Chapter 6

Summary, Application and Recommendations

As discussed in the Introduction to this thesis, the disparities and constraints of existing water quality guidelines for poultry production called for a new approach to their formulation. This study has highlighted the need to fine-tune Water Quality Guidelines in South Africa for specific species under specific conditions. Investigation of water quality on poultry farms in South Africa revealed that Bicarbonates, Chlorides, Fluoride, Nitrates, Phosphates, Sodium, Cadmium, Iron, Lanthanum, Lead, Manganese, Mercury, Titanium, Zirconium, Bromine, Chromium and Selenium occurred at levels higher than the recommended maximums established by Kempster *et al*. (1981), Waggoner *et al*. (1994) and Vohra (1980). The consequences of elevated levels of water quality constituents on poultry production are shown in Table 6.1.

Table 6.1 Water quality constituents and effects on poultry production found in water analysed.

Variable	PHC	COC	
	>	= / <	Adverse effects of excess #
Bicarbonate	98	88.2	Non-toxic.
Calcium	600	540	Non-toxic, clog up pipes.
Chloride	250	225	Reduced growth immature chickens, but effect largely overcome by adding Na and K.
Fluoride	6	5.4	Lower feed intakes and growth rates.
Magnesium	350	315	Laxative effect. Reduced growth and bone mineralization in immature chickens. Magnesium form part of the hardness of water.
Nitrate	10	9	Reduced growth, increase mortality rate. Impaired the oxygen carrying capacity of blood.
Nitrite	1	0.9	Thyroid enlargement methaemoglobinaemia.
Phosphate	2	1.8	Indicator of sewage contamination.
Sodium	50	45	Diuretic, reduced egg production and growth.
Sulphate	125	112.5	Laxative effect, reduced egg production.
TDS	3000	2700	Indication of excessive mineral content.
Bromine	3000	2700	Reduced growth rate.
Cadmium	5	4.5	Excess has severe health effects.
Chromium	100	90	Contributes to hardness, low toxicity, essential nutrient; absence causes diabetes.
Iron	10	9	Causes odour, bad taste & precipitate. Can encourage iron bacteria growth.
Lanthanum	1	0.9	Low to moderate acute toxicity rating.
Lead	20	18	A toxic element
Manganese	1000	900	Contributes to hardness and turbidity, deposits in pipes and bitterness of water.
Mercury	2	1.8	A toxic element with no beneficial physiological function.
Selenium	50	45	Reduced growth.
Titanium	100	90	Soluble salts potentially toxic.
Zirconium	1	0.9	Low toxicity.

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

Because of their documented effects on poultry production and the interactions between some of them, Magnesium, Chlorides, Sodium, Nitrates, Sulphates, Calcium and Phosphorus were isolated for further experimental investigation.

The literature surveyed recommended the following allowable constituent levels (Table 6.2). In the subsequent studies the maximum allowed levels were sometimes exceeded.

Table 6.2. Maximum allowed levels of constituents investigated and the maximum levels administered in the subsequent trials.

Constituent	Maximum allowed level (mg/l)	Author	Maximum inclusions in experiments (mg/l)
Magnesium	125	Schwartz, 1994	250
Sodium	75	Keshavarz, 1987	250
Sulphate	60	Keshavarz, 1987	500
Calcium	200	Vohra, 1980	300
Phosphate	5	Kempster et.al., 1981	300
Chloride	250	Schwartz, 1994	500
Nitrate	10	Zimmerman, 1995	300

This study revealed that:

1. Twelve different combinations of Mg, Na, Cl and SO_4 had no significant effect on growth, food and water intake, and egg production or egg quality. Poultry producers in areas with naturally high levels of these minerals in their ground water can therefore continue to function successfully if the concentrations present are up to 250 mg/l of Mg, 500 mg/l of Cl, 500 mg/l of SO_4 and 250 mg/l of Na. At these levels the minerals manifested themselves in the egg contents and the effect thereof on the consumer needs to be investigated further. Since artificially enriched eggs are the order of the day in this century, creating a niche market for "mineral enriched eggs" is a possibility.
2. Hens receiving up to 300 mg/l of nitrate in the drinking water showed no significant differences in egg production or egg weight over a 12 week period. This indicates that intensive commercial egg production units, with naturally elevated levels of nitrate in the drinking water up to a level of 300 mg/l, do not run the risk of lowered egg production or weight.
3. Broilers receiving up to 300 mg/l of nitrate in the drinking water showed increased body weights in some weeks. The addition of Vitamin A to the nitrate treated water further increased body weights of chicks. The increase in body weight was not due to increased food intakes, as food intakes decreased in chicks receiving elevated levels of nitrate in the drinking water. No negative effects on broiler production and growth were observed.
4. Ca and P in the water up to levels of 300 mg/l can be a valuable asset to increase eggshell integrity. Waterline management may be increased because Ca tends to precipitate.

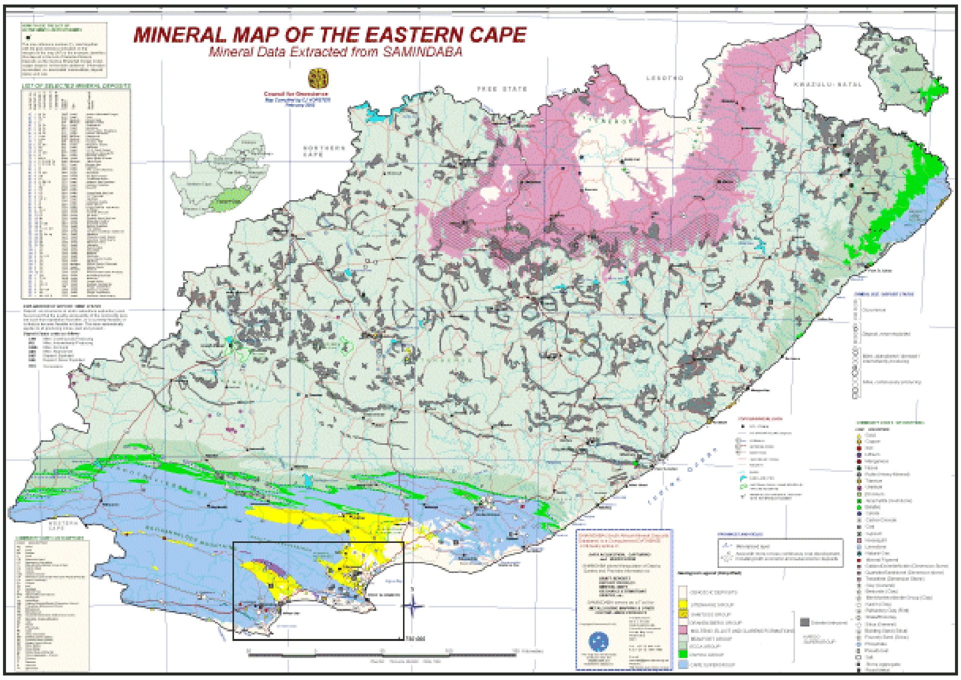
The results obtained in the experiments motivated a new approach to assessing water quality guidelines for poultry. This was addressed in the previous chapter. The practical implementation and workability of the academically correct approach might be considered questionable. Little of the information needed is usually on hand for the farmer with a potential water quality problem. Implementing at least some of the principles will, however, have a substantial effect on the usability of the water source. The main criteria for developing this system was to capitalise on water sources that were previously considered potentially hazardous or un-useable while avoiding potentially hazardous effects.

The development of this theoretical model (Chapter 5) highlighted the complex concepts required for water quality guidelines and the many factors influencing them. Unfortunately the academic approach is not always feasible. In this light it was decided to present a workable case study to demonstrate how the information gathered in the previous chapters could be applied to an on-farm situation.

Case study

1. A water sample was received from a farmer situated in the coastal areas of the Eastern Cape. The farmer is a poultry farmer and is home mixing his feed.

Map 6.1 Mineral map of the Eastern Cape



Source:http://www.geoscience.org.za/samindaba/maps/easterncape.htm

The 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 in), while Cradock, in the interior, receives an average annual rainfall of 310 mm (10 in). Most rain falls during the warmer months of October through April. Average temperatures 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.

The province consists of the subtropical coast along the Indian Ocean and the semi-arid plains of the Karoo. Inland, the predominant vegetation is dense indigenous forests in the region near the coast and succulents and hardy plants in the Karoo (http://www.places.co.za/html).

Unlike the mineral rich provinces in the rest of South Africa, the Eastern Cape is without large, valuable mineral deposits. In particular the age of the rocks and strata are much younger than in provinces to the north. Notwithstanding this, several mineral deposits are located in the province but remain unexploited. Most are not precious metal deposits but minerals with industrial applications. Deposits that have value are stone quarried for export and building industry minerals, such as sand, aggregate, limestone and heavy mineral sands. (http://www.geoscience.org.za/samindaba/maps/easterncape.htm)

2. The sample was submitted for analysis to an accredited laboratory.
3. The water quality analysis results are presented in Table 6.3.

Table 6.3 Analysis results obtained from water sample taken in the Eastern Cape Province.

Mineral analysis results				
ELEMENT	**Borehole "Diptenk"**	**Borehole "Stal"**	**Borehole "Oom Dirk"**	**Max Allowed**
pH	6.41	6.5	6.69	6 to 9 *c*
Electrical conductivity	374 mS/m 25°C	686 mS/m 25°C	311 mS/m 25°C	370 *c*
Carbonate	None	None	None	0
Bicarbonate (mg/l)	658.91	812.53	646.71	98 *a*
Chloride (mg/l)	1290.74	>1773	1028.34	250 *b*
Sulphate (mg/l)	50.2	69.4	47.8	60 *e*
Calcium (mg/l)	177.4	234.4	142.8	200 *d*
Magnesium (mg/l)	703.9	1643.8	1004	125 *b*
Sodium (mg/l)	625	1171	482	75 *e*
Potassium (mg/l)	39.2	48.9	172.8	2000 *b*
Iron (mg/l)	0.067	0.088	0.071	0.2 *c*

a)Kempster et al., 1981, b)Schwarz, 1994, c)Carter, 1985, d)Vohra, 1980, e)Kehavarz, 1987.

4. The implications for poultry production using this water source.

Only the Borehole "Stal" will be discussed here, but it is obvious from the analysis above that boreholes on the same farm can differ in quality. When taking a water sample at a specific production facility, it is important to ensure a representative sample. To achieve this and to minimize cost, multiple samples from each borehole or watering site should be pooled and a sample taken of that.

In the "Borehole Stal" water analysis, elevated levels of almost all the constituents analysed occurred and the high electrical conductivity (686mS/m) is indicative of this. In Chapter 2 the interactions between Cl, Mg, Na and SO_4 were investigated. According to Schwartz *et al*. (1984) Cl levels as low as 14 mg/l may be detrimental to chickens if the Na level is higher than 50 mg/l and levels greater than 50 mg/l of Mg or Na may be detrimental if the $^{-}SO_4$ or Cl levels are high. Keshavarz (1987) found the permissible levels of Mg, SO_4, Na and Cl for poultry production to be Mg 10 mg/l, SO_4 50 mg/l, Na 50 mg/l, and Cl 20 mg/l. If the these levels are exceeded, the water is considered toxic.

The outcome of the work done in Chapter 2 showed that 12 different combinations of Mg, Na, Cl and SO_4 had no significant effect on growth, food and water intake, and egg production or egg quality. Poultry producers in areas with naturally high levels of these minerals in their ground water can therefore continue to function successfully if the concentrations present are up to 250 mg/l of Mg, 500 mg/l of Cl, 500 mg/l of SO_4 and 250 mg/l of Na.

If the Generic Application Level of the model (Figure 5.1) were applied to the analysed results, the outcome would be that this water source is not suitable for poultry drinking since the inclusions are much higher than the maximum levels allowed. When the same set of data is interpreted by the Specific Application Level of the model (Figure 5.2), this water source can be identified as a useable one, provided that all site-specific information is considered.

Exposure time to elevated levels of constituents is important in assessing water quality. This particular water source is suitable for broilers rather than layers because of the shorter period of exposure.

Table 6.4 shows the Ingestion rate (mg) of each constituent, assuming a worst case scenario of water intake determined when the environmental temperature is 32°C. The importance of determining ingestion rates instead of working with constituent levels present in the water can be seen. Sulphate no longer qualifies as a Potentially Hazardous Constituent.

Table 6.4 Ingestion rates (mg) of constituents present in the water.

Constituent	Level present in water (mg/l)	Water intake (l)	Ingestion rate (mg)	Max Allowed
Chloride	1773	0.5	886.5	250
Sulphate	69.4	0.5	34.7	60
Magnesium	1643.8	0.5	821.9	125
Sodium	1171	0.5	585.5	75

The vitamin and mineral premixes and diets used are shown in Tables 6.5 and Table 6.7.

Table 6.5 Vitamin and mineral premixes used in the broiler diets.

		STANDARD BROILER STARTER	**STANDARD BROILER FINISHER**
Vitamin A	iu	12 000 000	10 000 000
Vitamin D3	iu	3 000 000	2 000 000
Vitamin E	iu	40 000	30 000
Vitamin K3	g	2.5	2
Vitamin B1	g	4	2
Vitamin B2	g	6.5	5.5
Niacin	g	42	35
Calpan	g	13	11
Vitamin B12	mg	30	20
Vitamin B6	g	5	4
Choline	g	350	300
Folic Acid	g	1.2	0.8
Biotin	mg	120	100
Vitamin C	g	60	- - -
Zinc Bac. Active	g	22.5	22.5
Manganese Oxide	g	126	144
Zinc Sulphate	g	113.2	141.5
Copper Sulphate	g	23.7	29.6
Potassium Iodate	g	1.6	1.6
Cobalt Sulphate	g	2.3	2.3
Ferrous Sulphate	g	71.2	57.0
Selenium (5%)	g	6	6
Limestone Powder	g	Filler	Filler
UNIT SIZE	**:**	**2.5KG**	**2.5KG**
USAGE RATE	**:**	**ADD 1 UNIT TO 1 TON FINAL FEED**	**ADD 1 UNIT TO 1 TON FINAL FEED**

The premix contribution to the sulphate intake is presented in Table 6.6 and is negligible.

Table 6.6 Sulphate content of water ingested as well as premix ingested.

Mineral	Unit	Level Present Starter	Level Present Finisher	Sulphate contribution (%)	Total Sulphate present Starter	Total Sulphate present Finisher	Sulphate ingestion from water
Zinc Sulphate ($ZnSO_4.H_2O$)	g	113.2	141.5	16.4	18.6	23.2	
Copper Sulphate ($CuO_4S.5H_2O$)	g	23.7	29.6	12.84	3.0	3.8	
Cobalt Sulphate ($CoSO_4.7H_2O$)	g	2.3	2.3	14.77	0.3	0.3	
Ferrous Sulphate ($Fe_2(SO_4)_3.H_2O$)	g	71.2	57	23.02	16.4	13.1	
Total g of sulphate present in premix					**38.3**	**40.5**	
Feed intake of a 3 and 6 week old broiler					95 g/day	180 g/day	
Ingestion of sulphate through feed (premix included at 2.5 kg/ton)					**0.0036421**	**0.007284**	**34.7**
Total Sulphate intake					**34.703642**	**34.70728**	

Table 6.7 Diets fed

Raw materials	Broiler Starter kg	Broiler Grower kg	Broiler Finisher kg
Yellow Maize	548	663	707
Soya Oilcake	324	227	169
Dried Brewers Grain	38	22	32
Extruded Full Fat Soya	60	58	64
Limestone	12	15	17
Monocalcium Phos	11.5	7	4.5
Salt	4.5	4.5	4.5
Natuphos	0.05	0.05	0.05
DL Methionine	2.5	2	1.8
Lysine HCL	1.3	1.5	1.5
Broiler Starter Premix	2.5		
Broiler Finisher Premix		2.5	2.5
VOLUME	100	100	100
	g/kg	**g/kg**	**g/kg**
Dry Matter	886.7	883.1	881.7
ME Poultry	12.7	13.2	13.4
DE Swine	14.1	14.2	14.1
Crude Protein	229.3	189.4	169.5
Lysine	13.5	11.0	9.6
Fat	42.1	43.2	45.6
Fibre	37.6	33.5	34.6
Calcium	9.1	8.9	9.0
Total Phosphorus	7.5	6.2	5.5
Avl Phosphorus	4.5	3.5	3.0
Sodium	1.9	1.9	1.9
Chloride	3.3	3.4	3.4
Potassium	9.5	7.8	6.8
Magnesium	1.7	1.6	1.5

The feed contributes a further 0.342 g of sodium, 0.612 g of chloride and 0.270 g of magnesium, assuming an intake of 180 g of feed. The total intake of these minerals derived from the feed and water is then 0.928 g of sodium, 1.499 g of chloride and 1.092 g of magnesium. These levels are still too high to ensure optimal broiler production.

The diet has 4.5 kg of salt added to it. The contribution of this salt to the sodium and chloride levels ingested are shown in Table 6.8.

Table 6.8 The contribution of salt to the sodium and chloride intake of a 3 week and 6 week old broiler

	Salt %	Na and Cl in 1 ton of feed	Na and Cl in 1 kg of feed	Starter feed intake (g)	Finisher Feed intake (g)
Sodium	39.337	1770.165	1.770165	95	180
Chloride	60.663	2729.835	2.729835	95	180
Salt in feed (g)			4.5	0.427	0.81
Sodium intake from salt in diet				**0.168**	**0.319**
Chloride intake from salt in diet				**0.259**	**0.491**

Removing the salt from the diet would definitely alleviate the effects of Na and Cl in the water. Table 6.9 shows the levels of Na and Cl remaining in the feed after the salt has been removed from the diet. The total Na and Cl intake is now 0.609g Na and 1.007g Cl (Table 6.8) compared to the 0.928g Na and 1.499g Cl before it was removed.

Table 6.9 The effect of removing the salt from the diet.

	Starter g/kg	95g feed intake	Finisher g/kg	180g feed intake	Removing salt from the diet Starter	Removing salt from the diet Finisher
Sodium	1.9	0.1805	1.9	0.342	**0.013**	**0.023**
Chloride	3.3	0.3135	3.4	0.612	**0.054**	**0.121**
Magnesium	1.7	0.1615	1.5	0.27		

Table 6.10 Total Na and Cl intake after the salt was removed from the diet and adding the minerals from the water.

	Water	Starter	Finisher	Total Starter	Total Finisher
Sodium	0.5855	0.013	0.023	0.598	0.609
Chloride	0.886	0.054	0.121	0.940	1.007
Total intakes (g/kg)					

Final recommendations:

- This borehole is not to be used for layer production, as the exposure time to the high levels of Na, Mg and Cl would have the following effects :

Chlorides - High incidence

Chlorides Range (mg/l)	**Effects - Poultry**
TWQR 0 - 200	*No adverse effects*
200 - 500	**Adverse chronic effects** such as wet faeces, excessive water consumption, ascites and reduced eggshell strength may occur. Can be detrimental when more than 50 mg/l Na is present. Affects the taste of the water, and may corrode the water pipes. Short and medium term exposure tolerated>.
>500	Adverse chronic effects such as osmotic disturbances, hypertension, dehydration and renal damage may occur. Chicks are more tolerant than turkey poults. Tolerance in chicks increases after 3 weeks of age>.

Magnesium - High incidence

Magnesium Range (mg/l)	**Effects - Poultry**
TWQR 0 - 125	*No adverse effects*
125 - 250	**Adverse chronic effects** such as diarrhoea, intestinal irritation, watery droppings and lethargy may occur, but are unlikely if: - the sulphate level is low; - exposure is short>.
> 250	**Adverse chronic and acute effects** such as: Increased mortality and bone deformity, depressed growth rate and bone calcification, depressed egg production and watery feces may occur. Possibly interferes with vaccination programs. Short-term exposure could be tolerated>.

Sodium - High incidence

Sodium Range (mg/l)	**Effects - Poultry**
TWQR 0 - 50	*No adverse effects*
50 - 250	**Adverse chronic effects** such as increased water consumption and wet litter may occur. Chloride and sulphate enhances effect. Could be tolerated if 500 mg/l bicarbonate is present.
> 250	**Adverse chronic effects** as above and **adverse acute effects** such as ascites resulting from pulmonary hypertension, increased mortality, reduced egg production, feed efficiency and egg weight, and reduced growth rate, particularly in males may occur. Short-term exposure tolerated>.

- Broilers on a 6-week cycle will be able to produce adequately when drinking this water. Tolerance to these high levels of minerals will increase with age.
- Bedding management would be of utmost importance as the presence of Cl, Mg and Na at such high levels will lead to wet litter and breast blisters if not managed correctly.
- Removing the salt from the diet will greatly lessen the Na and Cl level ingested.

Conclusion:

The case study presented in this Chapter shows the workability of the model described in Chapter 5. The software program will conduct all calculations and a report presenting recommendations on water use will be supplied with each water sample entered.

The hypothesis that international water quality guidelines are adequate as a basis for water quality assessment for poultry production in South Africa is therefore rejected. This work should contribute to the final development of a tool to enable poultry farmers in South Africa to use the water sources on their farms optimally.