INORGANIC CHEMICAL CHARACTERIZATION OF SOUTH AFRICAN MUNICIPAL SEWAGE SLUDGES

By R Smith & H Vasiloudis

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SYNOPSIS

The application of sewage sludge to agricultural land can be beneficial in that, in addition to its soil-conditioning properties, it also contains significant amounts of the major nutrients nitrogen, phosphorus and, to a lesser extent, potassium, as well as minor nutrients such as calcium and magnesium and certain trace elements. As well as ensuring that sludges destined for agricultural application are disinfected in order to eliminate any pathogenic organisms present, it is also essential that the sludges be adequately monitored for the presence of organic and inorganic chemical contaminants which could have adverse crop and food chain effects.

Twelve major inorganic chemical contaminants (cadmium, chromium, copper, lead, nickel, zinc, mercury, molybdenum, arsenic, selenium, boron, fluoride) were identified as being commonly present in sewage sludge and suitable analytical methods were developed and tested for their determination, as well as for the determination of the nutrients previously mentioned. Samples of air-dried sludge were collected from seventy-seven South African sewage works and analysed for both inorganic chemical contaminant and nutrient content.

The results obtained, as well as providing valuable information on the chemical quality of South African sewage sludges, were used, in conjunction with previous related work conducted by the National Institute for Water Research, and with reference to limits laid down by various overseas countries, to prepare a set of suggested guidelines for the application of disinfected sewage sludge to agricultural land in this country.

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1. INTRODUCTION

The treatment and disposal of sewage sludge is frequently the most costly phase of municipal wastewater treatment, and also presents environmental, health and aesthetic problems. The sludge may be disposed of by any of the following means:

(a) Application, in raw or composted form, to agricultural land.

(b) Burial in sanitary land fill sites.

(c) Disposal at sea.

(d) Incineration.

Some form of pretreatment and dewatering is generally required prior to disposal by methods (a), (b) and (d) above.

Although the properly designed disposal of sewage sludge to sea is unlikely to have any direct effects on public health when adequate dilution is provided for, careful selection of the disposal site is advisable in order to avoid any detrimental effects on the marine environment, in particular on accumulator organisms such as mussels and oysters[1].

Incineration will avoid many of the problems associated with the disposal of sludge to land or sea, but it requires considerable capital outlay, while operating costs are relatively high, and careful control is necessary in the removal of the resulting ash, dust and scrubber water and on chimney emissions[2].

The application of sewage sludge to agricultural land, as well as being often the least expensive disposal alternative, can also be beneficial in that, in addition to its soil - conditioning properties, valuable nutrients such as nitrogen and phosphorus, and to a lesser extent, potassium, calcium magnesium, and certain trace elements, are also utilized. In many overseas countries it is being increasingly

used for this purpose. Burial in land fill sites, although unproductive, often has economic advantages, and may avoid many of the risks associated with land application. Since many sludges will contain toxic substances in concentrations higher than those found in typical soils, their continued use could lead to adverse crop and food chain effects, due to plant uptake of certain trace metals and to other contaminants which may be present in the sludge, not only in the organic and inorganic chemical form, but also in the form of pathogens. Contamination of groundwater could also result from toxic substances leached from the sludge[2].

It is therefore essential that sludges destined for agricultural applications be adequately monitored for the presence of these contaminants. In this regard, countries such as the UK, USA and Canada have carried out countrywide chemical analyses of their sewage sludges, and, based on the results obtained, have subsequently established suitable guidelines for the application of this material to agricultural land.

Since the chemical nature of sewage sludge varies widely, and sludge in many parts of South Africa may not be contaminated with hazardous compounds to the same extent as in highly industrialized countries abroad, the National Institute for Water Research (NIWR), now the Division of Water Technology (DWT) of the CSIR proposed that a similar exercise be carried out in this country, rather than merely adapt overseas guidelines[3]. The analysis results obtained would also provide useful 'baseline' information on the concentrations of the various contaminants and nutrients present in a wide range of South African sewage sludges, and would assist in assessing the suitability of individual municipal sludges for agricultural and horticultural use. In this regard, it should be noted that the Department of National Health and Population Development in South Africa stipulates that sewage sludges destined for agricultural and horticultural use be disinfected to remove pathogenic organisms[4].

The NIWR proposed, under the sponsorship of the Water Research Commission (WRC) to carry out an investigation into the concentrations of inorganic chemical contaminants and nutrients in S.A. sewage sludges. The project, commenced in July, 1982, came under the sponsorship of the WRC in January, 1986[3]. A parallel project, on the organic contaminants found in sewage sludges, was also carried out by the NIWR/DWT, under the sponsorship of the Foundation for Research and Development (FRD), between 1986 and 1989[5].

The results of the work carried out by the NIWR/DWT between July 1982 until its completion in January, 1989, on the inorganic chemical characterization of South African municipal sewage sludges, are summarized and discussed in this report.

The project had four major aims, viz[3]:

(a) To carry out a literature study on the inorganic chemical contaminants and nutrients commonly found in sewage sludge, their beneficial and adverse effects apropos the use of sewage sludge as supplementary 'fertilizer' for agricultural land, and the analytical methods used for their determination.

(b) To investigate and test the most suitable of these methods for eventual incorporation in a laboratory manual for the determination of inorganic chemical contaminants and nutrients in sewage sludge.

(c) To sample a countrywide range of South African municipal sewage sludges on a 4 times per year basis and to analyse them for the presence of the most common inorganic chemical contaminants and nutrients by means of the methods described in the aforementioned manual.

(d) To use the analysis results obtained, in conjunction with previous related work conducted by the NIWR, and with reference to limits laid down by various overseas countries, to prepare a set of suggested guidelines for the application of disinfected sewage sludge to agricultural land in this country. These results would also provide a fairly universal indication of the quality of South African sewage sludges in respect of their inorganic chemical contaminant and nutrient content.

2. IMPORTANCE, DETERMINATION AND OCCURRENCE OF INORGANIC CHEMICAL CONTAMINANTS AND NUTRIENTS IN SOUTH AFRICAN MUNICIPAL SEWAGE SLUDGES

2.1 Importance [2,6,7,8,9]

Increased yields from the application of sewage sludge to agricultural land come mainly from the nutrients nitrogen and phosphorus contained in the sludge. Other components of sludge, such as potassium, magnesium, calcium and certain trace elements may also be beneficial to crops.

Nitrogen: Nitrogen is an important and necessary element for the health and growth of crops. About 85% of the nitrogen in liquid digested sludges and about 33% of that in dried sludges is available to crops within the growing season. The 'available' nitrogen may be taken as all the soluble nitrogen, mainly ammonia nitrogen, although this may somewhat underestimate the true availability. An excess of nitrogen over the requirements of crops should be avoided, however, as it may result in the reduction of yields and an increase in susceptibility to disease and pest attack, as well as, in some situations, increasing the risk of nitrates leaching into rivers or underground water supplies.

Phosphorus: This element is also necessary for the health and growth of crops. Information on the availability to crops of phosphorus in sewage sludge is limited, but it is assumed that in the first growing season after application it is about two thirds as effective as a similar amount of water-soluble phosphorus applied as fertilizer. Calcium phosphates are rather more soluble and available to crops than those of iron, aluminium, or heavy metals.

Potassium: The potassium content of sewage sludge is normally low, as potassium salts are generally soluble in water and discharged in the sewage treatment effluent. Therefore, only a small amount of this nutrient is available in sewage sludge at normal application rates, and additional fertilized potassium is necessary for crops with a high potassium requirement.

Magnesium: This element has a minor nutritional effect and is present in sewage sludges at concentrations of around 1% of the dry solids.

Calcium: Where lime has been used as a stabilizer or conditioner, the calcium content (as Ca) may be as high as 20% of the dry solids. In this case, the sludge can be used as a source of calcium for crops and to correct acidity in soils of low pH value. Over-liming, however, can reduce the availability of major nutrients.

Inorganic chemical contaminants may be present in sewage sludge in any or all of the following forms:

Major contaminants: Arsenic, boron, cadmium, chromium, copper, fluoride, lead, mercury, molybdenum, nickel, selenium, zinc.

Minor contaminants: Antimony, beryllium, cobalt, silver, thallium, tin, tungsten, vanadium.

Some of the contaminants listed, for example copper, zinc, boron, selenium and molybdenum, are, in low concentrations, essential to the growth of plants, and may be regarded as trace nutrients. When they are present in higher concentrations, however, adverse effects can occur, viz:-

(a) Phytotoxicity, in which crop growth and productivity are reduced.

(b) Elements may be taken up into the edible parts of crop plants and enter the food chain of animals and humans, with possible deleterious effects.

Other elements such as arsenic, cadmium, lead, mercury and nickel, appear to have no beneficial effects.

Specific characteristics of the various contaminants listed are discussed below:

Zinc: This metal, although essential to plant life, can be phytotoxic in excessive qualities. It is readily taken up by plants from the soil and translocated to the leaves and shoots. It has a relatively low toxicity to animals and humans.

Copper: This metal is also essential to plant life, but can also be phytotoxic in large quantities. It is taken up by the plant roots but translocated only to a limited extent. Copper is also essential in animal diet, but can be toxic in excessive amounts, particularly to sheep. The toxicity effects of copper are reduced in the presence of other metals such as iron, zinc and molybdenum.

Nickel: Highly toxic to most plants, nickel appears to occupy an intermediate position as regards uptake, with some translocation from the roots into the shoots and leaves. It is not very toxic to animals or humans.

Zinc equivalent: Zinc, copper and nickel often occur together in sewage sludge, and since their effects appear to be additive when present in high concentrations, the 'zinc equivalent' can be used for determining the maximum permissible sludge addition and soil concentration. It provides a convenient means of expressing in a single figure the total level of these three phytotoxic elements, viz:

Zinc equivalent = (1 x mg/kg Zn)+(2xmg/kg Cu)+(8 x mg/kg Ni)

Cadmium: This metal is not only phytotoxic, but is also highly toxic to humans. It is readily absorbed from soils and translocated by plants, the major route of exposure of man to cadmium through food being from cereals and vegetable crops.

Lead: Although it has not been shown to be particularly phytotoxic, lead is both toxic and cumulative in humans and animals. It is a non-essential element. When lead is equilibrated in soil it tends to become very insoluble, and is not readily translocated by plants. The main risks from this metal are from surface contamination of crops and the ingestion of lead-contaminated sludge or soil by grazing animals.

Chromium: This metal is normally present in sewage sludge predominantly in the insoluble trivalent form, which is relatively non-toxic. The more toxic and soluble hexavalent form is unlikely to be found in significant concentrations in raw sludge. Toxic effects due to chromium in sewage sludge have not been observed in plants or in animals consuming crops grown on sludge - treated land.

Mercury: This element is very toxic to animals and humans, but is taken up by plants to only a slight extent, being mainly concentrated in the roots. It is largely lost from the surface of soils by volatilization, and the content in soils is usually low.

Major sources of the foregoing heavy metals in sewage sludge are listed in Table 1.

Molybdenum: This metal is not phytotoxic, but high intakes by grazing animals can cause or exacerbate copper deficiency problems. Molybdenum becomes more available to plants with increasing soil pH.

Arsenic: Plant growth can be affected in soils with 'available' arsenic content of 5 mg/kg or more.

Selenium: This is an essential element for livestock but is toxic in high amounts. Its availability to crops increases at higher soil pH. In alkaline soils a total content of 5 mg/kg or more would have adverse effects.

Boron: Although toxic in excess, the presence of boron in soils is essential for plant growth. It is not toxic to animals at the levels normally found in plants.

Fluoride: This constituent is taken up by plant roots to a limited extent but does not normally inhibit plant growth. Excess fluoride can cause fluorosis in grazing animals.

The pH value of sewage sludge is used to assess the application rate of disposal of the sludge to land. The availability of selenium and molybdenum to plants increases with increasing soil pH. Aluminium and manganese can be toxic in very low pH soils.

TABLE 1 : Major sources of heavy metals in sewage sludge

Metal	Major source
Zinc	Domestic wastes. Galvanizing, cosmetics, pharmaceutical and rubber industries.
Copper	Electroplating and chemical industries.
Nickel	Electroplating, motor vehicle, aircraft, printing and chemical industries.
Cadmium	Electroplating, pigment and chemical industries.
Lead	Battery, printing and paint industries. Petrol additives washed from road surfaces.
Chromium	Electroplating, tanning and dyestuff industries.
Mercury	Electrical, explosives, pharmaceutical, pesticides and chemical industries. Laboratory wastewaters.

2.2 Determination

When this project was first commenced in 1982, a literature survey of the analytical methods then available for the determination of inorganic chemical contaminants and nutrients in sewage sludge showed a lack of acceptable standard methods not only for the actual analysis of sewage sludge but also for its collection, preparation and pretreatment prior to analysis. Subsequent to this survey the UK Department of the Environment have published several recommended methods for the analysis of many of the major inorganic chemical contaminants and nutrients, and several of these were investigated and either adapted or incorporated in the methods manual eventually produced by the NIWR/DWT. Details of specific method investigations are as follows:

(a) Sample collection and preparation: The importance of applying valid sampling techniques cannot be too strongly emphasized if the subsequent analysis is to have any significant value. Because of their heterogeneous nature, sampling and sample preparation of sewage sludges prior to pretreatment and analysis should be carried out with extreme care if the sample is to be a truly representative one. In the case of wet sludges, gross atypical solids should first be removed by passing the sample through a 5 mm sieve, and the sample analysed as soon as possible. If samples are to be stored prior to analysis, their temperature should be maintained between 0 and 5°C, and/or suitable preservatives added, depending on the constituent or parameter being determined. For the sampling of air-dried sludges from drying beds, portions of sludge should be selected from throughout the bulk and not only from the surface. A composite sample should be prepared from about 20 to 25 'core' samples collected from throughout the bulk. Sub-sampling of this composite and subsequent drying and grinding procedures should be aimed at producing a truly homogeneous sample which can pass through a 0,5 mm sieve[10].

Sewage sludge samples for analysis may be in any of the following forms[11]:

(i) Sample 'asis': In this case the sample will be in the same form as it was collected. If 'dry basis' results are required, a total residue determination should be carried out on a separate portion and a correction applied.

(ii) Sample after air-drying (below 30°C): Again, for 'dry basis' results, a total residue determination should be carried out.

(iii) Sample after freeze-drying or oven-drying at 105°C. Results of this sample will be 'dry basis'.

(iv) Water-washed sample: The sample will have been filtered, the residue washed with cold water to remove extraneous sewage effluent and other water-soluble material, then either air-dried, freeze-dried, or oven-dried at 105°C. This sample will contain only water-insoluble constituents.

(b) Total, fixed and volatile residue: This determination is applicable to the measurement of total residue on evaporation at 105°C and its fixed and volatile fractions in sewage sludge, the fixed residue providing an indication of the ash content and the volatile residue an indication of the organic matter present. The method selected was an adaptation of an existing standard technique[11].

(c) pH: This determination was also adapted from an existing standard technique in which a suitable aqueous suspension is prepared from the semi-liquid or solid sludge and the pH measured potentiometrically[12].

(d) Total Kjeldahl nitrogen: The method recommended for the measurement of this determinand was again derived from an existing standard technique, which involved digestion of the sample with sulphuric acid, potassium sulphate and mercuric sulphate, followed by distillation of the ammonia formed into boric acid and titration with standard sulphuric acid[11]. Later, in 1985, the UK Department of the Environment published standard methods for the determination of total nitrogen and total phosphorus in sewage sludge, including, as well as a manual determination of both of these parameters (mercury catalysed, flask digestion), two semi-automated determinations (copper-catalysed, multiple tube, block digestion method for dried sludges and hydrogen peroxide, multiple tube, block digestion method for 'wet' sludges, both followed by air-segmented, continuous flow colorimetric measurement of the ammonia and orthophosphate formed)[13]. The manual determination is basically similar to the method originally recommended for TKN measurement.

(e) Total phosphorus: The method selected for the measurement of this determinand was based on a method obtained from the US Environmental Protection Agency, involving digestion of the sample with sulphuric acid and potassium persulphate, followed by photometric measurement of the complex formed on addition of antimonyl tartrate and ammonium molybdate and reduction with ascorbic acid[14]. Again the UK Department of the Environment manual method[13] is basically similar to the method originally recommended for TP determination.

(f) Cadmium, chromium, copper, lead, nickel, zinc: Six techniques were evaluated for their suitability for the pretreatment of sewage sludge prior to trace metal analysis by atomic absorption spectrometry, viz:[15]

(i) Ashing at 500°C followed by extraction with dilute hydrochloric acid.

(ii) Dry ashing at 500°C followed by extraction with aqua regia.

(iii) Nitric acid digestion followed by extraction with hydrochloric acid.

(iv) Extraction with aqua regia.

(v) Ashing with magnesium nitrate solution at 550°C followed by digestion with hydrochloric acid and extraction with nitric acid.

(vi) Extraction with nitric acid.

Procedures involving the use of perchloric acid, hydrofluoric acid and hydrogen peroxide were not considered for reasons of safety. The most suitable of these techniques was found to be direct extraction of the sample with aqua regia. The method recommended by the U.K. Department of the Environment is somewhat similar except that the extraction is carried out using nitric acid only[16]. Results obtained on samples of sewage sludge by both procedures were not significantly different.

(g) Calcium and magnesium: The method employed for the determination of cadmium, chromium, copper, lead, nickel and zinc was also found to give satisfactory results for the determination of these two constituents.

(h) Mercury: A suitable technique for this metal was adopted from various other recommended techniques,[11,17,18], and involved prolonged oxidation of the sample with sulphuric acid, potassium persulphate and potassium permanganate, followed by determination of the mercury by cold vapour generation / atomic absorption.

At this stage a draft manual of methods for the determination of inorganic chemical constituents and nutrients in sewage sludges was prepared, which incorporated the methods described above, as well as methods for arsenic and selenium which in the light of later investigations were subsequently replaced.

The methods were further tested by carrying out an inter-laboratory comparison study involving the measurement of the various determinands mentioned in a sample of dried sewage sludge by 29 laboratories using the proposed methods[19]. On completion of this study, the manual was slightly revised and published in the form of a CSIR Technical Guide[20]. (The method for selenium was omitted from this manual).

Suitable methods had not yet been found, at the time of publication of the manual, for selenium, boron, molybdenum and fluoride. Methods for these constituents were subsequently investigated and evaluated and eventually included in a revised edition of the manual[21]. The method for arsenic was also revised and incorporated in a combined method for arsenic and selenium in the revised manual. Potassium was added to the method for calcium and magnesium.

(i) Molybdenum: Instrumental techniques reported for the determination of molybdenum in sewage sludge include neutron activation, spark source mass spectrometry, and inductively - coupled plasma optical emission spectrometry[6]. These were, for obvious reasons, omitted from further consideration. Direct flame atomic absorption spectrometry is not quite sensitive enough for detection of the levels of molybdenum normally found in sewage sludges. Solvent extraction atomic absorption spectrometry techniques were investigated, but with unsuccessful results. The most promising technique appeared to be a colorimetric one, involving the formation of an orange-coloured complex by reaction of molybdenum with thiocyanate ions in the presence of a reducing agent. A method based on this technique has been published by the UK Department of the Environment,[22] and this technique was therefore selected for further investigation. The method eventually adopted was basically similar to that of the Department of the Environment except for some minor modifications.

(j) Boron: As in the case of molybdenum, direct flame atomic absorption spectrometry is not sufficiently sensitive for the determination of boron at the levels normally found in sewage sludges. Instrumental techniques reported for the determination of boron in sewage sludge include a spectrographic technique with boron-free anodes, spark-source mass spectrometry, and inductively-coupled plasma optical emission spectrometry[6].

Colorimetric techniques are normally employed, based on carmine red, curcumin, or azomethine-H. Nitrate and nitrite interferes in the methods using carmine red or curcumin, but not in the azomethine-H method.[6]

The portion of the total boron content in a sample of sewage sludge which is available to plants can be assessed by extraction with boiling water. Soluble or extractable boron in the sample is present both as water-soluble and adsorbed borate, which is then determined in the extract by a suitable method. If total boron is required, fusion with sodium peroxide at 480°C is a necessary pretreatment step.[23]

The most suitable technique, therefore, appeared to be the azomethine-H colorimetric determination of water-soluble boron. A method based on this technique has been published by the UK Department of the Environment for the measurement of boron in waters, effluents, sewage and solids such as soils, sediments and sewage sludges,[23] and this method was selected for further investigation. The method adopted eventually was basically similar to that of the Department of the Environment method, with a few modifications.

(k) Fluoride: Classical methods for fluoride determination involve oxidation of the sample to destroy organic matter, separation of the fluoride by distillation or microdiffusion, follwed by colorimetric measurement of the fluoride.[6] Although giving good recoveries, these techniques are time-consuming.

Potentionetic determinations offer better possibilities, and current investigations suggest that sodium fusion or acid extraction of the sludge followed by addition of buffer solutions to prevent complexing, then direct measurement of the fluoride by ion-selective electrode, is a suitable technique.[6] Methods involving this technique have been described by the UK Yorkshire Water Authority[24], Rea[25], and the UK Department of the Environment.[26]

It was decided initially to investigate two techniques, viz:

(i) Sodium hydroxide fusion of the sludge, followed by dissolution in acid, addition of sodium citrate buffer solution, and ion-selective electrode determination of the (total) fluoride.[25]

(ii) Acid extraction of the sludge, followed by addition of sodium citrate buffer solution, then ion-selective electrode determination of the (acid-soluble) fluoride.[26]

Sodium citrate buffer solution was used as it was claimed to be more effective than the normally used 'TISAB' for samples containing high concentrations of aluminium, which strongly interferes in the determination.[27] It was found, however, that the electrode was rather drastically attacked by the sodium citrate buffer solution, and that electrode readings appeared to remain constant irrespective of the quantity of fluoride added. The fusion technique was also found to be extremely time-consuming, and not very reliable. Therefore, other sample pretreatment techniques were investigated, and it was eventually found that satisfactory results were obtained using the following technique:

Sulphuric acid extraction of the fluoride followed by precipitation of the interfering aluminium and other metals with ammonium hydroxide, addition of 'TISAB' buffer solution, then ion-selective determination of the (acid-soluble) fluoride, using a single standard addition procedure.

(1) Selenium: In order to avoid volatilization losses, careful preparation of samples for selenium determination is essential. Several digestion procedures have been described, viz:

(i) Fusion with potassium bisulphate.[27]

(ii) Digestion with nitric and perchloric acids.[27]

(iii) Digestion with nitric acid and perchloric acids, followed by ashing with nickel nitrate.[28]

(iv) Digestion with nitric acid followed by ashing with magnesium nitrate.[29]

For the actual determination of the selenium, several techniques have been described, viz:

(i) Spectrophotometric methods, eg. diaminobenzidine colorimetric method.[6]

(ii) Fluorimetric methods.[30]

(iii) Hydride generation techniques, in conjunction with either atomic absorption or inductively-coupled plasma optical emission spectrometry.[6]

As in the case of the fluoride determination, a fusion procedure was considered to be too time-consuming. Digestions involving the use of perchloric acid were not considered for reasons of safety, while the use of nickel nitrate could possibly enhance interference effects if hydride generation was also employed in the determination.

It was decided to investigate and develop a method involving digestion of the sludge with nitric acid, following by ashing with magnesium nitrate, and determining the selenium by hydride generation,[28] but using sodium borohydride in place of the aluminium slurry stipulated in the referred method.

In addition, the determination of arsenic by this technique was also investigated, as the simultaneous determination of arsenic and selenium would be less time-consuming and less costly. Reanalysis of the sludge samples for arsenic by this technique gave, in many cases, slightly higher results than previously were obtained. A combined method was therefore prepared.

Interference from copper and other metals was also investigated, but it was found that addition of interference suppression agents, such as thiourea,[31] did not significantly affect the results obtained.

The foregoing methods for the determination of molybdenum, boron, fluoride and arsenic/selenium, although not evaluated by means of an interlaboratory comparison study, were subjected to rigorous precision and recovery tests, as well as being tested on reference sludge samples of known concentrations. Acceptable values were obtained in all cases, and the four methods were therefore added to the revised manual for the determination of inorganic chemical contaminants and nutrients.[21]

The methods presented in the manual described above were selected as being the most suitable in terms of safety and simplicity. In this regard, the use of such hazardous chemicals as hydrofluoric acid, hydrogen peroxide and perchloric acid for the pretreatment of the sludge samples prior to analysis has been avoided, while the use of instrumental analytical techniques has been limited basically to potentiometric, UV/visible and atomic absorption spectrophotometric measurements.

A brief summary of the analysis techniques employed for the sewage sludge analysis is given in Table 2. Full details of the methods used are given in Appendix 1.

2.3 Occurrence

Seventy-seven sewage works throughout South Africa, mostly those serving populations of over 25 000, were contacted by letter and a questionnaire requesting their cooperation in sampling air-dried

TABLE 2: Summary of analysis techniques

Determinand	Analysis technique
Total, volatile and fixed residue	Gravimetric: 5-10g sample, 105°C and 550°C.
pH	Potentiometric: 5g sample (db) → 100 ml.
Total Kjeldahl nitrogen	Acidimetric titration: 0,5g sample (db); digest with sulphuric acid, potassium sulphate, mercuric sulphate; distil into boric acid; titrate with standard sulphuric acid.
Total phosphorus	Colorimetric: 0,2g dried sample; digest with sulphuric acid and potassium persulphate, treat with sodium bisulphite; react with ammonium molybdate, potassium antimonyl tartrate and ascorbic acid; measure blue complex formed at 660 nm.
Calcium, magnesium, potassium (acid-soluble)	Atomic absorption (direct flame): 0,5g dried sample, extract with aqua regia, add caesium-lanthanum; measure calcium and magnesium by nitrous oxide-acetylene flame and potassium by air-acetylene flame.
Cadmium, chromium, copper, lead, nickel, zinc (acid-soluble)	Atomic absorption (direct flame): 0,5g dried sample, extract with aqua regia, add caesium-lanthanum; measure cadmium, copper, lead, nickel and zinc by air-acetylene flame and chromium by nitrous oxide-acetylene flame.
Mercury (total)	Atomic absorption (cold vapour generation): 0,5g sample (db), digest with potassium permanganate, potassium persulphate, sulphuric acid; add sodium chloride/hydroxylamine sulphate, nitric acid, then stannous chloride; measure mercury in evolved vapour.
Arsenic and selenium (total)	Atomic absorption (hydride generation): 0,25g sample (db), digest with nitric acid and ash with magnesium nitrate at 550°C; extract with hydrochloric acid; add sodium borohydride and measure arsenic and selenium in evolved hydrides.
Molybdenum (total)	Colorimetric: 0,5g dried sample, ash at 500°C, extract with hydrochloric acid; add potassium thiocyanate, extract amber complex formed with MIBK and measure at 470 nm.
Boron (water-soluble)	Colorimetric: 0,2g dried sample, extract with hot water; add azomethine-H, measure yellow complex formed at 420 nm.
Fluoride (acid-soluble)	Potentiometric: 0,5g dried sample, extract with sulphuric acid; add ammonium hydroxide to pH 8-8,5; filter; measure fluoride by ion-selective electrode.

sludge from their works and in supplying information in respect of population served, type of sewage treatment process, sludge type, annual sludge production and method of sludge disposal. During the period between June 1983 and May 1987, a sample of air-dried sludge was collected, at approximately 3-monthly intervals, for a period of one year, from each of 9 sewage works in the Orange Free State, 33 in the Transvaal, 7 in Natal, and 28 in Cape Province, and submitted for analysis for the presence of the inorganic contaminants and nutrients previously discussed.

The completed questionnaires were processed, and the information supplied by each sewage works is shown in Table 3. The details given are reproduced exactly as supplied by the various works, and are included in the report mainly for background information.

A recommended sample collection procedure, as previously described (2.2), was supplied to each sewage works. The submitted samples were pretreated according to the flow diagram shown in Figure 1. (The freezing step was included mainly to eliminate small insects, etc).

The samples were analyzed by means of the analytical methods previously established.[20,21] Summaries of the analysis results obtained are given in Table 4 and 5. In the case of cadmium, chromium, copper, lead, nickel, zinc, calcium, magnesium, potassium and pH, the results shown are the average of four determinations, while in the case of mercury, arsenic, selenium, molybdenum, boron, fluoride, total Kjeldahl nitrogen and total phosphorus, the results are of the composite of four samples. pH Values are in pH units; calcium, magnesium, potassium, total Kjeldahl nitrogen and total phosphorus values are in g/kg, dry basis; the remaining values are in mg/kg, dry basis. The tables also show the overall range, mean value and median value for each determinand. These results are reproduced in the form of histograms in Figures 2 to 19. Results obtained for individual samples from each sewage works are shown in Appendix 2.

For purposes of comparison, results from similar surveys on contaminant and nutrient concentrations in United Kingdom sewage sludges[6,7] are shown in Tables 6 and 7.

TABLE 3: Sludge details

Sewage works	Total population served	Annual sludge production (metric tons, db)	Type of sewage treatment process	Sludge type	Method of sludge disposal
Bethlehem	56 000	408	(1)BF (2)AS	(1)PD (2)WA	Drying beds : Land disposal
Bloemfontein	200 000	2 000	BF	(1)PD (2)SD	Dumping on city dumps
Harrismith	11 600	310	(1)BF (2)AS	(1)PD (2)WA	Land disposal
Kroonstad	100 000	1 000	BF	PD	Parks and gardens
Parys	8 500	2	BF	PD	Drying beds
Sasolburg	49 500	1 278	BF	PD	Drying beds
Virginia	63 000	2 690	BF	(1)PD (2)SD	Parks, sports grounds, gardens
Welkom (Theronia)	91 000	400	BF	PD	Drying beds
Welkom (Witpan)		400	BF	PD	Drying beds
Boksburg	224 000	5 110	BF	PD	Composting, new parks or works
Brits	8 000	150	AS	WA	Drying beds
Carletonville	21 000	265	BF	PD	Composting
Ermelo	41 000	182	(1)BF (2)AS	(1)PD (2)WA	Drying beds
Evander	39 000	300	AS	WA	Fertilizing
Germiston (Dekema)	541 000	5 700	BF	PD	Land disposal
Germiston (Rondebult)		3 400	(1)BF (2)AS	PD	Land disposal
Germiston (Waterval)		5 000	AS	(1)PD (2)WA	Land disposal
Johannesburg (Goud Koppies)	890 000	11 000	(1)BF (2)AS	PD	'Dedicated' land
Johannesburg (Northern Activated)	850 000	5 100	AS	WA	Lagoons; land
Johannesburg (Northern Digested)		6 850	BF	PD	Lagoons; land
Johannesburg (Olifantsvlei)	1 177 000	11 200	(1)BF (2)AS	PD	'Dedicated' land
Kempton Park	80 000	5 500	(1)BF (2)AS	(1)PD (2)WA	Sludge irrigation on land
Klerksdorp	110 000	Not supplied	AS	WA	On cultivated land
Krugersdorp	105 000	Not supplied	AS	(1)PD (2)WA	Sludge irrigation on instant lawn
Middelburg	40 000	672	AS	WA	Drying beds; composting
Nigel	24 000	138	BF	PD	Drying pans
Pietersburg (biological plant)	96 000	437	BF	PD	Composting; parks
Pietersburg (Pasveer ditch)	36 000	757	AS	WA	Composting; parks; ploughed into land
Phalaborwa	10 000	350	AS	WA	Composting for parks
Potchefstroom	85 000	1 240	(1)BF (2)AS	(1)PD (2)WA	Drying beds; cultivated land
Pretoria (Baviaanspoort)	65 000	Not known	AS	WA	Land disposal
Pretoria (Daspoort)	350 000	6 750	BF	PD	Drying beds; land disposal
Pretoria (Rooiwal)	380 000	14 515	BF	PD	Land disposal
Roodepoort	25 000	1 500	MB	WA	Ploughed into land
Rustenburg	70 000	1 250	BF	PD	Landfill
Sebokeng	170 000	2 200	BF	PD	Land disposal
Springs	144 000	2 500	BF	PD	Land disposal
Standerton	179 000	36	AS	WA	Parks
Vanderbijlpark	91 500	260	(1)BF (2)AS	PD	Drying beds; parks; sold to farmers
Vereeniging	111 000	2 200	(1)BF (2)AS	(1)PD (2)WA	Sludge lagoons, land application
Verwoerdburg	52 000	300	(1)BF (2)AS	(1)PD (2)WA	Ploughed into land; sold to farmers
Witbank	20 000	125	AS	WA	Drying beds

BF: Biological filter
AS: Activated sludge
MP: Maturation pond
MB: Modified Bardenpho
PD: Primary digested
WA: Waste activated
SD: Secondary digested
H : Humus
RSD: Raw secondary digested
ZHT: Zimpro heat treatment
db : dry basis

TABLE 3: (continued)

Sewage works	Total population served	Annual sludge production (metric tons, db)	Type of sewage treatment process	Sludge type	Method of sludge disposal
Amanzimtoti	50 000	832	AS	PD	Private tip site
Durban (Kwa Mashu)	190 000	1 800	(1)BF (2)AS	H and RSD	Stock pile on site; limited use
Durban (Northern)	150 000	1 500	AS	WA and RSD	by parks and gardens dept.
Ladysmith	38 000	800	BF	PD	Municipal parks and gardens
Newcastle	38 000	2 066	BF	PD	Land disposal
Pietermaritzburg	175 000	800	(1)BF (2)AS	PD	Land disposal
Port Shepstone	26 300	95	AS	WA	Refuse tip
Bellville	145 000	2 910	AS	WA	Sludge lagoons
Cape Town (Athlone)	360 000	7 200	(1)BF (2)AS	(1)PD (2)WA	Farming and horticulture
Cape Town (Cape Flats)	530 000	9 900	AS	(1)PD (2)WA	Kept at works
Cape Town (Mitchells Plain)	175 000	3 700	AS	(1)PD (2)WA	Horticulture
Cradock	27 000	38	AS	WA	Sludge lagoons; drying beds
De Aar	30 000	Not known	AS	WA	Sludge lagoons
Despatch	18 000	650	AS	WA	Burial
East London	8 000	118	BF	PD	Burial
Graaf Reinet	16 000	Not supplied	BF	PD	Municipal parks and gardens
Grahamstown	32 000	100	BF	PD	Stockpiled (land fill)
Kimberley	96 000	788	AS	WA	Municipal parks and gardens
King Williams Town	15 000	Not supplied	BF	PD	To farmers
Knysna	20 500	500	BF	PD	Dumping
Kraaifontein	36 000	260	BF	PD	Land fill
Milnerton	52 000	Not supplied	BF	ZHT	Parks and sports fields; land fill
Oudtshoorn	40 000	Not supplied	BF	PD	To farmers
Paarl	88 000	2 250	BF	PD	To farmers
Parow	6 500	28	AS	WA	Main sewes line
Port Elizabeth (Cape Receife)	50 000	800	AS	WA	Sludge lagoons
Port Elizabeth (Fishwater Flats)	450 000	9 125	AS	ZHT	Brickworks for brick manufacture
Robertson	140 000	200	BF	PD	Land fill
Stellenbosch	45 000	350	AS	PD	Land fill
Strand	100 000	2 400	AS	WA	Sludge lagoons
Uitenhage	70 500	600	BF	PD	Dumping
Upington	56 000	1 500	BF	PD	'For municipality's own use'
Vredenberg/Saldanha	25 000	750	AS	WA	Burial
Walvis Bay	20 000	270	BF	PD	Municipal parks; dumping
Worcester	55 000	550	BF	PD	Mixed with compost

BF: Biological filter
AS: Activated sludge
MP: Maturation pond
MB: Modified Bardenpho

PD: Primary digested
WA: Waste activated
SD: Secondary digested
H : Humus

RSD: Raw secondary digested
ZHT: Zimpro heat treatment
db : dry basis

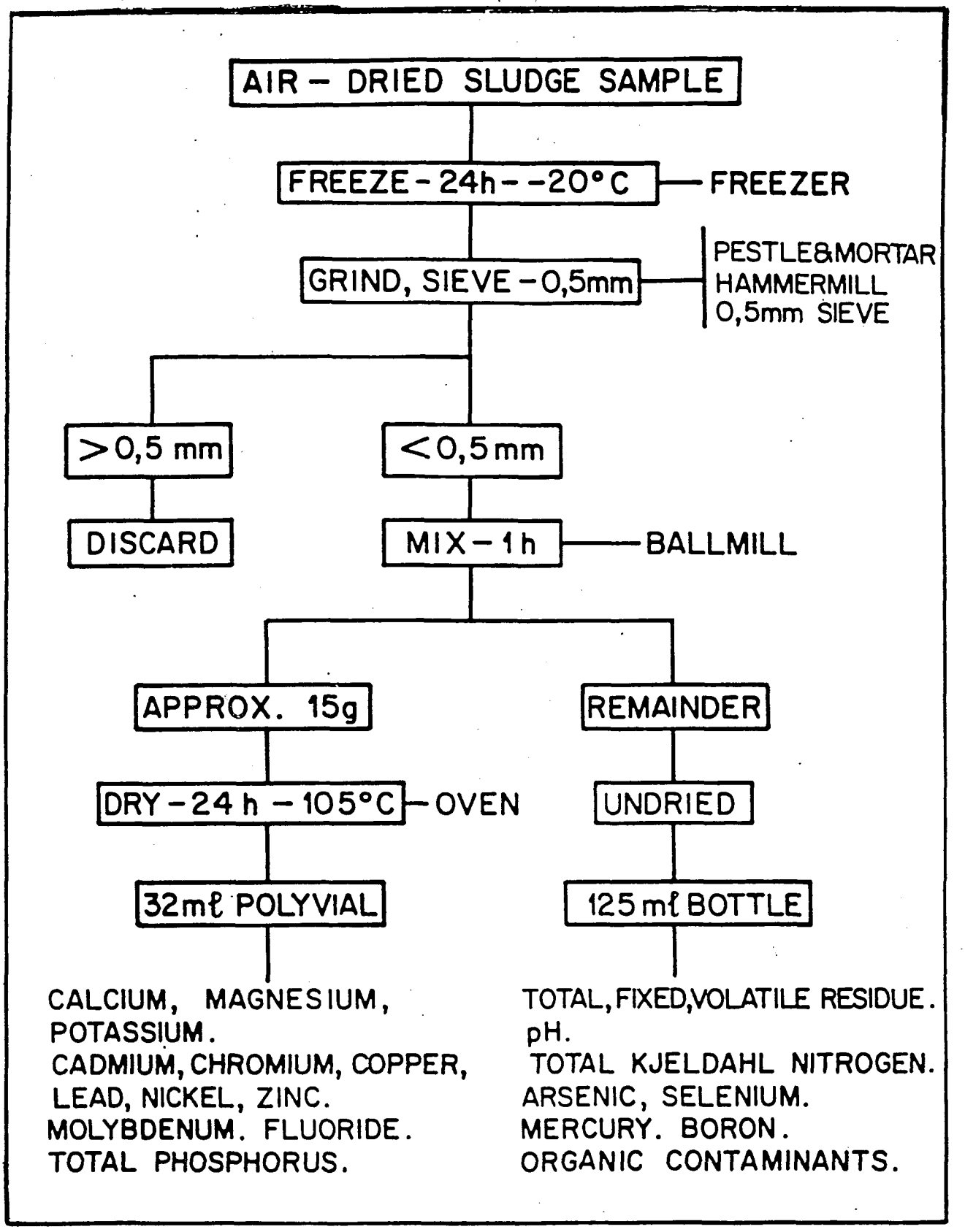

Figure 1: Flow diagram of sewage sludge sample preparation

TABLE 4: Summary of analysis results (Cd, Cr, Cu, Pb, Ni, Zn, Hg, As, Se)

Sewage works	Cd	Cr	Cu	Pb	Ni	Zn	Hg	As	Se
	mg/kg,db								
Bethlehem	1	25	134	103	17	771	5	3	<1
Bloemfontein	3	100	390	287	63	1432	8	6	<1
Harrismith	1	40	223	104	13	1000	3	3	<1
Kroonstad	3	49	192	166	28	1083	6	4	<1
Parys	6	179	212	97	54	1988	4	<1	3
Sasolburg	2	364	146	67	44	548	22	16	107
Virginia	1	71	186	169	55	1327	4	28	1
Welkom (Theronia)	10	59	747	1360	45	3143	8	17	1
Welkom (Witpan)	10	89	564	718	44	1838	6	11	<1
Boksburg	63	1067	502	325	410	4294	5	15	4
Brits	7	1098	1086	417	2660	6877	4	9	11
Carletonville	9	239	415	603	79	2339	10	6	3
Ermelo	3	139	245	209	75	2210	6	5	2
Evander	2	213	226	128	739	2297	3	7	<1
Germiston (Dekema)	22	369	716	770	158	4366	5	4	2
Germiston (Rondebult)	84	644	454	477	609	3889	9	34	<1
Germiston (Waterval)	49	388	752	949	118	3779	9	6	1
Johannesburg (Goud Koppies)	48	1551	1471	734	533	3955	13	8	2
Johannesburg(Northern activated)	112	554	487	295	243	3217	11	6	2
Johannesburg(Northern digested)	101	528	352	206	181	2645	9	6	3
Johannesburg(Olifants vlei)	27	1608	981	187	424	1606	5	8	2
Kempton Park	44	1365	2147	305	1069	2605	7	6	3
Klerksdorp	6	457	1838	229	70	1294	5	4	2
Krugersdorp	3	572	470	893	237	1509	4	11	<1

Cd,Cr,Cu,Pb,Ni,Zn: Average of 4 determinations

Hg,As,Se: Determined on composite of 4 samples

db: dry basis

TABLE 4: (continued)

Sewage works	Cd	Cr	Cu	Pb	Ni	Zn	Hg	As	Se
	mg/kg,db								
Middelburg	3	331	162	160	84	1312	7	3	2
Nigel	8	10 015	223	534	122	17 680	7	13	1
Pietersburg(biological plant)	2	334	298	384	55	1966	10	5	4
Pietersburg(Pasveer ditch)	1	258	241	222	51	1273	4	4	3
Phalaborwa	5	1867	80	453	48	1490	9	4	5
Potchefstroom	1	107	200	143	82	1307	4	6	2
Pretoria(Baviaans-poort)	<1	279	133	159	56	1209	3	2	<1
Pretoria (Daspoort)	7	375	673	299	53	1875	15	5	2
Pretoria (Rooiwal)	20	1812	613	448	93	1803	10	5	1
Roodepoort	1	444	244	149	85	1183	5	6	2
Rustenburg	2	363	311	344	71	1817	15	3	3
Sebokeng	1	156	183	113	97	1034	2	10	<1
Springs	30	1158	790	214	660	3578	5	14	2
Standerton	<1	434	240	149	43	1443	5	3	1
Vanderbijlpark	<1	506	386	557	180	3068	18	7	2
Vereeniging	3	2219	304	858	78	1688	4	5	1
Verwoerdburg	<1	685	246	169	43	1886	7	4	3
Witbank	14	518	187	146	41	1408	4	2	3
Amanzimtoti	4	376	879	494	246	3482	3	8	2
Durban (Kwa Mashu)	6	139	209	176	51	607	2	7	2
Durban (Northern)	3	77	298	176	39	796	2	7	4
Ladysmith	2	872	403	163	80	2466	3	8	1
Newcastle	4	176	230	292	110	1397	5	4	2
Pietermaritzburg	5	177	274	213	81	1517	2	6	1
Port Shepstone	3	189	362	533	37	2536	1	7	1
Bellville	3	191	312	269	74	2200	2	5	2
Cape Town (Athlone)	27	547	579	956	110	1896	3	6	3

Cd,Cr,Cu,Pb,Ni,Zn: Average of 4 determinations

Hg,As,Se: Determined on composite of 4 samples

db: dry basis

TABLE 4: (continued)

Sewage works	Cd	Cr	Cu	Pb	Ni	Zn	Hg	As	Se
	mg/kg,db								
Cape Town (Cape Flats)	4	323	381	143	42	774	1	4	3
Cape Town (Mitchell's Plain)	4	49	209	118	30	638	<1	4	3
Cradock	2	91	195	79	29	683	2	5	3
De Aar	<1	206	189	71	33	1015	<1	11	7
Despatch	1	82	231	140	39	834	1	4	4
East London	2	178	17217	10137	138	4618	2	5	2
Graaf Reinet	3	65	397	110	37	977	<1	4	2
Grahamstown	<1	130	383	151	36	1364	5	7	3
Kimberley	2	77	184	112	41	755	<1	3	2
King William's Town	3	220	419	328	24	5021	<1	4	2
Knysna	2	114	373	134	27	1355	2	6	1
Kraaifontein	122	264	385	204	84	1187	<1	11	3
Milnerton	6	126	410	307	54	1154	3	3	3
Oudtshoorn	2	62	580	173	24	913	3	5	2
Paarl	2	287	463	312	20	1406	3	6	2
Parow	1	80	129	70	6	237	1	2	1
Port Elizabeth (Cape Receife)	5	101	270	156	23	709	5	4	3
Port Elizabeth (Fish-water Flats)	3	2240	408	1300	55	1600	<1	4	2
Robertson	4	147	279	192	42	1048	3	8	5
Stellenbosch	4	76	951	211	30	982	14	6	2
Strand	2	107	407	230	41	872	3	7	3
Uitenhage	3	580	645	783	181	2392	3	5	2
Upington	4	98	348	159	26	1035	3	3	4
Vredenberg/Saldanha	2	220	213	226	45	560	2	3	3

Cd,Cr,Cu,Pb,Ni,Zn: Average of 4 determinations

Hg,As,Se: Determined on composite of 4 samples

db: dry basis

TABLE 4: (continued)

Sewage works	Cd	Cr	Cu	Pb	Ni	Zn	Hg	As	Se
	mg/kg,db								
Walvis Bay	3	57	380	306	34	1159	1	6	3
Worcester	2	93	355	311	31	986	<1	5	2
Overall range	<1-122	25-10015	80-17217	67-10137	6-2660	237-17680	<1-22	<1-34	<1-107
Overall mean value	12	551	654	452	154	2054	5	7	4
Overall median value	3	220	355	214	55	1432	3	6	2

Cd,Cr,Cu,Pb,Ni,Zn: Average of 4 determinations

Hg,As,Se: Determined on composite of 4 samples

db: dry basis

TABLE 5: Summary of analysis results (Mo,B,F,pH,TKN,TP,K,Ca,Mg)

Sewage works	Mo	B	F	pH	TKN	TP	K	Ca	Mg
	mg/kg,db			pH units	g/kg,db				
Bethlehem	2	11	59	7,6	21,4	9,8	2,0	25,9	8,3
Bloemfontein	1	22	124	7,0	26,7	11,8	2,1	42,6	9,7
Harrismith	4	14	61	6,4	25,7	8,4	2,4	20,0	7,1
Kroonstad	6	14	92	7,0	19,3	9,3	2,4	34,4	6,0
Parys	9	14	156	6,5	27,6	11,8	1,2	39,4	5,4
Sasolburg	14	60	1260	7,3	41,7	14,8	2,1	59,2	4,2
Virginia	3	58	144	6,7	20,0	5,8	1,6	28,1	4,7
Welkom (Theronia)	7	20	236	6,6	21,4	9,3	1,3	37,6	6,8
Welkom (Witpan)	6	14	162	6,0	17,3	7,9	1,3	34,2	4,5
Boksburg	15	50	191	7,3	25,1	30,3	1,9	41,2	5,2
Brits	12	53	94	7,2	25,8	34,9	2,9	31,7	5,6
Carletonville	8	23	177	6,4	32,5	16,1	1,0	49,7	7,6
Ermelo	7	27	98	6,5	31,0	8,2	2,1	25,2	5,9
Evander	4	29	218	7,5	37,1	17,0	3,2	19,6	6,1
Germiston (Dekema)	24	19	236	7,3	22,0	15,1	2,3	27,4	5,8
Germiston (Rondebult)	14	18	518	7,4	28,6	37,9	1,6	37,4	5,6
Germiston (Waterval)	23	35	136	7,4	27,3	17,8	5,5	26,7	7,4
Johannesburg (Goud (Koppies)	6	29	149	6,7	42,6	24,5	8,6	33,5	8,2
Johannesburg (Northern activated)	5	30	112	7,3	43,6	27,7	6,6	42,6	9,2
Johannesburg (Northern digested)	4	30	116	6,6	38,8	41,0	10,6	31,8	11,5
Johannesburg (Olifantsvlei)	2	34	94	7,2	36,2	26,8	4,8	32,4	5,8
Kempton Park	5	17	404	6,7	35,5	13,5	0,9	29,3	6,4
Klerksdorp	3	30	106	6,3	33,7	22,0	3,3	41,1	7,7
Krugersdorp	5	26	98	7,1	22,4	11,2	2,0	24,4	3,3

Mo, B, F, TKN, TP: Determined on composite of 4 samples

pH, K, Ca, Mg: Average of 4 determinations

db: dry basis

TABLE 5: (continued)

Sewage works	Mo	B	F	pH	TKN	TP	K	Ca	Mg
	mg/kg,db			pH units	g/kg,db				
Middelburg	6	46	65	7,1	51,0	13,5	4,9	17,7	5,9
Nigel	6	15	65	6,5	33,9	28,3	1,1	25,4	3,5
Pietersburg (biological plant)	4	27	56	6,8	35,4	12,2	1,8	39,3	7,1
Pietersburg (Pasveer ditch)	3	46	60	7,3	50,6	11,0	2,7	27,5	7,0
Phalaborwa	5	34	115	6,8	51,6	16,0	4,5	29,4	9,5
Potchefstroom	7	78	122	7,3	44,2	23,1	4,1	21,8	9,9
Pretoria (Baviaanspoort)	2	6	42	7,0	16,7	7,4	1,6	28,0	3,3
Pretoria (Daspoort)	2	18	97	6,3	22,2	20,5	1,3	40,2	7,5
Pretoria (Rooiwal)	4	25	92	6,7	24,9	23,0	2,0	43,6	7,7
Roodepoort	2	32	47	7,0	44,7	24,4	0,8	21,3	6,3
Rustenburg	3	31	52	6,4	38,2	13,4	2,3	37,2	7,7
Sebokeng	8	28	119	7,1	20,8	32,5	1,4	30,2	4,3
Springs	12	23	200	6,7	26,8	16,9	1,5	38,3	4,6
Standerton	3	35	56	6,9	29,7	16,8	4,5	18,2	8,2
Vanderbijlpark	7	39	208	6,6	30,9	20,1	2,6	49,7	6,1
Vereeniging	9	22	186	7,1	39,7	11,6	1,8	39,5	5,4
Verwoerdburg	5	37	76	7,1	37,1	16,1	4,4	29,8	7,7
Witbank	4	22	92	7,2	58,4	12,6	4,1	16,5	6,9
Amanzimtoti	11	36	90	6,6	27,4	10,8	2,1	21,9	4,1
Durban (Kwa Mashu)	7	31	46	5,4	33,1	16,1	1,7	15,0	3,1
Durban (Northern)	7	35	46	6,1	35,4	23,1	1,5	24,2	4,9
Ladysmith	5	14	59	5,9	17,8	31,1	1,5	18,1	3,4
Newcastle	10	35	146	6,6	24,9	10,9	1,3	28,5	4,0
Pietermaritzburg	5	12	54	6,2	28,9	14,3	1,4	22,1	3,0
Port Shepstone	4	45	56	7,5	34,5	25,9	10,9	22,5	8,9
Bellville	6	21	69	7,1	23,3	10,7	1,3	42,1	3,0
Cape Town (Athlone)	18	18	141	6,5	30,4	15,0	1,2	29,1	3,7

Mo, B, F, TKN, TP: Determined on composite of 4 samples

pH, K, Ca, Mg: Average of 4 determinations

db: dry basis

TABLE 5: (continued)

Sewage works	Mo	B	F	pH	TKN	TP	K	Ca	Mg
	mg/kg,db			pH units	g/kg,db				
Cape Town (Cape Flats)	4	29	52	7,0	34,8	18,9	1,8	39,8	4,7
Cape Town (Mitchell's Plain)	3	18	62	7,1	22,2	6,8	1,1	54,8	2,8
Cradock	5	57	89	6,9	53,4	9,4	4,0	21,6	5,0
De Aar	4	24	81	6,4	48,4	13,9	4,3	25,5	8,0
Despatch	3	43	85	6,6	36,9	19,4	5,2	24,4	10,4
East London	6	27	144	6,7	23,7	8,5	1,4	28,6	3,1
Graaf Reinet	7	18	79	7,3	21,3	7,1	2,1	36,4	6,7
Grahamstown	6	23	56	6,5	27,8	11,1	1,3	30,0	4,2
Kimberley	6	46	119	7,1	45,1	14,4	3,4	23,2	7,1
King William's Town	5	23	41	6,2	21,4	6,1	1,3	18,8	3,5
Knysna	10	23	111	6,7	20,0	9,5	0,9	29,4	3,3
Kraaifontein	6	28	82	6,6	27,4	10,5	1,0	33,5	3,9
Milnerton	6	20	98	6,2	22,4	11,8	0,7	22,6	2,3
Oudtshoorn	4	32	98	6,9	23,0	13,6	2,1	60,3	13,2
Paarl	8	20	133	7,8	28,9	20,0	1,1	79,3	2,4
Parow	4	16	32	7,6	16,8	4,1	1,9	52,0	2,4
Port Elizabeth (Cape Receife)	4	46	46	6,8	45,5	11,9	2,3	27,4	4,5
Port Elizabeth (Fish-water Flats)	10	13	87	6,7	32,7	13,3	1,2	21,0	3,5
Robertson	4	40	120	6,0	32,3	8,8	1,8	20,0	4,2
Stellenbosch	4	31	37	5,8	20,6	7,1	0,9	11,4	1,9
Strand	4	60	84	7,1	42,4	12,5	2,0	47,3	4,0
Uitenhage	7	38	69	7,1	20,6	11,6	1,3	37,4	3,4
Upington	7	53	246	6,4	28,5	6,1	1,6	25,3	5,2
Vredenberg/Saldanha	4	65	146	7,0	23,5	7,1	3,0	15,1	3,8

Mo, B, F, TKN, TP: Determined on composite of 4 samples

pH, K, Ca, Mg: Average of 4 determinations

db: dry basis

TABLE 5: (continued)

Sewage works	Mo	B	F	pH	TKN	TP	K	Ca	Mg
	mg/kg,db			pH units	g/kg,db				
Walvis Bay	4	43	116	7,2	25,6	14,3	3,1	49,4	8,1
Worcester	13	21	59	6,4	31,6	10,7	1,2	23,0	3,5
Overall range	1-24	6-78	32-1260	5,4-7,8	16,7-58,4	4,1-41,0	0,7-10,9	11,4-79,3	1,9-13,2
Overall mean value	6	31	128	6,8	31,0	15,6	2,5	31,8	5,7
Overall median value	5	28	97	6,8	28,9	13,5	1,9	29,3	5,4

Mo, B, F, TKN, TP: Determined on composite of 4 samples

pH, K, Ca, Mg: Average of 4 determinations

db: dry basis

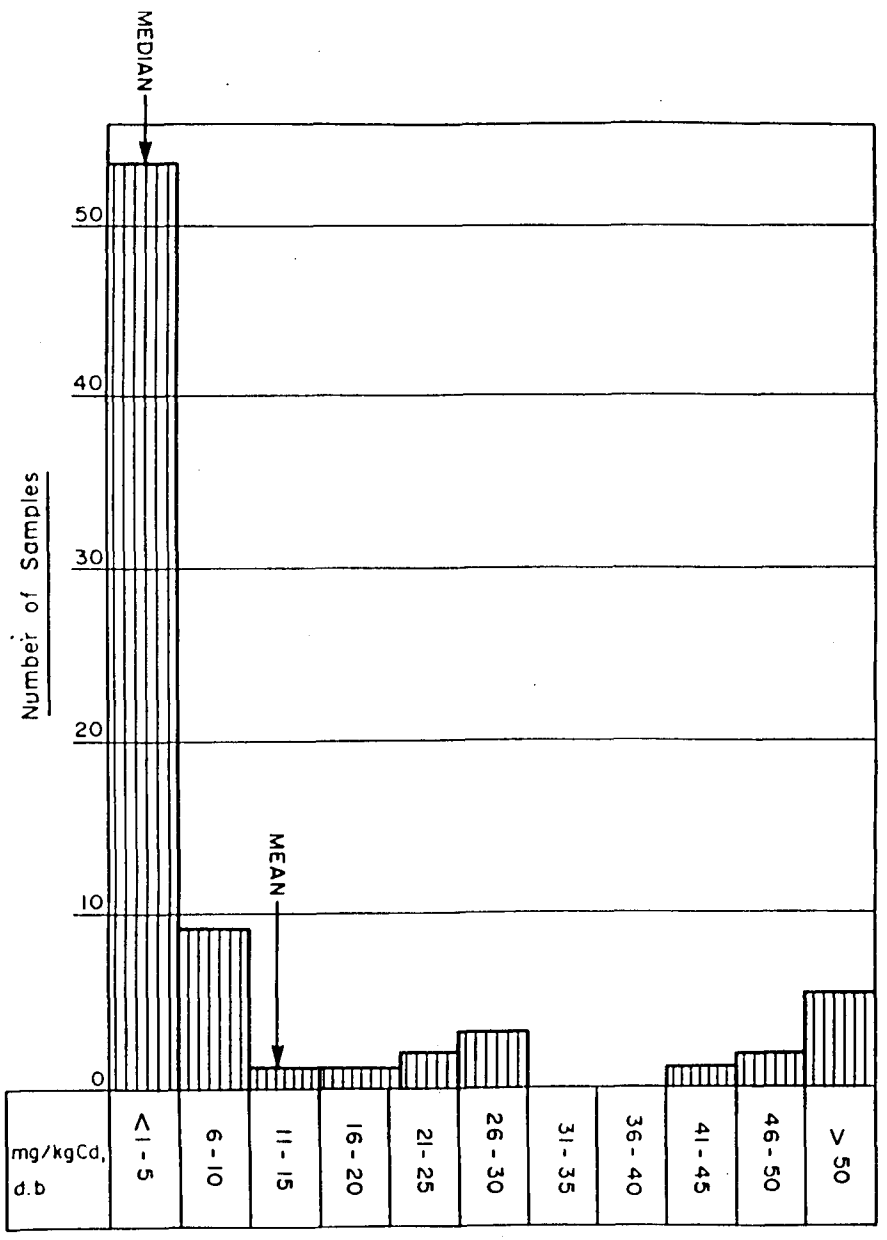

Figure 2: *Cadmium concentrations in S.A. sewage sludges.*

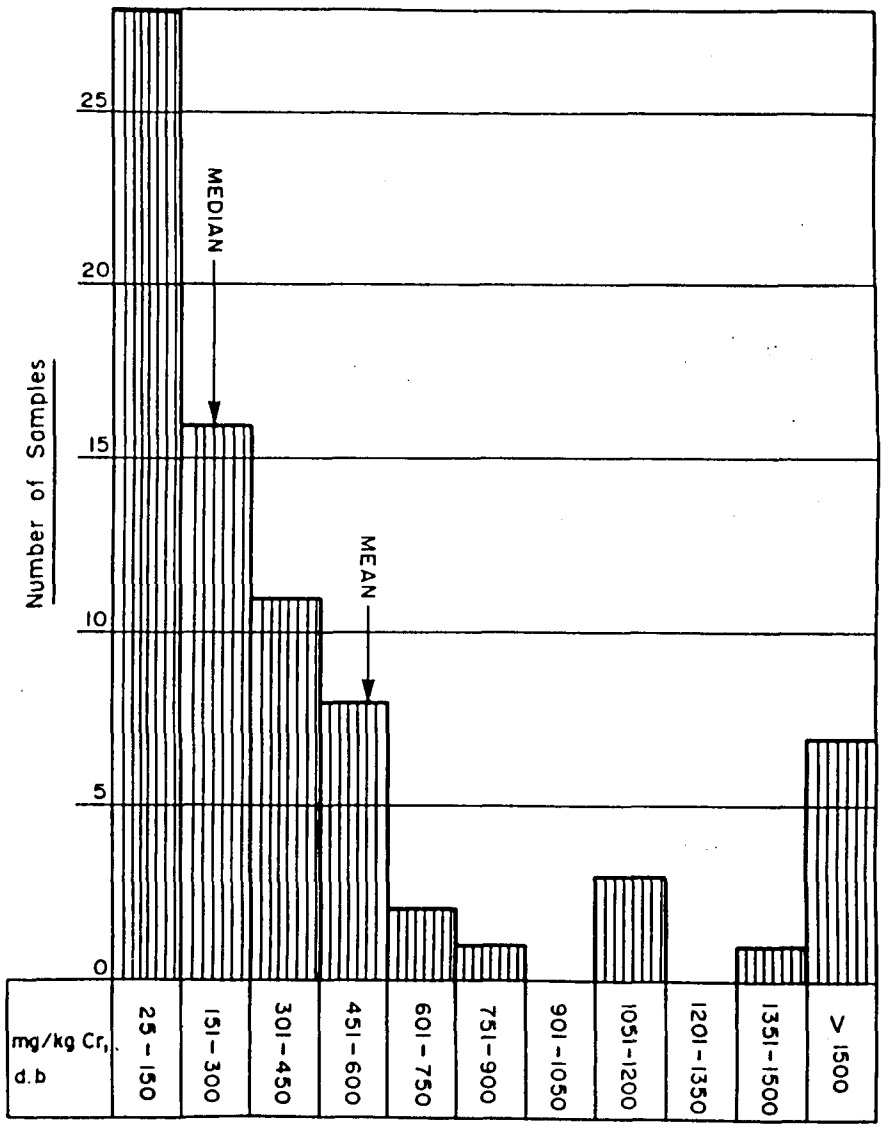

Figure 3: *Chromium concentrations in S.A. sewage sludges.*

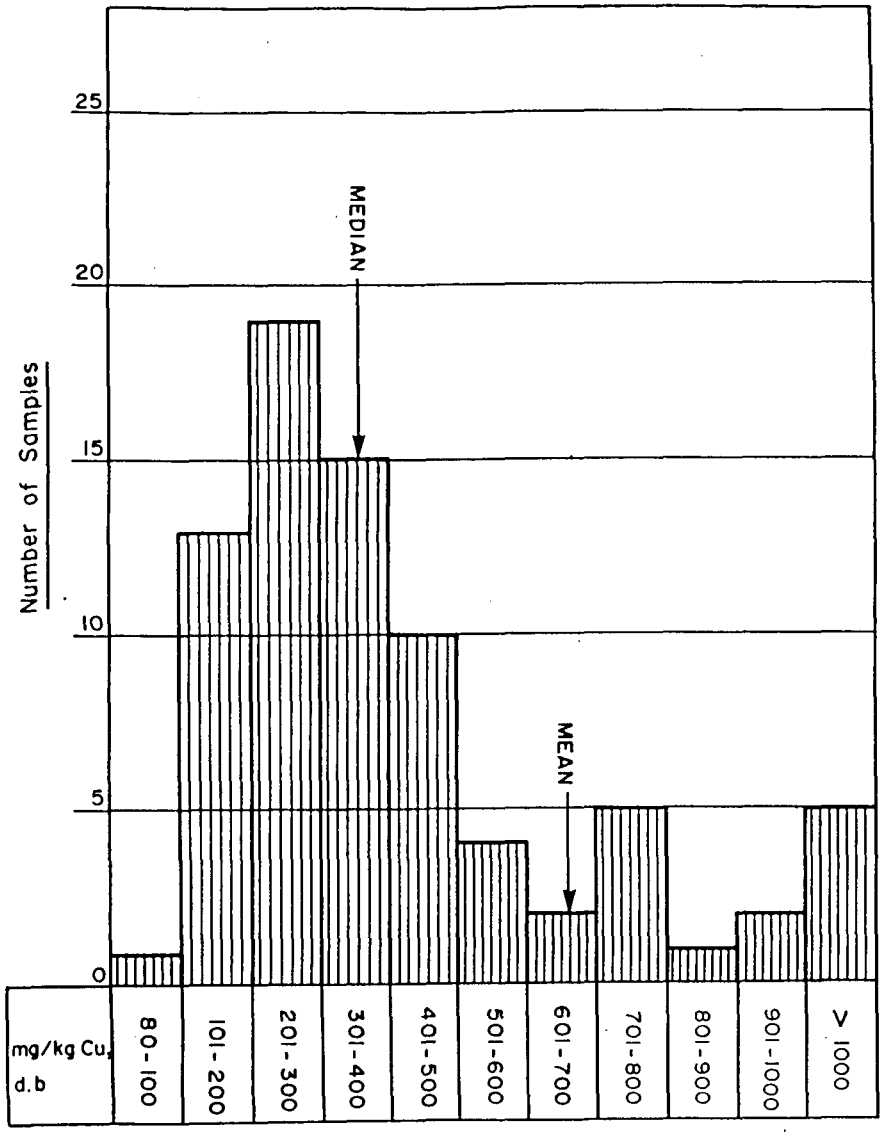

Figure 4 : *Copper concentrations in S.A. sewage sludges.*

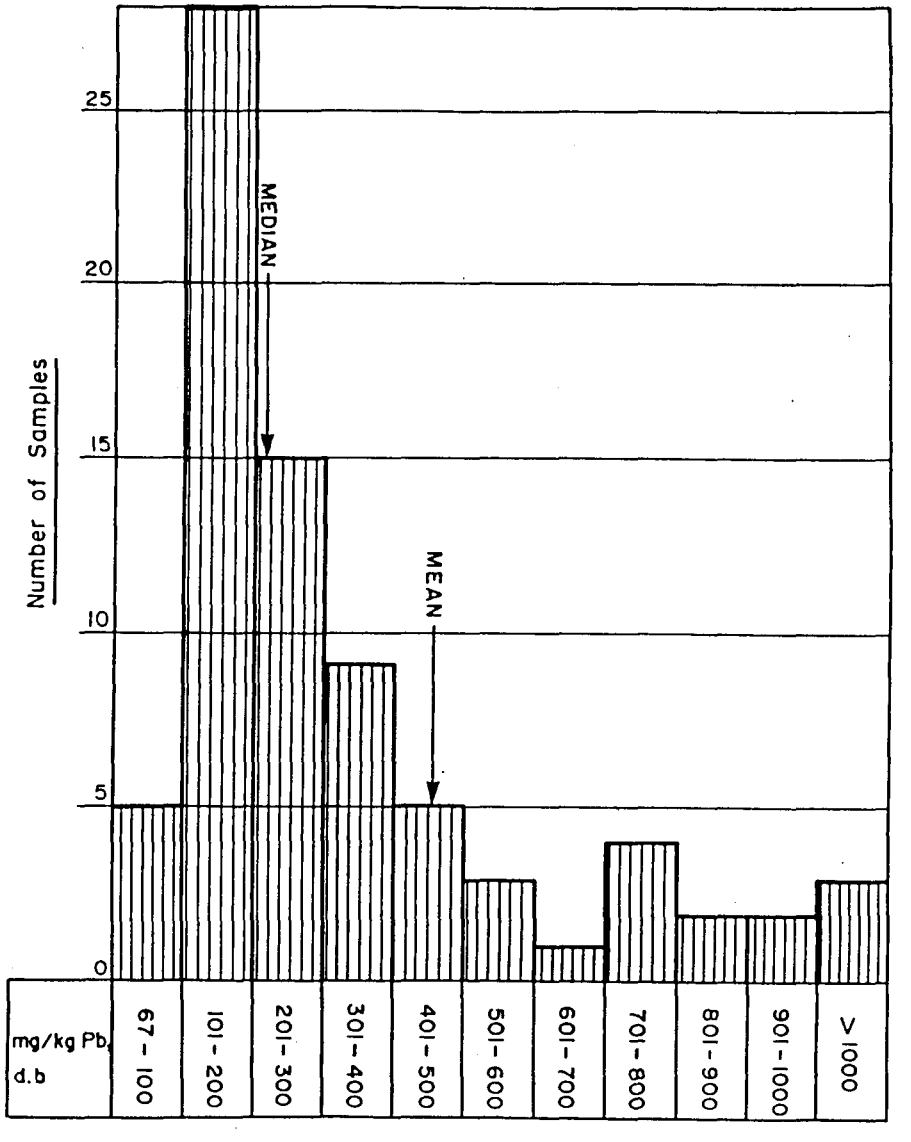

Figure 5 : *Lead concentrations in S.A. sewage sludges.*

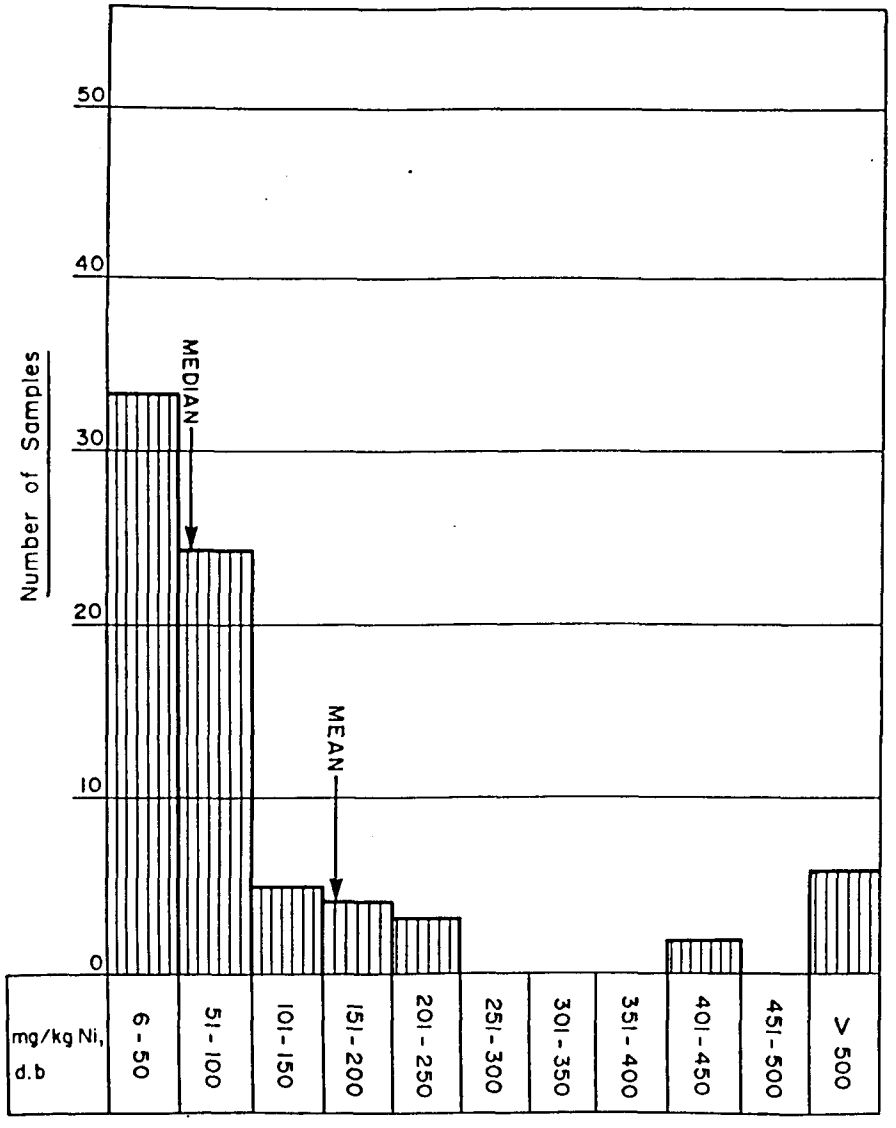

Figure 6: *Nickel concentrations in S.A. sewage sludges.*

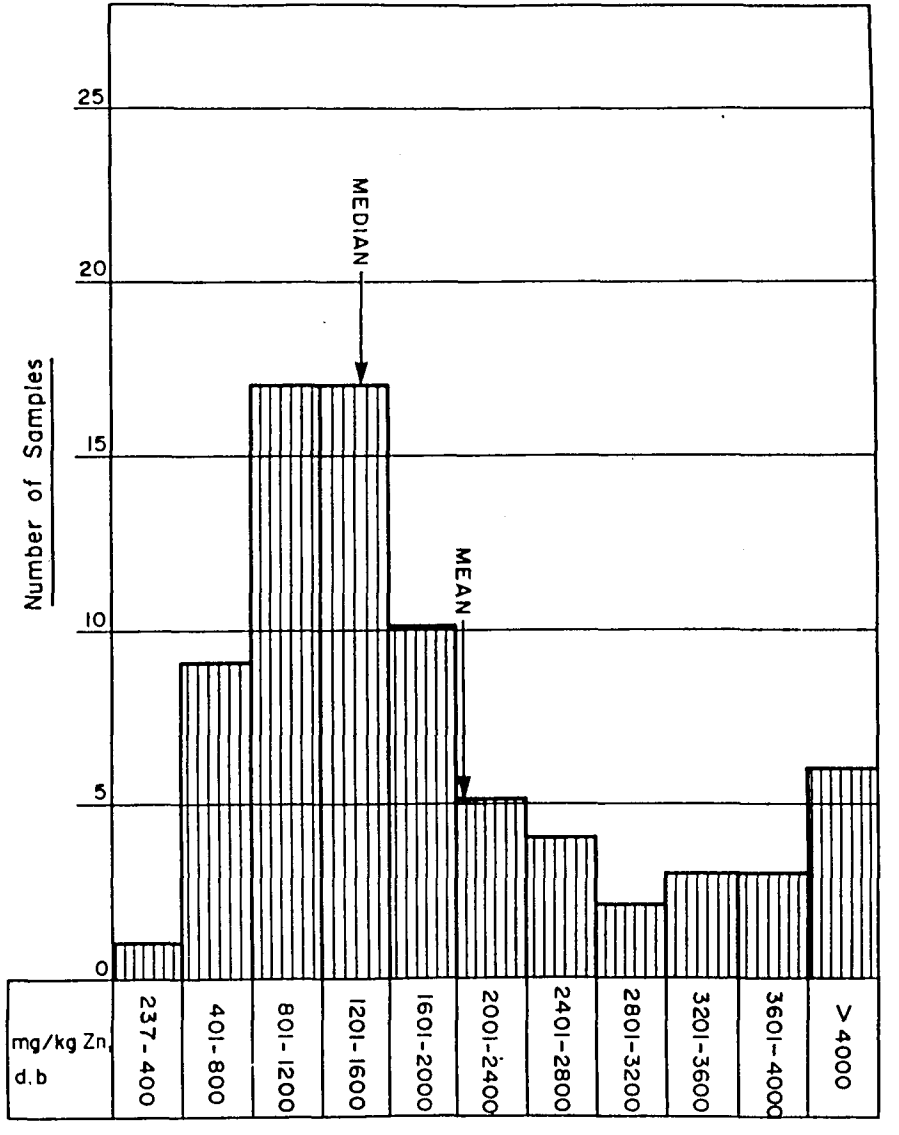

Figure 7: *Zinc concentrations in S.A. sewage sludges.*

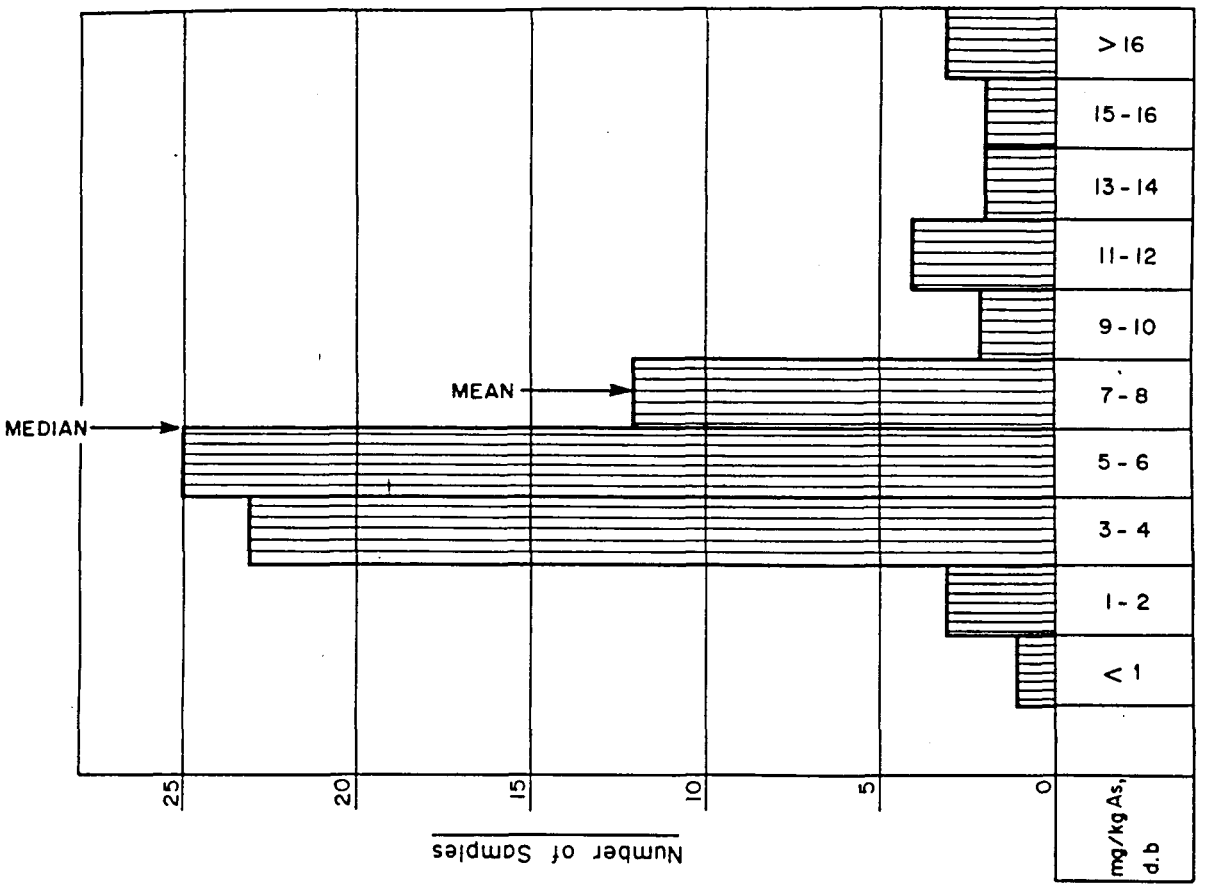

Figure 9 : *Arsenic concentrations in S.A. sewage sludges.*

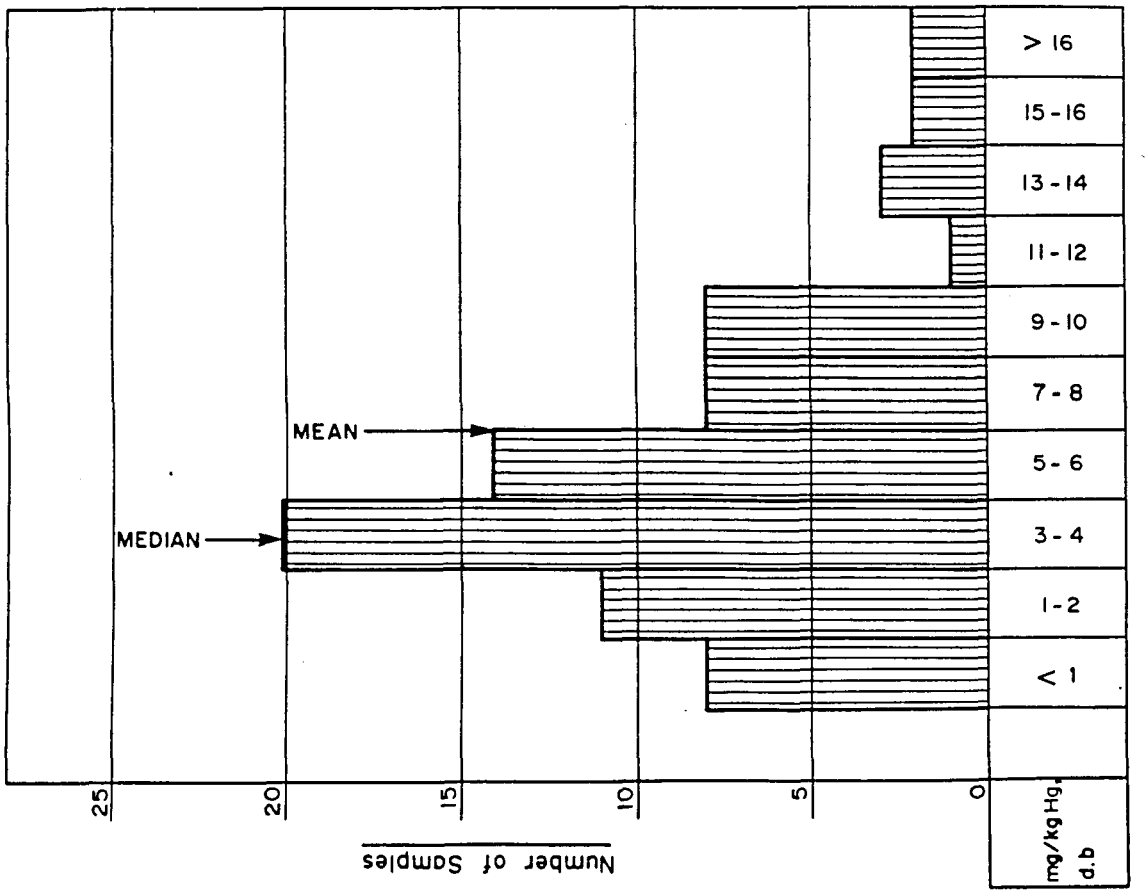

Figure 8 : *Mercury concentrations in S.A. sewage sludges.*

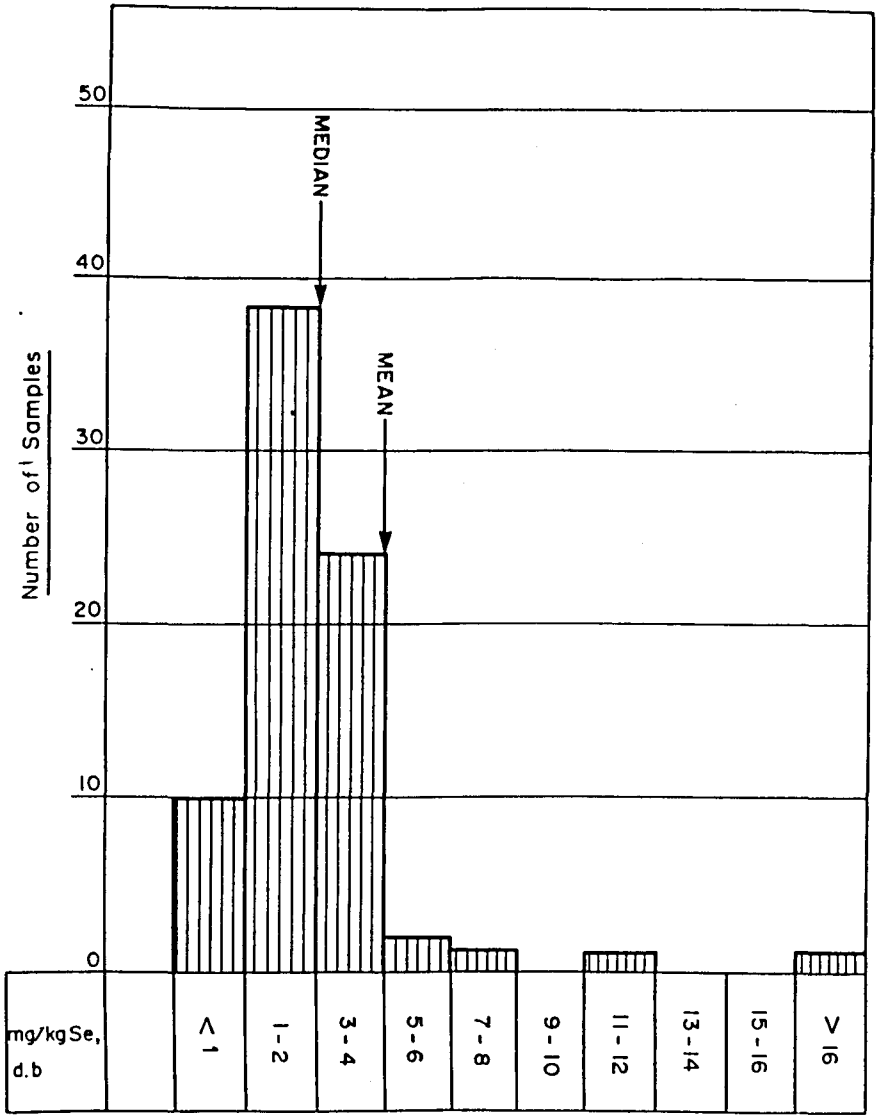

Figure 10 : *Selenium concentrations in S.A. sewage sludges.*

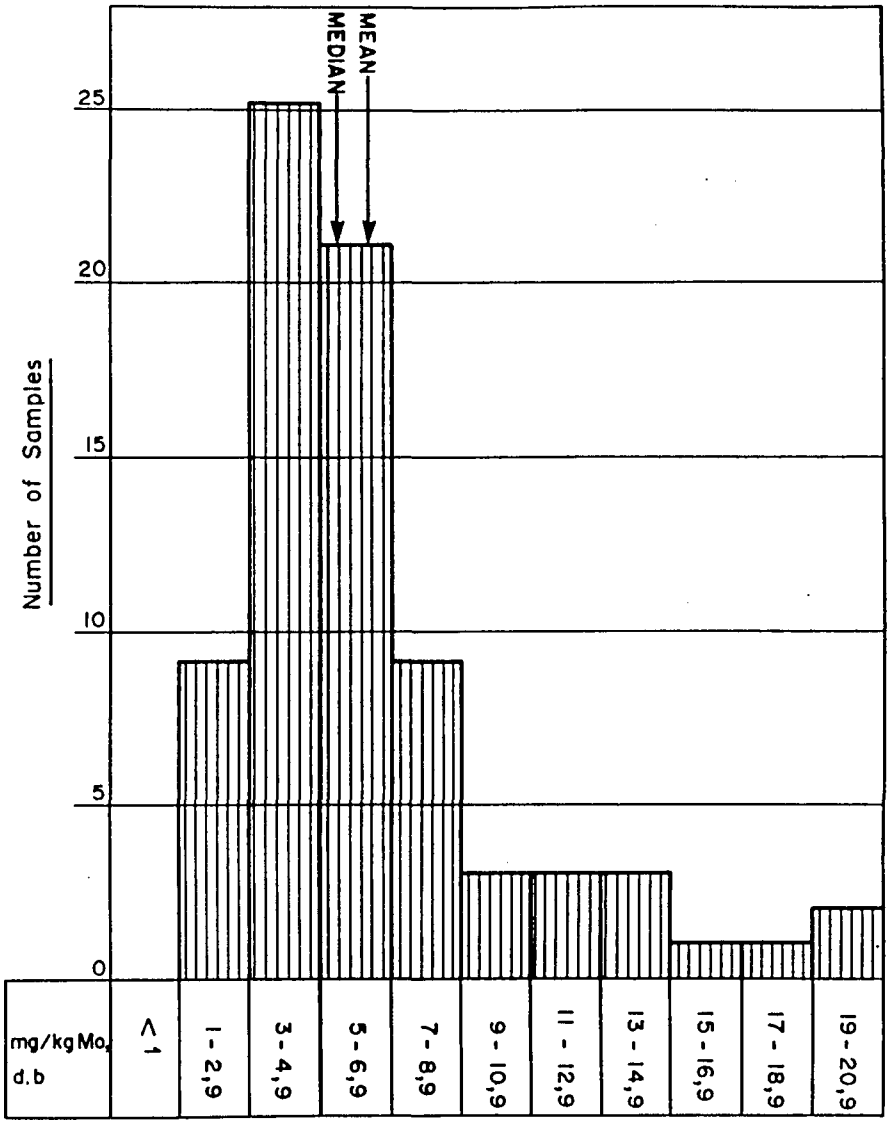

Figure 11 : *Molybdenum concentrations in S.A. sewage sludges.*

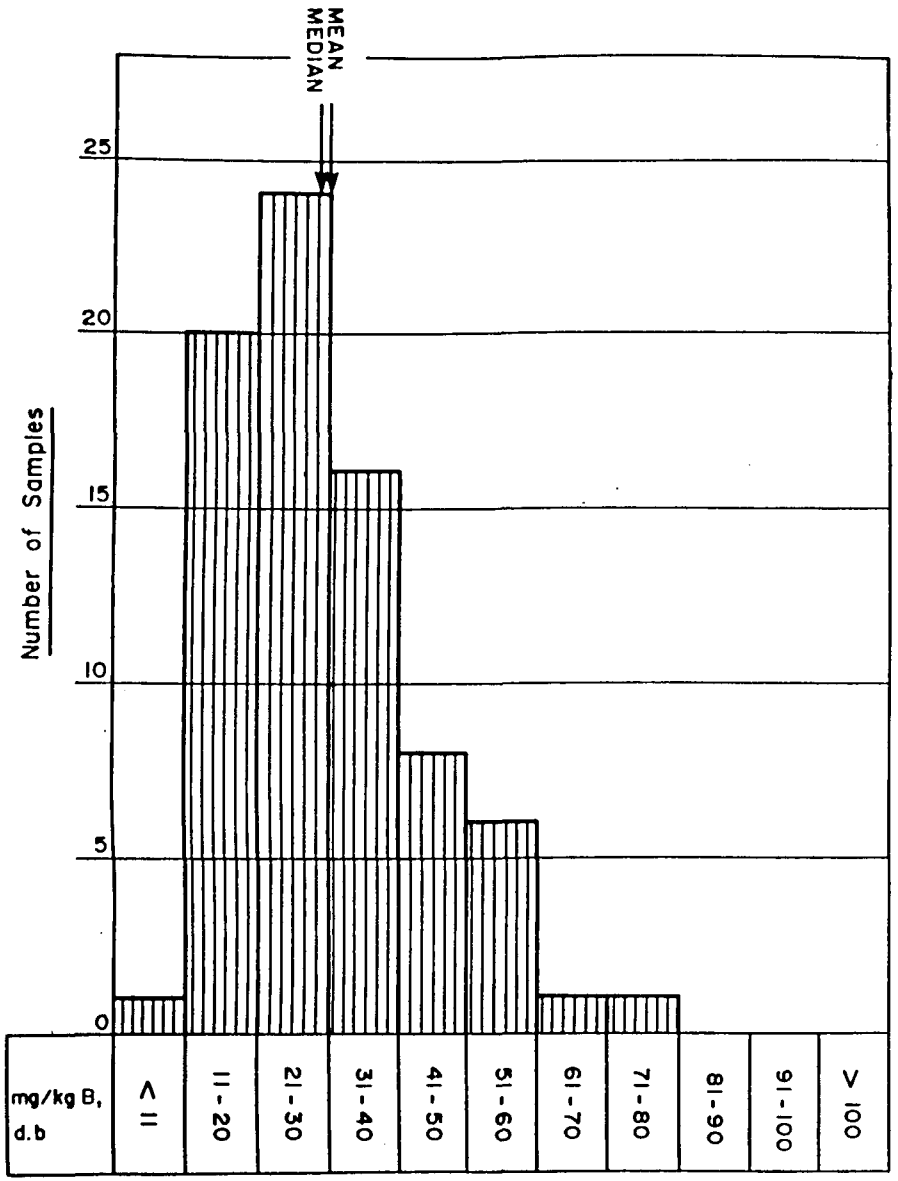

Figure 12: *Boron concentrations in S.A. sewage sludges.*

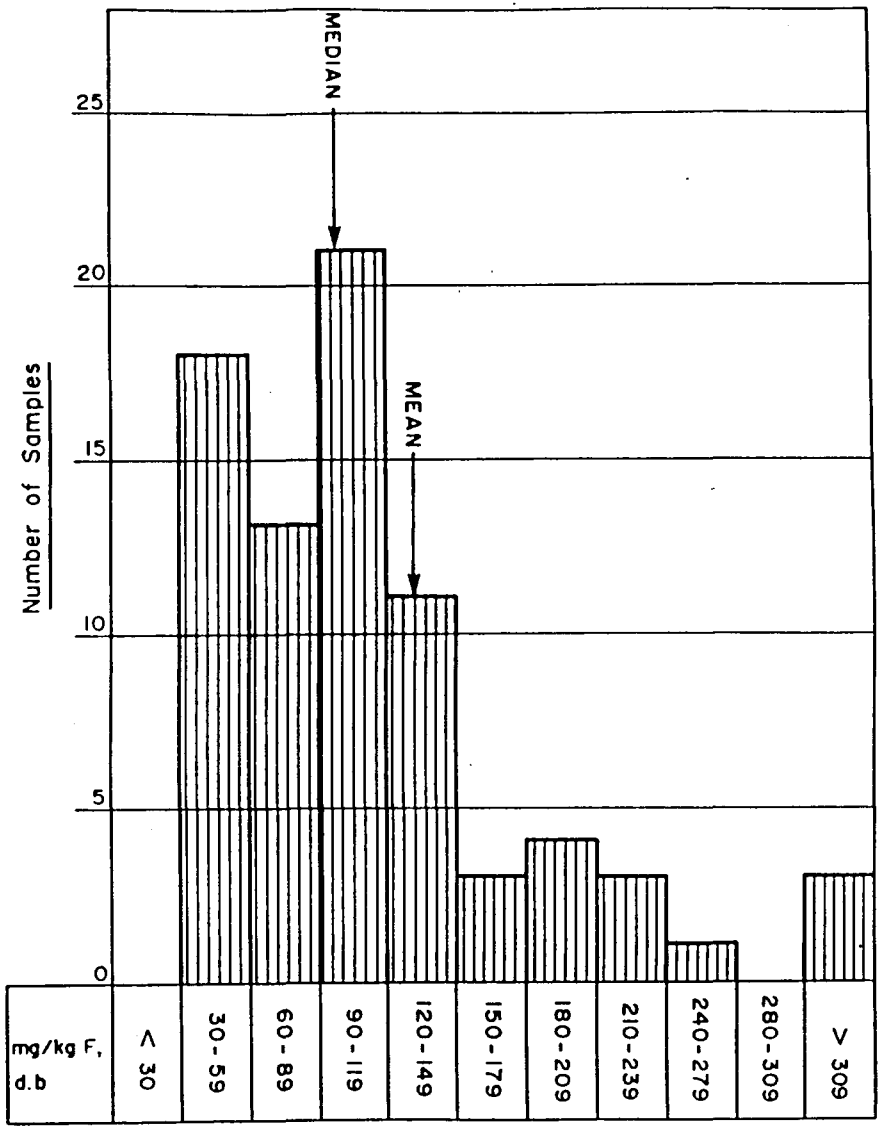

Figure 13: *Fluoride concentrations in S.A. sewage sludges.*

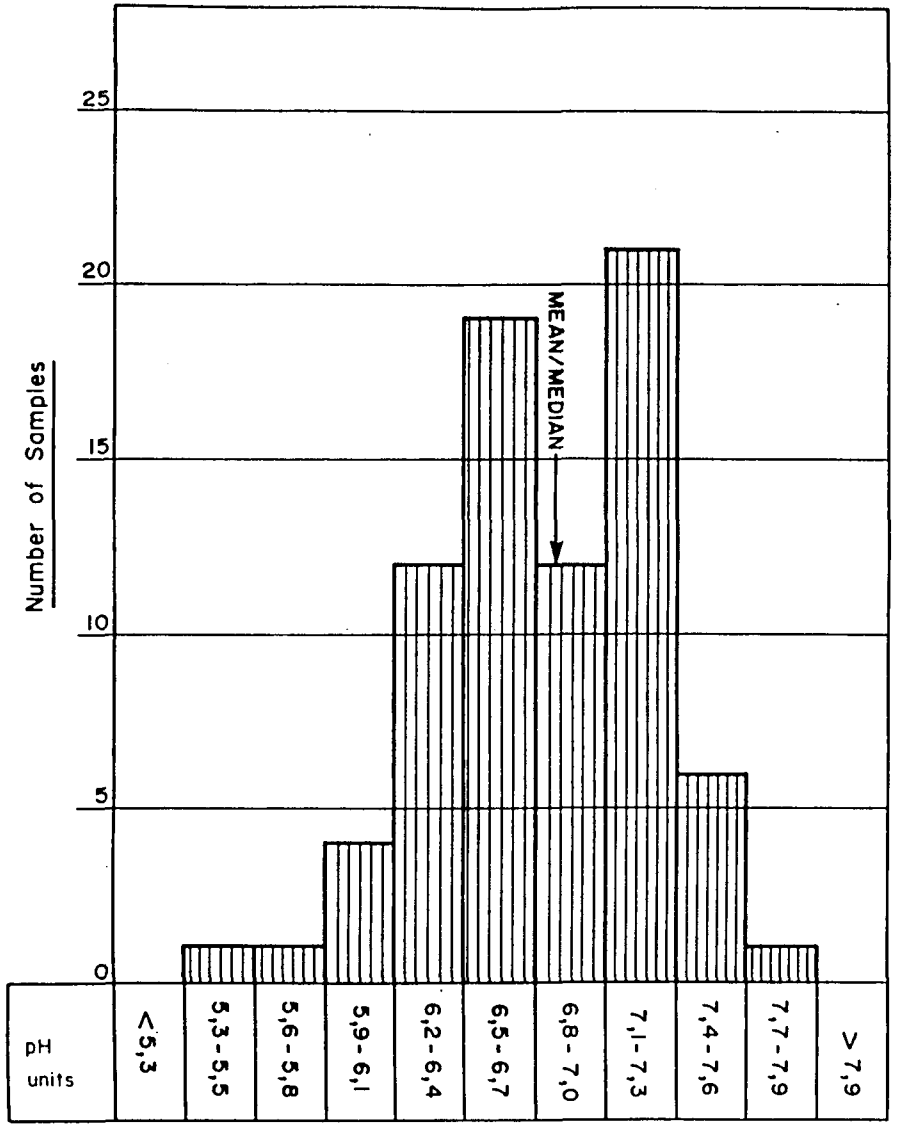

Figure 14: *pH values of S.A. sewage sludges.*

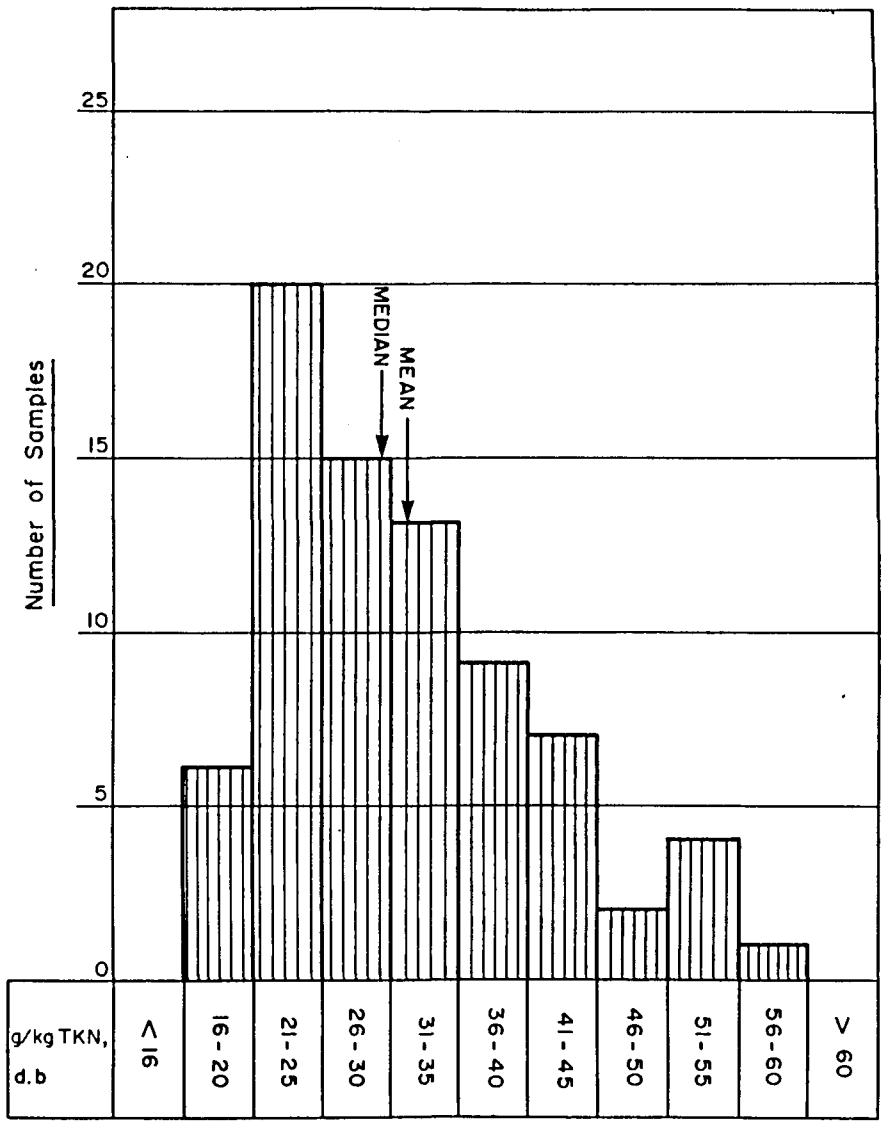

Figure 15: *Total Kjeldahl Nitrogen concentrations in S.A. sewage sludges.*

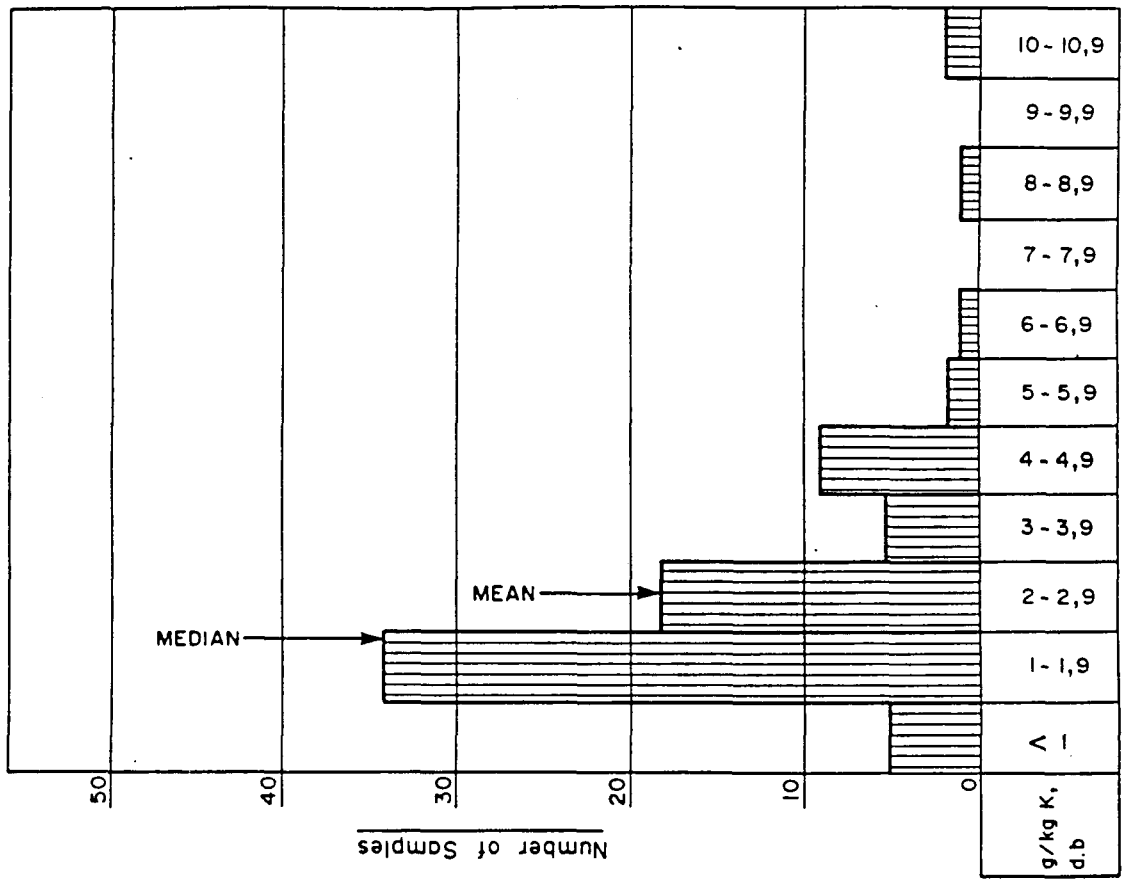

Figure 17: *Potassium concentrations in S.A. sewage sludges.*

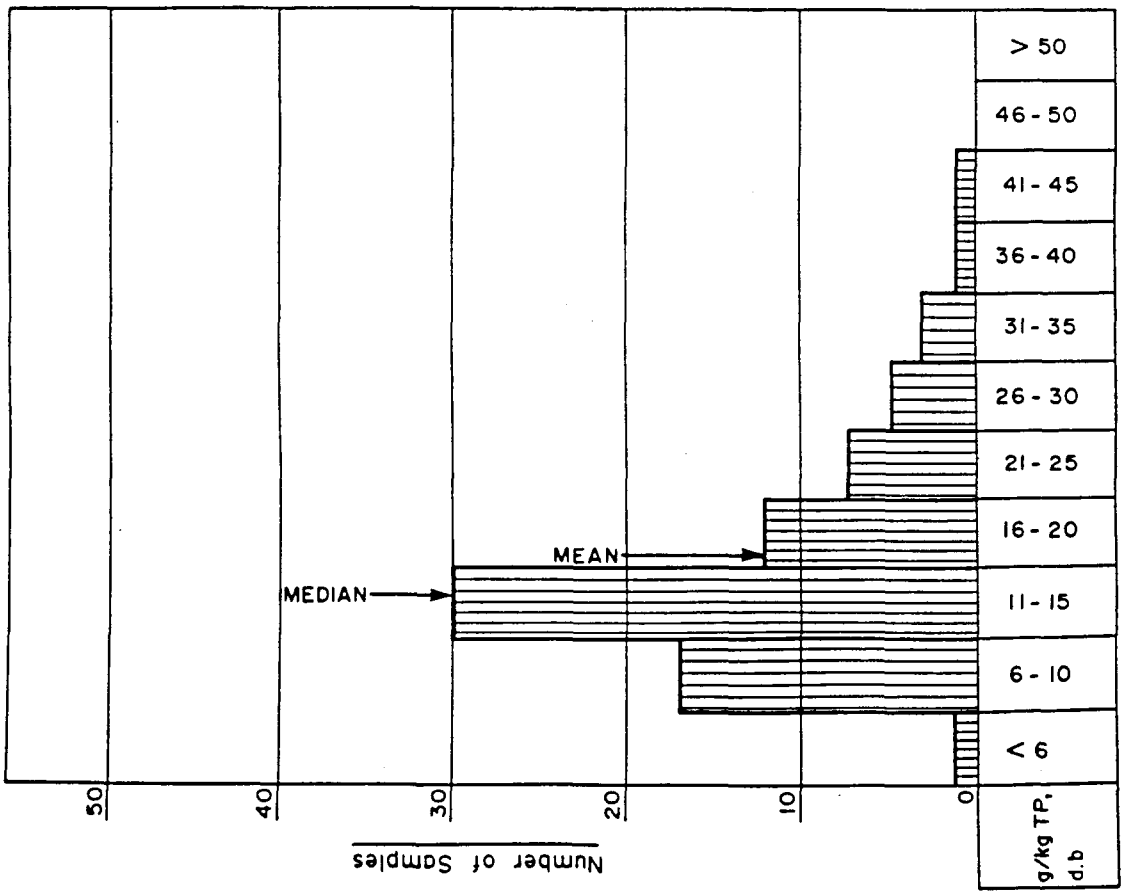

Figure 16: *Total Phosphorus concentrations in S.A. sewage sludges.*

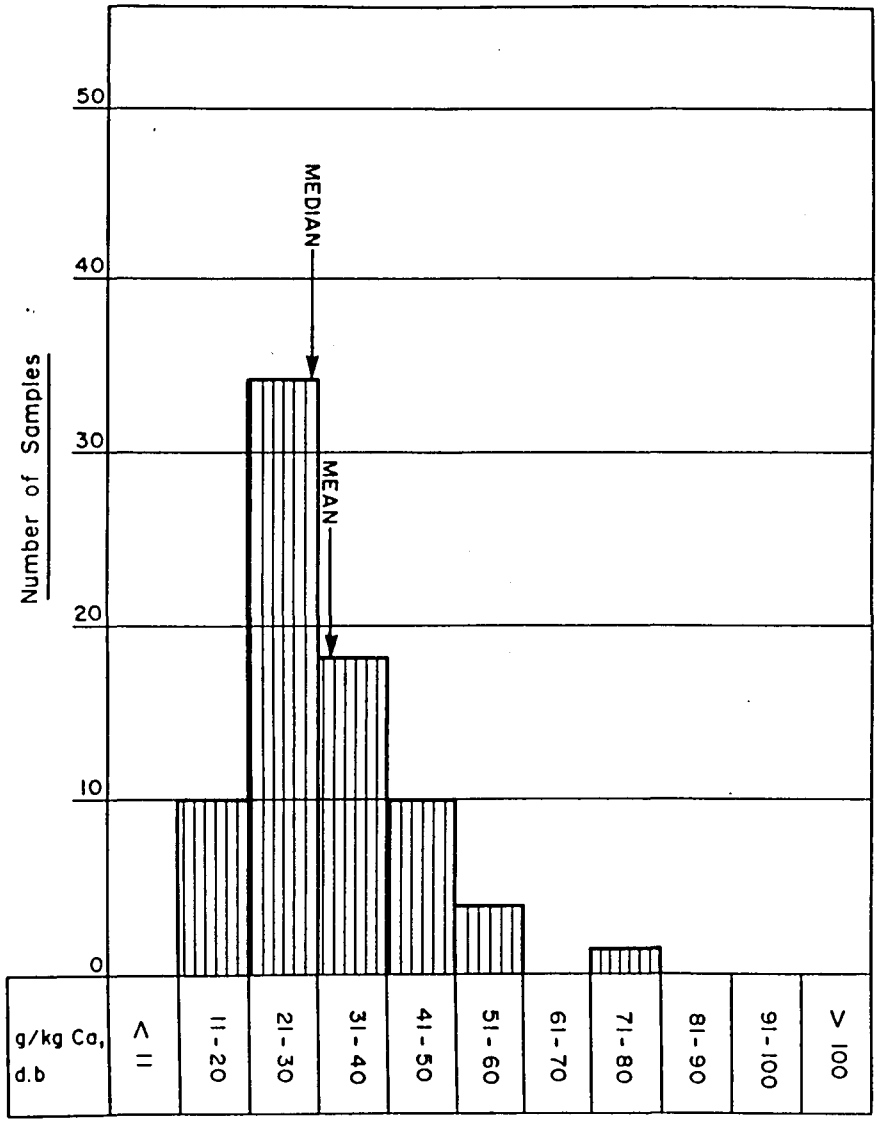

Figure 18: *Calcium concentrations in S.A. sewage sludges.*

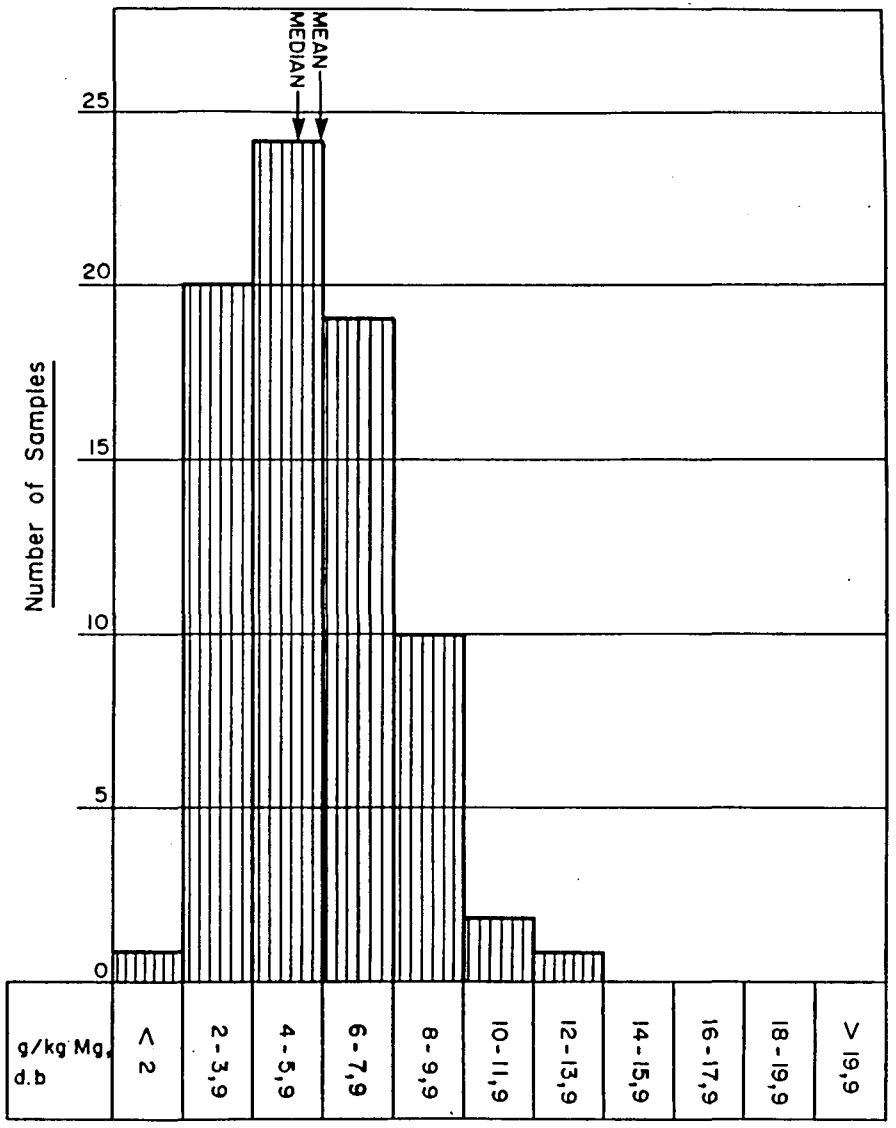

Figure 19: *Magnesium concentrations in S.A. sewage sludges.*

TABLE 6: Contaminant concentrations (mg/kg, dry basis) found in UK sludges.[6]

Contaminant	Range	'Common value'	RSA-range	RSA-mean value	RSA-median value
Cadmium	2 - 1 500	20	<1 - 122	12	3
Chromium	40 - 14 000	400	25 - 10015	551	220
Copper	200 - 8 000	650	80 - 17217	654	355
Lead	50 - 3 600	400	67 - 10137	452	214
Nickel	20 - 5 300	100	6 - 2660	154	55
Zinc	600 - 20 000	1 500	237 - 17680	2054	1432
Mercury	<1 - 18	5	<1 - 22	5	3
Arsenic	3 - 30	20	<1 - 34	7	6
Selenium	1 - 10	3	<1 - 107	4	2
Molybdenum	1 - 40	6	1 - 24	6	5
Boron	15 - 1 000	30	6 - 78	31	28
Fluoride	60 - 40 000	250	32 - 1260	128	97

TABLE 7: Nutrient concentrations (g/kg, dry basis) found in UK air-dried (mainly digested) sewage sludges.[7]

Nutrient		Range	RSA: range
Nitrogen	(N)	15 - 25	17 - 58
Phosphorus	(P)	5 - 18	4 - 41
Potassium	(K)	1 - 3	1 - 11
Calcium	(Ca)	16 - 25	11 - 79
Magnesium	(Mg)	1 - 5	2 - 13

2.4 Analysis of reference standards

The use of standard or certified reference materials in an analysis is highly recommended. These samples have a certified content of a constituent, or constituents, being determined, and the analysis of these samples in conjunction with the analysis of the unknown samples can indicate whether the particular analytical procedure being used is satisfactory or unsatisfactory.

Standard reference materials used in the determinations of the various constituents were:

(a) US Environmental Protection Agency: Quality Control Sample - Municipal Digested Sludge.

(b) Community Bureau of Reference: Reference Material 32 - Natural Moroccan Phosphate Rock.

(c) Community Bureau of Reference: Reference Material 143 - Sewage Sludge Amended Soil.

(d) Community Bureau of Reference: Reference Material 145 - Sewage Sludge.

For every set of analyses carried out, the appropriate reference material was also analysed. Actual results obtained, along with the certified values, are shown in Table 8. With only a few exceptions, the results obtained were close enough to the certified value to ensure confidence in the analytical procedures employed. The only significant deviation was in the arsenic determination on the EPA sample where the values found were somewhat lower than the 'certified' value. No apparent reason could be found in this case. On the other hand, the arsenic values found for the BCR reference material were acceptably close.

TABLE 8: Comparison between reference standard certified values and values found using the same methods as for the sewage sludge samples

Determinand	Reference standard	Units	Certified value	Values found	Average
Copper	BCR 145	mg/kg, db.	429	439; 433; 427; 424; 436.	431
	EPA	mg/kg, db.	1095	1100; 1113	1107
Cadmium	BCR 145	mg/kg, db.	18,0	15,8; 16; 16; 16; 15,6	15,9
	EPA	mg/kg, db.	20,8	18,0; 18,5; 19,0	18,5
Chromium	BRC 145	mg/kg, db.	105*	87; 88; 84	86
	EPA	mg/kg, db.	204	175; 184	180
Lead	BRC 145	mg/kg, db.	394	359; 364; 354; 344	355
	EPA	mg/kg, db.	519	556; 562	559
Nickel	BRC 145	mg/kg, db.	41,4	42; 43; 42; 42; 41	42
	EPA	mg/kg, db.	198	193; 193; 197; 189	193
Zinc	BRC 145	mg/kg, db.	2843	2884; 2859; 2810; 2820; 2820; 2884; 2988	2874
	EPA	mg/kg, db.	1323	1443; 1440; 1390	1424
Mercury	BCR 145	mg/kg, db.	8,8	7,1; 6,5; 6,0; 9,0	7,2
	EPA	mg/kg, db.	16,3	18	18
Arsenic	BRC 145	mg/kg, db.	3,7*	4,0; 4,0; 3,9; 3,9; 3,9	3,9
	EPA	mg/kg, db.	16,9	10,1; 11.1; 9,8; 11,2	10,6
Calcium	BRC 145	g/kg, db.	104*	118; 106; 107; 106; 104	108

TABLE 8: (continued)

Determinand	Reference standard	Units	Certified value	Values found	Average
Magnesium	BCR 145	g/kg, db.	15,5*	17,6; 17,8	17,7
Potassium	BCR 145	g/kg, db.	2,5*	1,3; 1,4; 1,4; 1,4; 1,5; 1,5	1,4
Total Kjeldahl nitrogen	EPA	g/kgN, db.	25,2	24,5; 24,4; 24,4; 24,5	24,5
Total phosphorus	BCR 145	g/kgP, db.	30,7*	30,8; 30,9; 30,9; 30,5	30,8
	EPA	g/kgP, db.	11,6	10,4; 10,0; 10,2	10,2
Molybdenum	BCR 143	mg/kg, db.	6,7*	6,3; 6,1; 6,0; 6,0; 6,1; 6,0; 5,9; 5.3	6,0
Selenium	BCR 145	mg/kg, db.	3,3*	3,1; 3,1; 3,1;	3,1
Fluoride	BCR 32	mg/kg, db.	40,4	38; 40; 41; 40; 38; 41; 40	40

* : 'Indicative' values

: Aqua regia-soluble value: 85,2 mg/kg, db.

EPA : US Environmental Protection Agency: Quality Control Sample - Municipal Digested Sludge

BCR 32 : Community Bureau of Reference: Reference Material 32 - Natural Moroccan Phosphate Rock

BCR 143 : Community Bureau of Reference: Reference Material 143 - Sewage Sludge Amended Soil

BCR 145 : Community Bureau of Reference: Reference Material 145 - Sewage Sludge

db : dry basis

3. PROPOSED SOUTH AFRICAN GUIDELINES FOR MAXIMUM PERMISSIBLE CONCENTRATIONS OF INORGANIC CHEMICAL CONTAMINANTS IN SEWAGE SLUDGES FOR LAND APPLICATION

It is advisable that the application of sewage sludge to agricultural land should be strictly controlled in order to minimise the risks associated with this practice. Guidelines in existence in many overseas countries [32] at the time this project was commenced were reviewed (Table 9). It can be seen from this table that there are, in many cases, significant differences in the guidelines laid down by the various countries.

In 1984, there being no guidelines in existence in South Africa for the application of sewage sludge to agricultural land, the National Institute for Water Research prepared a set of suggested guidelines for the Department of National Health and Population Development, based largely on results of a survey on the concentrations of heavy metals in sewage sludges in the Cape Province.[33,34,35] Limits were suggested for cadmium, cobalt, chromium, copper, mercury, molybdenum, nickel, lead and zinc, in the case of 'Type D' sludge (i.e. pasteurised, heat-treated, irradiated, lime-stabilised, fumigated or composted sludge) produced for unlimited use on land at a maximum application rate of 8 dry tons/hectare/year (Table 10).

In formulating the suggested guidelines listed in Table 11 cognisance was taken of the following:

(i) Existing overseas guidelines [32] (Table 9).
(ii) Guidelines proposed by the National Institute for Water Research for the Department of National Health and Population Development[35] (Table 10).
(iii) Results obtained from the analysis of sludges from the seventy-seven South African sewage works co-operating in this project (Tables 4, 5).

In addition to those contaminants for which maximum limits were established for the Department of National Health and Population Development (Table 10), maximum permissible concentrations were also proposed for arsenic, selenium, boron and fluoride, while a recommended range

TABLE 9: Maximum permissible contaminant concentrations (mg/kg, dry basis) in sewage sludges for application to agricultural land (overseas)[32]

Country \ Contaminant	Cd	Cr	Cu	Pb	Ni	Zn	Hg	As	Se	Mo
Belgium	10	500	500	300	100	2000	10	10	25	-
Denmark	8	-	-	400	30	-	6	-	-	-
Finland	30	1000	3000	1200	500	5000	25	-	-	-
France	20	1000	1000	800	200	3000	10	-	100	-
Germany	20	1200	1200	1200	200	3000	25	-	-	-
Netherlands	10	500	600	500	100	2000	10	10	-	-
Norway	10	200	1500	300	100	3000	7	-	-	-
Sweden	15	1000	3000	300	500	10000	8	-	-	-
Switzerland	30	1000	1000	1000	200	3000	10	-	-	20
Canada*	20	-	-	500	180	1850	5	75	14	20
EEC-recommended	20	750	1000	750	300	2500	16	-	-	-
EEC-mandatory	40	-	1500	1000	400	3000	-	-	-	-
Lowest recommended value	8	200	500	300	30	1850	5	10	14	20
Highest recommended value	40	1200	3000	1200	500	10000	25	75	100	20
Mean of recommended values	19	795	1430	690	235	3485	12	32	25	20
Median recommended value	20	1000	1100	675	200	3000	10	10	46	20

* Canada: Values apply to sludges and sludge-based commercial products containing <5% nitrogen.

TABLE 10: Maximum metal content in Type D sewage sludge[35]

Metal	Maximum metal content (mg/kg dry sludge)
Cadmium	20
Cobalt	100
Chromium	2750
Copper	750
Mercury	10
Molybdenum	25
Nickel	200
Lead	250
Zinc	2750

TABLE 11. Proposed South African guidelines for maximum permissible concentrations of inorganic chemical contaminants in sewage sludges for land application

Contaminant	Maximum permissible concentration (mg/kg, dry basis)
Cadmium	20
Chromium	1 500
Copper	1 000
Lead	750
Nickel	300
Zinc	3 000
Mercury	10
Arsenic	15
Selenium	15
Molybdenum	20
Boron	80
Fluoride	400
pH (pH units)	5,8 - 7,8

was proposed for pH value. No criteria were suggested for cobalt as this metal is not generally included in existing guidelines for sludge utilization.[6,32]

Of the 77 sludges characterized, 45 were found to have met the suggested guidelines, while another 16 were over the suggested maximum permissible concentrations in the case of one contaminant only. The remaining 16 sludges exceeded the suggested maximum permissible concentrations for two or more contaminants. (Tables 4,5,11; Figures 2-14).

4. RECOMMENDATIONS

The regular monitoring of sewage sludges destined for agricultural application for the presence of the chemical contaminants identified as possible causes of adverse crop and food chain effects is strongly recommended. Cognisance should be taken of the suggested guidelines for the maximum permissible concentrations of these contaminants.

Sampling, sample preparation, and analysis of the sewage sludges for inorganic chemical contaminant and nutrient concentrations should be carried out by the methods recommended, or by methods shown to be equally as reliable.

With regard to the proposed guidelines, it is recommended that these be evaluated in conjunction with those presently under consideration by the Department of National Health and Population Development, along with the most recent guidelines published by the European Economic Community[36] and possibly those recently suggested for the Soil and Irrigation Research Institute[37], by a committee of representatives from the following organizations:

Water Research Commission
Department of National Health and Population Development
Department of Water Affairs
Soil and Irrigation Research Institute of the Department of Agriculture
CSIR Division of Water Technology
United Municipal Executive

This committee should be entrusted with the task of preparing, from the results of this evaluation, a set of mutually acceptable guidelines for the maximum permissible concentration of inorganic chemical contaminants in sewage sludges for application to agricultural land in South Africa.

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APPENDIX 1

METHODS USED FOR THE DETERMINATION OF INORGANIC CHEMICAL CONTAMINANTS AND NUTRIENTS IN SOUTH AFRICAN SEWAGE SLUDGES

DETERMINATION OF TOTAL, FIXED AND VOLATILE RESIDUE

Principle

This method is applicable to the determination of total residue on evaporation and its fixed and volatile fractions in sewage sludge. The determination of both total and volatile residue in this material is subject to negative error due to loss of ammonium carbonate and volatile organic matter while drying. Results for residues high in oil or grease content may be questionable because of the difficulty of drying to constant weight in a reasonable time. 'Fixed' residue does not distinguish precisely between organic and inorganic residue because the loss on ignition is not confined to organic matter, but includes losses due to decomposition or volatilization of certain mineral salts.

Apparatus

(1) Muffle furnace, for operation at 550 °C .

(2) Drying oven, for operation at 103-105 °C .

(3) Desiccator, with desiccant.

Procedure

(1) Total residue: Ignite a clean evaporating dish at 550 °C for 1 h in the muffle furnace. Cool in a desiccator and weigh. Place 5-10 g sample in the dish and weigh to the nearest 0,01 g . Place the dish in the drying oven at 103-105 °C overnight. Cool in a desiccator and reweigh.

(2) Fixed residue (ash) and volatile residue: Determine on the total residue obtained in (1) above. Place the dish in a cool muffle furnace, heat to 550 °C and ignite sample for 1 h . Cool in a desiccator and reweigh.

Calculation

$$\text{Total residue (\%)} = \frac{B \times 100}{A}$$

$$\text{Volatile residue (\% dry basis)} = \frac{(B-C) \times 100}{B}$$

$$\text{Fixed residue (\% dry basis)} = \frac{C \times 100}{B}$$

where : A = mass of sample (g)
B = mass of dried solids (g)
C = mass of ash (g)

Reference

STANDARD METHODS FOR THE EXAMINATION OF WATER AND WASTEWATER 1980 15th Edition, American Public Health Association, American Water Works Association, Water Pollution Control Federation, Washington, D.C.

DETERMINATION OF pH VALUE

Principle

For semi-liquid and solid sludges, a suitable aqueous suspension is prepared and the pH determined potentiometrically. For liquid sludges, the pH is determined directly.

Apparatus

(1) pH meter, consisting of potentiometer, glass electrode, reference electrode, and a temperature compensating device. For routine work, the meter should be accurate and reproducible to 0,1 pH units, with a range of 0-14 units.

2) Mechanical shaker.

Reagents

(1) Water: Use fresh deionized distilled water.

(2) Standard pH buffer solutions of pH values 4,0, 7,0 and 9,0: Use commercially available tablets or powders for the preparation of these solutions.

Procedure

(1) Preparation of samples:

(a) Liquid sludges (generally less than 100 g/ℓ solids). These do not require any preparation. If oil or grease is present, it should be removed by filtration through a cotton wool pad before determining the pH, otherwise a film may form on the electrodes of the meter.

(b) Semi-liquid and solid sludges (generally more than 100 g/ℓ solids). Determine the total residue of the sample as described in Section 3. Weigh an amount of sample equal to a mass of 5,0 ± 0,1 g of sludge dried at 105 °C into a 150 mℓ stoppered conical flask. Add to the flask sufficient water to make the total volume 100 ± 2 mℓ . Stopper the flask and shake, preferably on a

mechanical shaker, until the sample is thoroughly dispersed (it may be necessary to break down the solids into small pieces prior to shaking), but in any event for not less than 15 min .

(2) Measurement of pH value: Set up the pH meter according to the manufacturer's instructions. Standardize the meter using standard buffer solutions of pH value close to that of the sample being tested. Sample solutions, buffer solutions, and electrodes should all be at the same temperature (± 1 °C).

Rinse the electrodes thoroughly with water and immerse in the sample after ensuring that the sample is thoroughly dispersed by stirring. Read the steady pH value after 30 - 60 s .

Remove the electrodes and rinse thoroughly with water. At the end of the batch of samples clean the electrodes with a soft wet tissue and rinse thoroughly with water (If necessary,

Reference

DEPARTMENT OF THE ENVIRONMENT 1978 *Determination of the pH Value of Sludge, Soil, Mud and Sediment; and Lime Requirement of Soil* 1977. Methods for the Examination of Waters and Associated Materials, Her Majesty's Stationery Office, London.

DETERMINATION OF TOTAL KJELDAHL NITROGEN

Principle

A sample of the sludge, equivalent to 0,5 g of total solids, is digested with a mixture of sulphuric acid, potassium sulphate and a mercuric sulphate catalyst in order to convert ammonia nitrogen and organic nitrogen compounds to ammonium sulphate. After decomposition of the mercury ammonium complex by addition of an alkaline solution of sodium thiosulphate, the ammonia is distilled into a boric acid solution and measured by titration with standard sulphuric acid.

This procedure converts nitrogen compounds of biological origin, such as amino acids, proteins and peptides to ammonia. Organic nitrogen in the form of azide, azine, azo, hydrazone, nitrile, nitro, nitroso, oxime and semicarbazone is not determined. Total kjeldahl nitrogen represents the sum of the organic nitrogen and the ammonia nitrogen. Nitrate and nitrite are not determined.

Apparatus

(1) Digestion apparatus: Kjeldahl digestion unit, block digester, or other heating device capable of adjustment so that 250 mℓ of water at an initial temperature of 25 °C can be heated to a rolling boil in approximately 5 min . A heating device meeting this specification should provide the temperature range of 365-370 °C for effective digestion. A suitable fume hood for the removal of SO_3 fumes should also be provided.

(2) Distillation apparatus: Kjeldahl distillation unit, or a steam distillation or other heating unit and condenser with condensing tube of borosilicate glass or block tin or aluminium.

Reagents

(1) Water: Use deionized distilled water.

(2) Sulphuric acid: Use concentrated AR grade.

(3) Sulphuric acid solution, 170 mℓ/ℓ: Add, slowly and carefully with swirling, 170 mℓ sulphuric acid to 500 mℓ water, allow to cool, and dilute to 1ℓ with water.

(4) Mercuric sulphate solution, 80 g/ℓ : Dissolve 80 g red mercuric oxide (AR grade) in 500 mℓ of 170 g/ℓ sulphuric acid solution and dilute to 1 ℓ with water.

(5) Digestion reagent: Dissolve 134 g potassium sulphate (AR grade) in 650 mℓ water and 200 mℓ sulphuric acid. Add 25 mℓ of 80 g/ℓ mercuric sulphate solution and dilute to 1 ℓ with water. Maintain this solution at a temperature close to 20 °C to prevent crystallization.

(6) Sodium hydroxide/sodium thiosulphate solution, 500 g/ℓ/25 g/ℓ : Dissolve 500 g sodium hydroxide (AR grade) and 25 g sodium thiosulphate pentahydrate (AR grade) in water and dilute to 1 ℓ with water.

(7) Mixed indicator solution: Dissolve 0,2 g methyl red indicator in 100 mℓ 95 % ethyl alcohol. Dissolve 0,1 g methylene blue indicator in 50 mℓ 95 % ethyl alcohol. Combine the two solutions. Prepare a fresh solution monthly.

(8) Indicating boric acid solution, 20 g/ℓ: Dissolve 20 g boric acid (AR grade) in water, add 10 mℓ mixed indicator solution, and dilute to 1 ℓ with water. Prepare a fresh solution monthly.

(9) Standard sulphuric acid solution, 0,01 mol/ℓ: Prepare by appropriate dilution of an ampoule of concentrated volumetric solution of sulphuric acid (Riedel-de Haën 'Fixanal'* or equivalent) in a standard volumetric flask with water.

One mℓ of 0,01 mol/ℓ sulphuric acid solution ≡ 0,28 mg N.

Pretreatment of samples

(1) Digestion procedure: Weigh into an 800 mℓ Kjeldahl flask an amount of the sample equal to a mass of approximately 0,5 g of

*Mention of trade names is for information purposes only and does not imply endorsement by the Division of Water Technology of the CSIR

the sludge dried at 105 °C . Add carefully 50 mℓ of digestion mixture, followed by a few boiling granules. Mix by swirling. At low to medium heat, slowly digest the mixture until SO_3 fumes are evolved and the solution turns colourless or pale yellow. Increase the temperature to full heat and continue digestion for a further 30 min . Allow the mixture to cool and dilute to about 300 mℓ with water. Tilt the flask and carefully add 50 mℓ sodium hydroxide/sodium thiosulphate solution. Connect the flask to a previously steamed-out distillation apparatus, and swirl the contents of the flask to ensure complete mixing.

(2) Distillation procedure: Attach a 500 mℓ Erlenmeyer flask containing 50 mℓ of indicating boric acid solution to the condenser outlet of the distillation apparatus, ensuring that the tip of the outlet is below the surface of the boric acid solution. Distill and collect 200 mℓ of distillate at a rate of about 6 to 10 mℓ/min . Lower the flask and rinse the outlet tip into the distillate with water.

Measurement of ammonia concentration

Titrate the ammonia in the distillate with the standard 0,01 mol/ℓ sulphuric acid solution to a pale lavender end-point. Note the volume of 0,01 mol/ℓ sulphuric acid solution required.

A blank solution should be carried through all the steps of the digestion, distillation and titration procedures, and the necessary correction applied.

Calculation

Concentration of total Kjeldahl nitrogen in sample (mg/kgN, dry basis)

$$= \frac{28\,000\ (B-C)}{AT}$$

where : A = mass of sample (g)

B = volume of 0,01 mol/ℓ sulphuric acid solution titrated for sample (mℓ)

C = volume of 0,01 mol/ℓ sulphuric acid solution titrated for blank (mℓ)

T = total residue (%)

Notes

(1) Determinations of total Kjeldahl nitrogen on samples of sewage sludge dried at 105 °C are not accurate, as drying by this procedure can result in the loss of ammonium salts. The total solids content should therefore be determined on a separate portion of the sludge.

(2) Commercially available Kjeldahl digestion tablets may be used in the digestion mixture instead of potassium sulphate and mercuric sulphate.

Reference

STANDARD METHODS FOR THE EXAMINATION OF WATER AND WASTEWATER 1980 15th Edition, American Public Health Association, American Water Works Association, Water Pollution Control Federation, Washington, D.C.

DETERMINATION OF TOTAL PHOSPHORUS

Principle

Approximately 0,2 g of the sludge dried at 105 °C is digested with sulphuric acid and potassium persulphate to convert polyphosphates and organic phosphorus compounds to the orthophosphate form. The mixture is diluted and filtered and the filtrate diluted to 100 mℓ . An aliquot of the solution is treated with sodium bisulphite solution to reduce ferric to ferrous iron, after which the orthophosphate is determined colorimetrically by measurement of the intensely blue-coloured complex formed by reaction with ammonium molybdate and potassium antimonyl tartrate, followed by addition of ascorbic acid.

The total phosphorus content of a sample includes all of the orthophosphates and condensed phosphates, both soluble and insoluble, and organic and inorganic species.

Apparatus

(1) Hot-plate, thermostatically controlled.

(2) Water bath, thermostatically controlled.

(3) Spectrophotometer or filter photometer suitable for measurements at 660 nm with a light path of 1 cm or longer.

Reagents

(1) Water: Use deionized distilled water.

(2) Sulphuric acid solution, 300 mℓ/ℓ: Add slowly and carefully, with swirling, 300 mℓ sulphuric acid (concentrated, AR grade) to 600 mℓ water, allow to cool, and dilute to 1 ℓ with water.

(3) Potassium persulphate: Use AR grade.

(4) Sodium bisulphite solution, 50 g/ℓ: Dissolve 50 g sodium bisulphite (AR grade) in 1 ℓ of water containing 3 mℓ sulphuric acid (concentrated, AR grade).

(5) Ammonium molybdate-potassium antimonyl tartrate solution, 8 g/ℓ/ 0,2 g/ℓ: Dissolve 8 g ammonium molybdate (AR grade) and 0,2 g potassium antimonyl tartrate (AR grade) in 800 mℓ water and dilute to 1 ℓ .

(6) Ascorbic acid solution, 60 g/ℓ: Dissolve 60 g ascorbic acid (AR grade) in 800 mℓ water and dilute to 1 ℓ with water. Add 2 mℓ acetone.

(7) Standard stock solution: Dissolve 0,4394 g of potassium dihydrogen phosphate (AR grade), which has been dried at 105 °C, in water and dilute to 1 ℓ with water. This solution contains 100 mg/ℓ P.

Preparation of standard solution

Transfer, by pipette, 100 mℓ of standard stock solution to a 1 ℓ standard volumetric flask and dilute to 1 ℓ with water. This solution contains 10 mg/ℓ P.

Pretreatment of samples

Weigh accurately approximately 0,2 g of the sample dried at 105 °C into a 150 mℓ Erlenmeyer flask. Add 50 mℓ water and 1 mℓ of 300 mℓ/ℓ sulphuric acid solution, swirling to mix, followed by 0,5 g potassium persulphate. Add a boiling granule and boil on a preheated hot-plate until a volume of about 10 mℓ is reached (do not allow the mixture to spatter). Cool and dilute to about 60 mℓ with water, filter through a Whatman No. 42 paper into a 100 mℓ standard volumetric flask, and dilute to 100 mℓ with water.

Measurement of orthophosphate concentration

Pipette 5 mℓ (or, if necessary, a smaller aliquot) into a 150 mℓ Erlenmeyer flask and dilute to about 30 mℓ . Transfer, from a burette, 0, 5, 10, 15, 20, 25 and 30 mℓ portions of the standard solution (10 mg/ℓ P) to a series of 150 mℓ Erlenmeyer flasks and dilute each solution to about 30 mℓ .

DETERMINATION OF CALCIUM, MAGNESIUM AND POTASSIUM

Principle

Approximately 0,5 g of the sludge dried at 105 °C is extracted with 12 mℓ of aqua regia for a minimum of 30 min . After addition of 5 mℓ of water, the mixture is filtered and the filtrate diluted to 200 mℓ . The calcium, magnesium and potassium present in this solution are determined by means of flame atomic absorption spectrometry, using a nitrous oxide-acetylene or an air-acetylene flame.

Apparatus

(1) Hot-plate, thermostatically controlled.

(2) Atomic absorption spectrometer, equipped with air-acetylene and nitrous oxide-acetylene burners and suitable hollow cathode lamps.

Reagents

(1) Water: Use deionized distilled water.

(2) Aqua regia: Add 3 mℓ of nitric acid (concentrated, AR grade) to 9 mℓ of hydrochloric acid (concentrated, AR grade). Prepare this reagent only as required.

(3) Caesium-lanthanum interference suppressant solution: Add 400 mℓ of hydrochloric acid (concentrated, AR grade) slowly and carefully (fume cupboard) to 117,0 g of lanthanum oxide (AR grade) in a 2 ℓ pyrex beaker. Stir the mixture until the lanthanum oxide is completely dissolved, then add 25,3 g of caesium chloride (AR grade) and again stir until dissolved. Cool the solution and add it to 800 mℓ of water. Dilute to 2 ℓ with water. This solution contains 10 g/ℓ Cs and 50 g/ℓ La.

(4) Standard stock solutions: Use standard solutions of metals (1 000 mg/ℓ) for atomic absorption spectrometry (BDH 'Spectrosol'* or equivalent).

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*Mention of trade names is for information purposes only and does not imply endorsement by the Division of Water Technology of the CSIR.

Add to each flask 1 mℓ of 300 mℓ/ℓ sulphuric acid solution and 5 mℓ of sodium bisulphite solution, and swirl to mix. Transfer to a water bath and heat at 95 °C for 30 min . Cool and dilute to 50 mℓ with water. Add 4 mℓ of ammonium molybdate-potassium antimonyl tartrate solution and mix. Add 2 mℓ ascorbic acid solution and mix. After 10 min , measure the absorbance at 660 nm (1 cm cell).

Determine the mass of orthophosphate in each sample aliquot by reference to the calibration curve obtained by plotting the mass of orthophosphate contained in each standard solution aliquot (0, 0,05; 0,10; 0,15; 0,20; 0,25; 0,30 mg respectively) versus the corresponding absorbance readings.

Calculation

Concentration of total phosphorus in sample (mg/kgP, dry basis)

$$= \frac{1000\ B}{A \times \frac{V}{100}}$$

where : A = mass of sample (g)
B = mass of orthophosphate in sample aliquot (mgP)
V = Volume of sample aliquot (mℓ)

References

STANDARD METHODS FOR THE EXAMINATION OF WATER AND WASTEWATER 1980 15th Edition, American Public Health Association, American Water Works Association, Water Pollution Control Federation, Washington, D.C.

ENVIRONMENTAL PROTECTION AGENCY No date Total Phosphorus in Bottom Material.

Preparation of standard solutions

Add from a burette, the following quantities of standard stock solutions (1 000 mg/ℓ) of calcium, magnesium and potassium to 500 mℓ standard volumetric flasks, each containing 6,8 mℓ nitric acid, 20,3 mℓ hydrochloric acid, and 50 mℓ caesium-lanthanum solution:

Standard No.	Volume added (mℓ)
MS1	0
MS2	1,25
MS3	2,5
MS4	5,0
MS5	10,0

Dilute these solutions to 500 mℓ with water and transfer to 500 mℓ polythene bottles. The concentrations of the solution are as follows:

Standard No.	Concentration (mg/ℓ)
MS1	0
MS2	2,5
MS3	5
MS4	10
MS5	20

Pretreatment of samples

Weigh accurately approximately 0,5 g of the sample dried at 105 °C into a tall-form 100 mℓ beaker and add 12 mℓ of aqua regia and a

boiling granule. Cover the beaker with a watch-glass and heat on a hot-plate at medium heat until all bubbling has ceased (30 min minimum). Add 5 mℓ of water, filter through a Whatman No. 42 paper into a 200 mℓ standard volumetric flask, and dilute to 200 mℓ with water. (This solution can also be used for the determination of cadmium, chromium, copper, lead, nickel and zinc - refer Section 8.)

Measurement of calcium, magnesium and potassium concentrations

Add 5 mℓ of caesium-lanthanum solution to a clean dry 50 mℓ standard volumetric flask and dilute to 50 mℓ with the pretreated sample solution.

Aspirate the standard and caesium-lanthanum treated sample solutions under the conditions stipulated for the particular instrument being operated (see also table below) and note the absorbance values obtained. Calculate the concentration of each metal ion in the sample solution by reference to the calibration curves obtained by plotting concentrations of the standard solutions versus the corresponding absorbance readings. (For instruments equipped with direct concentration readout, this step will be unnecessary.) A correction factor of $^{10}/_{9}$ should be applied to each result in order to allow for the addition of the caesium-lanthanum solution.

A blank solution should be carried through the digestion and measurement procedures and the necessary corrections applied.

Element	Wavelength (nm)	Flame
Calcium	422,7	N_2O-acetylene
Magnesium	285,2/202,5	N_2O-acetylene
Potassium	766,5	Air-acetylene

Calculation

Concentration of metal in sample (mg/kg, dry basis) = $\frac{V(B-C)}{A}$

where : V = volume of pretreated sample solution (mℓ)

A = mass of sample (g)

B = concentration of metal in sample solution (mg/ℓ)

C = concentration of metal in blank solution (mg/ℓ)

Notes

(1) Different amounts of sample and/or diluent may be required, depending on the number of constituents in the sample pretreatment solution being determined and their concentration. In this case, for greater accuracy, the quantity of nitric and hydrochloric acids added to the standard solutions should be adjusted accordingly.

(2) The same sample solution and procedure may be used for the determination, if required, of sodium (air-acetylene flame), in which case standard solutions containing this metal should also be prepared.

References

SMITH, R. 1983 Evaluation of various techniques for the pretreatment of sewage sludges prior to trace metal analysis by atomic absorption spectrophotometer. *Water S.A* 9(1), 31-36.

SMITH, R. 1983 *A laboratory manual for the determination of metals in water and wastewater by atomic absorption spectrophotometry*. CSIR Technical Guide K63, Pretoria.

SMITH, R., BEZUIDENHOUT, E.M. and VAN HEERDEN, A.M. 1983 The use of interference suppressants in the direct flame atomic absorption determination of metals in water: Some practical considerations. *Water Res.* 17 (11), 1483-1489.

STANDARD METHODS FOR THE EXAMINATION OF WATER AND WASTEWATER 1980 15th Edition, American Public Health Association, American Water Works Association, Water Pollution Control Federation, Washington, D.C.

VAN LOON, J.C. and LICHWA, J. A study of the atomic absorption determination of some important heavy metals in domestic sewage treatment plant wastes. *Water, Air and Soil Pollution* 2, 473-482.

DETERMINATION OF CADMIUM, CHROMIUM, COPPER, LEAD, NICKEL AND ZINC

Principle

Approximately 0,5 g of the sludge dried at 105 °C is extracted with 12 mℓ of aqua regia for a minimum of 30 min . After addition of 5 mℓ of water, the mixture is filtered and the filtrate diluted to 200 mℓ . The cadmium, chromium, copper, lead, nickel and zinc present in this solution are determined by means of flame atomic absorption spectrometry, using either an air-acetylene or a nitrous oxide-acetylene flame.

Apparatus

(1) Hot-plate, thermostatically controlled.

(2) Atomic absorption spectrometer, equipped with air-acetylene and nitrous oxide-acetylene burners, suitable hollow cathode lamps, and background correction facilities.

Reagents

(1) Water: Use deionized distilled water.

(2) Aqua regia: Add 3 mℓ nitric acid (concentrated, AR grade) to 9 mℓ of hydrochloric acid (concentrated, AR grade). Prepare this reagent only as required.

(3) Caesium-lanthanum interference suppressant solution: Add 400 mℓ of hydrochloric acid (concentrated, AR grade) slowly and carefully (fume cupboard) to 47,0 g of lanthanum oxide (AR grade) in a 2 ℓ pyrex beaker. Stir the mixture until the lanthanum oxide is completely dissolved, then add 12,7 g caesium chloride (AR grade) and again stir until dissolved. Cool the solution and add it to 800 mℓ of water. Dilute to 2 ℓ with water. This solution contains 5 g/ℓ Cs and 20 g/ℓ La.

(4) Standard stock solutions: Use standard solutions of metals (1 000 mg/ℓ) for atomic absorption spectrometry (BDH 'Spectrosol'* or equivalent).

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*Mention of trade names is for information purposes only and does not imply endorsement by the Division of Water Technology of the CSIR

Preparation of standard solutions

Secondary stock solution 1: Transfer, by pipette, 100 mℓ of the standard stock solutions (1 000 mg/ℓ) of chromium, copper, lead, nickel and zinc and 20 mℓ of the standard stock solution (1 000 mg/ℓ) of cadmium to a 1 ℓ standard volumetric flask, and dilute to 1 ℓ with water. This solution contains 20 mg/ℓ Cd and 100 mg/ℓ Cr, Cu, Pb, Ni, Zn.

Secondary stock solution 2: Transfer, by pipette, 100 mℓ of secondary stock solution 1 to a 1 ℓ standard volumetric flask, and dilute to 1 ℓ with water. This solution contains 2 mg/ℓ Cd and 10 mg/ℓ Cr, Cu, Pb, Ni, Zn.

Add the following quantities of secondary stock solutions 1 and 2 to 250 mℓ standard volumetric flasks, each containing 3,4 mℓ nitric acid, 10,1 mℓ hydrochloric acid, and 25 mℓ caesium-lanthanum solution, and dilute to 250 mℓ with water:

Standard No.	Secondary stock solution No.	Volume of secondary stock solution added (mℓ)	Concentration (µg/ℓ)	
			Cadmium	Other
TS1	-	0	0	0
TS2	2	5,0	40	200
TS3	2	12,5	100	500
TS4	1	2,5	200	1000
TS5	1	5,0	400	2000
TS6	1	10,0	800	4000
TS7	1	15,0	1200	6000

Pretreatment of samples

Refer Section 7 - determination of calcium, magnesium and potassium.

Measurement of metal concentrations

Add 5 mℓ of caesium-lanthanum solution to a clean dry 50 mℓ standard volumetric flask and dilute to 50 mℓ with the pretreated sample solution.

Aspirate the standard and caesium-lanthanum treated sample solutions under the conditions stipulated for the particular instrument being operated (see also table below) and note the absorbance values obtained. Background correction should be applied where necessary. Calculate the concentration of each metal ion in the sample solution by reference to the calibration curves obtained by plotting concentrations of the standard solutions versus the corresponding absorbance readings. (For instruments equipped with direct concentration readout, this step will be unnecessary.) A correction factor of $^{10}/_{9}$ should be applied to each result in order to allow for the addition of the caesium-lanthanum solution.

A blank solution should be carried through the digestion and measurement procedures and the necessary correction applied.

Element	Wavelength (nm)	Flame
Cadmium	228,8	Air-acetylene
Chromium	357,9	N_2O-acetylene
Copper	324,7	Air-acetylene
Lead	217,0	Air-acetylene
Nickel	232,0	Air-acetylene
Zinc	213,9	Air-acetylene

Calculation

Concentration of metal in sample (mg/kg, dry basis) = $\frac{V\ (B-C)}{1000A}$

where : V = volume of pretreated sample solution (mℓ)

A = mass of sample (g)

B = concentration of metal in sample solution (μg/ℓ)

C = concentration of metal in blank solution (μg/ℓ)

Notes

(1) Different amounts of sample and/or diluent may be required, depending on the number of constituents in the sample pretreatment solution being determined and their concentrations. In this case, for greater accuracy, the quantity of nitric and hydrochloric acids added to the standard solutions should be adjusted accordingly.

(2) The same sample solution and procedure may be used for the determination, if required, of cobalt, iron and manganese (air-acetylene flame), in which case standard solutions containing these metals should also be prepared.

References

SMITH, R. 1983 Evaluation of various techniques for the pretreatment of sewage sludges prior to trace metal analysis by atomic absorption spectrophotometry. *Water S.A.* 9(1), 31-36.

SMITH, R. 1983 *A laboratory manual for the determination of metals in water and wastewater by atomic absorption spectrophotometry.* CSIR Technical Guide, K63, Pretoria.

SMITH, R., BEZUIDENHOUT, E.M. and VAN HEERDEN, A.M. 1983 The use of interference suppressants in the direct flame atomic absorption determination of metals in water: Some practical considerations. *Water Res.* 17 (11), 1483-1489.

STANDARD METHODS FOR THE EXAMINATION OF WATER AND WASTEWATER 1980 15th Edition, American Public Health Association, American Water Works Association, Water Pollution Control Federation, Washington, D.C.

VAN LOON, J.C. and LICHWA, J. 1973 A study of the atomic absorption determination of some important heavy metals in domestic sewage treatment plant wastes. *Water, air and soil pollution* 2, 473-482.

DETERMINATION OF MERCURY

Principle

A sample of the sludge, equivalent to 0,5 g of total solids, is subjected to prolonged oxidation with sulphuric acid, potassium persulphate and potassium permanganate, in order to convert any organic mercury compounds to the inorganic form. The mercury is then determined by a cold vapour generation/atomic absorption technique.

Apparatus

(1) Ice bath.

(2) Water bath, thermostatically controlled.

(3) Atomic absorption spectrometer; mercury hollow cathode lamp.

(4) Chart recorder, with fast response (0,5 sec).

(5) Mercury vapour generation accessory (Figure 1).

Reagents

(1) Water: Use deionized distilled water.

(2) Sulphuric acid: Use concentrated AR grade.

(3) Potassium persulphate solution, 50 g/ℓ: Dissolve 50 g potassium persulphate (AR grade) in water and dilute to 1 ℓ with water.

(4) Potassium permanganate solution, 50 g/ℓ: Dissolve 50 g potassium permanganate (AR grade) in water and dilute to 1 ℓ with water.

(5) Nitric acid: Use concentrated AR grade.

(6) Sodium chloride/hydroxylamine sulphate solution, 120 g/ℓ/ 120 g/ℓ: Dissolve 120 g sodium chloride (AR grade) and 120 g hydroxylamine sulphate (AR grade) in water and dilute to 1 ℓ with water.

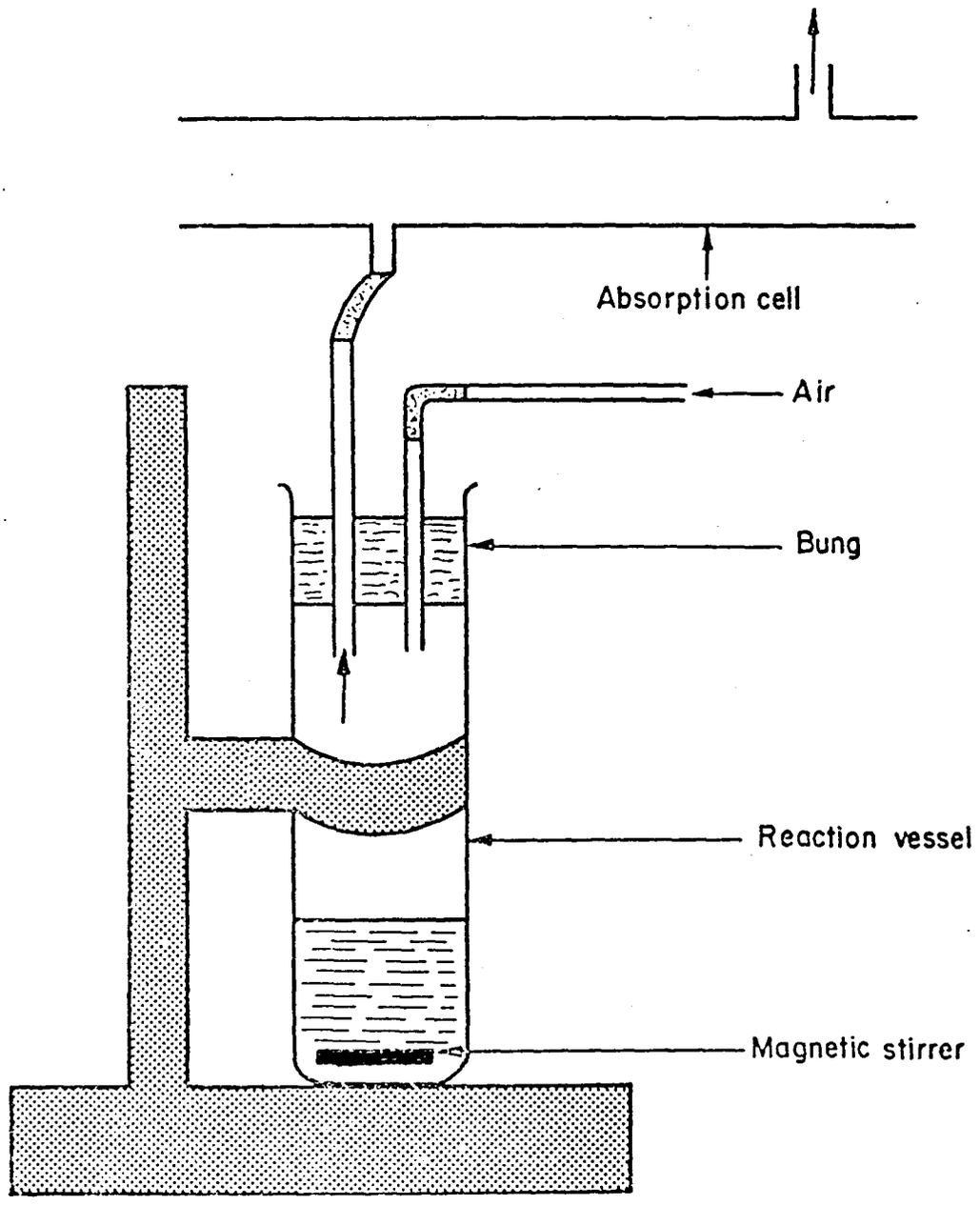

Figure 1. Vapour generation accessory - mercury

(7) Stannous chloride solution, 100 g/ℓ: Dissolve 50 g stannous chloride dihydrate (AR grade) in 100 mℓ hydrochloric acid (concentrated, AR grade) and dilute to 500 mℓ with water. Filter if necessary. Add one piece of granulated tin (AR grade).

(8) Standard stock solution: Use a standard solution of mercury (1 000 mg/ℓ) for atomic absorption spectrometry (BDH Spectrosol* or equivalent).

Preparation of standard solution

Transfer, by graduated pipette, 2,5 mℓ of the standard stock solution of mercury to a 1 ℓ standard volumetric flask, add 10 mℓ nitric acid and dilute to 1 ℓ with water. This solution contains 2,5 mg/ℓ Hg.

Pretreatment of samples and standard solution

Weigh accurately into a 250 mℓ Erlenmeyer flask an amount of the sludge sample equal to a mass of approximately 0,5 g of the sludge dried at 105 °C . Transfer, by graduated pipette, 0, 0,2, 0,4, 0,8 and 1,2 mℓ portions of the standard solution into a series of 250 mℓ Erlenmeyer flasks.

Place the flasks in an ice bath and add to each flask 10 mℓ of 50 g/ℓ potassium persulphate solution. Add slowly and carefully, with swirling, 10 mℓ of sulphuric acid, stopper the flasks lightly, and leave in the ice bath for approximately 1 h .

Transfer the stoppered flasks to a water bath and heat at 60 °C for 4 to 5 h , with occasional shaking. Remove the flasks from the water bath and allow to stand overnight at room temperature.

Slowly add 15 mℓ of 50 g/ℓ potassium permanganate solution and replace the stopper. (If the permanganate colour disappears, add further 5 mℓ aliquots of 50 g/ℓ potassium permanganate solution

*Mention of trade names is for information purposes only and does not imply endorsement by the Division of Water Technology of the CSIR.

until the colour remains.) Allow to stand overnight at room temperature.Add 1 mℓ of nitric acid and 6 mℓ of 120 g/ℓ sodium chloride, 120 g/ℓ hydroxylamine sulphate solution and mix by swirling. Allow to stand for at least 5 min until the solution has decolorized (addition of more sodium chloride-hydroxylamine sulphate solution may be necessary).

Quantitatively transfer the solution to a 250 mℓ graduated cylinder and dilute with water to 150 mℓ . Return the solution to the 250 mℓ Erlenmeyer flask and restopper.

Measurement of mercury concentration

Set the operating parameters of the atomic absorption spectrophotometer and connected chart recorder according to the manufacturers' instructions (wavelength: 253,7 nm) and connect the mercury vapour generation accessory to the instrument. Transfer, by graduated cylinder, 50 mℓ (or if necessary, a smaller aliquot diluted to 50 mℓ, in which case the appropriate allowance should be made in the calculation) of the pretreated sample or standard solution to the reaction vessel of the accessory, and add 3 mℓ of 100 g/ℓ stannous chloride solution. Immediately insert the bung assembly in the reaction vessel and stir the solution vigorously with the magnetic stirrer for 90 sec. Simultaneously turn off the stirrer and turn on the air supply to the vessel. Record the absorbance obtained as peak height on the chart recorder. (Possible interference may occur due to the presence of volatile organic compounds which absorb at the same wavelength. These may be removed by bubbling air through the solution for 5 min prior to the addition of the nitric acid and sodium chloride-hydroxylamine sulphate solution.)

Determine the mass of mercury in each sample by reference to the calibration curve obtained by plotting the mass of mercury contained in each standard solution aliquot (0; 0,5; 1,0; 2,0; 3,0 µg respectively) versus the corresponding peak height.

Calculation

Concentration of mercury in sample (mg/kgHg, dry basis) = $\frac{100\ B}{AT}$

where : A = mass of sample (g)
B = mass of mercury in the sample (µgHg)
T = total residue (%)

Note

Cleanliness of glassware is essential in mercury determinations. If possible, glassware should be reserved solely for mercury determinations and all residual mercury from previous determinations should be removed.

All glassware should be cleaned by filling with a solution of 10 mℓ/ℓ sulphuric acid and 0,5 mg/ℓ potassium permanganate in water and leaving overnight, after which it should be rinsed thoroughly with 500 mℓ/ℓ hydrochloric acid solution and then with water.

References

DEPARTMENT OF THE ENVIRONMENT 1978 *Mercury in Water, Effluents and Sludges by Flameless Absorption Spectrophotometry* 1978. Methods for the Examination of Water and Associated Materials, Her Majesty's Stationery Office, London.

PARKER, C.R. 1972 *Water analysis by atomic absorption spectroscopy.* Varian-Techtron (Pty) Ltd., Springvale, Australia.

SMITH, R. 1983 *A laboratory manual for the determination of metals in water and wastewater by atomic absorption spectrophotometry.* CSIR Technical Guide, K63, Pretoria.

STANDARD METHODS FOR THE EXAMINATION OF WATER AND WASTEWATER 1980 15th Edition, American Public Health Association, American Water Works Association, Water Pollution Control Federation, Washington, D.C.

DETERMINATION OF ARSENIC AND SELENIUM

Principle

A sample of the sludge, equivalent to 0,25 g of total solids, is digested with nitric acid and ashed at 550 °C with magnesium nitrate in order to destroy organic matter under oxidising conditions, then extracted with hydrochloric acid. The arsenic and selenium are then determined by a hydride generation/atomic absorption technique.

Apparatus

(1) Muffle furnace for operation at 550 °C.

(2) Hot plate, thermostatically controlled.

(3) Atomic absorption spectrometer equipped with background correction facility, arsenic and selenium hollow cathode lamps, air-acetylene burner.

(4) Hydride generation accessory (Figure 2 - Varian Techtron Ltd: Vapor Generation Accessory* or equivalent.)

(5) Chart recorder, with fast response (0,5 sec).

Reagents

(1) Water: Use deionized distilled water.

(2) Nitric acid: Use concentrated AR grade.

(3) Magnesium nitrate hexahydrate: Use AR grade.

(4) Hydrochloric acid: Use concentrated AR or higher grade, containing <1 µg/ℓ As or Se.

(5) Hydrochloric acid solution, 500 mℓ/ℓ: Add 500 mℓ hydrochloric acid slowly and carefully to 500 mℓ water.

(6) Potassium iodide solution, 200 g/ℓ: Dissolve 200 g potassium iodide (AR grade) in water, and dilute to 1 litre.

(7) Sodium borohydride pellets, 98%: Use $^{10}/_{32}$" pellets made by Alfa Division, Ventron Corporation, Danvers, Massachusetts, USA* (available from various SA suppliers).

(8) Standard stock solutions: Use standard solutions of arsenic and selenium (1000 mg/ℓ) for atomic absorption spectrometry (BDH 'Spectrosol'* or equivalent).

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* Mention of trade names is for information purposes only and does not imply endorsement by the Division of Water Technology of the CSIR.

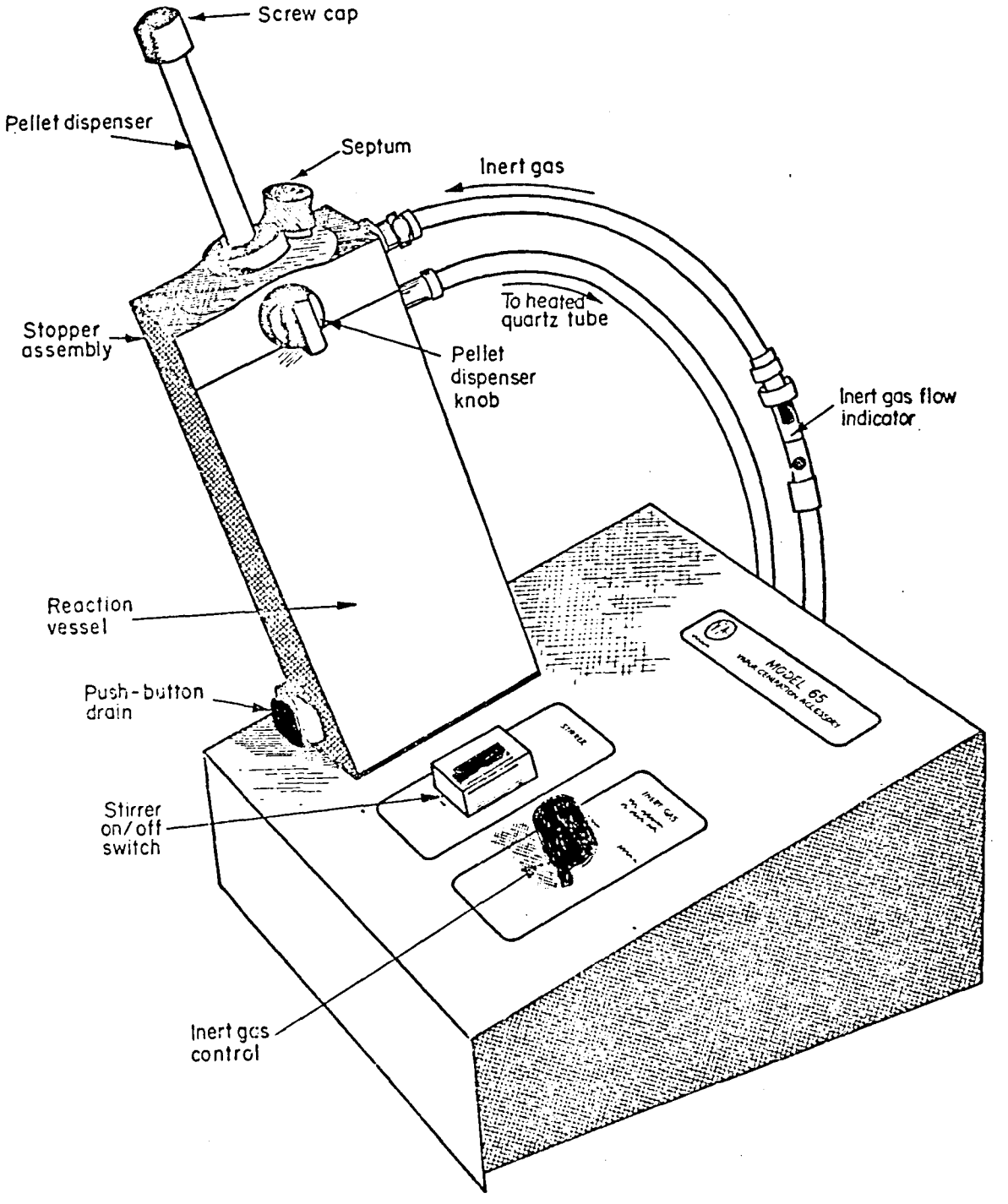

Figure 2. Vapour generation accessory - arsenic and selenium

(Reproduced by permission of Varion-Techtron Ltd., Springvale, Australia, through their agents, SMM Instruments (Pty) Ltd., Johannesburg)

Preparation of standard solution

Transfer, by pipette, 1,0 mℓ of each of the standard stock solutions of arsenic and selenium to a 1 ℓ standard volumetric flask, add 50 mℓ of hydrochloric acid, and dilute to 1 ℓ with water. This solution contains 1 mg/ℓ As and 1 mg/ℓ Se.

Pretreatment of samples and standard solutions

Weigh accurately into a 100 mℓ beaker an amount of the sludge sample equal to a mass of approximately 0,25 g of the sludge dried at 105 °C. Transfer, by graduated pipette, 0, 0,5, 1,0, 2,0 and 3,0 mℓ portions of the standard solution into a series of 100 ml glass beakers. Add 2,0 g of magnesium nitrate hexahydrate, 4,0 mℓ nitric acid, and a boiling granule. Cover with a watch glass and heat gently on a hot-plate until the vigorous reaction subsides. Continue digestion at medium heat for 30 min. Remove watch glass, increase heat and evaporate to dryness. Allow to cool, add 1,0 mℓ nitric acid and again evaporate to dryness. Transfer the beaker and contents into a cold muffle furnace, increase the temperature to 550 °C, and maintain at this temperature for 2 h.

Add 10,0 mℓ of 500 mℓ hydrochloric acid solution and simmer gently on a hot-plate for 10 min. Allow to cool, transfer quantitatively to a 100 mℓ standard volumetric flask, and dilute to 100 mℓ with water.

Measurement of arsenic and selenium concentrations

Separate portions of the pretreated sample and standard solutions should be taken for arsenic and selenium determinations.

Transfer, by pipette, 10,0 mℓ (or, if necessary, a smaller aliquot diluted to 10 mℓ, in which case the appropriate allowance should be made in the calculation) of the pretreated sample or standard solutions to a 100 mℓ beaker. Add 10,0 mℓ of 500 mℓ/ℓ hydrochloric acid solution.

(1) Arsenic - reduction of AS^{v} to As^{iii}: Add 1 mℓ of 200 g/ℓ potassium iodide solution. Reduction will be complete in about 50 min at room temperature. Alternatively, heat the solution to 50 °C for about 4 min and cool to room temperature.

(2) Selenium - reduction of Se^{vi} to Se^{iv}: Heat the solution to 70 °C for 10 min and cool to room temperature.

Set the operating parameters of the atomic absorption spectrometer and connected chart recorder according to the manufacturer's instructions (wavelength: As - 193,7 nm, Se - 196,0 nm) and connect the vapour generation accessory to the instrument. Set the nitrogen supply regulator to 140 kPa. Turn the inert gas control of the accessory to NORMAL. Remove the stopper assembly from the reaction vessel of the accessory. Remove the cap from the pellet dispenser, and, using tweezers, load the dispenser with sodium borohydride pellets. Replace the dispenser cap and stopper assembly. Set the acetylene and air flows to give a fuel-rich air-acetylene mixture. Raise the quartz tube clear of the burner, ignite the flame, and lower the tube back to its normal position. Adjust the fuel flow so that the flame has a primary zone (blue cone) between 2 and 3 mm high.

Ensure that the stirrer is OFF and remove the stopper assembly from the reaction vessel. Using the funnel supplied, transfer the contents of the beaker containing the reduced sample or standard solution to the reaction vessel. Replace the stopper assembly and switch the stirrer ON. Wait about 25 sec to ensure that all the air has been flushed from the system, then turn the dispenser knob back to the closed position. Wait until the reaction is complete, then, with the stirrer still ON, press the drain button on the reaction vessel and keep it pressed until all the solution has drained from the vessel. Rinse the reaction vessel with water. Turn the stirrer OFF. Record the absorbance obtained as peak height on the chart recorder.

Determine the mass of arsenic/selenium in each sample by reference to the calibration curve obtained by plotting the mass of arsenic/selenium contained in each standard solution aliquot (0; 0,5; 1,0; 2,0; 3,0 µg respectively) versus the corresponding peak height.

Calculation

Concentration of arsenic/selenium in sample (mg/kg, dry basis) = $\frac{100\ B}{AT}$

where A = mass of sample (g)

B = mass of arsenic/selenium in sample (µg As/Se)

T = total residue (%)

Notes

(1) For most determinations, satisfactory results can be obtained by measurement of the peak heights. In some cases, however, the sample matrix may be such that the peaks obtained may 'tail-off' considerably, or multiple peaks may be produced due to delayed reactions. Under these circumstances, linearity of the calibration curve, as well as reproducibility and accuracy of the results, may be significantly improved by using peak area measurements.

(2) It is recommended that, if possible, background correction be employed.

(3) Copper, silver, ferric iron, antimony, bismuth, cobalt, mercury, nickel, fluoride and oxidizing agents can interfere. The extent of this interference will vary from sample to sample, but in most cases will not be significant.

(4) Sodium borohydride in solution form may be used instead of pellets, in which case it is injected through the septum.

(5) Cleanliness of glassware is essential in arsenic and selenium determinations. All glassware should be of good quality low arsenic borosilicate glass. If possible, glassware should be reserved solely for arsenic and selenium determinations and all residual arsenic and selenium from previous determinations should be removed.

All glassware should be cleaned by filling with or rinsing in a solution of 100 mℓ/ℓ nitric acid solution and leaving for two days, after which it should be rinsed thoroughly with water. Thereafter a thorough rinse with 100 mℓ/ℓ nitric acid solution, followed by rinsing with water should suffice.

References

DEPARTMENT OF THE ENVIRONMENT 1987 *Selenium in Waters 1984. Selenium and Arsenic in Sludges, Soils and Related Materials 1985 . A note on the Use of Hydride Generator Kits 1987.* Methods for the Examination of Waters and Associated Materials, Her Majesty's Stationery Office, London.

GUNN, A.M. 1981 *The Determination of Arsenic and Selenium in Raw and Potable Waters by Hydride Generation/Atomic Absorption Spectrometry - A Review.* Technical Report TR 169, Water Research Centre, Medmenham, England.

SMITH, R. 1983 *A laboratory manual for the determinaiton of metals in water and wastewater by atomic absorption spectrophotometry.* CSIR Technical Guide K63, Pretoria.

STANDARD METHODS FOR THE EXAMINATION OF WATER AND WASTEWATER 1980 15th Edition, American Public Health Association, American Water Works Association, Water Pollution Control Federation, Washington D.C.

VARIAN-TECHTRON LTD. 1979 *Model 65 Vapor Generation Accessory - Operation Manual.* Springvale, Australia.

DETERMINATION OF MOLYBDENUM

Principle

Approximately 0,5 g of the sludge dried at 105 °C is ashed at 500 °C, extracted with dilute hydrochloric acid, and the molybdenum present reacted with thiocyanate ions to form an amber-coloured complex which is then extracted into 4-methylpentan-2-one (MIBK) and measured spectrophotometrically.

Apparatus

(1) Muffle furnace, for operation at 500 °C.

(2) Centrifuge.

(3) Water bath, thermostatically controlled.

(4) Spectrophotometer or filter photometer suitable for measurements at 470 nm with a light path of 4 cm or longer.

(5) Culture vials: Borosilicate glass with plastic screw caps fitted with PTFE liners, 100 x 25 mm or other size suitable for centrifuge.

Reagents

(1) Water: Use deionized distilled water.

(2) Hydrochloric acid solution, 360 mℓ/ℓ: Add 360 mℓ of hydrochloric acid (concentrated, AR grade) slowly and carefully to 500 mℓ of water, and dilute to 1 litre with water.

(3) Ascorbic acid solution, 150 g/ℓ: Dissolve 15,0 g of ascorbic acid (AR grade) and 2,0 g of citric acid monohydrate (AR grade) in water, dilute with water to 100 mℓ, and mix well. Store in a cool dark place. Prepare a fresh solution when required.

(4) Cuprous chloride solution, 2,5 g/ℓ: Dissolve 0,25 g of cuprous chloride (AR grade) in 90 mℓ of hydrochloric acid, add 10 mℓ of water and mix well.

(5) Reducing/complexing solution: Dilute 10,0 mℓ of 2,5 g/ℓ cuprous chloride solution with 40 mℓ of water, add 50 mℓ of 150 g/ℓ ascorbic acid solution and mix well. Prepare a fresh solution when required.

(6) Potassium thiocyanate solution, 250 g/ℓ: Dissolve 25 g of potassium thiocyanate (AR grade) in water, dilute with water to 100 mℓ, and mix well.

(7) 4-Methylpentan-2-one (MIBK): Use AR grade (purify by distillation if necessary). Store in an amber glass bottle. This reagent is flammable and has a harmful vapour, irritating to the eyes and mucous membranes. It must NOT be pipetted by mouth.

(8) Stannous chloride solution, 100 g/ℓ: Dissolve (with warming) 10 g of stannous chloride dihydrate (AR grade) in 18 mℓ of hydrochloric acid, cool, dilute with water to 100 mℓ, and mix well.

(9) Standard stock solution: Use a standard solution of molybdenum (1000 mg/ℓ) for atomic absorption spectrometry (BDH 'Spectrosol'* or equivalent).

Preparation of standard solutions

(1) Transfer, by pipette, 2,5 mℓ of standard stock solution to a 100 mℓ standard volumetric flask and dilute to 100 mℓ with 360 mℓ/ℓ hydrochloric acid solution. This solution contains 25 mg/ℓ Mo.

(2) Transfer, by pipette, 0, 1,0, 2,5, and 5,0 mℓ portions of standard solution (1) to a series of 100 mℓ standard volumetric flasks and dilute to 100 mℓ with 360 mℓ/ℓ hydrochloric acid solution. These solutions contain 0, 0,25, 0,625 and 1,25 mg/ℓ Mo, respectively.

Pretreatment of samples

Weigh accurately approximately 0,5 g of the sample dried at 105 °C into an evaporating dish, place in a cold muffle furnace, increase the temperature to 500 °C, and maintain at this temperature overnight. Remove the dish from the furnace, allow to cool, and transfer the contents, by means of a brush and small filter funnel, to a culture vial. Add 10 mℓ of 360 mℓ/ℓ hydrochloric acid solution, cap the vial, and mix well. Digest in a water bath at 85 °C for 15 min, with occasional shaking to ensure complete extraction. Remove from the water bath, allow to cool, and filter through a dry Whatman no. 541 paper into another culture vial.

Measurement of molybdenum concentration

Transfer, by pipette, 4,0 mℓ of 360 mℓ/ℓ hydrochloric acid solution, 4,0 mℓ of the filtrate and 4,0 mℓ of each of the

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standard solutions to a series of 50 mℓ separating funnels, add 4,0 mℓ of reducing/complexing solution, mix, add 2,0 mℓ of 250 g/ℓ potassium thiocyanate solution, mix, add 10,0 mℓ of MIBK, stopper, and shake for at least 20 sec. Allow the layers to separate, discard the aqueous portions and transfer, by pipette, 8,0 mℓ of the MIBK layers to another series of 50 mℓ separating funnels. Add 5,0 mℓ of 100 g/ℓ stannous chloride solution, stopper, and shake for at least 1 min (refer Notes 1 and 2). Allow the layers to separate, discard the aqueous portions, and transfer the MIBK layers to a series of culture vials. Loosen the cap of each vial and centrifuge at 7 000 rpm for approximately 2 min (refer Note 3). Measure the absorbances of the sample extracts and calibration standards at 470 nm (4 cm thick-walled cell).

Determine the mass of molybdenum in each sample extract aliquot by reference to the calibration curve obtained by plotting the mass of molybdenum contained in each standard solution aliquot (0; 1; 2,5; 5 µg respectively) versus the corresponding absorbance readings.

Calculation

$$\text{Concentration of molybdenum in sample (mg/kg, dry basis)} = \frac{2,5\ B}{A}$$

where A = mass of sample (g)

B = mass of molybdenum in sample extract aliquot (µg Mo).

Notes

(1) The stannous chloride solution is added to remove any pink interference colour due to $iron^{iii}$. The shaking time necessary to remove this colouration depends on several factors, including temperature, iron and molybdenum concentrations, and the quality of the MIBK and stannous chloride. The pink colour due to iron is easily distinguished from the amber colour due to molybdenum, and the shaking time must be long enough to remove the pink colour. If the pink colour is not removed within 1 min. the technique or reagents are suspect, and appropriate action should be taken, e.g.:

(a) Add a further 1 mℓ of stannous chloride or double the strength of the solution.

(b) Prepare fresh stannous chloride solution.

(c) Redistil the MIBK.

(d) Use a dilution (with 360 mℓ/ℓ hydrochloric acid solution) of the acid extract of the sample.

(2) If colours other than amber/orange are present, then possible interference should be suspected and appropriate action taken, e.g.:

(a) If pink, probably due to iron (see note (1)).

(b) If faintly blue, probably due to exceptionally high concentrations of cobalt, chromium, nickel or copper, which are unlikely to interfere anyway.

(c) If yellow/green, probably due to exceptionally high concentrations of vanadium or tungsten, which may cause slight interference.

(d) If yellow, green or brown, could be caused by organic matter, and the use of an ashing aid should be considered.

(3) The solution after the centrifuging step should be free of turbidity. If not, cool the extracts in a refrigerator for 2 to 3 min and reshake before centrifuging.

Reference

DEPARTMENT OF THE ENVIRONMENT 1983 *Molybdenum, especially in Sewage Sludges and Soils by Spectrophotometry 1982* Methods for the Examination of Waters and Associated Materials, Her Majesty's Stationery Office, London.

DETERMINATION OF BORON

Principle

A sample of the sludge, equivalent to 2,0 g of total solids, is extracted with water and the boron present reacted with azomethine-H to form a yellow complex which is then measured spectrophotometrically.

Apparatus

(1) Water-cooled reflux condenser (14 cm).

(2) Heating mantle suitable for 500 mℓ r.b. flasks.

(3) Spectrophotometer or filter photometer suitable for measurements at 420 nm with a 1 cm light path.

Reagents

(1) Water: Use deionized distilled water.

(2) Azomethine-H solution, 10 g/ℓ: Dissolve 1,0 g azomethine-H (AR grade) and 2,0 g of ascorbic acid (AR grade) in about 70 mℓ of water. Transfer to a 100 mℓ standard volumetric flask and dilute to 100 mℓ with water. Allow the solution to stand for 90 min before using. Prepare a fresh solution when required.

(3) Buffer/complexing solution: Dissolve 3,0 g of the disodium salt of ethylenediamine tetraacetic acid (AR grade) in 150 mℓ of water, add 125 mℓ of acetic acid (AR grade), and dissolve 250 g of ammonium acetate (AR grade) in the resulting mixture by means of stirring and gentle heating (refer Note 1). Store in a polythene bottle.

(4) Standard stock solution: Use a standard solution of boron (1 000 mg/ℓ) for atomic absorption spectrometry (BDH 'Spectrosol'* or equivalent).

Preparation of standard solutions

(1) Transfer, by pipette, 10,0 mℓ of standard stock solution to a 100 mℓ standard volumetric flask and dilute to 100 mℓ with water. This solution contains 100 mg/ℓ B.

(2) Transfer, by pipette, 10 mℓ of standard solution (1) to a 1 000 mℓ standard volumetric flask and dilute to 1 000 mℓ with water. This solution contains 1 mg/ℓ B.

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Pretreatment of samples

Weigh accurately into a 500 mℓ r.b. flask an amount of the sludge sample equal to a mass of approximately 2,0 g of the sludge dried at 105 °C. Add 80 mℓ of water. Attach the water-cooled condenser to the flask, place in the heating mantle, and heat to boiling. Allow to boil for 10 min ± 30 sec (refer Note 2). Immediately filter through a prewashed filter paper (Whatman No. 541) under vacuum. This filtration should be as rapid as possible and should be terminated when approximately 30 mℓ of filtrate has been collected. Refilter the filtrate through a Whatman No. 42 filter paper under vacuum (refer Note 3).

Measurement of boron concentration

Transfer, by pipette, a suitable volume (not exceeding 15 mℓ) of the second filtrate into a 25 mℓ polythene volumetric standard flask, and dilute, if necessary to 15 mℓ with water. Transfer, by graduated pipette, 0, 2,0, 5,0 and 10,0 mℓ portions of the standard solution (2) into a series of 25 mℓ polythene volumetric standard flasks.

Transfer, by pipette, 5,0 mℓ of azomethine-H reagent to each flask. Mix by swirling. Transfer, again by pipette, 4,0 mℓ of buffer/complexing solution to each flask. Dilute to 25 mℓ with water, mix, and allow to stand in a water bath at a temperature of not more than 20 °C for 20 min (refer Note 4). Measure the absorbance at 420 nm (1 cm cell).

To compensate for colour and turbidity in the sample, transfer, by pipette, the same volume of sample and 4,0 mℓ of buffer/complexing solution into a 25 mℓ polythene standard volumetric flask, and dilute to 25 mℓ. Measure the absorbance at 420 nm, and subtract from the absorbance obtained by the corresponding sample.

Determine the mass of boron in each sample extract by reference to the calibration curve obtained by plotting the mass of boron contained in each standard solution aliquot (0,0; 2,0; 5,0; 10,0 μg respectively) versus the corresponding absorbance readings.

Calculation

Concentration of boron in sample (mg/kg B, dry basis) = $\frac{8000\ C}{AVT}$

where : A = mass of sample (g)
C = mass of boron in the sample extract (µg B)
V = volume of sample aliquot (mℓ)
T = total residue (%)

Notes

(1) The disodium salt of ethylenediamine tetraacetic acid is added to complex copper, iron, and aluminium, which interfere in the determination.

(2) The reflux time is critical; the commencement of boiling can be judged from the time when steam starts to condense on the condenser.

(3) Do not allow the sample to cool before or during the filtration step as this will lead to re-adsorption of the boron by the solids.

(4) Fading of the colour may occur at above 20 °C.

References

DEPARTMENT OF THE ENVIRONMENT 1981 *Boron in Water, Effluents, Sewage and some Solids 1980*. Methods for the Examination of Waters and Associated Materials, Her Majesty's Stationery Office, London.

YORKSHIRE WATER AUTHORITY 1981 *Methods of Analysis*. Yorkshire Water Authority, Leeds, England.

DETERMINATION OF FLUORIDE

Principle

Approximately 0,5 g of the sludge dried at 105 °C is extracted with 10 mℓ of sulphuric acid for 15 min. Aluminium and other interfering cations are removed by precipitation with ammonium hydroxide solution. After addition to the filtrate of a known amount of standard fluoride solution and a complexing agent, the fluoride present is measured potentiometrically by means of a fluoride ion-selective electrode.

Apparatus

(1) Digital pH meter-mV meter with fluoride ion-selective electrode and sleeve-type reference electrode.

(2) Magnetic stirrer with teflon-coated stirring bars.

Reagents

(1) Water: Use deionized distilled water.

(2) Sulphuric acid: Use concentrated AR grade.

(3) Sulphuric acid solution 56 mℓ/ℓ: Add, slowly and carefully with swirling, 56 mℓ sulphuric acid to 500 mℓ water, allow to cool and dilute to 1 ℓ with water.

(4) Sulphuric acid solution, 5,6 mℓ/ℓ: Dilute 100 mℓ of 56 mℓ/ℓ sulphuric acid to 1 ℓ with water.

(5) Ammonium hydroxide solution, 300 mℓ/ℓ: Dilute 300 mℓ of ammonium hydroxide (AR grade) to 1 ℓ with water.

(6) Complexing reagent: Dissolve 101,1 g potassium nitrate (AR grade), 16,8 g potassium hydroxide (AR grade), 89,8 g potassium hydrogen phthalate (AR grade), and 3,6 g cyclohexylenediaminetetraacetic acid (CDTA) (AR grade) in 800 mℓ water and dilute to 1 ℓ with water.

(7) Standard stock solution: Dissolve 2,21 g sodium fluoride (AR grade) in 500 mℓ water and dilute to 1 ℓ with water. This solution contains 1 000 mg/ℓ F.

Reagents for fluoride determination should be stored in polythene or polypropylene bottles.

Preparation of standard solution

Transfer by pipette, 10 mℓ of standard stock solution to a 1 ℓ polypropylene standard volumetric flask and dilute to 1 ℓ with water. This solution contains 10 mg/ℓ F.

Pretreatment of samples and standard solution

Weigh accurately approximately 0,5 g of the sample dried at 105 °C into a 100 mℓ polypropylene bottle. Add 10 mℓ water and allow to stand for 15 min. Add 10 mℓ of 56 mℓ/ℓ sulphuric acid solution, secure the cap and shake the bottle for several seconds. Shake occasionally during the next 15 min. Add 80 mℓ water, shake, and allow to stand for another 15 min. Transfer, by pipette, 25 mℓ sample solution to a 100 mℓ polypropylene beaker containing 2,0 mℓ standard solution. Adjust the pH of this solution to 8,0 - 8,5 with 300 mℓ/ℓ ammonium hydroxide solution. Allow the resulting precipitate to settle, then filter through a Whatman No. 40 paper into a 100 mℓ polypropylene beaker. Adjust the pH of the filtrate to 7,0 ± 0,1 with 5,6 mℓ/ℓ sulphuric acid solution, transfer quantitatively to a 100 mℓ polypropylene standard volumetric flask and dilute to 100 mℓ with water.

Transfer, by pipette, 2,0, 5,0, 10,0 and 20,0 mℓ of standard solution into a series of 100 mℓ polypropylene beakers, containing 2,5 mℓ of 56 mℓ/ℓ sulphuric acid solution. Adjust the pH to 8,0 - 8,5 with the 300 mℓ/ℓ ammonium hydroxide solution and then to 7,0 ± 0,1 with the 5,6 mℓ/ℓ sulphuric acid solution as before. Transfer quantitatively to a series of 100 mℓ polypropylene standard volumetric flasks and dilute to 100 mℓ with water.

Measurement of fluoride concentration

Transfer, by pipette, 20 mℓ of the pretreated sample or standard solution into a 50 mℓ polypropylene beaker and add 2,0 mℓ of complexing reagent. Insert the electrodes, stir gently and allow the system to reach a steady reading (up to 4 min). Note the reading, remove the electrodes, wash with water, and blot dry.

Determine the mass of fluoride in each sample aliquot by reference to the calibration curve obtained by plotting on semi-logarithmic paper the mass of fluoride contained in each standard solution aliquot (4;

10; 20; 40 µg respectively) versus the corresponding mV readings.

Calculation

Concentration of fluoride in sample (mg/kg F, dry basis) = $\frac{20\ (B-4)}{A}$

where A = mass of sample (g)

B = mass of fluoride in sample aliquot (µg F)

Notes

(1) Many soluble and insoluble simple and complex fluorides show complete release of fluoride and are determined quantitatively. Some insoluble fluorides may show only partial release of soluble ionic fluoride, while some complex fluorides may show little or no release of soluble ionic fluoride. In these cases recovery maybe improved by extended treatment (refer Note 2). Also, some complex fluorides show no release of fluoride. It should be assumed that organofluorine compounds show no release.

(2) Some compounds, eg. fluoroborates and fluorophosphates, require additional treatment in order to show fluoride release. The following treatment is recommended: After addition of the 10 mℓ of 56 mℓ/ℓ sulphuric acid solution during the pretreatment stage, loosen (but do not remove) the cap of the bottle after shaking, and place the bottle on a steambath for 30 min, swirling occasionally. Allow to cool to room temperature, then proceed with the rest of the pretreatment stage.

(3) In addition to aluminium, other interferences likely to occur in sewage sludges are calcium, magnesium, ferric iron and phosphate.

References

DEPARTMENT OF THE ENVIRONMENT 1983 *Fluoride in Waters, Effluents, Sludges, Plants and Soils 1982* Methods for the Examination of Waters and Associated Materials, Her Majesty's Stationery Office, London.

HAHNE, H.C.H. 1988 *Private communication.*

RADIOMETER A/S Undated *Instructions for F1052 F fluoride electrode.* Copenhagen, Denmark.

APPENDIX 2

DETERMINATION OF INORGANIC CHEMICAL CONTAMINANTS AND NUTRIENTS IN SOUTH AFRICAN MUNICIPAL SEWAGE SLUDGES - RESULTS FOR INDIVIDUAL SAMPLES FROM EACH SEWAGE WORKS

NB: (1) Cd, Cr, Cu, Pb, Ni, Zn, pH, K, Ca, Mg : Mean value shown is average of 4 determinations

(2) Hg, As, Se, Mo, B, F, TKN, TP : Mean value shown is result obtained on composite of 4 samples

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CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: .....BETHLEHEM - OFS.....

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 June83	2 Oct.83	3 Nov.83	4 May84		
Total residue/ Totale reste	%	92,2	94,7	91,9	97,8	94,2	2,4
Volatile residue/ Vlugtige reste	% (d.b.)	40,3	23,3	58,5	14,7	34,2	16,8
Fixed residue/ Vaste reste	% (d.b.)	59,7	76,7	41,5	85,3	65,8	16,8
pH	pH units/ eenhede	7,6	7,9	7,7	7,2	7,6	0,3
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	21,4	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	9,8	-
Potassium/Kalium	g/kg K (d.b.)	2,5	2,0	2,1	1,5	2,0	0,4
Calcium/Kalsium	g/kg Ca (d.b.)	32,0	24,8	33,6	13,2	25,9	8,1
Magnesium	g/kg Mg (d.b.)	10,8	8,0	11,2	3,1	8,3	3,2
Cadmium/Kadmium	mg/kg Cd (d.b.)	<1	1	3	1	1	1
Chromium/Chroom	mg/kg Cr (d.b.)	28	31	30	9	25	9
Copper/Koper	mg/kg Cu (d.b.)	123	151	191	72	134	43
Lead/Lood	mg/kg Pb (d.b.)	96	112	156	47	103	39
Nickel/Nikkel	mg/kg Ni (d.b.)	18	18	16	14	17	2
Zinc/Sink	mg/kg Zn (d.b.)	727	750	1128	480	771	232
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	5	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	3	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	<1	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	2	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	11	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	59	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: BLOEMFONTEIN - OFS

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 June83	2 Oct.83	3 Nov.83	4 May84		
Total residue/ Totale reste	%	96,1	93,2	93,4	94,7	94,4	1,2
Volatile residue/ Vlugtige reste	% (d.b.)	41,8	60,2	46,7	34,1	45,7	9,5
Fixed residue/ Vaste reste	% (d.b.)	58,2	39,8	53,3	65,9	54,3	9,5
pH	pH units/ eenhede	6,4	7,3	7,6	6,8	7,0	0,5
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	26,7	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	11,8	-
Potassium/Kalium	g/kg K (d.b.)	2,2	2,4	1,8	2,0	2,1	0,2
Calcium/Kalsium	g/kg Ca (d.b.)	41,2	38,0	45,2	46,0	42,6	3,2
Magnesium	g/kg Mg (d.b.)	11,2	9,6	10,0	8,0	9,7	1,1
Cadmium/Kadmium	mg/kg Cd (d.b.)	3	4	4	2	3	1
Chromium/Chroom	mg/kg Cr (d.b.)	96	132	108	62	100	25
Copper/Koper	mg/kg Cu (d.b.)	288	394	392	486	390	70
Lead/Lood	mg/kg Pb (d.b.)	280	334	312	222	287	42
Nickel/Nikkel	mg/kg Ni (d.b.)	80	68	60	44	63	13
Zinc/Sink	mg/kg Zn (d.b.)	1324	1664	1520	1221	1432	172
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	8	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	6	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	< 1	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	1	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	22	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	124	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

HARRISMITH - OFS

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: .....

Determinand	Units / Eenheide	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 June83	2 Oct.83	3 Nov.83	4 May84		
Total residue/ Totale reste	%	96,6	94,2	87,9	94,2	93,2	3,2
Volatile residue/ Vlugtige reste	% (d.b.)	28,3	71,7	66,1	38,9	51,3	18,2
Fixed residue/ Vaste reste	% (d.b.)	71,7	28,3	33,9	61,1	48,7	18,2
pH	pH units/ eenhede	5,9	6,2	7,2	6,2	6,4	0,5
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	25,7	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	8,4	-
Potassium/Kalium	g/kg K (d.b.)	1,5	1,4	4,1	2,4	2,4	1,1
Calcium/Kalsium	g/kg Ca (d.b.)	14,8	22,0	19,6	23,5	20,0	3,3
Magnesium	g/kg Mg (d.b.)	3,8	4,0	16,0	4,6	7,1	5,2
Cadmium/Kadmium	mg/kg Cd (d.b.)	<1	1	2	2	1	1
Chromium/Chroom	mg/kg Cr (d.b.)	33	38	41	49	40	6
Copper/Koper	mg/kg Cu (d.b.)	123	123	125	522	223	172
Lead/Lood	mg/kg Pb (d.b.)	82	128	84	120	104	21
Nickel/Nikkel	mg/kg Ni (d.b.)	11	16	13	13	13	2
Zinc/Sink	mg/kg Zn (d.b.)	736	876	1016	1305	983	210
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	3	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	3	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	<1	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	4	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	14	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	61	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: KROONSTAD - OFS .....

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 June83	2 Oct.83	3 Nov.83	4 May84		
Total residue/ Totale reste	%	94,5	85,7	78,2	94,5	88,2	6,8
Volatile residue/ Vlugtige reste	% (d.b.)	40,1	44,3	30,0	31,8	36,6	5,9
Fixed residue/ Vaste reste	% (d.b.)	59,9	55,7	70,0	68,2	63,4	5,9
pH	pH units/ eenhede	6,9	7,1	6,7	7,4	7,0	0,3
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	19,3	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	9,3	-
Potassium/Kalium	g/kg K (d.b.)	2,3	2,3	2,2	2,8	2,4	0,2
Calcium/Kalsium	g/kg Ca (d.b.)	38,0	40,0	26,0	33,6	34,4	5,4
Magnesium	g/kg Mg (d.b.)	7,2	6,4	5,2	5,3	6,0	0,8
Cadmium/Kadmium	mg/kg Cd (d.b.)	3	3	2	2	3	1
Chromium/Chroom	mg/kg Cr (d.b.)	55	48	59	35	49	9
Copper/Koper	mg/kg Cu (d.b.)	199	226	166	178	192	23
Lead/Lood	mg/kg Pb (d.b.)	192	196	144	131	166	29
Nickel/Nikkel	mg/kg Ni (d.b.)	32	29	30	21	28	4
Zinc/Sink	mg/kg Zn (d.b.)	1146	1178	934	1074	1083	94
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	6	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	4	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	<1	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	6	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	14	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	92	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

PARYS - OFS

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: .....

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 June83	2 Oct.83	3 Nov.83	4 May84		
Total residue/ Totale reste	%	95,6	94,9	94,4	93,6	94,6	0,7
Volatile residue/ Vlugtige reste	% (d.b.)	36,4	45,3	52,3	49,7	45,9	6,0
Fixed residue/ Vaste reste	% (d.b.)	63,6	54,7	47,7	50,3	54,1	6,0
pH	pH units/ eenhede	5,8	6,7	6,7	6,8	6,5	0,4
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	27,6	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	11,8	-
Potassium/Kalium	g/kg K (d.b.)	0,8	1,6	1,1	1,2	1,2	0,3
Calcium/Kalsium	g/kg Ca (d.b.)	38,0	41,2	41,2	37,2	39,4	1,8
Magnesium	g/kg Mg (d.b.)	6,0	6,0	5,2	4,3	5,4	0,7
Cadmium/Kadmium	mg/kg Cd (d.b.)	2	10	8	3	6	3
Chromium/Chroom	mg/kg Cr (d.b.)	152	204	230	129	179	40
Copper/Koper	mg/kg Cu (d.b.)	178	299	198	174	212	51
Lead/Lood	mg/kg Pb (d.b.)	100	82	108	98	97	9
Nickel/Nikkel	mg/kg Ni (d.b.)	56	56	68	34	54	12
Zinc/Sink	mg/kg Zn (d.b.)	2332	1776	2042	1802	1988	224
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	4	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	< 1	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	3	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	9	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	14	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	156	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: SASOLBURG - OFS

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 June83	2 Oct.83	3 Nov.83	4 May84		
Total residue/ Totale reste	%	94,4	94,7	85,8	92,9	92,0	3,6
Volatile residue/ Vlugtige reste	% (d.b.)	52,4	54,6	57,6	47,0	52,9	3,9
Fixed residue/ Vaste reste	% (d.b.)	47,6	45,4	42,4	53,0	47,1	3,9
pH	pH units/ eenhede	7,0	7,3	7,6	7,4	7,3	0,2
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	41,7	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	14,8	-
Potassium/Kalium	g/kg K (d.b.)	1,4	2,4	2,6	1,8	2,1	0,5
Calcium/Kalsium	g/kg Ca (d.b.)	58,4	65,2	48,8	64,4	59,2	6,6
Magnesium	g/kg Mg (d.b.)	3,7	5,2	3,8	4,0	4,2	0,6
Cadmium/Kadmium	mg/kg Cd (d.b.)	< 1	3	4	1	2	1
Chromium/Chroom	mg/kg Cr (d.b.)	482	248	468	257	364	111
Copper/Koper	mg/kg Cu (d.b.)	164	165	147	107	146	23
Lead/Lood	mg/kg Pb (d.b.)	56	114	44	53	67	28
Nickel/Nikkel	mg/kg Ni (d.b.)	49	49	38	40	44	5
Zinc/Sink	mg/kg Zn (d.b.)	508	762	392	531	548	134
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	22	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	16	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	107	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	14	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	59	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	1260	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: VIRGINIA - OFS .....

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 June83	2 Sept.83	3 Nov.83	4 May84		
Total residue/ Totale reste	%	97,8	-	94,5	95,3	96,9	1,4
Volatile residue/ Vlugtige reste	% (d.b.)	47,1	47,2	51,9	29,6	44,0	8,5
Fixed residue/ Vaste reste	% (d.b.)	52,9	52,8	48,1	70,4	56,0	8,5
pH	pH units/ eenhede	7,0	6,6	6,8	6,4	6,7	0,2
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	20,0	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	5,8	-
Potassium/Kalium	g/kg K (d.b.)	1,7	1,5	1,5	1,8	1,6	0,1
Calcium/Kalsium	g/kg Ca (d.b.)	31,6	25,2	27,6	28,0	28,1	2,3
Magnesium	g/kg Mg (d.b.)	5,6	4,4	4,4	4,4	4,7	0,5
Cadmium/Kadmium	mg/kg Cd (d.b.)	< 1	2	< 1	2	1	1
Chromium/Chroom	mg/kg Cr (d.b.)	92	76	76	40	71	19
Copper/Koper	mg/kg Cu (d.b.)	218	186	195	144	186	27
Lead/Lood	mg/kg Pb (d.b.)	184	190	168	133	169	22
Nickel/Nikkel	mg/kg Ni (d.b.)	68	55	56	42	55	9
Zinc/Sink	mg/kg Zn (d.b.)	1614	1328	1416	950	1327	241
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	4	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	28	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	1	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	3	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	58	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	144	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

WELKOM(THERONIA) - OFS

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: .....

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 June83	2 Sept.83	3 Nov.83	4 May84		
Total residue/ Totale reste	%	96,2	96,2	-	96,5	96,3	0,1
Volatile residue/ Vlugtige reste	% (d.b.)	40,0	51,3	46,5	20,5	39,6	11,7
Fixed residue/ Vaste reste	% (d.b.)	60,0	48,7	53,5	79,5	60,4	11,7
pH	pH units/ eenhede	7,1	6,0	6,9	6,3	6,6	0,4
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	21,4	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	9,3	-
Potassium/Kalium	g/kg K (d.b.)	1,3	1,5	1,3	1,2	1,3	0,1
Calcium/Kalsium	g/kg Ca (d.b.)	34,4	37,6	45,4	32,8	37,6	4,9
Magnesium	g/kg Mg (d.b.)	8,0	7,6	8,4	3,3	6,8	2,1
Cadmium/Kadmium	mg/kg Cd (d.b.)	5	6	15	13	10	4
Chromium/Chroom	mg/kg Cr (d.b.)	98	103	92	44	59	23
Copper/Koper	mg/kg Cu (d.b.)	859	1029	714	386	747	236
Lead/Lood	mg/kg Pb (d.b.)	1336	2192	1366	547	1360	582
Nickel/Nikkel	mg/kg Ni (d.b.)	52	50	51	28	45	10
Zinc/Sink	mg/kg Zn (d.b.)	4052	4304	3040	1177	3143	151
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	8	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	17	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	1	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	7	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	20	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	236	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: WELKOM(WITPAN) - OFS

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 June83	2 Sept.83	3 Nov.83	4 May84		
Total residue/ Totale reste	%	96,4	96,3	97,7	95,9	96,6	0,7
Volatile residue/ Vlugtige reste	% (d.b.)	38,9	44,2	40,6	24,2	35,0	7,6
Fixed residue/ Vaste reste	% (d.b.)	61,1	55,8	59,4	75,8	65,0	7,6
pH	pH units/ eenhede	6,4	6,1	5,7	5,6	6,0	0,3
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	17,3	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	7,9	-
Potassium/Kalium	g/kg K (d.b.)	0,9	1,0	1,3	1,9	1,3	0,4
Calcium/Kalsium	g/kg Ca (d.b.)	32,8	33,2	34,4	36,4	34,2	1,4
Magnesium	g/kg Mg (d.b.)	4,4	4,8	4,8	4,0	4,5	0,3
Cadmium/Kadmium	mg/kg Cd (d.b.)	6	8	16	9	10	4
Chromium/Chroom	mg/kg Cr (d.b.)	110	102	102	40	89	28
Copper/Koper	mg/kg Cu (d.b.)	600	502	832	323	564	183
Lead/Lood	mg/kg Pb (d.b.)	584	506	1196	587	718	278
Nickel/Nikkel	mg/kg Ni (d.b.)	48	46	52	28	44	9
Zinc/Sink	mg/kg Zn (d.b.)	1916	2102	1856	1479	1838	226
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	6	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	11	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	< 1	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	6	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	14	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	162	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: BOKSBURG - TVL

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Mar.85	2 June85	3 Oct.85	4 Jan.86		
Total residue/ Totale reste	%	92,4	93,0	93,2	82,0	90,2	4,7
Volatile residue/ Vlugtige reste	% (d.b.)	51,9	48,3	53,3	43,3	49,2	3,9
Fixed residue/ Vaste reste	% (d.b.)	48,1	51,7	46,7	56,7	50,8	3,9
pH	pH units/ eenhede	7,2	7,2	7,7	7,0	7,3	0,3
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	25,1	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	30,3	-
Potassium/Kalium	g/kg K (d.b.)	1,8	2,3	2,1	1,5	1,9	0,3
Calcium/Kalsium	g/kg Ca (d.b.)	44,8	42,0	40,4	37,6	41,2	2,6
Magnesium	g/kg Mg (d.b.)	5,2	5,6	4,8	5,2	5,2	0,3
Cadmium/Kadmium	mg/kg Cd (d.b.)	64	64	60	64	63	2
Chromium/Chroom	mg/kg Cr (d.b.)	1160	1088	896	1124	1067	102
Copper/Koper	mg/kg Cu (d.b.)	585	580	424	417	502	81
Lead/Lood	mg/kg Pb (d.b.)	317	288	348	345	325	24
Nickel/Nikkel	mg/kg Ni (d.b.)	489	480	319	352	410	75
Zinc/Sink	mg/kg Zn (d.b.)	4860	4636	3904	3776	4294	463
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	5	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	15	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	4	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	15	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	50	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	191	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: BRITS - TVL

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Mar.85	2 June85	3 Oct85	4 Jan86		
Total residue/ Totale reste	%	88,7	87,9	89,2	91,3	89,3	1,3
Volatile residue/ Vlugtige reste	% (d.b.)	35,7	42,0	40,2	36,2	38,5	2,7
Fixed residue/ Vaste reste	% (d.b.)	64,3	58,0	59,8	63,8	61,5	2,7
pH	pH units/ eenhede	6,7	8,1	7,0	7,0	7,2	0,5
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	25,8	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	34,9	-
Potassium/Kalium	g/kg K (d.b.)	2,8	3,4	3,1	2,2	2,9	0,4
Calcium/Kalsium	g/kg Ca (d.b.)	24,4	33,2	39,6	29,6	31,7	5,5
Magnesium	g/kg Mg (d.b.)	5,2	6,0	5,6	5,6	5,6	0,3
Cadmium/Kadmium	mg/kg Cd (d.b.)	9	6	6	6	7	1,3
Chromium/Chroom	mg/kg Cr (d.b.)	1008	769	1256	1360	1098	229
Copper/Koper	mg/kg Cu (d.b.)	723	744	1524	1351	1086	357
Lead/Lood	mg/kg Pb (d.b.)	297	622	490	258	417	148
Nickel/Nikkel	mg/kg Ni (d.b.)	4504	3080	1724	1332	2660	1247
Zinc/Sink	mg/kg Zn (d.b.)	8624	6744	7260	4880	6877	1342
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	4	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	9	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	11	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	12	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	53	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	94	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

CARLETONVILLE - TVL

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: .....

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Mar85	2 June85	3 Oct.85	4 Jan86		
Total residue/ Totale reste	%	94,1	94,6	91,0	91,4	92,8	1,6
Volatile residue/ Vlugtige reste	% (d.b.)	56,8	58,4	51,1	53,7	55,0	2,8
Fixed residue/ Vaste reste	% (d.b.)	43,2	41,6	48,9	46,3	45,0	2,8
pH	pH units/ eenhede	5,5	6,2	7,1	6,6	6,4	0,6
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	32,5	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	16,1	-
Potassium/Kalium	g/kg K (d.b.)	1,0	1,1	1,3	0,7	1,0	0,2
Calcium/Kalsium	g/kg Ca (d.b.)	49,6	52,4	47,2	49,6	49,7	1,8
Magnesium	g/kg Mg (d.b.)	6,8	8,0	8,0	7,6	7,6	0,5
Cadmium/Kadmium	mg/kg Cd (d.b.)	10	11	8	8	9	1
Chromium/Chroom	mg/kg Cr (d.b.)	281	229	222	224	239	24
Copper/Koper	mg/kg Cu (d.b.)	429	433	394	403	415	17
Lead/Lood	mg/kg Pb (d.b.)	629	615	537	631	603	39
Nickel/Nikkel	mg/kg Ni (d.b.)	94	85	72	66	79	11
Zinc/Sink	mg/kg Zn (d.b.)	2512	2412	2136	2296	2339	140
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	10	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	6	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	3	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	8	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	23	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	177	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: ERMELO - TVL

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Mar85	2 June85	3 Oct85	4 Jan86		
Total residue/ Totale reste	%	93,2	95,7	91,6	79,9	90,1	6,1
Volatile residue/ Vlugtige reste	% (d.b.)	47,2	36,5	50,9	50,2	46,2	5,8
Fixed residue/ Vaste reste	% (d.b.)	52,8	63,5	49,1	49,8	53,8	5,8
pH	pH units/ eenhede	7,2	7,0	5,4	6,3	6,5	0,7
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	31,0	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	8,2	-
Potassium/Kalium	g/kg K (d.b.)	2,7	1,5	2,5	1,6	2,1	0,5
Calcium/Kalsium	g/kg Ca (d.b.)	22,8	15,2	36,4	26,4	25,2	7,6
Magnesium	g/kg Mg (d.b.)	6,8	4,0	7,2	5,6	5,9	1,2
Cadmium/Kadmium	mg/kg Cd (d.b.)	4	2	4	3	3	0,8
Chromium/Chroom	mg/kg Cr (d.b.)	124	138	173	120	139	21
Copper/Koper	mg/kg Cu (d.b.)	237	182	292	269	245	41
Lead/Lood	mg/kg Pb (d.b.)	201	128	288	217	209	57
Nickel/Nikkel	mg/kg Ni (d.b.)	44	42	171	43	75	55
Zinc/Sink	mg/kg Zn (d.b.)	2360	1580	2196	2704	2210	407
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	6	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	5	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	2	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	7	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	27	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	98	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

EVANDER - TVL

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: .....

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Mar85	2 June85	3 Oct.85	4 Jan86		
Total residue/ Totale reste	%	90,4	92,3	79,8	93,5	89,0	5,4
Volatile residue/ Vlugtige reste	% (d.b.)	58,7	61,0	39,1	42,9	50,4	9,6
Fixed residue/ Vaste reste	% (d.b.)	41,3	39,0	60,9	57,1	49,6	9,6
pH	pH units/ eenhede	7,8	6,7	8,8	6,6	7,5	0,9
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	37,1	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	17,0	-
Potassium/Kalium	g/kg K (d.b.)	3,5	5,5	2,8	1,1	3,2	1,6
Calcium/Kalsium	g/kg Ca (d.b.)	21,2	16,0	19,2	22,0	19,6	2,2
Magnesium	g/kg Mg (d.b.)	6,0	5,6	8,0	4,8	6,1	1,2
Cadmium/Kadmium	mg/kg Cd (d.b.)	3	2	1	2	2	1
Chromium/Chroom	mg/kg Cr (d.b.)	320	249	147	136	213	76
Copper/Koper	mg/kg Cu (d.b.)	248	183	228	244	226	26
Lead/Lood	mg/kg Pb (d.b.)	133	93	108	177	128	32
Nickel/Nikkel	mg/kg Ni (d.b.)	992	532	744	688	739	166
Zinc/Sink	mg/kg Zn (d.b.)	2856	1688	2240	2404	2297	418
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	3	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	7	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	< 1	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	4	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	29	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	218	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: GERMISTON (DEKEMA) - TVL

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Mar85	2 June85	3 Oct85	4 Jan86		
Total residue/ Totale reste	%	95,2	94,8	95,0	96,0	95,3	0,5
Volatile residue/ Vlugtige reste	% (d.b.)	50,5	47,7	47,4	41,5	46,8	3,3
Fixed residue/ Vaste reste	% (d.b.)	49,5	52,3	52,6	58,5	53,2	3,3
pH	pH units/ eenhede	7,0	7,2	7,6	7,4	7,3	0,2
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	22,0	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	15,1	-
Potassium/Kalium	g/kg K (d.b.)	2,4	2,3	2,8	1,7	2,3	0,4
Calcium/Kalsium	g/kg Ca (d.b.)	24,4	28,0	30,4	26,8	27,4	2,2
Magnesium	g/kg Mg (d.b.)	5,2	6,0	6,4	5,6	5,8	0,4
Cadmium/Kadmium	mg/kg Cd (d.b.)	20	14	29	24	22	5
Chromium/Chroom	mg/kg Cr (d.b.)	304	460	402	311	369	65
Copper/Koper	mg/kg Cu (d.b.)	770	721	646	728	716	45
Lead/Lood	mg/kg Pb (d.b.)	711	733	873	762	770	62
Nickel/Nikkel	mg/kg Ni (d.b.)	156	153	209	114	158	34
Zinc/Sink	mg/kg Zn (d.b.)	3480	3668	3988	6328	4366	1147
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	5	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	4	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	2	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	24	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	19	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	236	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

GERMISTON (RONDEBULT) - TVL

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: .....

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Mar85	2 June85	3 Oct85	4 Jan86		
Total residue/ Totale reste	%	91,2	91,8	88,4	93,7	91,3	1,9
Volatile residue/ Vlugtige reste	% (d.b.)	47,9	49,2	48,4	45,8	47,8	1,3
Fixed residue/ Vaste reste	% (d.b.)	52,1	50,8	51,6	54,2	52,2	1,3
pH	pH units/ eenhede	7,6	7,7	6,7	7,5	7,4	0,4
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	28,6	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	37,9	-
Potassium/Kalium	g/kg K (d.b.)	1,7	1,6	1,7	1,4	1,6	0,1
Calcium/Kalsium	g/kg Ca (d.b.)	31,6	38,4	40,8	38,8	37,4	3,5
Magnesium	g/kg Mg (d.b.)	5,6	6,0	5,6	5,2	5,6	0,3
Cadmium/Kadmium	mg/kg Cd (d.b.)	68	83	90	93	84	10
Chromium/Chroom	mg/kg Cr (d.b.)	658	622	716	578	644	51
Copper/Koper	mg/kg Cu (d.b.)	464	436	446	468	454	13
Lead/Lood	mg/kg Pb (d.b.)	531	448	433	497	477	39
Nickel/Nikkel	mg/kg Ni (d.b.)	615	612	645	563	609	29
Zinc/Sink	mg/kg Zn (d.b.)	4952	3924	3296	3384	3889	659
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	9	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	34	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	< 1	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	14	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	18	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	518	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: GERMISTON (WATERVAL) - TVL

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Mar85	2 June85	3 Oct85	4 Jan86		
Total residue/ Totale reste	%	93,5	93,2	94,3	91,6	93,2	1,0
Volatile residue/ Vlugtige reste	% (d.b.)	47,6	49,0	46,2	48,2	47,8	1,0
Fixed residue/ Vaste reste	% (d.b.)	52,4	51,0	53,8	51,8	52,3	1,0
pH	pH units/ eenhede	7,4	7,3	7,7	7,3	7,4	0,2
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	27,3	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	17,8	-
Potassium/Kalium	g/kg K (d.b.)	5,0	6,5	4,3	6,2	5,5	0,9
Calcium/Kalsium	g/kg Ca (d.b.)	25,6	26,0	28,0	27,2	26,7	1,0
Magnesium	g/kg Mg (d.b.)	6,4	7,6	7,2	8,4	7,4	0,7
Cadmium/Kadmium	mg/kg Cd (d.b.)	46	42	54	53	49	5
Chromium/Chroom	mg/kg Cr (d.b.)	556	500	244	252	388	141
Copper/Koper	mg/kg Cu (d.b.)	846	768	676	718	752	63
Lead/Lood	mg/kg Pb (d.b.)	846	980	924	1044	949	73
Nickel/Nikkel	mg/kg Ni (d.b.)	124	121	113	113	118	5
Zinc/Sink	mg/kg Zn (d.b.)	4036	3676	3532	3872	3779	191
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	9	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	6	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	1	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	23	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	35	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	136	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: JOHANNESBURG(GOUDKOPPIES) - TVL

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Mar85	2 June85	3 Oct85	4 Jan86		
Total residue/ Totale reste	%	91,4	90,9	92,2	90,0	91,1	0,8
Volatile residue/ Vlugtige reste	% (d.b.)	62,2	68,7	67,7	61,4	65,0	3,3
Fixed residue/ Vaste reste	% (d.b.)	37,8	31,3	32,3	38,6	35,0	3,2
pH	pH units/ eenhede	6,2	6,9	6,9	6,7	6,7	0,3
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	42,6	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	24,5	-
Potassium/Kalium	g/kg K (d.b.)	1,9	9,9	10,5	8,8	8,6	2,6
Calcium/Kalsium	g/kg Ca (d.b.)	36,8	34,0	29,6	33,6	33,5	2,6
Magnesium	g/kg Mg (d.b.)	8,0	9,6	7,6	7,6	8,2	0,8
Cadmium/Kadmium	mg/kg Cd (d.b.)	72	38	48	32	48	15
Chromium/Chroom	mg/kg Cr (d.b.)	1928	760	1012	2504	1551	701
Copper/Koper	mg/kg Cu (d.b.)	1812	1364	1432	1276	1471	204
Lead/Lood	mg/kg Pb (d.b.)	956	532	760	688	734	152
Nickel/Nikkel	mg/kg Ni (d.b.)	620	387	488	636	533	102
Zinc/Sink	mg/kg Zn (d.b.)	5012	3692	3692	3424	3955	620
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	13	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	8	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	2	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	6	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	29	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	149	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: JOHANNESBURG(NORTHERN ACTIVATED) - TVL

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Mar85	2 June85	3 Oct85	4 Jan86		
Total residue/ Totale reste	%	92,5	84,8	92,0	92,4	90,4	3,3
Volatile residue/ Vlugtige reste	% (d.b.)	49,7	48,5	59,3	54,4	53,0	4,3
Fixed residue/ Vaste reste	% (d.b.)	50,3	51,5	40,7	45,6	47,0	4,3
pH	pH units/ eenhede	7,3	8,4	6,6	7,0	7,3	0,7
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	43,6	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	27,7	-
Potassium/Kalium	g/kg K (d.b.)	1,3	13,7	2,7	1,6	6,6	5,8
Calcium/Kalsium	g/kg Ca (d.b.)	56,0	20,8	34,8	58,8	42,6	15,6
Magnesium	g/kg Mg (d.b.)	10,4	11,2	7,2	8,0	9,2	1,6
Cadmium/Kadmium	mg/kg Cd (d.b.)	184	92	44	128	112	51
Chromium/Chroom	mg/kg Cr (d.b.)	916	504	312	484	554	222
Copper/Koper	mg/kg Cu (d.b.)	681	384	288	595	487	158
Lead/Lood	mg/kg Pb (d.b.)	508	189	187	296	295	131
Nickel/Nikkel	mg/kg Ni (d.b.)	319	424	50	177	243	142
Zinc/Sink	mg/kg Zn (d.b.)	5356	2308	1628	3576	3217	1419
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	11	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	6	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	2	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	5	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	30	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	112	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: JOHANNESBURG (NORTHERN DIGESTED) - TVL

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Mar85	2 June85	3 Oct85	4 Jan86		
Total residue/ Totale reste	%	92,2	91,4	93,6	92,6	92,5	0.8
Volatile residue/ Vlugtige reste	% (d.b.)	52,9	52,8	47,6	45,4	49,7	3,3
Fixed residue/ Vaste reste	% (d.b.)	47,1	47,2	52,4	54,6	50,3	3,3
pH	pH units/ eenhede	6,3	6,6	6,8	6,7	6,6	0,2
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	38,8	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	41,0	-
Potassium/Kalium	g/kg K (d.b.)	11,0	14,5	15,3	4,4	10,6	4,6
Calcium/Kalsium	g/kg Ca (d.b.)	20,4	42,8	22,6	41,2	31,8	10,3
Magnesium	g/kg Mg (d.b.)	11,2	8,8	13,6	12,4	11,5	1,8
Cadmium/Kadmium	mg/kg Cd (d.b.)	96	26	108	172	101	52
Chromium/Chroom	mg/kg Cr (d.b.)	500	340	480	792	528	164
Copper/Koper	mg/kg Cu (d.b.)	306	150	324	626	352	172
Lead/Lood	mg/kg Pb (d.b.)	219	92	160	351	206	95
Nickel/Nikkel	mg/kg Ni (d.b.)	189	54	177	302	181	88
Zinc/Sink	mg/kg Zn (d.b.)	2384	1000	2124	5072	2645	1495
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	9	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	6	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	3	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	4	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	30	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	116	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: JOHANNESBURG (OLIFANTSVLEI) - TVL

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Mar85	2 June85	3 Oct85	4 Jan86		
Total residue/ Totale reste	%	93,5	92,9	91,9	92,3	92,7	0,6
Volatile residue/ Vlugtige reste	% (d.b.)	59,2	64,0	56,3	56,8	59,1	3,0
Fixed residue/ Vaste reste	% (d.b.)	40,8	36,0	43,7	43,2	40,9	3,0
pH	pH units/ eenhede	7,4	7,7	7,0	6,8	7,2	0,3
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	36,2	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	26,8	-
Potassium/Kalium	g/kg K (d.b.)	3,8	4,1	4,8	7,4	4,8	1,3
Calcium/Kalsium	g/kg Ca (d.b.)	32,4	35,6	29,2	32,4	32,4	2,3
Magnesium	g/kg Mg (d.b.)	5,6	6,4	4,8	6,4	5,8	0,7
Cadmium/Kadmium	mg/kg Cd (d.b.)	36	24	38	10	27	11
Chromium/Chroom	mg/kg Cr (d.b.)	1884	1920	1912	716	1608	515
Copper/Koper	mg/kg Cu (d.b.)	802	1256	1244	621	981	277
Lead/Lood	mg/kg Pb (d.b.)	210	205	142	189	187	27
Nickel/Nikkel	mg/kg Ni (d.b.)	708	516	315	155	424	208
Zinc/Sink	mg/kg Zn (d.b.)	1664	1768	1616	1376	1606	144
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	5	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	8	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	2	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	2	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	34	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	94	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

KEMPTON PARK - TVL

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: .....

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Mar85	2 June85	3 Oct85	4 Jan86		
Total residue/ Totale reste	%	75,9	94,4	83,8	94,3	87,1	7,8
Volatile residue/ Vlugtige reste	% (d.b.)	60,4	60,8	27,8	63,3	53,1	14,6
Fixed residue/ Vaste reste	% (d.b.)	39,6	39,2	72,2	36,7	46,9	14,6
pH	pH units/ eenhede	6,5	6,7	6,2	7,2	6,7	0,4
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	35,5	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	13,5	-
Potassium/Kalium	g/kg K (d.b.)	0,8	1,1	0,9	0,9	0,9	0,1
Calcium/Kalsium	g/kg Ca (d.b.)	28,4	33,2	30,4	25,2	29,3	2,9
Magnesium	g/kg Mg (d.b.)	5,2	4,8	11,6	4,0	6,4	3,0
Cadmium/Kadmium	mg/kg Cd (d.b.)	40	38	40	56	44	7
Chromium/Chroom	mg/kg Cr (d.b.)	1280	1176	1088	1916	1365	325
Copper/Koper	mg/kg Cu (d.b.)	2152	2048	1884	2504	2147	227
Lead/Lood	mg/kg Pb (d.b.)	307	331	276	304	305	20
Nickel/Nikkel	mg/kg Ni (d.b.)	876	1092	796	1512	1069	278
Zinc/Sink	mg/kg Zn (d.b.)	2492	2877	1912	3140	2605	462
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	7	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	6	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	3	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	5	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	17	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	404	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: KLERKSDORP - TVL

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Mar85	2 June85	3 Oct85	4 Jan86		
Total residue/ Totale reste	%	94,4	94,0	91,9	93,1	93,4	1,0
Volatile residue/ Vlugtige reste	% (d.b.)	54,6	29,8	73,6	57,3	53,8	15,7
Fixed residue/ Vaste reste	% (d.b.)	45,4	70,2	26,4	42,5	46,1	15,7
pH	pH units/ eenhede	5,9	6,2	6,8	6,2	6,3	0,3
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	33,7	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	22,0	-
Potassium/Kalium	g/kg K (d.b.)	2,5	3,5	3,8	3,4	3,3	0,5
Calcium/Kalsium	g/kg Ca (d.b.)	46,0	54,8	27,6	36,0	41,1	10,2
Magnesium	g/kg Mg (d.b.)	7,2	9,6	6,8	7,2	7,7	1,1
Cadmium/Kadmium	mg/kg Cd (d.b.)	11	4	3	7	6	3
Chromium/Chroom	mg/kg Cr (d.b.)	588	424	384	432	457	78
Copper/Koper	mg/kg Cu (d.b.)	1660	1536	2300	1856	1838	290
Lead/Lood	mg/kg Pb (d.b.)	296	200	192	227	229	41
Nickel/Nikkel	mg/kg Ni (d.b.)	67	78	56	79	70	9
Zinc/Sink	mg/kg Zn (d.b.)	1660	1116	1120	1280	1294	221
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	5	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	4	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	2	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	3	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	30	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	106	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: KRUGERSDORP - TVL

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Mar85	2 June85	3 Oct85	4 Jan86		
Total residue/ Totale reste	%	96,3	95,4	94,9	94,8	95,4	0,6
Volatile residue/ Vlugtige reste	% (d.b.)	26,4	34,9	36,9	40,7	34,7	5,2
Fixed residue/ Vaste reste	% (d.b.)	73,6	65,1	63,1	59,3	65,3	5,2
pH	pH units/ eenhede	7,2	7,0	7,2	6,9	7,1	0,1
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	22,4	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	11,2	-
Potassium/Kalium	g/kg K (d.b.)	1,4	1,6	2,5	2,4	2,0	0,5
Calcium/Kalsium	g/kg Ca (d.b.)	18,4	25,6	24,8	28,8	24,4	3,8
Magnesium	g/kg Mg (d.b.)	2,8	2,8	3,6	4,0	3,3	0,5
Cadmium/Kadmium	mg/kg Cd (d.b.)	3	3	4	4	3	1
Chromium/Chroom	mg/kg Cr (d.b.)	464	464	568	792	572	134
Copper/Koper	mg/kg Cu (d.b.)	680	284	364	552	470	155
Lead/Lood	mg/kg Pb (d.b.)	684	888	1080	920	893	141
Nickel/Nikkel	mg/kg Ni (d.b.)	148	167	325	308	237	80
Zinc/Sink	mg/kg Zn (d.b.)	856	1364	1848	1968	1509	440
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	4	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	11	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	< 1	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	5	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	26	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	98	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: MIDDELBURG - TVL

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Mar85	2 June85	3 Oct85	4 Jan86		
Total residue/ Totale reste	%	91,6	92,5	94,1	92,7	92,7	1,0
Volatile residue/ Vlugtige reste	% (d.b.)	63,1	66,9	66,6	64,7	65,3	1,5
Fixed residue/ Vaste reste	% (d.b.)	36,9	33,1	33,4	35,3	34,7	1,5
pH	pH units/ eenhede	7,7	6,7	6,6	7,3	7,1	0,5
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	51,0	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	13,5	-
Potassium/Kalium	g/kg K (d.b.)	4,8	7,6	4,8	3,8	4,9	1,2
Calcium/Kalsium	g/kg Ca (d.b.)	19,6	16,0	17,2	18,0	17,7	1,3
Magnesium	g/kg Mg (d.b.)	6,4	6,4	6,0	4,8	5,9	0,7
Cadmium/Kadmium	mg/kg Cd (d.b.)	3	2	4	2	3	1
Chromium/Chroom	mg/kg Cr (d.b.)	368	252	320	384	331	51
Copper/Koper	mg/kg Cu (d.b.)	202	146	145	155	162	23
Lead/Lood	mg/kg Pb (d.b.)	181	142	145	170	160	17
Nickel/Nikkel	mg/kg Ni (d.b.)	144	51	60	80	84	36
Zinc/Sink	mg/kg Zn (d.b.)	1392	1276	1076	1504	1312	158
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	7	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	3	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	2	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	6	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	46	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	65	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: .....NIGEL.-.TVL.....

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Mar85	2 June85	3 Oct85	4 Jan86		
Total residue/ Totale reste	%	90,9	90,8	91,9	93,3	91,7	1,0
Volatile residue/ Vlugtige reste	% (d.b.)	46,5	44,9	48,7	49,7	47,5	1,9
Fixed residue/ Vaste reste	% (d.b.)	53,5	55,1	51,3	50,3	52,6	1,9
pH	pH units/ eenhede	5,7	6,1	7,4	6,8	6,5	0,7
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	33,9	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	28,3	-
Potassium/Kalium	g/kg K (d.b.)	0,7	1,3	1,3	1,1	1,1	0,3
Calcium/Kalsium	g/kg Ca (d.b.)	24,0	22,4	24,8	30,4	25,4	3,0
Magnesium	g/kg Mg (d.b.)	3,2	3,6	3,6	3,6	3,5	0,2
Cadmium/Kadmium	mg/kg Cd (d.b.)	8,9	7,6	5,3	8,4	8	1,4
Chromium/Chroom	mg/kg Cr (d.b.)	13608	9592	7572	9288	10015	2212
Copper/Koper	mg/kg Cu (d.b.)	210	232	199	251	223	20
Lead/Lood	mg/kg Pb (d.b.)	310	598	526	702	534	144
Nickel/Nikkel	mg/kg Ni (d.b.)	144	145	95	103	122	23
Zinc/Sink	mg/kg Zn (d.b.)	8560	23320	21320	17520	17680	5662
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	7	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	13	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	1	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	6	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	15	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	65	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: ..PIETERSBURG..(PASVEER)..-..TVL.....

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Mar85	2 June85	3 Oct85	4 June86		
Total residue/ Totale reste	%	92,4	91,5	91,6	84,5	90,0	3,2
Volatile residue/ Vlugtige reste	% (d.b.)	70,2	77,5	76,4	71,1	73,8	3,2
Fixed residue/ Vaste reste	% (d.b.)	29,8	22,5	23,6	28,9	26,2	3,2
pH	pH units/ eenhede	7,3	7,0	7,3	7,4	7,3	0,2
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	50,6	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	11,0	-
Potassium/Kalium	g/kg K (d.b.)	2,0	2,8	4,4	1,7	2,7	1,1
Calcium/Kalsium	g/kg Ca (d.b.)	29,6	20,0	23,6	36,8	27,5	6,4
Magnesium	g/kg Mg (d.b.)	8,8	5,6	6,8	6,8	7,0	1,1
Cadmium/Kadmium	mg/kg Cd (d.b.)	< 1	1	< 1	3	1	0,9
Chromium/Chroom	mg/kg Cr (d.b.)	188	224	192	428	258	99
Copper/Koper	mg/kg Cu (d.b.)	245	192	191	334	241	58
Lead/Lood	mg/kg Pb (d.b.)	199	146	152	390	222	99
Nickel/Nikkel	mg/kg Ni (d.b.)	38	27	24	113	51	36
Zinc/Sink	mg/kg Zn (d.b.)	1276	856	884	2076	1273	492
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	4	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	4	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	3	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	3	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	46	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	60	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: PIETERSBURG (BIOLOG.PLANT) - TVL

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Mar85	2 June85	3 Oct85	4 Jan86		
Total residue/ Totale reste	%	92,9	87,7	92,4	92,8	91,5	2,2
Volatile residue/ Vlugtige reste	% (d.b.)	58,9	59,4	59,5	56,0	58,5	1,4
Fixed residue/ Vaste reste	% (d.b.)	41,1	40,6	40,5	44,0	41,6	1,4
pH	pH units/ eenhede	6,8	6,3	6,9	7,3	6,8	0,4
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	35,4	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	12,2	-
Potassium/Kalium	g/kg K (d.b.)	1,5	2,0	2,0	1,8	1,8	0,2
Calcium/Kalsium	g/kg Ca (d.b.)	39,2	39,6	35,6	42,8	39,3	2,6
Magnesium	g/kg Mg (d.b.)	7,6	8,0	6,4	6,4	7,1	0,7
Cadmium/Kadmium	mg/kg Cd (d.b.)	3	3	1	2	2	1
Chromium/Chroom	mg/kg Cr (d.b.)	348	348	312	328	334	15
Copper/Koper	mg/kg Cu (d.b.)	364	344	248	234	298	57
Lead/Lood	mg/kg Pb (d.b.)	447	449	331	310	384	64
Nickel/Nikkel	mg/kg Ni (d.b.)	65	56	52	47	55	7
Zinc/Sink	mg/kg Zn (d.b.)	2224	2716	1548	1376	1966	536
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	10	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	5	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	4	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	4	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	27	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	56	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: ..PHALABORWA..TVL.....

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Mar85	2 June85	3 Oct85	4 Jan86		
Total residue/ Totale reste	%	91,9	90,9	92,8	92,0	91,9	0,7
Volatile residue/ Vlugtige reste	% (d.b.)	64,3	65,6	73,6	68,2	67,9	3,6
Fixed residue/ Vaste reste	% (d.b.)	35,7	34,4	26,4	31,8	32,1	3,6
pH	pH units/ eenhede	7,1	6,8	6,4	6,8	6,8	0,2
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	51,6	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	16,0	-
Potassium/Kalium	g/kg K (d.b.)	4,4	3,7	7,2	4,3	4,5	1,1
Calcium/Kalsium	g/kg Ca (d.b.)	30,4	29,2	22,8	35,2	29,4	4,4
Magnesium	g/kg Mg (d.b.)	9,6	8,4	10,4	9,6	9,5	0,7
Cadmium/Kadmium	mg/kg Cd (d.b.)	4	4	4	7	5	1
Chromium/Chroom	mg/kg Cr (d.b.)	1764	1920	1908	1876	1867	62
Copper/Koper	mg/kg Cu (d.b.)	77	84	65	92	80	10
Lead/Lood	mg/kg Pb (d.b.)	479	438	444	452	453	16
Nickel/Nikkel	mg/kg Ni (d.b.)	79	51	32	28	48	20
Zinc/Sink	mg/kg Zn (d.b.)	1620	1560	1248	1532	1490	143
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	9	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	4	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	5	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	5	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	34	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	115	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: ..POTCHEFSTROOM - TVL.....

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Aug 86	2 Nov86	3 Feb87	4 May87		
Total residue/ Totale reste	%	87,7	88,2	89,2	90,5	88,9	1,1
Volatile residue/ Vlugtige reste	% (d.b.)	61,2	53,1	54,4	51,9	55,2	3,6
Fixed residue/ Vaste reste	% (d.b.)	38,8	46,9	45,6	48,1	44,9	3,6
pH	pH units/ eenhede	7,8	7,7	7,0	6,7	7,3	0,5
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	44,2	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	23,1	-
Potassium/Kalium	g/kg K (d.b.)	4,1	4,2	3,9	4,3	4,1	0,1
Calcium/Kalsium	g/kg Ca (d.b.)	20,7	22,9	21,8	21,6	21,8	0,8
Magnesium	g/kg Mg (d.b.)	9,7	11,0	9,8	9,2	9,9	0,7
Cadmium/Kadmium	mg/kg Cd (d.b.)	< 1	< 1	2	2	1	1
Chromium/Chroom	mg/kg Cr (d.b.)	100	94	102	131	107	14
Copper/Koper	mg/kg Cu (d.b.)	20[illegible]	206	197	196	200	4
Lead/Lood	mg/kg Pb (d.b.)	14[illegible]	141	150	140	143	4
Nickel/Nikkel	mg/kg Ni (d.b.)	84	81	80	83	82	2
Zinc/Sink	mg/kg Zn (d.b.)	1278	1358	1342	1249	1307	45
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	4	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	6	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	2	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	7	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	78	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	122	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: PRETORIA(BAVIAANSPOORT) - TVL

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Mar86	2 Mar86	3 Apr86	4 Apr86		
Total residue/ Totale reste	%	96,4	94,4	96,6	95,2	95,7	0,9
Volatile residue/ Vlugtige reste	% (d.b.)	39,2	60,3	37,4	52,1	47,3	9,4
Fixed residue/ Vaste reste	% (d.b.)	60,8	39,7	62,6	47,9	52,8	9,4
pH	pH units/ eenhede	6,9	7,0	7,0	7,0	7,0	0,4
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	16,7	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	7,4	-
Potassium/Kalium	g/kg K (d.b.)	1,8	1,9	1,4	1,4	1,6	0,3
Calcium/Kalsium	g/kg Ca (d.b.)	24,8	15,2	16,8	55,2	28,0	16,1
Magnesium	g/kg Mg (d.b.)	4,4	3,6	2,4	2,8	3,3	0,8
Cadmium/Kadmium	mg/kg Cd (d.b.)	<1	<1	<1	<1	<1	-
Chromium/Chroom	mg/kg Cr (d.b.)	288	276	280	272	279	5,9
Copper/Koper	mg/kg Cu (d.b.)	140	150	115	126	133	13
Lead/Lood	mg/kg Pb (d.b.)	200	156	152	128	159	26
Nickel/Nikkel	mg/kg Ni (d.b.)	58	67	52	48	56	7
Zinc/Sink	mg/kg Zn (d.b.)	1080	1240	1132	1384	1209	116
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	3	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	2	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	<1	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	2	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	6	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	42	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: PRETORIA(DASPOORT) - TVL

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Mar85	2 June85	3 Oct85	4 Jan86		
Total residue/ Totale reste	%	95,6	91,8	90,0	92,8	92,6	2,0
Volatile residue/ Vlugtige reste	% (d.b.)	41,1	50,0	44,1	45,3	45,1	3,2
Fixed residue/ Vaste reste	% (d.b.)	58,9	50,0	55,9	54,7	54,9	3,2
pH	pH units/ eenhede	6,9	6,3	5,8	6,1	6,3	0,4
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	22,2	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	20,5	-
Potassium/Kalium	g/kg K (d.b.)	1,5	1,3	1,0	1,4	1,3	0,2
Calcium/Kalsium	g/kg Ca (d.b.)	48,8	39,6	41,6	30,8	40,2	6,4
Magnesium	g/kg Mg (d.b.)	8,8	7,2	6,8	7,2	7,5	0,8
Cadmium/Kadmium	mg/kg Cd (d.b.)	5,8	4,9	4,4	12,4	7	3,2
Chromium/Chroom	mg/kg Cr (d.b.)	304	400	360	436	375	49
Copper/Koper	mg/kg Cu (d.b.)	700	540	460	992	673	203
Lead/Lood	mg/kg Pb (d.b.)	219	306	324	347	299	48
Nickel/Nikkel	mg/kg Ni (d.b.)	44	59	52	55	53	6
Zinc/Sink	mg/kg Zn (d.b.)	1604	2260	1788	1848	1875	240
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	15	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	5	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	2	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	2	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	18	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	97	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: PRETORIA (ROOIWAL) - TVL

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Apr86	2 Apr86	3 Apr86	4 Apr86		
Total residue/ Totale reste	%	91,4	91,3	95,0	91,4	92,3	1,6
Volatile residue/ Vlugtige reste	% (d.b.)	62,1	61,1	15,3	59,1	49,4	19,7
Fixed residue/ Vaste reste	% (d.b.)	38,0	38,9	84,7	40,9	50,6	19,7
pH	pH units/ eenhede	6,8	6,6	6,8	6,7	6,7	0,8
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	24,9	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	23,0	-
Potassium/Kalium	g/kg K (d.b.)	3,4	1,7	1,4	1,6	2,0	0,8
Calcium/Kalsium	g/kg Ca (d.b.)	46,0	49,2	39,6	39,6	43,6	4,2
Magnesium	g/kg Mg (d.b.)	7,2	7,6	11,2	4,8	7,7	2,3
Cadmium/Kadmium	mg/kg Cd (d.b.)	12,9	19,1	10,2	37,8	20	10,8
Chromium/Chroom	mg/kg Cr (d.b.)	1176	1888	968	3216	1812	879
Copper/Koper	mg/kg Cu (d.b.)	848	476	396	732	613	184
Lead/Lood	mg/kg Pb (d.b.)	609	360	333	490	448	110
Nickel/Nikkel	mg/kg Ni (d.b.)	119	87	72	93	93	17
Zinc/Sink	mg/kg Zn (d.b.)	2164	1600	1116	2332	1803	480
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	10	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	5	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	1	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	4	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	25	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	92	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

ROODEPOORT - TVL

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: .....

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Mar85	2 June85	3 Oct85	4 Jan86		
Total residue/ Totale reste	%	93,4	93,5	90,4	92,6	92,5	1,2
Volatile residue/ Vlugtige reste	% (d.b.)	51,1	50,4	62,0	56,4	55,0	4,7
Fixed residue/ Vaste reste	% (d.b.)	48,9	49,6	38,0	43,6	45,0	4,7
pH	pH units/ eenhede	7,4	7,1	6,6	7,0	7,0	0,3
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	–	–	–	–	44,7	–
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	–	–	–	–	24,4	–
Potassium/Kalium	g/kg K (d.b.)	0,7	0,6	0,9	0,8	0,8	1,0
Calcium/Kalsium	g/kg Ca (d.b.)	22,0	22,0	21,2	20,0	21,3	0,8
Magnesium	g/kg Mg (d.b.)	6,4	6,8	5,6	6,4	6,3	0,4
Cadmium/Kadmium	mg/kg Cd (d.b.)	<1	<1	2	3	1	1
Chromium/Chroom	mg/kg Cr (d.b.)	456	428	436	456	444	12
Copper/Koper	mg/kg Cu (d.b.)	198	192	279	306	244	50
Lead/Lood	mg/kg Pb (d.b.)	160	155	141	140	149	9
Nickel/Nikkel	mg/kg Ni (d.b.)	54	48	116	120	85	34
Zinc/Sink	mg/kg Zn (d.b.)	1288	1172	1108	1164	1183	65
Mercury/Kwik	mg/kg Hg (d.b.)	–	–	–	–	5	–
Arsenic/Arseen	mg/kg As (d.b.)	–	–	–	–	6	–
Selenium	mg/kg Se (d.b.)	–	–	–	–	2	–
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	–	–	–	–	2	–
Boron/ Boor	mg/kg B (d.b.)	–	–	–	–	32	–
Fluoride/ Fluoried	mg/kg F (d.b.)	–	–	–	–	47	–

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

RUSTENBURG - TVL

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: .....

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Mar85	2 June85	3 Oct85	4 Jan86		
Total residue/ Totale reste	%	94,2	94,8	93,5	95,9	94,6	0,9
Volatile residue/ Vlugtige reste	% (d.b.)	59,2	52,4	49,3	58,2	54,8	4,1
Fixed residue/ Vaste reste	% (d.b.)	40,8	47,6	50,7	41,8	45,2	4,1
pH	pH units/ eenhede	6,6	6,0	6,4	6,5	6,4	0,2
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	38,2	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	13,4	-
Potassium/Kalium	g/kg K (d.b.)	1,4	1,5	1,7	3,4	2,3	0,9
Calcium/Kalsium	g/kg Ca (d.b.)	38,4	42,8	39,6	28,0	37,2	5,5
Magnesium	g/kg Mg (d.b.)	6,4	8,4	7,6	8,4	7,7	0,8
Cadmium/Kadmium	mg/kg Cd (d.b.)	4	3	<1	<1	2	2
Chromium/Chroom	mg/kg Cr (d.b.)	464	340	432	216	363	96
Copper/Koper	mg/kg Cu (d.b.)	351	358	317	217	311	56
Lead/Lood	mg/kg Pb (d.b.)	472	397	341	165	344	113
Nickel/Nikkel	mg/kg Ni (d.b.)	107	42	107	26	71	37
Zinc/Sink	mg/kg Zn (d.b.)	2024	2256	1840	1148	1817	413
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	15	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	3	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	3	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	3	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	31	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	52	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: SEBOKENG- TVL

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Aug 86	2 Nov 86	3 Feb 87	4 May 87		
Total residue/ Totale reste	%	93,1	93,4	92,2	92,2	92,7	0,5
Volatile residue/ Vlugtige reste	% (d.b.)	52,9	47,1	37,4	36,0	43,4	7,0
Fixed residue/ Vaste reste	% (d.b.)	47,1	52,9	62,6	64,0	56,7	7,0
pH	pH units/ eenhede	7,2	7,3	7,3	6,6	7,1	0,3
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	–	–	–	–	20,8	–
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	–	–	–	–	32,5	–
Potassium/Kalium	g/kg K (d.b.)	1,5	1,8	1,1	1,3	1,4	0,3
Calcium/Kalsium	g/kg Ca (d.b.)	33,0	30,8	28,6	28,6	30,2	1,8
Magnesium	g/kg Mg (d.b.)	4,0	4,4	4,8	4,0	4,3	0,3
Cadmium/Kadmium	mg/kg Cd (d.b.)	4	<1	<1	<1	1	1,5
Chromium/Chroom	mg/kg Cr (d.b.)	137	170	152	163	156	12
Copper/Koper	mg/kg Cu (d.b.)	185	205	169	174	183	14
Lead/Lood	mg/kg Pb (d.b.)	117	112	114	107	113	4
Nickel/Nikkel	mg/kg Ni (d.b.)	94	103	92	99	97	4
Zinc/Sink	mg/kg Zn (d.b.)	988	1085	854	1208	1034	130
Mercury/Kwik	mg/kg Hg (d.b.)	–	–	–	–	2	–
Arsenic/Arseen	mg/kg As (d.b.)	–	–	–	–	10	–
Selenium	mg/kg Se (d.b.)	–	–	–	–	< 1	–
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	–	–	–	–	8	–
Boron/ Boor	mg/kg B (d.b.)	–	–	–	–	28	–
Fluoride/ Fluoried	mg/kg F (d.b.)	–	–	–	–	119	–

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: SPRINGS - TVL .....

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Mar85	2 June85	3 Oct85	4 Jan86		
Total residue/ Totale reste	%	89,4	92,5	95,0	93,6	92,6	2,1
Volatile residue/ Vlugtige reste	% (d.b.)	45,3	47,5	57, 2	54,8	51,2	4,9
Fixed residue/ Vaste reste	% (d.b.)	54,7	52,5	42,8	45,2	48,8	4,9
pH	pH units/ eenhede	6,3	6,5	6,9	6,9	6,7	0,3
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	26,8	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	16,9	-
Potassium/Kalium	g/kg K (d.b.)	1,4	1,6	1,7	1,1	1,5	0,2
Calcium/Kalsium	g/kg Ca (d.b.)	38,4	38,4	38,4	38,0	38,3	0,2
Magnesium	g/kg Mg (d.b.)	4,8	5,2	4,4	4,0	4,6	0,4
Cadmium/Kadmium	mg/kg Cd (d.b.)	36	40	19	23	30	9
Chromium/Chroom	mg/kg Cr (d.b.)	1240	1188	1000	1204	1158	93
Copper/Koper	mg/kg Cu (d.b.)	860	856	676	768	790	75
Lead/Lood	mg/kg Pb (d.b.)	208	240	202	207	214	15
Nickel/Nikkel	mg/kg Ni (d.b.)	810	584	432	815	660	161
Zinc/Sink	mg/kg Zn (d.b.)	3700	4280	3064	3268	3578	466
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	5	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	14	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	2	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	12	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	23	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	200	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: STANDERTON - TVL

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Mar85	2 June85	3 Oct85	4 Jan86		
Total residue/ Totale reste	%	91,4	93,3	94,7	92,4	93,0	1,2
Volatile residue/ Vlugtige reste	% (d.b.)	57,3	58,0	59,6	67,1	60,5	3,9
Fixed residue/ Vaste reste	% (d.b.)	42,7	42,0	40,4	32,9	39,5	3,9
pH	pH units/ eenhede	7,4	6,2	6,5	7,3	6,9	0,5
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	29,7	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	16,8	-
Potassium/Kalium	g/kg K (d.b.)	5,0	4,4	4,8	4,0	4,5	0,4
Calcium/Kalsium	g/kg Ca (d.b.)	18,8	16,8	20,0	17,2	18,2	1,3
Magnesium	g/kg Mg (d.b.)	10,4	5,6	8,0	8,8	8,2	1,7
Cadmium/Kadmium	mg/kg Cd (d.b.)	< 1	< 1	< 1	< 1	< 1	0
Chromium/Chroom	mg/kg Cr (d.b.)	568	356	376	436	434	83
Copper/Koper	mg/kg Cu (d.b.)	213	260	296	192	240	41
Lead/Lood	mg/kg Pb (d.b.)	136	159	172	128	149	16
Nickel/Nikkel	mg/kg Ni (d.b.)	48	48	38	39	43	5
Zinc/Sink	mg/kg Zn (d.b.)	1748	1292	1436	1256	1433	194
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	5	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	3	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	1	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	3	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	35	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	56	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: VANDERBIJLPARK- TVL

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Mar85	2 June85	3 Oct85	4 Jan86		
Total residue/ Totale reste	%	80,9	95,1	83,7	92,4	88,0	5,9
Volatile residue/ Vlugtige reste	% (d.b.)	49,2	37,1	60,7	48,0	48,8	8,4
Fixed residue/ Vaste reste	% (d.b.)	50,8	62,9	39,3	52,0	51,3	8,4
pH	pH units/ eenhede	6,9	6,4	6,7	6,2	6,6	0,3
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	30,9	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	20,1	-
Potassium/Kalium	g/kg K (d.b.)	1,6	1,6	4,0	1,7	2,6	1,1
Calcium/Kalsium	g/kg Ca (d.b.)	58,4	43,2	38,4	58,8	49,7	9,1
Magnesium	g/kg Mg (d.b.)	7,2	5,6	5,2	6,4	6,1	0,8
Cadmium/Kadmium	mg/kg Cd (d.b.)	<1	<1	<1	3	<1	1
Chromium/Chroom	mg/kg Cr (d.b.)	540	440	548	496	506	43
Copper/Koper	mg/kg Cu (d.b.)	476	311	341	417	386	65
Lead/Lood	mg/kg Pb (d.b.)	992	757	388	90	557	345
Nickel/Nikkel	mg/kg Ni (d.b.)	204	143	83	289	180	76
Zinc/Sink	mg/kg Zn (d.b.)	4020	2500	2636	3116	3068	595
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	18	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	7	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	2	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	7	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	39	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	208	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: VEREENIGING - TVL

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Mar85	2 June85	3 Oct85	4 Jan86		
Total residue/ Totale reste	%	92,7	91,5	92,9	91,3	92,1	0,7
Volatile residue/ Vlugtige reste	% (d.b.)	67,2	63,4	66,5	64,8	65,5	1,5
Fixed residue/ Vaste reste	% (d.b.)	32,8	36,6	33,5	35,2	34,5	1,5
pH	pH units/ eenhede	6,7	7,2	7,4	7,2	7,1	0,3
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	39,7	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	11,6	-
Potassium/Kalium	g/kg K (d.b.)	1,5	2,1	2,2	1,6	1,8	0,3
Calcium/Kalsium	g/kg Ca (d.b.)	36,4	33,2	44,4	44,0	39,5	4,8
Magnesium	g/kg Mg (d.b.)	5,6	5,2	5,2	5,6	5,4	0,2
Cadmium/Kadmium	mg/kg Cd (d.b.)	1,8	<1	4,4	4,0	3	1,6
Chromium/Chroom	mg/kg Cr (d.b.)	564	3088	3160	2064	2219	1049
Copper/Koper	mg/kg Cu (d.b.)	305	220	296	395	304	62
Lead/Lood	mg/kg Pb (d.b.)	1232	792	824	582	858	235
Nickel/Nikkel	mg/kg Ni (d.b.)	72	60	104	75	78	16
Zinc/Sink	mg/kg Zn (d.b.)	1628	1456	1776	1892	1688	163
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	4	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	5	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	1	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	9	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	22	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	186	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: VERWOERDBURG - TVL

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Mar85	2 June85	3 Oct85	4 Jan86		
Total residue/ Totale reste	%	92,8	88,0	92,9	74,0	86,9	7,7
Volatile residue/ Vlugtige reste	% (d.b.)	57,9	71,2	63,9	40,6	58,4	11,3
Fixed residue/ Vaste reste	% (d.b.)	42,1	28,8	36,1	59,4	41,6	11,3
pH	pH units/ eenhede	6,5	6,7	6,7	8,7	7,1	0,9
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	37,1	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	16,1	-
Potassium/Kalium	g/kg K (d.b.)	1,6	5,2	4,9	4,5	4,4	1,2
Calcium/Kalsium	g/kg Ca (d.b.)	39,6	24,0	24,8	30,8	29,8	6,2
Magnesium	g/kg Mg (d.b.)	6,4	7,6	7,6	9,2	7,7	1,0
Cadmium/Kadmium	mg/kg Cd (d.b.)	<1	2	<1	<1	<1	1
Chromium/Chroom	mg/kg Cr (d.b.)	572	600	788	780	685	100
Copper/Koper	mg/kg Cu (d.b.)	317	238	221	209	246	42
Lead/Lood	mg/kg Pb (d.b.)	219	164	155	136	169	31
Nickel/Nikkel	mg/kg Ni (d.b.)	56	39	34	41	43	8
Zinc/Sink	mg/kg Zn (d.b.)	2220	2084	1700	1540	1886	276
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	7	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	4	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	3	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	5	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	37	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	76	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: ..WITBANK - TVL.....

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Mar85	2 June85	3 Oct85	4 Jan86		
Total residue/ Totale reste	%	90,7	91,5	90,1	92,4	91,2	0,9
Volatile residue/ Vlugtige reste	% (d.b.)	63,5	61,4	60,7	72,0	64,4	4,5
Fixed residue/ Vaste reste	% (d.b.)	36,5	38,6	39,3	28,0	35,6	4,5
pH	pH units/ eenhede	7,6	7,0	6,8	7,4	7,2	0,3
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	58,4	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	12,6	-
Potassium/Kalium	g/kg K (d.b.)	3,5	4,1	5,3	3,8	4,1	0,7
Calcium/Kalsium	g/kg Ca (d.b.)	18,4	15,6	14,4	17,6	16,5	1,6
Magnesium	g/kg Mg (d.b.)	7,6	6,4	6,0	7,6	6,9	0,7
Cadmium/Kadmium	mg/kg Cd (d.b.)	<1	55	<1	<1	14	24
Chromium/Chroom	mg/kg Cr (d.b.)	580	496	504	492	518	36
Copper/Koper	mg/kg Cu (d.b.)	232	196	144	175	187	32
Lead/Lood	mg/kg Pb (d.b.)	150	158	125	149	146	12
Nickel/Nikkel	mg/kg Ni (d.b.)	50	22	63	30	41	16
Zinc/Sink	mg/kg Zn (d.b.)	1628	1508	1144	1352	1408	181
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	4	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	2	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	3	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	4	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	22	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	92	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: .. AMANZIMTOTI - NATAL .....

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Aug 86	2 Nov 86	3 Feb 87	4 May 87		
Total residue/ Totale reste	%	94,0	94,1	92,8	91,8	93,2	0,9
Volatile residue/ Vlugtige reste	% (d.b.)	54,7	50,3	52,1	51,3	52,1	1,6
Fixed residue/ Vaste reste	% (d.b.)	45,3	49,7	47,9	48,7	47,9	1,6
pH	pH units/ eenhede	6,8	6,4	6,4	6,9	6,6	0,2
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	27,4	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	10,8	-
Potassium/Kalium	g/kg K (d.b.)	1,5	2,0	1,6	3,3	2,1	0,7
Calcium/Kalsium	g/kg Ca (d.b.)	19,4	23,8	22,9	21,6	21,9	1,7
Magnesium	g/kg Mg (d.b.)	4,4	3,7	4,0	4,1	4,1	0,3
Cadmium/Kadmium	mg/kg Cd (d.b.)	4	5	4	4	4	0,4
Chromium/Chroom	mg/kg Cr (d.b.)	429	350	348	377	376	33
Copper/Koper	mg/kg Cu (d.b.)	1012	788	906	808	879	89
Lead/Lood	mg/kg Pb (d.b.)	494	507	487	486	494	8
Nickel/Nikkel	mg/kg Ni (d.b.)	350	252	185	197	246	65
Zinc/Sink	mg/kg Zn (d.b.)	3538	3142	3680	3568	3482	203
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	3	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	8	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	2	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	11	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	36	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	90	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: DURBAN (KWAMASHU) COMP. SAMPLE*- NATAL

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1-4 Comp* Aug 86	2 Nov 86	3 Feb 87	4 May 87		
Total residue/ Totale reste	%	91,9	-	-	-	91,9	-
Volatile residue/ Vlugtige reste	% (d.b.)	53,6	-	-	-	53,6	-
Fixed residue/ Vaste reste	% (d.b.)	46,4	-	-	-	46,4	-
pH	pH units/ eenhede	5,4	-	-	-	5,4	-
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	33,1	-	-	-	33,1	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	16,1	-	-	-	16,1	-
Potassium/Kalium	g/kg K (d.b.)	1,7	-	-	-	1,7	-
Calcium/Kalsium	g/kg Ca (d.b.)	15,0	-	-	-	15,0	-
Magnesium	g/kg Mg (d.b.)	3,1	-	-	-	3,1	-
Cadmium/Kadmium	mg/kg Cd (d.b.)	6	-	-	-	6	-
Chromium/Chroom	mg/kg Cr (d.b.)	139	-	-	-	139	-
Copper/Koper	mg/kg Cu (d.b.)	209	-	-	-	209	-
Lead/Lood	mg/kg Pb (d.b.)	176	-	-	-	176	-
Nickel/Nikkel	mg/kg Ni (d.b.)	51	-	-	-	51	-
Zinc/Sink	mg/kg Zn (d.b.)	607	-	-	-	607	-
Mercury/Kwik	mg/kg Hg (d.b.)	2	-	-	-	2	-
Arsenic/Arseen	mg/kg As (d.b.)	7	-	-	-	7	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	2	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	7	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	31	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	46	-

d.b.:dry basis/droë basis

* Insufficient individual samples received

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: DURBAN (NORTHERN WORKS) COMPOSITE SAMPLE* - NATAL

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1-4 Comp.* Aug 86	2 Nov 86	3 Feb 87	4 May 87		
Total residue/ Totale reste	%	91,7	-	-	-	91,7	-
Volatile residue/ Vlugtige reste	% (d.b.)	55,4	-	-	-	55,4	-
Fixed residue/ Vaste reste	% (d.b.)	44,6	-	-	-	44,6	-
pH	pH units/ eenhede	6,1	-	-	-	6,1	-
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	35,4	-	-	-	35,4	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	23,1	-	-	-	23,1	-
Potassium/Kalium	g/kg K (d.b.)	1,5	-	-	-	1,5	-
Calcium/Kalsium	g/kg Ca (d.b.)	24,2	-	-	-	24,2	-
Magnesium	g/kg Mg (d.b.)	4,9	-	-	-	4,9	-
Cadmium/Kadmium	mg/kg Cd (d.b.)	3	-	-	-	3	-
Chromium/Chroom	mg/kg Cr (d.b.)	77	-	-	-	77	-
Copper/Koper	mg/kg Cu (d.b.)	298	-	-	-	298	-
Lead/Lood	mg/kg Pb (d.b.)	176	-	-	-	176	-
Nickel/Nikkel	mg/kg Ni (d.b.)	39	-	-	-	39	-
Zinc/Sink	mg/kg Zn (d.b.)	796	-	-	-	796	
Mercury/Kwik	mg/kg Hg (d.b.)	2	-	-	-	2	-
Arsenic/Arseen	mg/kg As (d.b.)	7	-	-	-	7	-
Selenium	mg/kg Se (d.b.)	4	-	-	-	4	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	7	-	-	-	7	-
Boron/ Boor	mg/kg B (d.b.)	35	-	-	-	35	-
Fluoride/ Fluoried	mg/kg F (d.b.)	46	-	-	-	46	-

d.b.:dry basis/droë basis

* Insufficient individual samples received

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: LADYSMITH - NATAL

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Aug 86	2 Nov 86	3 Feb 87	4 May 87		
Total residue/ Totale reste	%	92,2	89,9	88,2	92,4	90,7	1,7
Volatile residue/ Vlugtige reste	% (d.b.)	31,2	17,7	37,6	33,6	30,0	7,5
Fixed residue/ Vaste reste	% (d.b.)	68,8	82,3	62,4	66,4	70,0	7,5
pH	pH units/ eenhede	5,7	5,8	6,2	5,7	5,9	0,2
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	17,8	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	31,1	-
Potassium/Kalium	g/kg K (d.b.)	1,5	1,5	1,4	1,6	1,5	0,7
Calcium/Kalsium	g/kg Ca (d.b.)	15,8	19,8	20,2	16,7	18,1	1,9
Magnesium	g/kg Mg (d.b.)	2,9	3,8	3,8	3,0	3,4	0,4
Cadmium/Kadmium	mg/kg Cd (d.b.)	2	3	2	2	2	0,4
Chromium/Chroom	mg/kg Cr (d.b.)	864	862	868	895	872	13
Copper/Koper	mg/kg Cu (d.b.)	439	436	455	283	403	70
Lead/Lood	mg/kg Pb (d.b.)	175	157	161	158	163	7
Nickel/Nikkel	mg/kg Ni (d.b.)	81	71	82	84	80	5
Zinc/Sink	mg/kg Zn (d.b.)	2367	2367	2719	2411	2466	147
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	3	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	8	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	1	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	5	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	14	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	59	

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: NEWCASTLE - NATAL

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Aug 86	2 Nov 86	3 Feb 87	4 May 87		
Total residue/ Totale reste	%	93,9	86,8	88,2	93,9	90,7	3,2
Volatile residue/ Vlugtige reste	% (d.b.)	45,2	52,2	53,7	54,1	51,3	3,6
Fixed residue/ Vaste reste	% (d.b.)	54,8	47,8	46,3	45,9	48,7	3,6
pH	pH units/ eenhede	6,7	6,8	6,3	6,7	6,6	0,2
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	24,9	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	10,9	-
Potassium/Kalium	g/kg K (d.b.)	0,7	1,8	1,2	1,4	1,3	0,4
Calcium/Kalsium	g/kg Ca (d.b.)	26,4	28,6	29,5	29,5	28,5	1,3
Magnesium	g/kg Mg (d.b.)	4,2	4,0	3,6	4,0	4,0	0,2
Cadmium/Kadmium	mg/kg Cd (d.b.)	3	3	4	5	4	0,8
Chromium/Chroom	mg/kg Cr (d.b.)	225	142	167	170	176	30
Copper/Koper	mg/kg Cu (d.b.)	224	223	249	224	230	11
Lead/Lood	mg/kg Pb (d.b.)	268	285	302	312	292	17
Nickel/Nikkel	mg/kg Ni (d.b.)	148	92	112	88	110	24
Zinc/Sink	mg/kg Zn (d.b.)	1284	1284	1597	1421	1397	129
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	5	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	4	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	2	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	10	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	35	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	146	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: PIETERMARITZBURG - NATAL

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Aug 86	2 Nov 86	3 Feb 87	4 May 87		
Total residue/ Totale reste	%	93,5	94,0	89,1	94,9	92,9	2,2
Volatile residue/ Vlugtige reste	% (d.b.)	59,6	66,3	40,3	27,4	48,4	15,4
Fixed residue/ Vaste reste	% (d.b.)	40,4	33,7	59,7	72,6	51,6	15,4
pH	pH units/ eenhede	6,8	6,6	5,7	5,7	6,2	0,5
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	28,9	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	14,3	-
Potassium/Kalium	g/kg K (d.b.)	1,6	1,2	1,2	1,6	1,4	0,2
Calcium/Kalsium	g/kg Ca (d.b.)	22,9	22,9	25,5	17,2	22,1	3,0
Magnesium	g/kg Mg (d.b.)	2,2	2,8	4,9	2,1	3,0	1,1
Cadmium/Kadmium	mg/kg Cd (d.b.)	7	4	3	4	5	1,5
Chromium/Chroom	mg/kg Cr (d.b.)	198	157	209	142	177	28
Copper/Koper	mg/kg Cu (d.b.)	286	278	307	226	274	30
Lead/Lood	mg/kg Pb (d.b.)	209	215	251	176	213	27
Nickel/Nikkel	mg/kg Ni (d.b.)	108	95	70	49	81	23
Zinc/Sink	mg/kg Zn (d.b.)	1808	1817	1395	1048	1517	320
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	2	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	6	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	1	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	5	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	12	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	54	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: PORT SHEPSTONE - NATAL

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Aug 86	2 Nov 86	3 Feb 87	4 May 87		
Total residue/ Totale reste	%	93,8	92,3	93,3	93,8	93,3	0,6
Volatile residue/ Vlugtige reste	% (d.b.)	39,2	60,2	49,7	48,3	49,4	7,4
Fixed residue/ Vaste reste	% (d.b.)	60,8	39,8	50,3	51,7	50,7	7,4
pH	pH units/ eenhede	7,5	7,0	7,4	8,0	7,5	0,4
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	34,5	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	25,9	-
Potassium/Kalium	g/kg K (d.b.)	10,4	17,2	10,0	5,9	10,9	4,1
Calcium/Kalsium	g/kg Ca (d.b.)	20,2	27,7	18,9	23,3	22,5	3,4
Magnesium	g/kg Mg (d.b.)	8,2	12,0	9,7	5,7	8,9	2,3
Cadmium/Kadmium	mg/kg Cd (d.b.)	3	3	3	2	3	0,4
Chromium/Chroom	mg/kg Cr (d.b.)	243	156	150	207	189	38
Copper/Koper	mg/kg Cu (d.b.)	305	449	363	331	362	54
Lead/Lood	mg/kg Pb (d.b.)	456	699	496	419	533	97
Nickel/Nikkel	mg/kg Ni (d.b.)	42	35	36	36	37	3
Zinc/Sink	mg/kg Zn (d.b.)	1997	3419	2460	2266	2536	536
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	1	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	7	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	1	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	4	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	45	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	56	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: BELLVILLE - C.P.

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Aug 86	2 Nov 86	3 Feb 87	4 May 87		
Total residue/ Totale reste	%	85,6	95,6	93,3	94,9	92,4	4,0
Volatile residue/ Vlugtige reste	% (d.b.)	52,3	42,2	52,3	35,4	45,6	7,2
Fixed residue/ Vaste reste	% (d.b.)	47,7	57,8	47,7	64,6	54,5	7,2
pH	pH units/ eenhede	7,5	6,6	7,5	6,9	7,1	0,4
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	23,3	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	10,7	-
Potassium/Kalium	g/kg K (d.b.)	1,2	1,0	2,0	0,8	1,3	0,5
Calcium/Kalsium	g/kg Ca (d.b.)	32,6	38,3	34,8	62,7	42,1	12,0
Magnesium	g/kg Mg (d.b.)	2,8	2,5	3,6	3,1	3,0	0,4
Cadmium/Kadmium	mg/kg Cd (d.b.)	3	2	5	2	3	1,2
Chromium/Chroom	mg/kg Cr (d.b.)	162	187	230	185	191	25
Copper/Koper	mg/kg Cu (d.b.)	311	293	357	285	312	28
Lead/Lood	mg/kg Pb (d.b.)	290	258	266	261	269	13
Nickel/Nikkel	mg/kg Ni (d.b.)	66	66	111	53	74	22
Zinc/Sink	mg/kg Zn (d.b.)	2702	1883	2473	1743	2200	399
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	2	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	5	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	2	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	6	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	21	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	69	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: CAPE TOWN (ATHLONE) C.P.

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Aug 86	2 Nov 86	3 Feb 87	4 May 87		
Total residue/ Totale reste	%	93,1	93,6	91,1	95,2	93,3	1,5
Volatile residue/ Vlugtige reste	% (d.b.)	64,5	67,2	27,3	56,8	54,0	15,9
Fixed residue/ Vaste reste	% (d.b.)	35,5	32,8	72,7	43,2	46,1	15,9
pH	pH units/ eenhede	6,6	6,3	6,8	6,2	6,5	0,3
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	30,4	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	15,0	-
Potassium/Kalium	g/kg K (d.b.)	1,0	1,7	0,7	1,5	1,2	0,4
Calcium/Kalsium	g/kg Ca (d.b.)	31,7	33,9	17,8	33,0	29,1	6,6
Magnesium	g/kg Mg (d.b.)	3,8	4,4	2,0	4,7	3,7	1,0
Cadmium/Kadmium	mg/kg Cd (d.b.)	26	28	18	37	27	6,8
Chromium/Chroom	mg/kg Cr (d.b.)	605	620	384	577	547	95
Copper/Koper	mg/kg Cu (d.b.)	641	681	329	664	579	145
Lead/Lood	mg/kg Pb (d.b.)	1151	1243	508	920	956	284
Nickel/Nikkel	mg/kg Ni (d.b.)	135	110	74	112	110	22
Zinc/Sink	mg/kg Zn (d.b.)	1975	2059	1160	2389	1896	452
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	3	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	6	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	3	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	18	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	18	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	141	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: CAPE TOWN (CAPE FLATS) - C.P.

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Aug 86	2 Nov 86	3 Feb 87	4 May 87		
Total residue/ Totale reste	%	89,9	92,8	90,6	92,2	91,4	1,2
Volatile residue/ Vlugtige reste	% (d.b.)	58,2	51,5	52,6	58,0	55,1	3,1
Fixed residue/ Vaste reste	% (d.b.)	41,8	48,5	47,4	42,0	44,9	3,1
pH	pH units/ eenhede	6,4	6,6	7,5	7,3	7,0	0,5
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	34,8	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	18,9	-
Potassium/Kalium	g/kg K (d.b.)	0,7	2,9	0,7	2,9	1,8	1,1
Calcium/Kalsium	g/kg Ca (d.b.)	37,0	39,6	44,0	38,7	39,8	2,6
Magnesium	g/kg Mg (d.b.)	3,6	5,5	3,6	6,1	4,7	1,1
Cadmium/Kadmium	mg/kg Cd (d.b.)	4	3	4	4	4	0,4
Chromium/Chroom	mg/kg Cr (d.b.)	457	211	269	353	323	93
Copper/Koper	mg/kg Cu (d.b.)	517	295	343	367	381	83
Lead/Lood	mg/kg Pb (d.b.)	172	126	129	145	143	18
Nickel/Nikkel	mg/kg Ni (d.b.)	47	41	34	44	42	4,8
Zinc/Sink	mg/kg Zn (d.b.)	1028	610	679	778	774	158
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	1	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	4	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	3	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	4	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	29	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	52	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: CAPE TOWN (MITCHELLS PLAIN) - C.P.

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Aug 86	2 Nov 86	3 Feb 87	4 May 87		
Total residue/ Totale reste	%	95,2	95,1	93,8	93,1	94,3	0,9
Volatile residue/ Vlugtige reste	% (d.b.)	41,2	46,0	63,2	62,6	53,3	9,8
Fixed residue/ Vaste reste	% (d.b.)	58,8	54,0	36,8	37,4	46,8	9,8
pH	pH units/ eenhede	6,6	7,4	7,2	7,2	7,1	0,3
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	22,2	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	6,8	-
Potassium/Kalium	g/kg K (d.b.)	0,4	0,9	1,8	1,2	1,1	0,5
Calcium/Kalsium	g/kg Ca (d.b.)	51,9	56,3	56,3	54,6	54,8	1,8
Magnesium	g/kg Mg (d.b.)	2,4	2,2	3,3	3,2	2,8	0,5
Cadmium/Kadmium	mg/kg Cd (d.b.)	3	4	4	4	4	0,4
Chromium/Chroom	mg/kg Cr (d.b.)	52	49	51	44	49	3,1
Copper/Koper	mg/kg Cu (d.b.)	198	170	229	238	209	27
Lead/Lood	mg/kg Pb (d.b.)	120	99	126	127	118	11
Nickel/Nikkel	mg/kg Ni (d.b.)	29	28	37	24	30	5
Zinc/Sink	mg/kg Zn (d.b.)	614	519	699	719	638	79
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	<1	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	4	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	3	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	3	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	18	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	62	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: .....CRADOCK - C.P.....

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Aug 86	2 Nov 86	3 Feb 87	4 May 87		
Total residue/ Totale reste	%	90,9	88,4	91,5	92,5	90,8	1,5
Volatile residue/ Vlugtige reste	% (d.b.)	79,0	74,8	62,0	73,3	72,3	6,3
Fixed residue/ Vaste reste	% (d.b.)	21,0	25,2	38,0	26,7	27,7	6,3
pH	pH units/ eenhede	7,1	7,2	6,6	6,6	6,9	0,3
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	53,4	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	9,4	-
Potassium/Kalium	g/kg K (d.b.)	4,0	3,6	4,0	4,2	4,0	0,2
Calcium/Kalsium	g/kg Ca (d.b.)	20,7	22,0	22,4	21,1	21,6	0,7
Magnesium	g/kg Mg (d.b.)	4,8	5,1	5,2	4,8	5,0	0,2
Cadmium/Kadmium	mg/kg Cd (d.b.)	3	2	2	<1	2	0,5
Chromium/Chroom	mg/kg Cr (d.b.)	68	102	101	92	91	14
Copper/Koper	mg/kg Cu (d.b.)	198	201	209	173	195	13
Lead/Lood	mg/kg Pb (d.b.)	76	79	77	85	79	3
Nickel/Nikkel	mg/kg Ni (d.b.)	22	31	33	28	29	4
Zinc/Sink	mg/kg Zn (d.b.)	621	706	653	752	683	50
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	2	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	5	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	3	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	5	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	57	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	89	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: DE AAR - C.P.

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Aug 86	2 Nov 86	3 Feb 87	4 –		
Total residue/ Totale reste	%	94,4	94,0	94,0	–	94,1	0,2
Volatile residue/ Vlugtige reste	% (d.b.)	60,0	62,6	61,9	–	61,5	1,1
Fixed residue/ Vaste reste	% (d.b.)	40,0	37,4	38,1	–	38,5	1,1
pH	pH units/ eenhede	6,6	6,6	6,0	–	6,4	0,3
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	–	–	–	–	48,4	–
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	–	–	–	–	13,9	–
Potassium/Kalium	g/kg K (d.b.)	4,3	4,3	4,4	–	4,3	0,5
Calcium/Kalsium	g/kg Ca (d.b.)	25,1	26,0	25,5	–	25,5	0,4
Magnesium	g/kg Mg (d.b.)	8,0	8,0	8,1	–	8,0	0,5
Cadmium/Kadmium	mg/kg Cd (d.b.)	<1	<1	<1	–	<1	<1
Chromium/Chroom	mg/kg Cr (d.b.)	231	218	170	–	206	26
Copper/Koper	mg/kg Cu (d.b.)	196	198	173	–	189	11
Lead/Lood	mg/kg Pb (d.b.)	66	73	75	–	71	4
Nickel/Nikkel	mg/kg Ni (d.b.)	41	33	26	–	33	6
Zinc/Sink	mg/kg Zn (d.b.)	1024	1038	984	–	1015	23
Mercury/Kwik	mg/kg Hg (d.b.)	–	–	–	–	<1	–
Arsenic/Arseen	mg/kg As (d.b.)	–	–	–	–	11	–
Selenium	mg/kg Se (d.b.)	–	–	–	–	7	–
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	–	–	–	–	4	–
Boron/ Boor	mg/kg B (d.b.)	–	–	–	–	24	–
Fluoride/ Fluoried	mg/kg F (d.b.)	–	–	–	–	81	–

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: ..DESPATCH - C.P.....

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Aug 86	2 Nov 86	3 Feb 87	4 May 87		
Total residue/ Totale reste	%	96,7	96,4	97,0	96,7	96,7	0,2
Volatile residue/ Vlugtige reste	% (d.b.)	51,6	51,3	61,7	51,6	54,1	4,4
Fixed residue/ Vaste reste	% (d.b.)	48,4	48,7	38,3	48,4	46,0	4,4
pH	pH units/ eenhede	6,6	6,6	6,7	6,6	6,6	0,4
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	36,9	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	19,4	-
Potassium/Kalium	g/kg K (d.b.)	2,1	5,4	7,0	6,1	5,2	1,9
Calcium/Kalsium	g/kg Ca (d.b.)	21,1	21,1	26,8	28,6	24,4	3,4
Magnesium	g/kg Mg (d.b.)	7,0	7,8	12,8	14,1	10,4	3,1
Cadmium/Kadmium	mg/kg Cd (d.b.)	2	<1	2	<1	1	0,8
Chromium/Chroom	mg/kg Cr (d.b.)	88	73	79	87	82	6
Copper/Koper	mg/kg Cu (d.b.)	304	158	221	239	231	52
Lead/Lood	mg/kg Pb (d.b.)	137	82	119	220	140	51
Nickel/Nikkel	mg/kg Ni (d.b.)	41	31	43	41	39	4,7
Zinc/Sink	mg/kg Zn (d.b.)	944	486	706	1201	834	267
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	1	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	4	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	4	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	3	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	43	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	85	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: EAST LONDON - C.P.

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Aug 86	2 Nov 86	3 Feb 87	4 May 87		
Total residue/ Totale reste	%	94,0	93,2	92,9	87,9	92,0	2,4
Volatile residue/ Vlugtige reste	% (d.b.)	49,5	48,0	44,6	47,9	47,5	1,8
Fixed residue/ Vaste reste	% (d.b.)	50,5	52,0	55,4	52,1	52,5	1,8
pH	pH units/ eenhede	6,7	6,8	6,7	6,4	6,7	0,2
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	23,7	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	8,5	-
Potassium/Kalium	g/kg K (d.b.)	1,4	1,2	1,6	1,2	1,4	0,2
Calcium/Kalsium	g/kg Ca (d.b.)	33,0	21,1	34,8	25,5	28,6	5,6
Magnesium	g/kg Mg (d.b.)	3,4	2,7	3,1	3,3	3,1	0,3
Cadmium/Kadmium	mg/kg Cd (d.b.)	4	1	<1	3	2	1,4
Chromium/Chroom	mg/kg Cr (d.b.)	201	222	179	108	178	43
Copper/Koper	mg/kg Cu (d.b.)	17578	17565	16100	17626	17217	645
Lead/Lood	mg/kg Pb (d.b.)	10270	9772	10045	10459	10137	256
Nickel/Nikkel	mg/kg Ni (d.b.)	106	129	158	158	138	22
Zinc/Sink	mg/kg Zn (d.b.)	3942	4620	4981	4928	4618	414
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	2	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	5	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	2	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	6	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	27	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	144	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: ..GRAAFF-REINET...C.P.....

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Aug 86	2 Nov 86	3 Feb 87	4 May 87		
Total residue/ Totale reste	%	94,7	96,8	94,9	95,9	95,6	0,8
Volatile residue/ Vlugtige reste	% (d.b.)	63,2	34,0	48,9	50,3	49,1	10,3
Fixed residue/ Vaste reste	% (d.b.)	36,8	66,0	51,1	49,7	50,9	10,3
pH	pH units/ eenhede	7,9	7,1	7,1	6,9	7,3	0,4
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	21,3	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	7,1	-
Potassium/Kalium	g/kg K (d.b.)	1,8	3,0	1,8	1,8	2,1	0,5
Calcium/Kalsium	g/kg Ca (d.b.)	31,7	29,5	41,8	42,7	36,4	5,9
Magnesium	g/kg Mg (d.b.)	5,6	6,8	7,2	7,0	6,7	0,6
Cadmium/Kadmium	mg/kg Cd (d.b.)	2	3	4	3	3	0,7
Chromium/Chroom	mg/kg Cr (d.b.)	82	63	57	58	65	10
Copper/Koper	mg/kg Cu (d.b.)	426	291	462	409	397	64
Lead/Lood	mg/kg Pb (d.b.)	100	99	121	121	110	11
Nickel/Nikkel	mg/kg Ni (d.b.)	38	86	37	37	37	1
Zinc/Sink	mg/kg Zn (d.b.)	1108	711	1050	1038	977	156
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	<1	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	4	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	2	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	7	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	18	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	79	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: ...GRAHAMSTOWN - C.P.....

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Aug 86	2 Nov 86	3 Feb 87	4 May 87		
Total residue/ Totale reste	%	92,8	93,4	93,1	92,7	93,0	0,3
Volatile residue/ Vlugtige reste	% (d.b.)	55,9	54,0	53,1	55,1	54,5	1,1
Fixed residue/ Vaste reste	% (d.b.)	44,1	46,0	46,9	44,9	45,5	1,1
pH	pH units/ eenhede	6,4	6,6	6,4	6,5	6,5	0,8
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	27,8	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	11,1	-
Potassium/Kalium	g/kg K (d.b.)	1,2	1,3	1,3	1,5	1,3	0,1
Calcium/Kalsium	g/kg Ca (d.b.)	26,0	31,2	30,8	32,1	30,0	2,4
Magnesium	g/kg Mg (d.b.)	3,9	4,1	4,5	4,3	4,2	0,2
Cadmium/Kadmium	mg/kg Cd (d.b.)	1	<1	<1	<1	<1	0,2
Chromium/Chroom	mg/kg Cr (d.b.)	140	121	121	139	130	9
Copper/Koper	mg/kg Cu (d.b.)	506	414	305	309	383	83
Lead/Lood	mg/kg Pb (d.b.)	158	158	134	154	151	10
Nickel/Nikkel	mg/kg Ni (d.b.)	32	38	33	40	36	3
Zinc/Sink	mg/kg Zn (d.b.)	1305	1390	1277	1483	1364	80
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	5	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	7	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	3	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	6	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	23	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	56	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: KIMBERLEY - C.P.

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Aug 86	2 Nov 86	3 Feb 87	4 May 87		
Total residue/ Totale reste	%	92,8	93,0	92,9	90,8	92,4	0,9
Volatile residue/ Vlugtige reste	% (d.b.)	60,8	63,5	63,4	66,4	63,5	2,0
Fixed residue/ Vaste reste	% (d.b.)	39,2	36,5	36,4	33,6	36,4	2,0
pH	pH units/ eenhede	7,0	7,3	7,0	6,9	7,1	0,2
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	45,1	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	14,4	-
Potassium/Kalium	g/kg K (d.b.)	4,0	3,4	3,3	2,9	3,4	0,4
Calcium/Kalsium	g/kg Ca (d.b.)	18,9	21,6	25,5	26,8	23,2	3,1
Magnesium	g/kg Mg (d.b.)	6,6	7,5	7,1	7,0	7,1	0,3
Cadmium/Kadmium	mg/kg Cd (d.b.)	1	1	2	3	2	1
Chromium/Chroom	mg/kg Cr (d.b.)	100	84	66	59	77	16
Copper/Koper	mg/kg Cu (d.b.)	170	184	179	201	184	11
Lead/Lood	mg/kg Pb (d.b.)	95	103	114	135	112	15
Nickel/Nikkel	mg/kg Ni (d.b.)	37	41	42	45	41	3
Zinc/Sink	mg/kg Zn (d.b.)	664	700	788	868	755	79
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	<1	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	3	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	2	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	6	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	46	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	119	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: ..KING WILLIAMSTOWN - C.P.....

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Aug 86	2 Nov 86	3 Feb 87	4 May 87		
Total residue/ Totale reste	%	96,7	94,8	92,6	95,4	94,9	1,5
Volatile residue/ Vlugtige reste	% (d.b.)	31,3	26,4	44,2	36,2	34,5	6,6
Fixed residue/ Vaste reste	% (d.b.)	68,7	73,6	55,8	63,8	65,5	6,6
pH	pH units/ eenhede	6,0	6,3	6,4	6,2	6,2	0,1
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	–	–	–	–	21,4	–
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	–	–	–	–	6,1	–
Potassium/Kalium	g/kg K (d.b.)	1,2	1,0	1,5	1,3	1,3	0,2
Calcium/Kalsium	g/kg Ca (d.b.)	17,6	18,0	18,5	21,1	18,8	1,4
Magnesium	g/kg Mg (d.b.)	3,7	4,2	3,1	3,0	3,5	0,5
Cadmium/Kadmium	mg/kg Cd (d.b.)	3	3	1	4	3	1
Chromium/Chroom	mg/kg Cr (d.b.)	260	225	205	189	220	27
Copper/Koper	mg/kg Cu (d.b.)	385	334	369	586	419	98
Lead/Lood	mg/kg Pb (d.b.)	357	281	350	323	328	30
Nickel/Nikkel	mg/kg Ni (d.b.)	22	18	30	26	24	4
Zinc/Sink	mg/kg Zn (d.b.)	6085	7291	3564	3142	5021	1728
Mercury/Kwik	mg/kg Hg (d.b.)	–	–	–	–	<1	–
Arsenic/Arseen	mg/kg As (d.b.)	–	–	–	–	4	–
Selenium	mg/kg Se (d.b.)	–	–	–	–	2	–
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	–	–	–	–	5	–
Boron/ Boor	mg/kg B (d.b.)	–	–	–	–	23	–
Fluoride/ Fluoried	mg/kg F (d.b.)	–	–	–	–	41	–

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: KNYSNA - C.P.

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Aug 86	2 Nov 86	3 Feb 87	4 May 87		
Total residue/ Totale reste	%	97,0	92,2	89,5	90,1	92,2	2,9
Volatile residue/ Vlugtige reste	% (d.b.)	40,7	42,2	49,0	49,3	45,3	3,9
Fixed residue/ Vaste reste	% (d.b.)	59,3	57,8	51,0	50,7	54,7	3,9
pH	pH units/ eenhede	5,6	6,7	7,3	7,3	6,7	0,7
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	20,0	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	9,5	-
Potassium/Kalium	g/kg K (d.b.)	0,6	1,1	1,1	0,9	0,9	0,2
Calcium/Kalsium	g/kg Ca (d.b.)	10,8	24,0	42,9	40,0	29,4	0,8
Magnesium	g/kg Mg (d.b.)	1,9	3,4	4,0	3,9	3,3	0,8
Cadmium/Kadmium	mg/kg Cd (d.b.)	2	2	2	2	2	0
Chromium/Chroom	mg/kg Cr (d.b.)	86	126	81	162	114	33
Copper/Koper	mg/kg Cu (d.b.)	156	390	504	441	373	131
Lead/Lood	mg/kg Pb (d.b.)	116	109	144	166	134	23
Nickel/Nikkel	mg/kg Ni (d.b.)	16	30	29	31	27	6
Zinc/Sink	mg/kg Zn (d.b.)	2761	788	828	1042	1355	818
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	2	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	6	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	1	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	10	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	23	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	111	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: KRAAIFONTEIN - C.P.

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Aug 86	2 Nov 86	3 Feb 87	4 May 87		
Total residue/ Totale reste	%	92,7	91,1	92,4	95,0	92,8	1,4
Volatile residue/ Vlugtige reste	% (d.b.)	51,8	62,7	54,8	35,8	51,3	9,8
Fixed residue/ Vaste reste	% (d.b.)	48,2	37,3	45,2	64,2	48,7	9,8
pH	pH units/ eenhede	6,4	6,5	6,5	6,8	6,6	0,2
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	27,4	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	10,5	-
Potassium/Kalium	g/kg K (d.b.)	0,7	0,9	0,8	1,5	1,0	0,3
Calcium/Kalsium	g/kg Ca (d.b.)	33,7	33,4	35,4	31,5	33,5	1,4
Magnesium	g/kg Mg (d.b.)	4,2	3,8	3,9	3,8	3,9	0,2
Cadmium/Kadmium	mg/kg Cd (d.b.)	140	136	140	70	122	30
Chromium/Chroom	mg/kg Cr (d.b.)	262	266	267	260	264	3
Copper/Koper	mg/kg Cu (d.b.)	430	411	401	297	385	52
Lead/Lood	mg/kg Pb (d.b.)	237	217	216	147	204	34
Nickel/Nikkel	mg/kg Ni (d.b.)	104	78	84	70	84	13
Zinc/Sink	mg/kg Zn (d.b.)	1344	1336	1233	836	1187	207
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	<1	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	11	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	3	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	6	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	28	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	82	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: ...MILNERTON...C.P.....

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Aug 86	2 Nov 86	3 Feb87	4 May 87		
Total residue/ Totale reste	%	96,1	95,3	96,5	95,1	95,8	0,6
Volatile residue/ Vlugtige reste	% (d.b.)	77,6	76,1	73,7	77,0	76,1	1,5
Fixed residue/ Vaste reste	% (d.b.)	22,4	23,9	26,3	23,0	23,9	1,5
pH	pH units/ eenhede	6,8	6,1	6,2	5,5	6,2	0,5
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	22,4	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	11,8	-
Potassium/Kalium	g/kg K (d.b.)	0,8	0,8	0,5	0,8	0,7	0,1
Calcium/Kalsium	g/kg Ca (d.b.)	22,2	24,4	22,4	21,4	22,6	1,1
Magnesium	g/kg Mg (d.b.)	2,5	2,4	1,9	2,2	2,3	0,2
Cadmium/Kadmium	mg/kg Cd (d.b.)	7	6	6	5	6	1
Chromium/Chroom	mg/kg Cr (d.b.)	125	152	117	110	126	16
Copper/Koper	mg/kg Cu (d.b.)	380	442	382	435	410	29
Lead/Lood	mg/kg Pb (d.b.)	286	341	289	312	307	22
Nickel/Nikkel	mg/kg Ni (d.b.)	52	64	53	47	54	6
Zinc/Sink	mg/kg Zn (d.b.)	1085	1296	1081	1155	1154	87
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	3	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	3	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	3	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	6	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	20	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	98	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: .....OUDTSHOORN - C.P.....

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Aug.86	2 Nov 86	3 Feb 87	4 May 87		
Total residue/ Totale reste	%	92,9	93,5	93,6	93,4	93,4	0,3
Volatile residue/ Vlugtige reste	% (d.b.)	45,9	47,6	43,8	46,8	46,0	1,4
Fixed residue/ Vaste reste	% (d.b.)	54,1	52,4	56,2	53,2	54,0	1,4
pH	pH units/ eenhede	5,6	7,0	7,9	7,2	6,9	0,8
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	23,0	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	13,6	-
Potassium/Kalium	g/kg K (d.b.)	1,8	2,1	2,3	2,1	2,1	0,2
Calcium/Kalsium	g/kg Ca (d.b.)	71,3	55,7	57,3	57,0	60,3	6,4
Magnesium	g/kg Mg (d.b.)	14,2	12,5	12,7	13,5	13,2	0,7
Cadmium/Kadmium	mg/kg Cd (d.b.)	2	1	2	1	2	1
Chromium/Chroom	mg/kg Cr (d.b.)	84	54	63	45	62	14
Copper/Koper	mg/kg Cu (d.b.)	638	677	553	451	580	87
Lead/Lood	mg/kg Pb (d.b.)	183	163	172	172	173	71
Nickel/Nikkel	mg/kg Ni (d.b.)	21	25	26	24	24	2
Zinc/Sink	mg/kg Zn (d.b.)	1040	873	873	865	913	74
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	3	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	5	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	2	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	4	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	32	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	98	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: PAARL - C.P.

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Aug 86	2 Nov 86	3 Feb 87	4 May 87		
Total residue/ Totale reste	%	87,1	81,3	95,4	95,0	89,7	5,9
Volatile residue/ Vlugtige reste	% (d.b.)	35,6	45,4	49,1	48,9	44,8	5,5
Fixed residue/ Vaste reste	% (d.b.)	64,4	54,6	50,9	51,1	55,2	5,5
pH	pH units/ eenhede	8,0	8,3	7,7	7,2	7,8	0,4
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	28,9	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	20,0	-
Potassium/Kalium	g/kg K (d.b.)	1,0	1,2	0,9	1,3	1,1	0,2
Calcium/Kalsium	g/kg Ca (d.b.)	59,6	76,2	84,5	97,0	79,3	14
Magnesium	g/kg Mg (d.b.)	2,6	2,3	2,2	2,3	2,4	0,2
Cadmium/Kadmium	mg/kg Cd (d.b.)	2	2	2	2	2	0
Chromium/Chroom	mg/kg Cr (d.b.)	281	298	298	271	287	12
Copper/Koper	mg/kg Cu (d.b.)	445	534	454	418	463	43
Lead/Lood	mg/kg Pb (d.b.)	248	332	332	337	312	37
Nickel/Nikkel	mg/kg Ni (d.b.)	16	21	21	21	20	2
Zinc/Sink	mg/kg Zn (d.b.)	1266	1456	1430	1470	1406	82
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	3	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	6	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	2	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	8	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	20	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	133	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: PAROW - C.P.

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Aug 86	2 Nov 86	3 Feb 87	4 May 87		
Total residue/ Totale reste	%	97,4	97,9	94,5	97,3	96,8	1,3
Volatile residue/ Vlugtige reste	% (d.b.)	17,0	13,4	48,5	25,4	26,1	13,7
Fixed residue/ Vaste reste	% (d.b.)	83,0	86,6	51,5	74,6	73,9	13,7
pH	pH units/ eenhede	7,2	7,9	7,9	7,3	7,6	0,3
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	16,8	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	4,1	-
Potassium/Kalium	g/kg K (d.b.)	1,7	1,1	2,7	1,9	1,9	0,6
Calcium/Kalsium	g/kg Ca (d.b.)	55,0	81,9	37,0	33,9	52,0	19,0
Magnesium	g/kg Mg (d.b.)	2,7	2,5	2,1	2,0	2,4	0,3
Cadmium/Kadmium	mg/kg Cd (d.b.)	1	1	1	1	1	0
Chromium/Chroom	mg/kg Cr (d.b.)	68	87	85	78	80	7
Copper/Koper	mg/kg Cu (d.b.)	91	108	197	121	129	41
Lead/Lood	mg/kg Pb (d.b.)	67	57	96	59	70	16
Nickel/Nikkel	mg/kg Ni (d.b.)	4	6	7	7	6	1
Zinc/Sink	mg/kg Zn (d.b.)	224	203	293	229	237	34
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	1	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	2	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	1	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	4	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	16	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	32	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: PORT ELIZABETH (CAPE RECEIFE) - C.P.

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Aug 86	2 Nov 86	3 Feb 87	4 May 87		
Total residue/ Totale reste	%	92,0	92,3	91,8	90,5	91,7	0,7
Volatile residue/ Vlugtige reste	% (d.b.)	46,6	49,6	54,7	46,4	49,3	3,4
Fixed residue/ Vaste reste	% (d.b.)	53,4	50,4	45,3	53,6	50,7	3,4
pH	pH units/ eenhede	5,7	6,6	7,3	7,7	6,8	0,8
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	45,5	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	11,9	-
Potassium/Kalium	g/kg K (d.b.)	1,8	2,1	2,3	2,8	2,3	0,4
Calcium/Kalsium	g/kg Ca (d.b.)	18,5	27,3	38,3	25,5	27,4	7,1
Magnesium	g/kg Mg (d.b.)	3,7	4,4	4,8	5,1	4,5	0,5
Cadmium/Kadmium	mg/kg Cd (d.b.)	7	4	3	4	5	2
Chromium/Chroom	mg/kg Cr (d.b.)	95	88	106	114	101	10
Copper/Koper	mg/kg Cu (d.b.)	271	217	270	320	270	36
Lead/Lood	mg/kg Pb (d.b.)	164	141	172	147	156	13
Nickel/Nikkel	mg/kg Ni (d.b.)	22	18	20	30	23	5
Zinc/Sink	mg/kg Zn (d.b.)	704	608	774	751	709	64
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	5	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	4	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	3	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	4	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	46	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	46	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: ...PORT ELIZABETH (FISHWATER FLATS) C.P.....

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		Aug[1] 86	Nov[2] 86	Feb[3] 87	May[4] 87		
Total residue/ Totale reste	%	94,0	93,4	93,5	97,2	94,5	1,6
Volatile residue/ Vlugtige reste	% (d.b.)	64,4	57,3	60,5	71,6	63,5	5,3
Fixed residue/ Vaste reste	% (d.b.)	35,6	42,7	39,5	28,4	36,5	5,3
pH	pH units/ eenhede	7,0	6,4	6,8	6,6	6,7	0,2
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	32,7	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	13,3	-
Potassium/Kalium	g/kg K (d.b.)	1,2	1,3	1,2	1,0	1,2	0,1
Calcium/Kalsium	g/kg Ca (d.b.)	24,6	25,5	20,7	13,2	21,0	4,9
Magnesium	g/kg Mg (d.b.)	3,9	4,1	3,4	2,4	3,5	0,6
Cadmium/Kadmium	mg/kg Cd (d.b.)	3	2	3	4	3	1
Chromium/Chroom	mg/kg Cr (d.b.)	2470	2200	2130	2150	2240	140
Copper/Koper	mg/kg Cu (d.b.)	340	474	411	406	408	47
Lead/Lood	mg/kg Pb (d.b.)	1161	1371	1338	1329	1300	82
Nickel/Nikkel	mg/kg Ni (d.b.)	58	48	68	44	55	9
Zinc/Sink	mg/kg Zn (d.b.)	1770	1470	1500	1660	1600	122
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	<1	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	4	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	2	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	10	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	13	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	87	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: ROBERTSON - C.P.

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Aug. 86	2 Nov 86	3 Feb 87	4 May 87		
Total residue/ Totale reste	%	92,6	94,9	94,2	93,6	93,8	0,8
Volatile residue/ Vlugtige reste	% (d.b.)	49,6	50,5	61,1	61,2	55,6	5,6
Fixed residue/ Vaste reste	% (d.b.)	50,4	49,5	38,9	38,8	44,4	5,6
pH	pH units/ eenhede	7,4	5,2	5,1	6,4	6,0	0,9
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	32,3	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	8,8	-
Potassium/Kalium	g/kg K (d.b.)	1,7	1,8	1,8	1,7	1,8	<0,1
Calcium/Kalsium	g/kg Ca (d.b.)	18,0	21,1	20,7	20,2	20,0	1,2
Magnesium	g/kg Mg (d.b.)	4,0	4,3	4,2	4,1	4,2	0,1
Cadmium/Kadmium	mg/kg Cd (d.b.)	4	4	5	4	4	<1
Chromium/Chroom	mg/kg Cr (d.b.)	136	141	150	161	147	10
Copper/Koper	mg/kg Cu (d.b.)	299	300	253	263	279	21
Lead/Lood	mg/kg Pb (d.b.)	203	172	190	203	192	13
Nickel/Nikkel	mg/kg Ni (d.b.)	48	40	44	37	42	4
Zinc/Sink	mg/kg Zn (d.b.)	1107	959	1040	1087	1048	57
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	3	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	8	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	5	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	4	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	40	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	120	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: .....STELLENBOSCH - C.P.....

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Aug 86	2 Nov 86	3 Feb 87	4 May 87		
Total residue/ Totale reste	%	96,7	97,9	99,3	99,2	98,3	1,1
Volatile residue/ Vlugtige reste	% (d.b.)	52,7	49,5	22,7	25,6	37,6	13,6
Fixed residue/ Vaste reste	% (d.b.)	47,3	50,5	77,3	74,4	62,4	13,6
pH	pH units/ eenhede	6,0	5,5	5,8	5,7	5,8	0,2
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	20,6	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	7,1	-
Potassium/Kalium	g/kg K (d.b.)	0,9	1,1	0,6	0,8	0,9	0,2
Calcium/Kalsium	g/kg Ca (d.b.)	14,1	14,1	8,4	8,8	11,4	2,8
Magnesium	g/kg Mg (d.b.)	2,6	2,5	1,1	1,2	1,9	0,7
Cadmium/Kadmium	mg/kg Cd (d.b.)	5	4	4	4	4	<1
Chromium/Chroom	mg/kg Cr (d.b.)	83	72	79	70	76	5
Copper/Koper	mg/kg Cu (d.b.)	1198	1192	618	796	951	252
Lead/Lood	mg/kg Pb (d.b.)	263	250	145	184	211	48
Nickel/Nikkel	mg/kg Ni (d.b.)	32	33	28	26	30	3
Zinc/Sink	mg/kg Zn (d.b.)	1280	1197	660	791	982	262
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	14	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	6	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	2	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	4	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	31	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	37	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: STRAND - C.P.

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Aug 86	2 Nov 86	3 Feb 87	4 May 87		
Total residue/ Totale reste	%	94,2	92,0	94,4	88,4	92,3	2,4
Volatile residue/ Vlugtige reste	% (d.b.)	44,5	72,3	50,6	33,7	50,3	14,0
Fixed residue/ Vaste reste	% (d.b.)	55,5	27,7	49,4	66,3	51,8	14,0
pH	pH units/ eenhede	6,8	7,0	7,7	6,9	7,1	0,4
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	42,4	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	12,5	-
Potassium/Kalium	g/kg K (d.b.)	2,8	2,3	1,4	1,4	2,0	0,6
Calcium/Kalsium	g/kg Ca (d.b.)	64,0	25,5	66,9	32,6	47,3	18,4
Magnesium	g/kg Mg (d.b.)	4,8	4,1	3,6	3,5	4,0	0,5
Cadmium/Kadmium	mg/kg Cd (d.b.)	2	2	2	2	2	0
Chromium/Chroom	mg/kg Cr (d.b.)	108	94	108	117	107	8
Copper/Koper	mg/kg Cu (d.b.)	370	493	340	424	407	58
Lead/Lood	mg/kg Pb (d.b.)	189	263	191	275	230	40
Nickel/Nikkel	mg/kg Ni (d.b.)	41	41	37	44	41	2
Zinc/Sink	mg/kg Zn (d.b.)	776	997	706	1010	872	134
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	3	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	7	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	3	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	4	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	59	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	84	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: UITENHAGE - C.P.

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Aug. 86	2 Nov 86	3 Feb 87	4 May 87		
Total residue/ Totale reste	%	93,0	94,0	95,5	88,0	92,6	2,8
Volatile residue/ Vlugtige reste	% (d.b.)	59,6	51,0	34,6	25,5	42,7	13,4
Fixed residue/ Vaste reste	% (d.b.)	40,4	49,0	65,4	74,5	57,3	13,4
pH	pH units/ eenhede	6,8	6,9	7,1	7,7	7,1	0,3
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	--	-	20,6	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	11,6	-
Potassium/Kalium	g/kg K (d.b.)	1,4	1,3	1,2	1,3	1,3	0,3
Calcium/Kalsium	g/kg Ca (d.b.)	40,0	40,5	33,0	36,1	37,4	3,1
Magnesium	g/kg Mg (d.b.)	4,4	3,3	2,8	3,0	3,4	0,6
Cadmium/Kadmium	mg/kg Cd (d.b.)	4	2	4	3	3	1
Chromium/Chroom	mg/kg Cr (d.b.)	660	590	510	550	580	60
Copper/Koper	mg/kg Cu (d.b.)	582	819	575	604	645	101
Lead/Lood	mg/kg Pb (d.b.)	931	997	741	461	783	208
Nickel/Nikkel	mg/kg Ni (d.b.)	339	170	118	95	181	95
Zinc/Sink	mg/kg Zn (d.b.)	4431	2156	1672	1307	2392	1215
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	3	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	5	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	2	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	7	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	38	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	69	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: UPINGTON - C.P.

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Aug 86	2 Nov 86	3 Feb 87	4 May 87		
Total residue/ Totale reste	%	95,2	95,6	89,7	92,2	93,2	2,4
Volatile residue/ Vlugtige reste	% (d.b.)	54,6	50,3	62,0	54,2	55,3	4,2
Fixed residue/ Vaste reste	% (d.b.)	45,4	49,7	38,0	45,8	44,7	4,2
pH	pH units/ eenhede	6,1	6,3	6,5	6,7	6,4	0,2
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	28,5	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	6,1	-
Potassium/Kalium	g/kg K (d.b.)	1,6	1,6	1,5	1,5	1,6	<0,1
Calcium/Kalsium	g/kg Ca (d.b.)	25,1	25,5	24,6	26,0	25,3	0,5
Magnesium	g/kg Mg (d.b.)	5,7	5,4	4,6	4,9	5,2	0,4
Cadmium/Kadmium	mg/kg Cd (d.b.)	4	3	3	4	4	1
Chromium/Chroom	mg/kg Cr (d.b.)	96	113	96	87	98	9
Copper/Koper	mg/kg Cu (d.b.)	317	319	266	488	348	84
Lead/Lood	mg/kg Pb (d.b.)	183	162	136	155	159	17
Nickel/Nikkel	mg/kg Ni (d.b.)	26	31	23	25	26	3
Zinc/Sink	mg/kg Zn (d.b.)	1045	1053	986	1054	1035	28
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	3	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	3	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	4	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	7	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	53	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	246	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: VREDENBURG - SALDANHA - C.P.

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Aug 86	2 Nov 86	3 Feb 87	4 May 87		
Total residue/ Totale reste	%	93,8	95,0	93,0	93,8	93,9	0,7
Volatile residue/ Vlugtige reste	% (d.b.)	63,8	37,4	51,4	63,8	54,1	11,0
Fixed residue/ Vaste reste	% (d.b.)	36,2	62,6	48,6	36,2	45,9	11,0
pH	pH units/ eenhede	7,0	7,1	6,7	7,0	7,0	0,2
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	23,5	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	7,1	-
Potassium/Kalium	g/kg K (d.b.)	2,5	2,8	2,7	3,9	3,0	0,5
Calcium/Kalsium	g/kg Ca (d.b.)	16,3	12,8	16,3	15,0	15,1	1,4
Magnesium	g/kg Mg (d.b.)	3,1	3,5	4,0	4,4	3,8	0,5
Cadmium/Kadmium	mg/kg Cd (d.b.)	2	1	2	2	2	0,4
Chromium/Chroom	mg/kg Cr (d.b.)	210	213	217	240	220	12
Copper/Koper	mg/kg Cu (d.b.)	303	160	196	194	213	54
Lead/Lood	mg/kg Pb (d.b.)	371	165	198	170	226	85
Nickel/Nikkel	mg/kg Ni (d.b.)	44	46	44	47	45	1
Zinc/Sink	mg/kg Zn (d.b.)	590	437	649	562	560	78
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	2	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	3	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	3	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	4	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	65	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	146	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: WALVIS BAY - C.P.

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Aug 86	2 Nov 86	3 Feb 87	4 May 87		
Total residue/ Totale reste	%	94,8	92,6	95,5	94,5	94,4	1,1
Volatile residue/ Vlugtige reste	% (d.b.)	40,6	45,0	44,2	42,2	43,0	1,7
Fixed residue/ Vaste reste	% (d.b.)	59,4	55,0	55,8	57,8	57,0	1,7
pH	pH units/ eenhede	7,3	7,2	7,1	7,1	7,2	0,8
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	25,6	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	14,3	-
Potassium/Kalium	g/kg K (d.b.)	3,3	2,7	2,9	3,5	3,1	0,3
Calcium/Kalsium	g/kg Ca (d.b.)	57,9	41,1	50,2	48,4	49,4	6,0
Magnesium	g/kg Mg (d.b.)	8,4	7,4	7,9	8,7	8,1	0,5
Cadmium/Kadmium	mg/kg Cd (d.b.)	3	2	3	2	3	<1
Chromium/Chroom	mg/kg Cr (d.b.)	48	66	63	51	57	8
Copper/Koper	mg/kg Cu (d.b.)	495	360	335	329	380	68
Lead/Lood	mg/kg Pb (d.b.)	217	358	340	309	306	54
Nickel/Nikkel	mg/kg Ni (d.b.)	39	35	31	29	34	4
Zinc/Sink	mg/kg Zn (d.b.)	1074	1421	1126	1016	1159	156
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	<1	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	6	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	3	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	13	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	43	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	116	-

d.b.:dry basis/droë basis

NATIONAL INSTITUTE FOR WATER RESEARCH/NASIONALE INSTITUUT VIR WATERNAVORSING

CHEMICAL CHARACTERIZATION OF SA MUNICIPAL SEWAGE SLUDGES/
CHEMIESE KARAKTERISERING VAN SA MUNISIPALE RIOOLSLYKE

SEWAGE WORKS / RIOOLSUIWERINGSWERKE: WORCESTER - C.P.

Determinand	Units / Eenhede	Sampling Date/Bemonsteringsdatum				Mean value/ Gem. waarde	Std. Dev./ Std. Afw.
		1 Aug 86	2 Nov 86	3 Feb 87	4 May 87		
Total residue/ Totale reste	%	93,6	94,7	95,4	95,3	94,8	0,7
Volatile residue/ Vlugtige reste	% (d.b.)	56,9	69,3	55,4	52,5	58,5	6,4
Fixed residue/ Vaste reste	% (d.b.)	43,1	30,7	44,6	47,6	41,2	6,4
pH	pH units/ eenhede	6,8	6,5	6,2	6,2	6,4	0,2
Total Kjeldahl nitrogen/Totale Kjeldahl stikstof	g/kg N (d.b.)	-	-	-	-	31,6	-
Total phosphorus/ Totale fosfaat	g/kg P (d.b.)	-	-	-	-	10,7	-
Potassium/Kalium	g/kg K (d.b.)	1,0	1,3	1,3	1,1	1,2	0,5
Calcium/Kalsium	g/kg Ca (d.b.)	26,4	18,0	22,0	25,5	23,0	3,3
Magnesium	g/kg Mg (d.b.)	4,1	3,2	3,3	3,3	3,5	0,4
Cadmium/Kadmium	mg/kg Cd (d.b.)	2	2	2	<1	2	<1
Chromium/Chroom	mg/kg Cr (d.b.)	87	81	107	95	93	10
Copper/Koper	mg/kg Cu (d.b.)	305	298	370	447	355	60
Lead/Lood	mg/kg Pb (d.b.)	332	282	332	297	311	22
Nickel/Nikkel	mg/kg Ni (d.b.)	22	30	29	41	31	7
Zinc/Sink	mg/kg Zn (d.b.)	1043	876	1060	964	986	73
Mercury/Kwik	mg/kg Hg (d.b.)	-	-	-	-	1	-
Arsenic/Arseen	mg/kg As (d.b.)	-	-	-	-	5	-
Selenium	mg/kg Se (d.b.)	-	-	-	-	2	-
Molybdenum/ Molybdeen	mg/kg Mo (d.b.)	-	-	-	-	4	-
Boron/ Boor	mg/kg B (d.b.)	-	-	-	-	21	-
Fluoride/ Fluoried	mg/kg F (d.b.)	-	-	-	-	59	-

d.b.:dry basis/droë basis

APPENDIX 3

PUBLICATIONS ARISING FROM WORK CARRIED OUT FOR THIS PROJECT

1. SMITH, R. 1983. Evaluation of various techniques for the pretreatment of sewage sludges prior to trace metal analysis by atomic absorption spectrophotometry. WaterSA, 9(1), 31-36.

2. SMITH, R. 1984. NIWR Interlaboratory comparison study No.83/B: Analysis of a sewage sludge for inorganic chemical contaminants and nutrients. CSIR Research Report 603, Pretoria.

3. SMITH, R. 1984. A laboratory manual for the determination of inorganic chemical contaminants and nutrients in sewage sludges. CSIR Technical Guide K62, Pretoria.

4. SMITH, R. 1989. A laboratory manual for the determination of inorganic chemical contaminants and nutrients in sewage sludges (SECOND EDITION). CSIR Technical Guide K62, Pretoria.

5. SMITH, R. 1986. Inorganic chemical characterization of South African municipal sewage sludges. Progress Report No.1: Work carried out prior to January, 1986. NIWR Contract Project No. 620/9224/2: Water Research Commission (Restricted).

6. SMITH, R. and VASILOUDIS, H. 1987. Inorganic chemical characterization of South African municipal sewage sludges. Progress Report No.2: Work carried out from January to December, 1986. NIWR Contract Project No. 620/9224/2: Water Research Commission (Restricted).

7. SMITH, R and VASILOUDIS, H. 1988. Inorganic chemical characterization of South African municipal sewage sludges. Progress Report No.3: Work carried out from January 1987 to February 1988. NIWR Contract Project No. 620/9224/2: Water Research Commission (Restricted).

8. SMITH, R. and VASILOUDIS, H. 1989. Inorganic chemical characterization of South African municipal sewage sludges. Progress Report No.4: Work carried out from March 1988 to January 1989. DWT Contract Project No. 670/3122/9: Water Research Commission (Restricted).