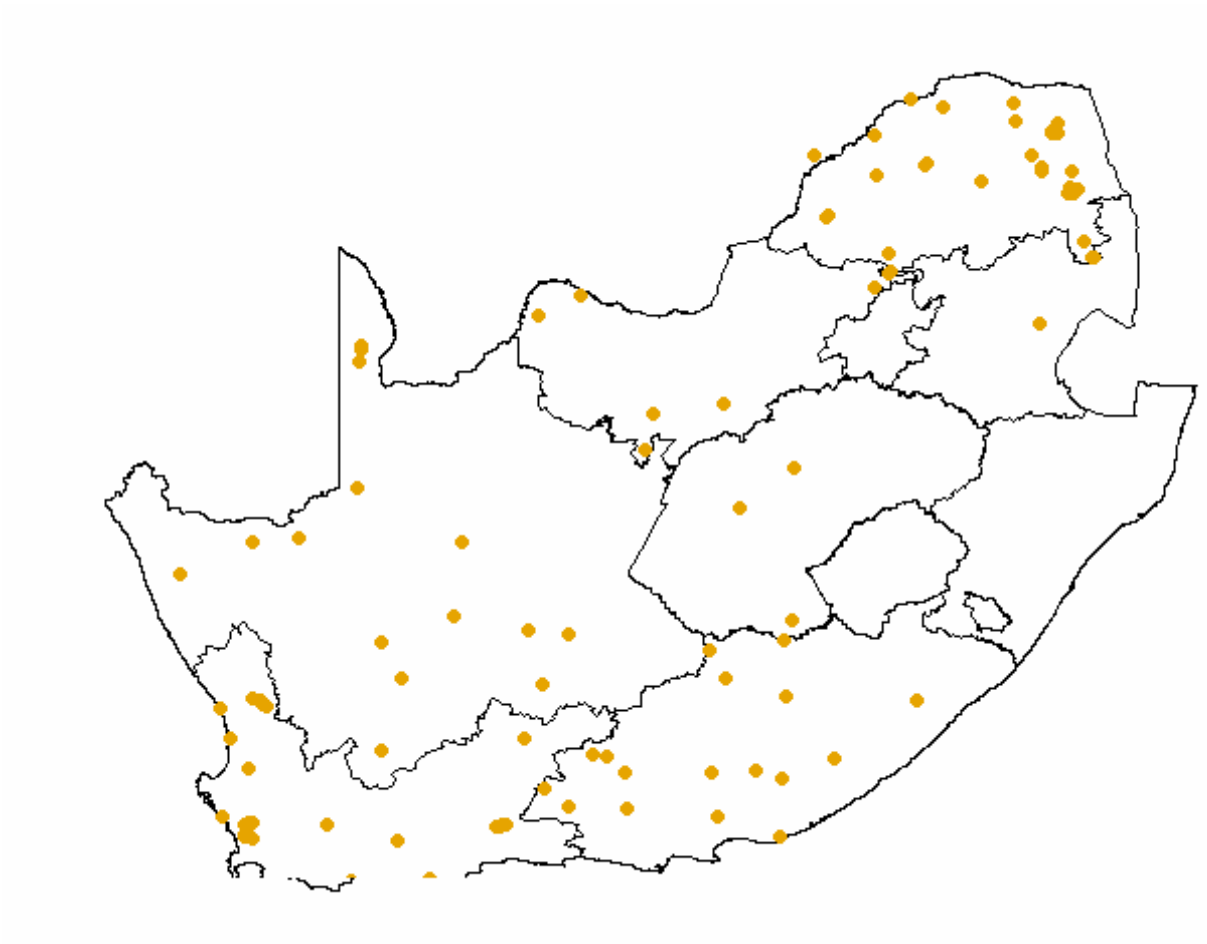
Map 1.8: Distribution of Poultry Producers (>20 000 birds) in South Africa (SA Poultry Association records 2001).



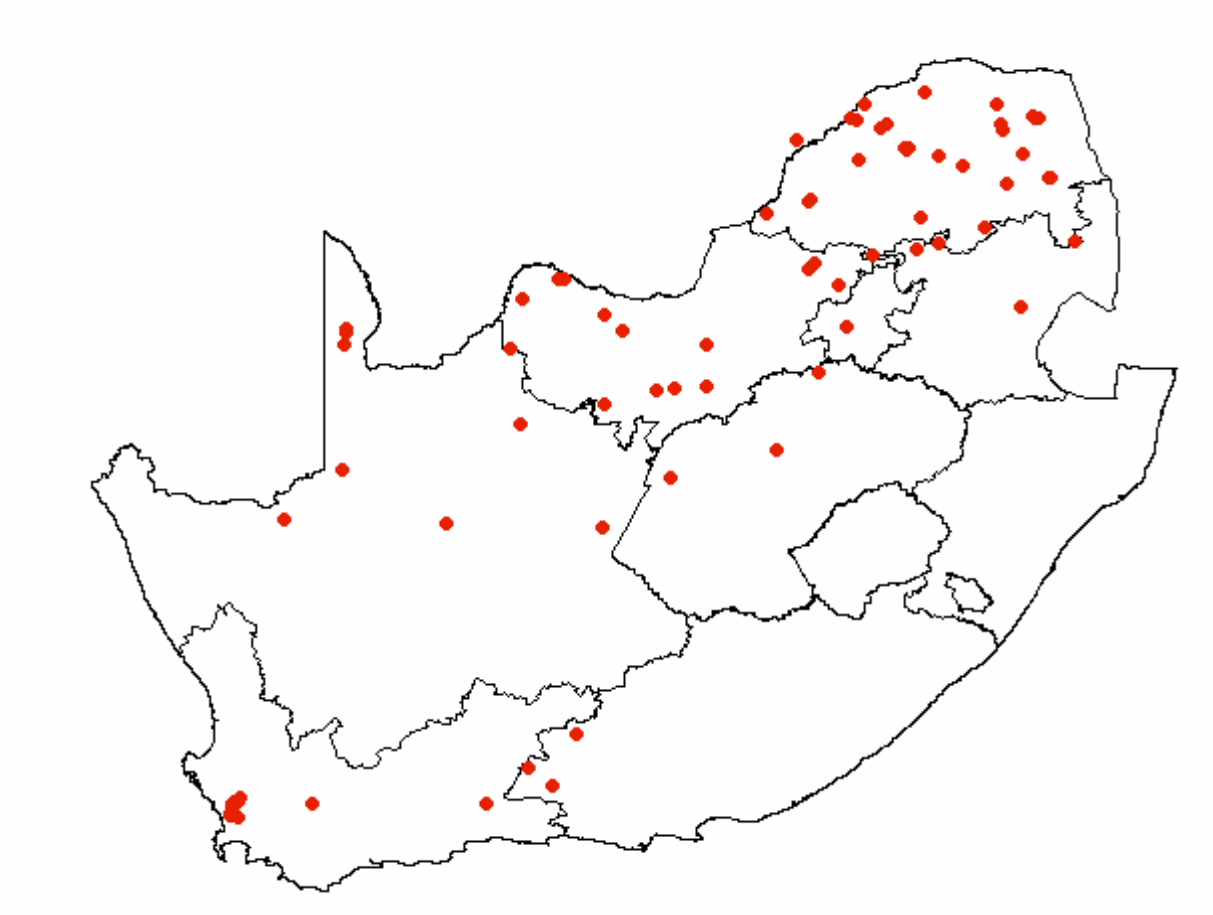
Map 1.9. The sample points where chloride was measured at levels higher than 250 mg/l.



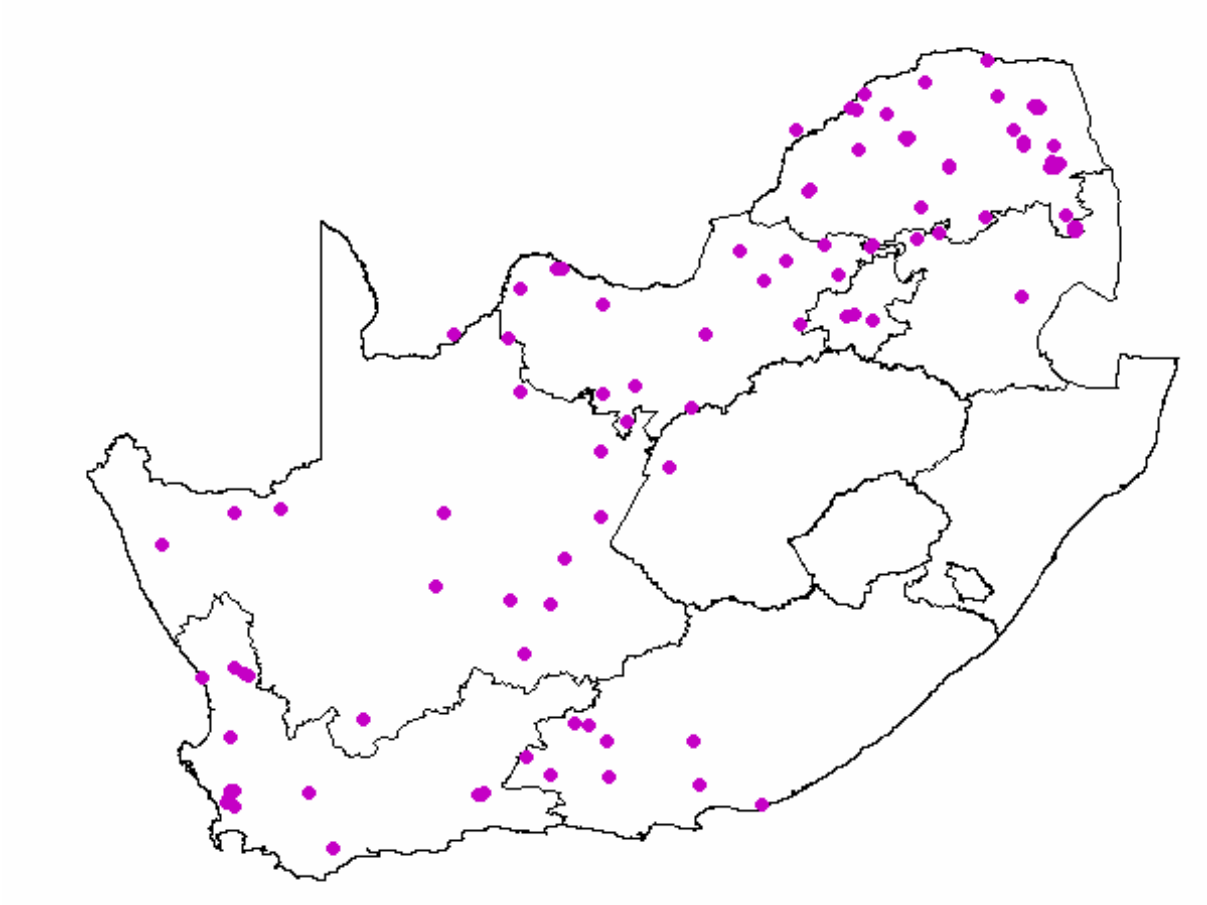
Map 1.10. The sample points where sodium was measured at levels higher than 50 mg/l.



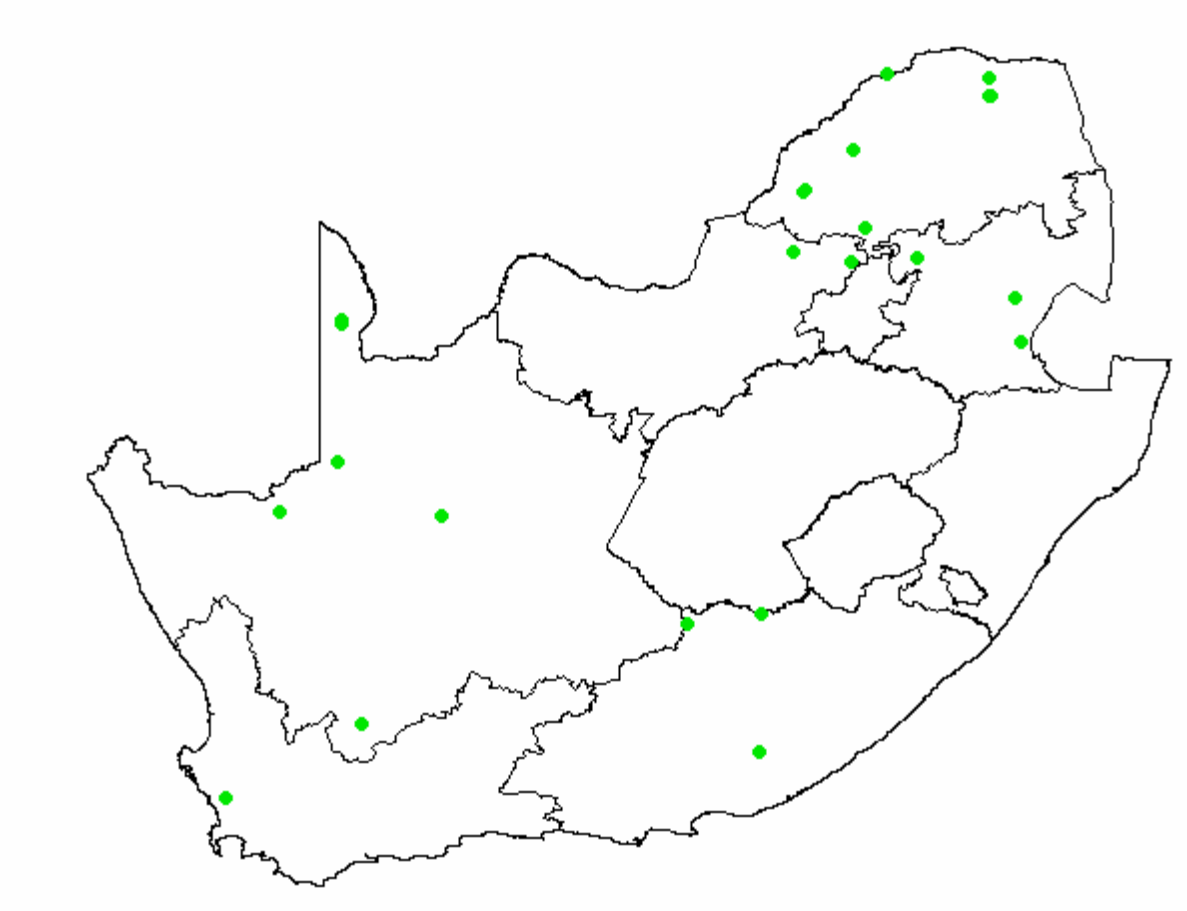
Map 1.11. The sample points where nitrates were measured at levels higher than 10 mg/l.



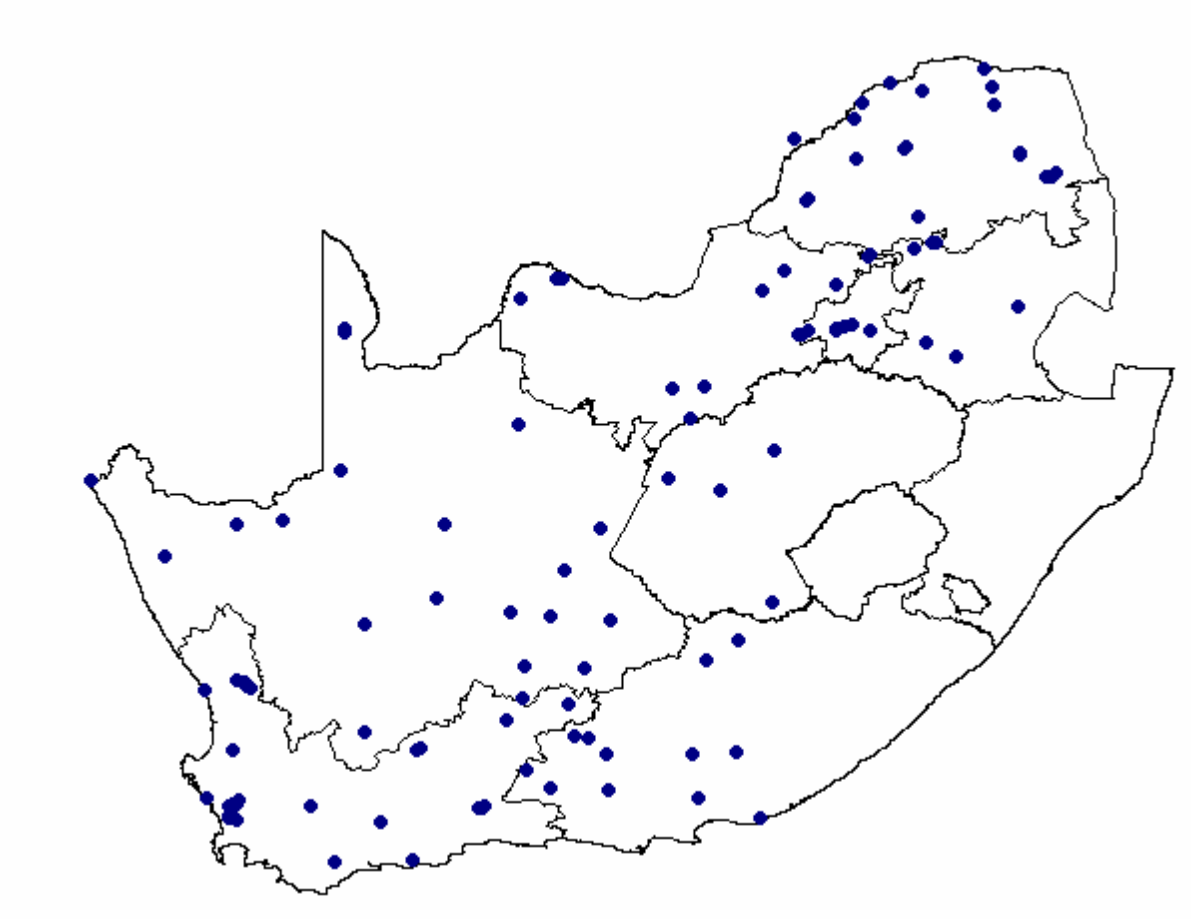
Map 1.12. The sample points where magnesium was measured at levels higher than 125 mg/l.



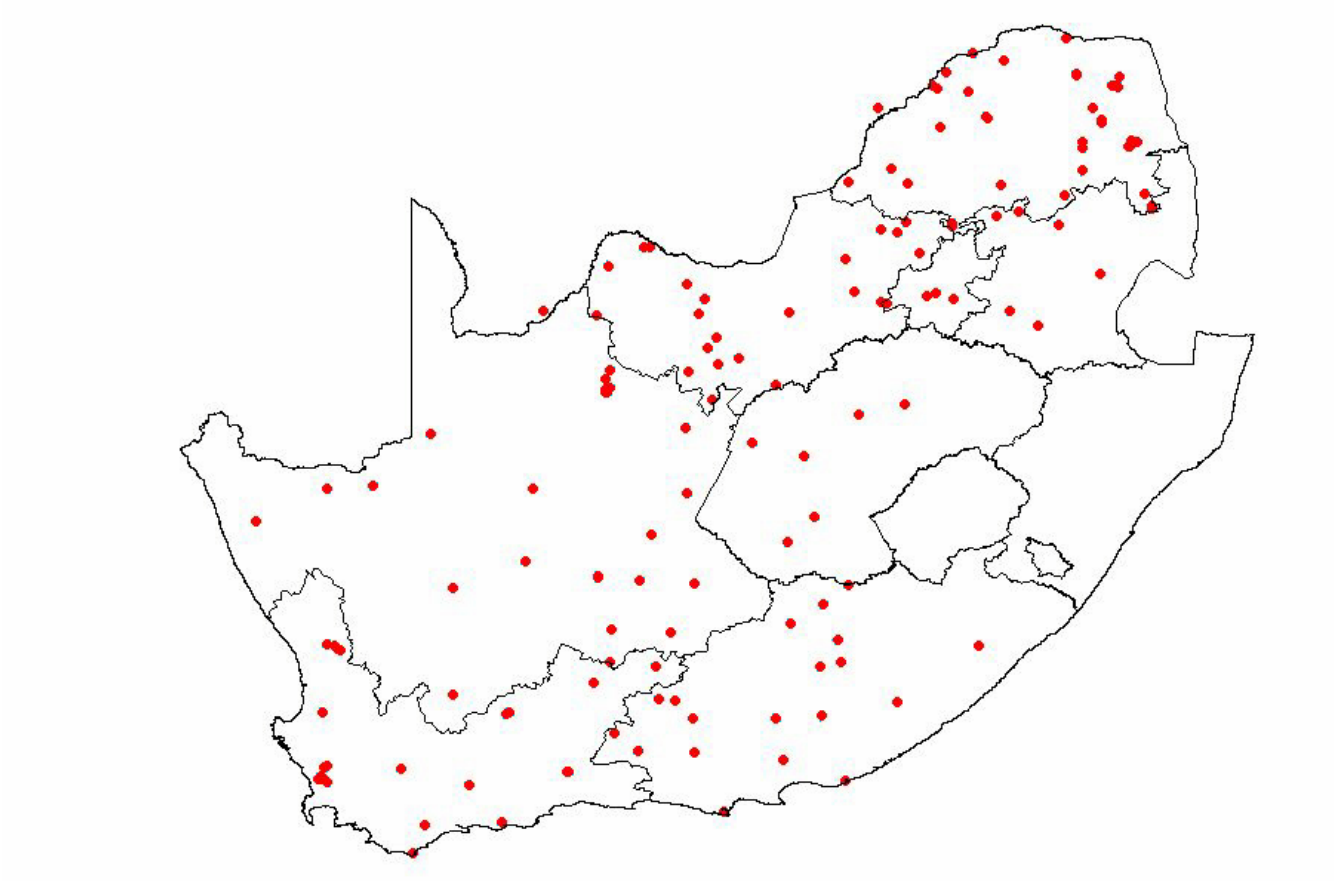
Map 1.13. The sample points where fluoride was measured at levels higher than 6 mg/l.



Map 1.14. The sample points where sulphates were measured at levels higher than 250 mg/l.



Map 1.15. The sample points where calcium was measured at levels higher than 600 mg/l.



Discussion.

The implications of the presence of elevated levels of potentially toxic water constituents, specifically including, fluoride, nitrates, chlorides, bicarbonates, phosphates, sodium, titanium, manganese, lanthanum, mercury and iron (Tables 1.16 and 1.17) on poultry production are that certain concentrations, combinations and/or ratios may have antagonistic or exacerbating effects resulting in sub-optimal production. Most effects are not all or none (Good, 1985). There may be serious detrimental effects on live weight, feed conversion and egg production and quality, often without any clinical symptoms. Water with inclusions higher than the prescribed maximum affects performance in a number of ways. High concentrations of bacteria or potentially toxic anions or cations in the water may affect normal physiological processes of the body, which can result in inferior performance. These concentrations may also reduce the absorption of nutritionally important substances, or reduce the efficacy of therapeutic treatments.

The presence of some constituents may lead to problems with watering systems, such as scaling,

sedimentation, clogging and encrustation. This impacts on the cost of equipment replacement, and may lead to other problems including reduced water and feed intake and a requirement for more frequent litter replacement. Leg problems and breast blisters in broilers raised on the floor can result (Keshavarz, 1987). The management of laying hens, which are in cages, is made more difficult.

The results reported by Coetzee et al. (1997), Casey et al. (1998 d) and Meyer (1998), showed that the maximum allowed levels as stipulated by Kempster et al., (1981), Waggoner et al. (1994) and Vohra et al. (1980), for fluoride (2 mg/l), chlorides (600 mg/l), sodium (75 mg/l) and nitrates (10 mg/l) in the drinking water of poultry are too restrictive and classify many South African boreholes as useless for animal production. This amplifies the need for a site-specific ingestion-based approach to water quality guidelines for livestock. Since bicarbonate is currently used to alleviate stress in chickens (Balnave and Gorman, 1993), the maximum allowed level of 98 mg/l recommended by Kempster et al., (1981) seems too restrictive and new recommendations should be established for bicarbonate.

Conclusion

With the developing scarcity of good quality water resources, it is becoming increasingly important that the quality of ground water supplies are monitored and managed properly. This study was the first that focussed on poultry producers in a monitoring exercise and that brought to light that many poultry producers use water sources with mineral and metal inclusions that far exceed existing guidelines. The solution is either to investigate alternative uses for the water sources or to refine current water quality guidelines for optimum use of existing water sources. To readdress water quality guidelines a more in depth look at the effect of individual constituents on growth and production of poultry is needed. Chapters 2 - 4 of this thesis address the effect on poultry production of the most relevant hazardous contituents and Chapter 5 presents a model for alternative use of the water sources.