# Quality of groundwater used for poultry production in the Western Cape

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## Abstract

Water samples were collected from 35 boreholes at poultry producers in the Western Cape and were analysed for 43 mineral and trace element constituent inclusion levels.

Bicarbonates, chlorides, fluoride, nitrates, phosphates, sodium, cadmium, iron, lanthanum, lead, manganese, mercury, titanium and zirconium were identified as potentially hazardous constituents (PHC) in some areas and bicarbonates, chloride, sodium, lanthanum, lead, mercury and zirconium were identified as constituents of concern (COC) in some areas.

## Introduction

Knowledge regarding water quality is important for poultry production as it affords the producer with the managerial information required to prevent the potential adverse consequences attributed to specific concentrations of water quality constituents. These typically pertain to health and production parameters, the quality of the livestock product and the watering systems used in intensive poultry production systems. Meyer, Casey and Coetzee (1997) reported that there is no national database on the water quality constituent profile of water sources utilised for livestock production. They suggested that a water quality monitoring system be formulated in which the relevant water quality constituents for the specific areas and production systems be identified, primarily based on the potential for adverse effects and their occurrence in the natural aquatic environment. Existing information lacks analyses for critical constituents and site-specific information, required to formulate a risk assessment. Analyses are often not standardised with the result that information on constituents that may affect the usability of the water source may be left out.

The Western Cape region west of the Hottentot 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 caused many producers to rely on, or supplement, their water from subterranean sources. The characteristics of the subterranean water may vary substantially (Hem, 1979), and in southern Africa this is largely due to the occurrence of fractured aquifers (Parsons and Tredoux, 1993).

Interim water quality guidelines published in 1996 by Casey and Meyer, have been surpassed by a water quality guideline index system, termed CIRRA (constituent ingestion rate risk assessment) (Casey et al., 1998). The system, described by Meyer (1998), utilises a modelling approach, taking into account the type of livestock and production system, the environment and the ingestion rate of single or multiple water quality constituents to identify potentially hazardous constituents (constituents in excess of recommended guidelines) and constituents of concern (constituents within 10% of the recommended upper limit), which are then used to formulate a risk assessment on a metabolic basis. The CIRRA system is functional for cattle, sheep, horses, swine and goats, but the component for poultry is under development.

The growth and health of poultry depend on a multitude of factors. These factors have been shown to be interdependent. This is another way of saying that a certain level of water constituent may not affect a bird's performance in one environment while it could cause a problem in another (Ralph, 1989). Recent studies (Coetzee et al., 1997 and Casey et al., 1998) have evaluated the effect of some water quality constituents on layers and broilers under practical flock conditions. They found that hens receiving 6 and 20 mg/ℓ of added fluoride had a significantly lower egg production rate. Fluoride significantly influenced the water intake of the hens. The hens receiving 6 and 20 mg/ℓ of added fluoride drank significantly more water.

These statistics highlighted the fact that there are inadequacies in existing water quality guidelines. Different species have different tolerances to different water quality constituents, exposure times and the ingestion rates of the constituent. Some poultry water quality standards have been derived from work on large animals. Others are based on poultry mortality rather than the effects on growth, reproduction or other production measures (Carter, 1985).

This paper reports on the quality of water used by poultry producers in the Western Cape. The objective was to identify PHCs (constituents in excess of the recommended guidelines) and COCs (constituents within 10% or the recommended upper limit) according to Meyer (1998) for poultry producers, in order to establish the validity of water quality guidelines currently in use for poultry, and to identify constituents which may require further investigation regarding potential hazards for site-specific poultry production on a site-specific basis.

## Procedures

### Geographical location and borehole selection

The area visited in the Western Cape is situated in a zone 17 to 19° longitude and 32 to 34° latitude (see Fig. 1). Poultry producers were

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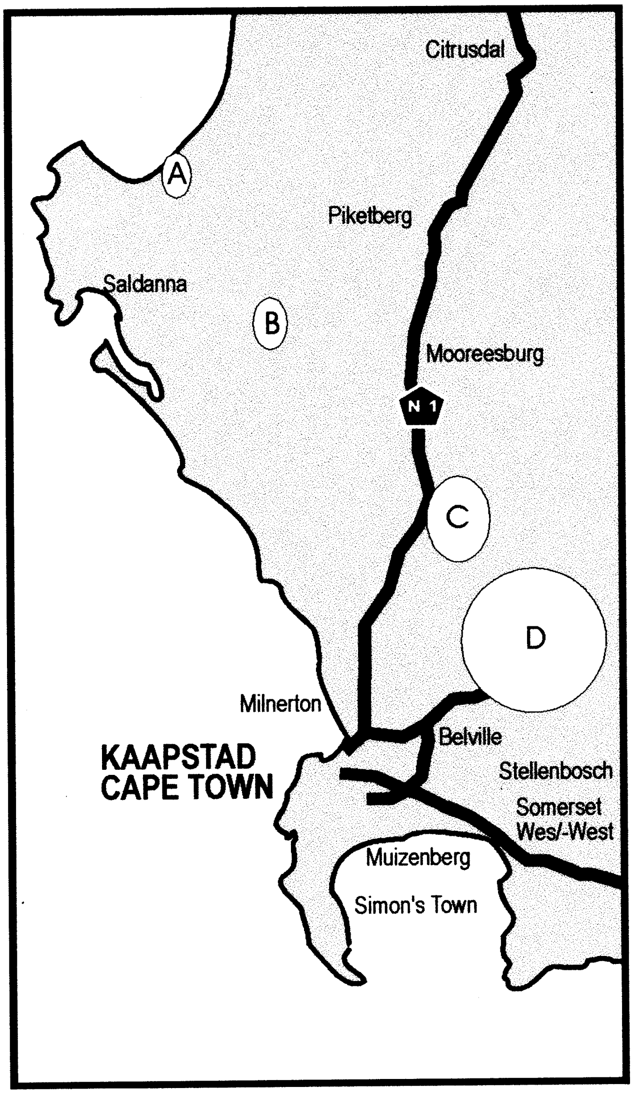


***Figure 1***
*Map of area visited (17 to 19° longitude and 32 to 34° latitude) with zones sampled indicated as A, B, C and D*

contacted and those who used groundwater were visited on site and boreholes were sampled.

## Materials and methods

The most orthodox method of exposing the existence of contrasting water supplies within this area was to sample as many water sources as possible. The quality of boreholes merely metres apart and at different sample times can vary markedly. This implied sampling the same source more than once to ensure that a sample taken from a specific water source was representative of the source. This would, however, be very costly and therefore the following sampling methods were used:

The sampling bottles were left in a solution of 1 mℓ concentrated nitric acid/ℓ water for 24 h. Bottles were rinsed with distilled water and dried. The borehole pump was allowed to run for at least 30 min. A tap near the borehole was located and allowed to run for at least 1 minute to purge the plumbing. More or less 1 ℓ of water was collected in a clean collection bucket from the running tap with 1 min intervals for at least 5 min. This sample was then stirred and 500 mℓ and 100 mℓ of water was collected respectively in acid treated plastic containers for mineral and metal analysis. The 500 mℓ sample was analysed for mineral content and the 100 mℓ sample for metal contents. 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 <5°C and returned to the water quality laboratory within a week of the sampling time (Goan et al., 1992).

### Laboratory analysis

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. See Tables 1 and 3 for a list of the constituents analysed.

### Statistical evaluation

Statistical analyses were conducted using the PC - SAS Version 6.08 commercial software. Means, standard deviations, minimum and maximum levels of constituents in water sources were determined using Proc Means.

**TABLE 1**
**Highest recorded levels of constituents**

| Constituents | Highest recorded level | Recommended maximum levels | Source |
|---|---|---|---|
| Bicarbonates | 216.6 mg/ℓ | 98.0 mg/ℓ | Kempster and Van Vliet, 1980 |
| Chlorides | 703.5 mg/ℓ | 250.0 mg/ℓ | Waggoner et al., 1984 |
| Fluoride | 7.2 mg/ℓ | 2.0 mg/ℓ | Kempster and Van Vliet, 1980 |
| Nitrates | 48.5 mg/ℓ | 10.0 mg/ℓ | Waggoner et al., 1984 |
| Phosphates | 5.2 mg/ℓ | 2.0 mg/ℓ | Kempster and Van Vliet, 1980 |
| Sodium | 357.0 mg/ℓ | 50.0 mg/ℓ | Waggoner et al., 1984 |
| Cadmium | 12.694 mg/ℓ | 5.0 µg/ℓ | Vohra, 1980 |
| Iron | 37.190 mg/ℓ | 10.0 mg/ℓ | Kempster and Van Vliet, 1980 |
| Lanthanum | 2.304 µg/ℓ | 1.0 µg/ℓ | Vohra, 1980 |
| Lead | 202.8 µg/ℓ | 20 µg/ℓ | Vohra, 1980 |
| Manganese | 2204.7 µg/ℓ | 1000.0 µg/ℓ | Kempster and Van Vliet, 1980 |
| Mercury | 4.182 µg/ℓ | 3.0 µg/ℓ | Kempster and Van Vliet, 1980 |
| Titanium | 430.68 µg/ℓ | 100.0 µg/ℓ | Kempster and Van Vliet, 1980 |
| Zirconium | 2.916 µg/ℓ | 1.0 µg/ℓ | Vohra, 1980 |

| TABLE 2<br>Results of water analyses from poultry farms in the Western Cape (n = 35) - Macro-elements | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Measured variable** | **Unit** | **Mean** | **SD** | **Minimum** | **Maximum** | **> PHC** | **COC** | **Adverse effects of excess #** |
| Bicarbonate | mg/ℓ | 108.249 | 43.208 | 18.300 | 216.600 | 98 | 88.2 | Non toxic. |
| Boron | mg/ℓ | 0 | 0 | 0 | 0 | 5 | 4.5 | Not a priority pollutant |
| Calcium | mg/ℓ | 33.391 | 15.390 | 9.300 | 68.500 | 600 | 540 | Non toxic, clog up pipes. |
| Carbonate | mg/ℓ | 0 | 0 | 0 | 0 | 500 | 450 | Lower egg production. |
| Chloride | mg/ℓ | 326.937 | 182.132 | 82.700 | 703.500 | 250 | 225 | May cause metabolic problems |
| Fluoride | mg/ℓ | 0.934 | 1.521 | 0 | 7.200 | 6 | 5.4 | Lower feed intakes and growth rates. |
| Magnesium | mg/ℓ | 24.471 | 12.398 | 6.700 | 53.700 | 350 | 315 | Laxative effect. |
| Nitrate | mg/ℓ | 8.271 | 8.886 | 0 | 48.500 | 10 | 9 | Reduced growth, increase mortality rate. |
| Nitrite | mg/ℓ | 0 | 0 | 0 | 0 | 1 | 0.9 | Thyroid enlargement, methaemoglobinaemia |
| Phosphate | mg/ℓ | 0.500 | 2.233 | 0 | 5.200 | 2 | 1.8 | Indicator of sewage contamination. |
| Potassium | mg/ℓ | 5.129 | 3.696 | 1.600 | 20.700 | 2000 | 1800 | A deficiency leads to weak muscles, lower growth and higher mortalities. |
| Sodium | mg/ℓ | 153.543 | 87.555 | 42.400 | 357.000 | 50 | 45 | Diuretic, reduced egg production and growth. |
| Sulphate | mg/ℓ | 27.360 | 25.413 | 4.900 | 87.000 | 125 | 112.5 | Laxative effect, reduced egg production. |
| TDS | mg/ℓ | 634.629 | 296.569 | 201.400 | 1216.000 | 3000 | 2700 | Indication of excessive mineral content. |
| Hardness | mg/ℓ | 87.2000 | 33.730 | 15.000 | 151.000 | - | - | Blocks water systems, scale formation. |
| pH | | 7.602 | 0.389 | 6.800 | 8.220 | 6-9 | 6-9 | Acid - corrosive to pipes, lower performance, lower egg production. |
| pHs | | 8.082 | 0.381 | 7.700 | 9.240 | - | - | Stability pH |
| NAV | | 4.822 | 2.259 | 2.240 | 9.750 | - | - | - |
| Electrical conductivity | mS/m | 109.171 | 49.666 | 37.000 | 208.000 | 1980 | 1782 | Related to ions in water, no influence on poultry production. |

* Kempster and Van Vliet (1980); Waggoner et al. (1984); Vohra (1980) and Zimmerman (1995)
\# Carter (1985); Phillips et al. (1935); Ralph (1989), Puls 1988 and Zimmerman (1995)

## Results and discussion

No complete reference to all the constituents which were problematic to poultry was found in the literature cited. Many different sources were used to compile a complete list of constituents involved in poultry water quality investigations, and often these sources used different methods to indicate a water quality guideline. The highest recorded levels of constituents are presented in Table 1. Bicarbonates, chlorides, fluoride, nitrates, phosphates, sodium, cadmium, iron, lanthanum, lead, manganese, mercury, titanium and zirconium were identified as potentially hazardous constituents (PHC) in some areas. The results of the survey with a list of possible/likely adverse effects which are linked to the relevant constituents are presented in Tables 2 and 3.

The PHCs and COCs were observed in four zones in the area (Fig. 1). Zone A is situated in an area around Velddrif, where the Bergriver disembogues into the sea. Zone B covers the area around Hopefield. Zone C is in the greater Malmesbury area and Zone D covers an area bounded by Wellington, Durbanville and Stellenbosch.

In Zone A, chloride, sodium, lanthanum, lead and titanium were identified as PHC and zirconium as a COC. In Zone B, bicarbonate, chloride, sodium, manganese and titanium were identified as PHC and mercury as a COC. In Zone C, bicarbonate, chloride, nitrate, sodium, lanthanum, lead, manganese, titanium and zirconium were identified as PHC and sodium, lanthanum and lead as COC. In Zone D bicarbonate, chloride, fluoride, nitrate, sodium, cadmium, iron, lanthanum, lead, manganese, mercury, phosphate, titanium and zirconium were identified as PHC and bicarbonate, chloride, lanthanum, lead and mercury as COC (Table 4).

The mean levels of chlorides, bicarbonates, sodium and lead, found in all the boreholes samples were higher than the maximum levels allowed, whereas the rest of the constituents identified as potentially hazardous were isolated cases of levels exceeding the allowed maximum levels.

The implications of the presence of elevated levels of minerals and metals, specifically those including, fluoride, nitrates, chlorides, bicarbonates, phosphates, sodium, titanium, manganese, lanthanum, mercury and iron on poultry production are that certain concentrations, combinations and/or ratios may have antagonistic effects resulting in sub-optimal production. Even then most effects are not “all or none” types (Good, 1985). There may be serious detriments to weights, feed conversions and egg production and quality, often without any clinical symptoms. Water with poor quality affects performance in a number of ways. High concentra-

**TABLE 3**
**Results of water analyses from poultry farms in the Western Cape (n = 35) - trace elements**

| Measured variable | Unit | Mean | SD | Minimum | Maximum | > PHC | COC | Adverse effects of excess # |
|---|---|---|---|---|---|---|---|---|
| Antimony | μg/ℓ | 0.420 | 0.707 | 0.108 | 4.223 | 6 | 54 | Emetic and a cardio-toxin. |
| Arsenic | μg/ℓ | 1.332 | 2.181 | 0 | 9.812 | 50 | 45 | Toxic substance. |
| Barium | μg/ℓ | 69.371 | 67.776 | 9.795 | 252.100 | 2000 | 1800 | Cardiotoxin. |
| Bismuth | μg/ℓ | 0.066 | 0.033 | 0.015 | 0.149 | 500 | 450 | Neuro-toxin. |
| Bromine | μg/ℓ | 56.442 | 30.594 | 20.103 | 123.330 | 3000 | 2700 | Reduce growth rate |
| Cadmium | μg/ℓ | 1.371 | 2.604 | 0 | 12.694 | 5 | 4.5 | Excess has severe health effects. |
| Caesium | μg/ℓ | 4.517 | 8.849 | 0 | 32.918 | 50000 | 45000 | Cyanosis and convulsions. |
| Chromium | μg/ℓ | 35.690 | 4.108 | 25.484 | 47.170 | 100 | 90 | May contribute to hardness of water, low toxicity, nutritionally essential and absence causes diabetes. |
| Cobalt | μg/ℓ | 4.043 | 6.706 | 0.557 | 27.166 | 1000 | 900 | Nutritionally essential, toxic in excess. |
| Copper | μg/ℓ | 25.609 | 35.602 | 5.082 | 194.990 | 1300 | 1170 | Bitter, causes liver damage. |
| Iodine | μg/ℓ | 110.942 | 82.558 | 43.131 | 485.470 | 1000 | 900 | Thyroid-related effects. |
| Iron | mg/ℓ | 3.731 | 7.858 | 0 | 37.190 | 10 | 9 | Causes odour, bad taste & precipitate. |
| Lanthanum | μg/ℓ | 0.946 | 0.393 | 0.272 | 2.304 | 1 | 0.9 | Low to moderate acute toxicity rating. |
| Lead | μg/ℓ | 40.288 | 36.900 | 112.432 | 202.800 | 20 | 18 | A toxic element. |
| Manganese | μg/ℓ | 649.986 | 661.358 | 27.157 | 2204.700 | 1000 | 900 | May contribute to hardness and turbidity, deposits in pipes and bitterness of water. |
| Mercury | μg/ℓ | 0.956 | 1.214 | 0 | 4.182 | 2 | 1.8 | A toxic element with no beneficial physiological function. |
| Molybdenum | μg/ℓ | 0.781 | 1.639 | 0 | 8.148 | 100 | 90 | Reduced growth, highly toxic. |
| Nickel | μg/ℓ | 41.755 | 21.399 | 19.342 | 109.960 | 5000 | 4500 | Reduced growth. |
| Platinum | μg/ℓ | 0.236 | 0.154 | 0.005 | 0.568 | - | - | Allergenic. |
| Rubidium | μg/ℓ | 7.895 | 7.435 | 0.486 | 27.463 | 5000 | 4500 | Non toxic. |
| Selenium | μg/ℓ | 0.076 | 0.447 | 0 | 2.645 | 50 | 45 | Reduced growth. |
| Strontium | μg/ℓ | 289.913 | 274.323 | 36.206 | 1328.400 | 10000 | 9000 | May contribute to hardness of water. |
| Tin | μg/ℓ | 0.565 | 0.677 | 0.070 | 3.281 | 200 | 180 | Nutritionally essential, low toxicity. |
| Titanium | μg/ℓ | 173.348 | 108.758 | 26.457 | 430.680 | 100 | 90 | Soluble salts potentially toxic. |
| Tungsten | μg/ℓ | 0.546 | 0.597 | 0.046 | 2.072 | 500 | 450 | Only soluble salts potentially toxic. |
| Uranium | μg/ℓ | 26.924 | 96.931 | 0.014 | 423.420 | 4000 | 3600 | Low toxicity. |
| Vanadium | μg/ℓ | 0.454 | 1.293 | 0 | 6.131 | 100 | 90 | Nutritionally essential. |
| Zinc | μg/ℓ | 256.827 | 388.630 | 50.319 | 1661.800 | 5000 | 4500 | Astringent taste, may contribute to hardness. |
| Zirconium | μg/ℓ | 0.731 | 0.577 | 0.237 | 2.916 | 1 | 0.9 | Low toxicity. |

* Kempster and Van Vliet (1980); Waggoner et al. (1984); Vohra (1980) and Zimmerman (1995)
# Carter (1985); Phillips et al. (1935); Ralph (1989), Puls, 1988 and Zimmerman (1995)

tions of bacteria or potentially toxic elements 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 also lead to problems with watering systems, such as scaling, sedimentation, clogging and encrustation. This impacts on replacement cost of equipment, and may lead to other problems including reduced water intakes, feed intakes and a higher requirement for litter replacement. These can result in leg problems and breast blisters in broilers raised on the floor (Keshavarz, 1987). It creates managerial problems for the laying hens, which are in cages.

Work done by Coetzee et al. (1997), Casey et al. (1998) and Meyer (1998), showed that the maximum allowed levels as stipulated by Kempster et al., (1980), Waggoner et al. (1984) and Vohra et al. (1980) for fluoride, chlorides, sodium, and nitrates in the drinking water of poultry are not applicable under South African conditions. This amplifies the need for a site-specific ingestion based approach to determining water quality guidelines for livestock. Since bicarbonate is lately used to alleviate stress in chickens (Balnave and Gorman, 1993), the maximum allowed level of 98 mg/ℓ recommended by Kempster et al., (1980) also seems to be to restrictive and new recommendations need to be established for bicarbonate as well.

**TABLE 4**
**Potentially hazardous constituents (PHC) and constituents of concern (COC) in the respective boreholes and zones**

| Borehole and zone | | PHC | COC |
|---|---|---|---|
| **1** | **D** | Bicarbonate, Nitrate, Sodium, Lead, Mercury, Titanium | Chloride |
| **2** | **D** | Nitrate, Sodium, Lead | Mercury |
| **3** | **C** | Bicarbonate, Nitrate, Sodium, Lead, Titanium, Zirconium | |
| **4** | **C** | Lanthanum, Lead, Zirconium | |
| **5** | **C** | Bicarbonate, Nitrate, Sodium, Lanthanum, Lead, Titanium, Zirconium | |
| **6** | **D** | Bicarbonate, Sodium, Lead, Titanium | |
| **7** | **D** | Bicarbonate, Chloride, Nitrate, Sodium, Lead, Titanium, Zirconium | |
| **8** | **D** | Bicarbonate, Chloride, Sodium, Cadmium, Lanthanum, Lead, Titanium, Zirconium | |
| **9** | **D** | Chloride, Sodium, Lead, Manganese, Titanium | |
| **10** | **D** | Chloride, Sodium, Cadmium, Iron, Lanthanum, Lead, Manganese, Titanium | Bicarbonate |
| **11** | **D** | Bicarbonate, Sodium, Lead, Titanium | |
| **12** | **D** | Bicarbonate, Sodium, Lead, Titanium | |
| **13** | **D** | Bicarbonate, Sodium, Lead, Titanium | |
| **14** | **D** | Bicarbonate, Chloride, Sodium, Titanium | |
| **15** | **D** | Bicarbonate, Chloride, Fluoride, Nitrate, Sodium, Titanium, Zirconium | Lead |
| **16** | **D** | Bicarbonate, Chloride, Sodium, Lanthanum, Titanium | |
| **17** | **D** | Bicarbonate, Chloride, Sodium, Lanthanum, Lead, Titanium | |
| **18** | **D** | Bicarbonate, Sodium, Cadmium, Lead, Titanium | Lanthanum |
| **19** | **D** | Chloride, Sodium, | Bicarbonate |
| **20** | **D** | Sodium, Iron, Lead, Manganese, Mercury | |
| **21** | **D** | Bicarbonate, Chloride, Nitrate, Sodium, Lead, Titanium | |
| **22** | **C** | Bicarbonate, Chloride, Sodium, Lanthanum, Lead, Manganese, Zirconium | |
| **23** | **C** | Chloride, Nitrate, Sodium, Lanthanum, Titanium | |
| **24** | **C** | Chloride, Nitrate, Sodium, Lanthanum, Lead, Titanium | |
| **25** | **C** | Chloride, Sodium, Manganese, Titanium | |
| **26** | **C** | Chloride, Sodium, Titanium | Lanthanum, Lead |
| **27** | **A** | Chloride, Sodium, Lanthanum, Lead, Titanium | |
| **28** | **A** | Chloride, Sodium, Lanthanum, Lead, Titanium | Zirconium |
| **29** | **D** | Bicarbonate, Chloride, Sodium, Lanthanum, Lead, Manganese, Mercury, Titanium | |
| **30** | **D** | Bicarbonate, Chloride, Nitrate, Phosphates, Sodium, Lead, Titanium | |
| **31** | **D** | Bicarbonate, Chloride, Sodium, Lead, Manganese | Lanthanum |
| **32** | **B** | Bicarbonate, Chloride, Sodium, Lead, Manganese, Titanium | Mercury |
| **33** | **C** | Bicarbonate, Sodium, Lead, Titanium | |
| **34** | **C** | Lead | Sodium |
| **35** | **C** | Sodium, Lanthanum, Lead | |

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