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CONSTRUCTION AND OPERATION OF THE CAPE FLATS WATER RECLAMATION PLANT AND THE SURVEILLANCE OF THE RECLAIMED WATER QUALITY

Report to the
WATER RESEARCH COMMISSION
by the
CITY ENGINEER'S DEPARTMENT
CAPE TOWN CITY COUNCIL

WRC Report No 75/1/90

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TABLE OF CONTENTS

LIST OF TABLES

TABLES IN APPENDICES

LIST OF FIGURES

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- This project was guided by a Steering Committee constituted as follows:

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EXECUTIVE SUMMARY

BACKGROUND

South Africa has a low rainfall with an annual average of 497 mm which is well below the world average of 860 mm (Anon, 1986a).

The ever increasing demands for fresh water have placed a severe strain on the available water resources. The estimated total annual water demand in South Africa is expected to exceed 22 x 10^9 m^3 by the year 2000 of which about 5 x 10^9 m^3/a is for urban and industrial use (Anon, 1986b).

Although the indirect reuse of treated wastewaters is well established in Southern Africa, especially in the inland areas, direct reuse, which is the planned and deliberate use of a treated wastewater, has only been used to a limited extent, e.g. Windhoek - Namibia. Growing water shortages, however, may well force direct reclamation before the turn of the century, especially in coastal centres where indirect use is generally not desirable (Odendaal, 1989).

As in the other centres around Southern Africa, Cape Town can no longer be assured of unlimited supplies of fresh water.

Against this background an investigatory pilot plant programme for the reclamation of treated wastewater was initiated in the Western Cape.

CONTRACT AGREEMENT

The agreement between the Water Research Commission (WRC) and the Cape Town City Council (CCC) stipulated that the WRC would make funds available on request to the CCC for the following:

- construction of the Cape Flats plant
- modifications as deemed necessary during the project
- surveillance of the reclaimed water quality

The CCC in turn would:

- provide the necessary personnel and facilities
- carry out the working programmes
- assume responsibility for the design and construction
- operate the plant
- be responsible for the financial administration

- compile a comprehensive final report on the results and findings for submission to the WRC.

OBJECTIVES

The main objective was to develop a practical process configuration to consistently produce potable water from the Cape Flats wastewater treatment works effluent as a possible resource for augmentation of existing potable water supplies.

Various secondary objectives were pursued in order to achieve this objective, namely:

- the application and evaluation of techniques and operating procedures
- the integration feasibility of reclaimed water with available resources
- the development and execution of chemical, bacteriological and virological surveillance programmes.

PROCESS DEVELOPMENT

The wealth of information which had already been obtained from the Windhoek, Pretoria and Athlone water reclamation projects was used as the basis of design and process development at the Cape Flats plant.

The flexible design of the plant provided a number of process configuration options. After the feed water was characterised with respect to its organic, inorganic and microbiological constituents an initial combination of unit processes was selected.

Subsequent thorough optimisation of the plant resulted in the selection of the following sequential process configuration:

- feed water quality equalisation and buffering
- chemical flocculation using ferric sulphate and a polyelectrolyte
- primary sedimentation
- primary chlorination
- rapid gravity sand filtration
- ozonation
- two stage activated carbon treatment
- final chlorination
- final calcium hydroxide stabilisation

PLANT OPERATION

The plant was commissioned during May 1982 and operated until December 1986. During this period various process adjustments were made and the flocculants ferric chloride, ferric sulphate and aluminium sulphate were successfully optimised. Ferric sulphate was chosen and used predominantly during the project as it was locally available and produced a good quality reclaimed water.

Throughout the project many operational and process configuration changes were made, viz:

- The variability in quality of the feed water from the adjacent wastewater treatment plant resulted in an optimisation programme of the activated sludge process being carried out by the University of Cape Town (UCT) (Ekama and Marais, 1984).

- An equalisation pond was constructed as a buffer between the activated sludge works and the reclamation plant.

- Break point chlorination between the primary settling and sand filtration processes resulted in the production of undesirable trihalomethanes (THM). The chlorine dose at this point was subsequently reduced but the final chlorine dose after activated carbon treatment was increased to achieve disinfection.

- Due to mechanical and operational problems the original pressure sand filters were found unacceptable and replaced with rapid gravity type sand filters.

- Ozonation, as an intermediate disinfection stage, was introduced during the final year of operation.

- Introduced a dry calcium hydroxide feed in place of a slurry feed.

SURVEILLANCE OF THE QUALITY OF THE RECLAIMED WATER.

An intensive surveillance programme using external testing laboratories was undertaken during the final three months of the project to obtain independent views of the quality of the reclaimed water. These included the CCC, UCT and the National Institute for Water Research (NIWR) now the Division of Water Technology (Watertek) of the CSIR.

The overall findings of the respective laboratories showed that the reclaimed water quality was well within the generally accepted standards for potable water.

CONCLUSIONS

1 Water reclamation, by the production of a potable water from an activated sludge plant effluent is a viable source for the supplementation of potable water supplies but should only be used when all other economical aspects of water supplementation have been explored and implemented.

2 The operational, maintenance and surveillance programmes proved conclusively

that larger local authorities are capable of owning, maintaining and running a water reclamation plant which consistently produces a water of potable quality.

3 The total cost of producing reclaimed water at the Cape Flats reclamation plant was about 88 c/m^3 which is much higher than the cost of about 20 c/m^3 of producing fresh water in the Cape Town area (1986 costs). Approximately 33% of the total cost was associated with the activated carbon process. It is envisaged that ozonation prior to activated carbon treatment and on site carbon regeneration would significantly reduce the production cost of a full scale plant. The costs of fresh and reclaimed waters will tend to converge in future.

4 The wastewater treatment works supplying the feed water to the Cape Flats reclamation plant is a nutrient removal plant of the five stage Bardenpho type and the process configuration of the reclamation plant was specifically selected for this type of effluent. Pilot or prototype plant studies should be undertaken before full scale implementation of a water reclamation scheme.

5 It is essential that the wastewater treatment works supplying the feed water to the reclamation process is properly optimised, operated and controlled. This would ensure that the quality of the feed water to the reclamation process would be free from major fluctuations in quality and that the consistent supply of an acceptable feed water would always be available. During periods where the quality is unacceptable this feed water should bypass the reclamation process.

6 The inclusion of a feedwater quality equalisation and buffer pond is essential to prevent water of fluctuating quality from being supplied to the reclamation plant.

7 The provision of backup or standby mechanical equipment is essential to maintain the uninterrupted production of a potable water supply.

8 A comprehensive virological study of the reclaimed water was conducted during the surveillance period. All the samples examined during this time were clear and no viruses or coliphages were detected. By virological standards the reclaimed water is perfectly potable (Hodgkiss *et al.*, 1989).

9 The chemical quality of the reclaimed water, during the intensive surveillance period, conformed to the recommended limits for drinking water (Kempster and Smith, 1985).

10 Bacteriological examination of the reclaimed water during the intensive surveillance period indicated that, except for the standard plate count, the quality of the reclaimed water was well within generally accepted limits for drinking water. However, the occasional high standard plate count does not necessarily constitute a health risk but it does reflect occasional inadequate final disinfection.

11 The trihalomethane (THM) results obtained during the intensive surveillance period showed that the quality of the reclaimed water was well within the USEPA criterium of 100 $\mu g/l$ for drinking water. An increase in the THM values over the last three weeks of the surveillance period indicated that the activated carbon had

become saturated with respect to the adsorption of THM's.

12 Consistently low dissolved organic carbon (DOC) concentrations were obtained on the reclaimed water throughout the intensive surveillance period.

13 The ongoing surveillance programmes which will be used in a full scale application will have to be intensive and will require more detailed analyses than for fresh water plants. It is essential that automatic surveillance equipment is provided.

14 Aluminium sulphate, ferric chloride and ferric sulphate were all successful as flocculants. Ferric sulphate however was used predominantly. Polyelectrolytes aided the flocculation process when added in low dosages.

15 The combined use of ferric sulphate and chlorine together with the poorly buffered feed water produced a corrosive water with a depressed pH value. Calcium hydroxide was used to stabilise this water to a pH value of about 9. This however resulted in the precipitation of relatively small quantities of calcium carbonate in the reclaimed water. This precipitate did not affect the final disinfection process as final chlorination preceded final stabilisation.

16 The use of ozonation prior to activated carbon treatment was found to increase the life of the carbon by about 40%. This concurs with other research findings (Van Leeuwen, 1988).

CHAPTER 1

1.1 INTRODUCTION

Water is by far one of the earth's most important natural resources and although it occurs abundantly, there are regions where water is scarce.

The amount of fresh water available for exploitation by man is limited to that present in the natural water cycle. In countries not blessed with high rainfall, the ever increasing demands for fresh water have placed a severe strain on the available water resources.

South Africa is blessed with fertile ground, abundant raw materials and labour, but water is the overall limiting factor. South Africa is among the drier regions of the world with an average annual rainfall of 497 mm which is well below the world average of 860 mm. (Anon, 1986a) Our largest river, namely the Orange, has an estimated flow rate of less than 14% of that of the Zambezi and only 0,3% of that of the Amazon in South America (van Leeuwen, 1988).

In South Africa today the supply of water from natural resources such as lakes and rivers is being tapped to the full. These natural resources are being extended through dam construction, supplementing underground aquifers and through the pumping of water from one catchment to another.

The estimated total annual water demand in South Africa will have increased from 16 x 10^9 m^3/a in 1980 to 22 x 10^9 m^3/a in the year 2000 and to 26 x 10^9 m^3/a by 2010. Of this 2,5 x 10^9, 5,3 x 10^9 and 7,4 x 10^9 m^3/a for 1980, 2000 2010 respectively is for urban and industrial use (Anon, 1986b).

According to projections by the Department of Water Affairs, the water demand and supply curves for South Africa as a whole will meet at about the year 2020. Meeting demands beyond that stage will involve considerable incremental cost (Odendaal, 1989).

The supplementation of natural resources by the indirect reuse of treated wastewater is already well established in Southern Africa, especially in the inland areas. The indirect reuse of treated effluents implies the reuse of treated wastewaters which have already been used one or more times and then discharged into fresh or underground waters from which it is extracted and used again in its diluted form. Direct reuse, which is the planned and deliberate use of treated wastewater in an undiluted form, has only been used to a limited extent in Southern Africa, i.e. Windhoek - Namibia, and by and large this source remains untapped.

It was in this light that the contract, as presented in the following report, between the Cape Town City Council (CCC) and the Water Research Commission (WRC) came into being.

CHAPTER 2

HISTORICAL BACKGROUND AND CONTRACT AGREEMENT

2.1 Historical background

Throughout the world and particularly in Africa, many countries are experiencing shortages of conventional fresh water supplies. The reasons for these shortages vary from country to country but can be summarised into the following:

- ever increasing population growth
- industrial and agricultural development
- ever improving living standards
- droughts etc

Effective use of the available water supplies worldwide is being hampered by the discharge of increasing volumes of untreated and partially treated wastewaters. This problem is further aggravated by the growth in the number of synthetic chemicals produced, many of which reach the water environment and are suspected to contain toxic or carcinogenic properties. Certain of these substances are resistant to degradation in conventional biological wastewater treatment facilities and to the self-purification properties of the water environment and can subsequently pass through conventional water treatment plants to reach consumers (Meiring, 1982).

In the USA, although direct reuse of municipal wastewaters for agricultural purposes has been practised since the beginning of this century, a more direct approach was taken by the South Lake Tahoe Public Utility District in 1968 and the Water Factory 21 at Orange County Water District in 1976, with the reclaimed water being put into reservoirs and aquifers which could be used for recreation and drinking water purposes (Hart, 1981).

The first case history of direct domestic reuse of sewage effluents was that of Chanute, USA, where because of five years of drought the City of Chanute was forced to recycle secondary sewage effluent through a 17-day retention pond directly to a water treatment plant. Although the water was bacteriologically acceptable it had a pale yellow colour which led to poor consumer acceptance (Hart, 1981).

Southern Africa is no stranger to water shortages although the rate of quality deterioration of fresh water supplies in this region has been retarded through the imposition of strict discharge regulations in terms of the Water Act (Act 54, 1956) and various subsequent regulations e.g. the phosphate standard of 1 mg/*l*.

In 1968, Windhoek, in Namibia, became the first city in the world to commission a reclamation plant as an integral part of its water supply system. During its first two years of operation this plant contributed an average of 13,4% of the total water consumed. Throughout this period the quality of the final water conformed to the criteria of the World Health Organisation (WHO) for potable water (Hart, 1981).

The importance of water reclamation for Southern Africa compelled the then National Institute for Water Research (NIWR), now Watertek, of the CSIR to continue its research and in 1970 the Stander water reclamation plant at the Daspoort sewage works near Pretoria, in the Republic of South Africa, was commissioned (Hart, 1981).

As in other centres around Southern Africa, Cape Town can no longer be assured of unlimited supplies of fresh water. During the seventies it was estimated that the water supply to Cape Town and environs from the Steenbras and Wemmershoek dams, the minor reservoirs on Table Mountain and the allocations of water by the Department of Water Affairs from the Voëlvlei and Theewaterskloof dams would within the next two decades be insufficient to meet demands. Future fresh water supplies will have to come from Phases 1 & 2 of the Palmiet Scheme, the augmentation of water in the Theewaterskloof dam through the Elands River/Klein Drakenstein dam project and the extraction of ground waters.

Against this background an investigatory pilot plant programme of water reclamation of treated sewage effluent was initiated in the Western Cape. This included the design, construction and operation of the 1,6 x 10^6 m^3/a Cape Flats pilot water reclamation plant located adjacent to the wastewater treatment plant.

A survey carried out during the mid eighties by the City Engineer's Department of the CCC has shown that if all the proposed fresh water projects are completed by the year 2000 less than 60% of the water resources of the south-western Cape will have been utilized, of which 70% will be used for agriculture. It is considered that the reclamation and reuse of sewage effluent on a large scale should be for a future period when at least 80% of the region's exploitable natural resources is being used. Therefore no provision has been made for water reclamation in the planning of the region's water resources to the year 2000 (Anon, 1985/1986).

2.2 Contract agreement

As a result of these envisaged water shortages, intensive investigatory research was undertaken to pre-empt any future water reclamation requirements and accordingly the CCC entered into various contracts for the design, construction and operation of the water reclamation plants. The project relating to the Athlone and Phase I of the Cape Flats agreements was completed during the latter part of the 1970's. The second phase of the Cape Flats project resulted in a new agreement. This project was completed at the end of 1986 after a seven year experimental period and forms the basis of this report.

This agreement between the WRC and the CCC stipulated that the WRC would make funds available on request to the CCC for the construction of the Cape Flats plant, modifications as deemed necessary during the project and the quality surveillance of the reclaimed water. The CCC in turn would provide the necessary personnel and facilities, carry out the working programmes approved by the steering committee, assume responsibility for the design, construction and operation of the plant, provide the funds necessary for the running of the plant, be responsible for the financial administration of the project and compile a comprehensive final report on the results and findings of the project for submission to the WRC.

The agreement was initially to remain in force for a period of five years from January 1980,

however, due to unforeseen problems encountered with some of the unit processes the duration of the project was lengthened by a further two years until December 1986.

Investigations leading up to this agreement were initiated in 1966. During the course of these investigations the following aspects were investigated:

- surveys of the volumes and qualities of sewage from different sources and areas
- the possible segregation of predominantly industrial effluents from those of essentially domestic origin
- modernization and upgrading of existing sewage works and construction of new regionalized works
- application and evaluation of reclamation technology for the treatment of sewage effluents to a potable quality standard
- geohydrology of the coastal sand deposits to determine the potential of this aquifer for the exploitation of ground water and the possible storage of reclaimed water during periods of decreased demand
- hydraulics of the sand aquifer to determine water mass balance and associated parameters in relation to the infiltration and abstraction of reclaimed water.

These investigations were initially guided by a steering committee of the Cape Provincial Administration. The contributing bodies i.e. CCC, Watertek of the CSIR etc were financed by the WRC. These contracts had all expired by the time the aforementioned new contract between the CCC and WRC was initiated.

CHAPTER 3

PROJECT OBJECTIVES

3.1 Objectives

The main objective of the Cape Flats project was to develop reclaimed water as a possible resource for augmentation of existing fresh water supplies. In order to achieve this the following secondary objectives each pertaining to a specific aspect have been pursued:

- the application and evaluation of techniques and operational procedures to reclaim treated sewage effluents from the adjacent Cape Flats activated sludge wastewater treatment works to a potable quality.

- the integration feasibility of reclaimed water with available resources in order to ensure adequate supplies for the future.

- the development and execution of suitable programmes for independent surveillance and control of the chemical, bacteriological and virological quality of reclaimed water in order that assurance can be given that the reclaimed water can be safely integrated into the existing water supply distribution system.

- the development and execution of virological surveillance programmes of the population in areas that will possibly be supplied with reclaimed water, both before and after the introduction of reclaimed water.

3.2 Comments on objectives

The main objective of the project was accomplished. With respect to the secondary objectives the following comments apply:

- the application and evaluation of techniques and operational procedures were established.

- integration feasibility of reclaimed water; this was established in Windhoek.

- development and execution of independent surveillance programmes: independent surveillance merely reinforced in-house plant control surveillance and showed that the various quality specifications of existing water supply systems could be attained.

- Virological studies were carried out by the Medical School virological laboratories (UCT) on samples taken at various stages throughout the process.

CHAPTER 4

PROCESS DEVELOPMENT AND DESCRIPTION

4.1 Plant design and process development

Laboratory and/or pilot plant scale experiments often comprise the initial step in the design of a water reclamation scheme but this necessity is questionable for those regions in which similar reclamation schemes are already operational and from which design data may be obtained.

In the case of the design of the Cape Flats water reclamation plant, the great wealth of information which had already been obtained from earlier projects, like those carried out in Windhoek, Pretoria and Athlone, virtually eliminated the need for laboratory or pilot plant experiments being carried out prior to the design and the construction of the 1,6 x 10^6 m^3/a demonstration plant.

4.2 Phase I

Discussions held between the CCC and the WRC during 1976 led to an agreement for commencement of phase I of the project. This took place during 1977 and included high calcium hydroxide dosing as well as flocculation, sedimentation, recarbonation and chlorination units. The plant was officially opened during March 1978 and remained in operation until the end of July 1978. Operation recommenced during January 1979 and continued up to May 1979. The objective of the interim plant was to provide water of good quality for the NIWR aquifer infiltration studies. During these periods oxidation pond effluent was used as feed water followed by flocculation and coagulation with ferric chloride and a polyelectrolyte. This was followed by clarification and chlorination after which the renovated water was pumped to the infiltration bed site. The plant configuration for phase I is shown in Fig 4.1.

4.3 Phase II

The wastewater to be treated was characterised with respect to its organic, inorganic and bacteriological constituents. A tentative combination of unit processes to achieve the required objectives as far as quality of the reclaimed water was concerned, was then drawn up.

The initial configuration consisted of the following unit processes: flocculation using calcium hydroxide, ferric chloride and a polyelectrolyte, primary sedimentation, breakpoint chlorination, secondary sedimentation, pressure sand filtration, activated carbon treatment and final chlorination. This plant configuration is shown diagramatically in Fig 4.2.

4.3.1 Operation

The Phase II configuration was commissioned during May 1982, and operated intermittently until August 1982 to eliminate any problems. During the first year or so of operation a number of design faults were isolated, investigated and subsequently rectified.

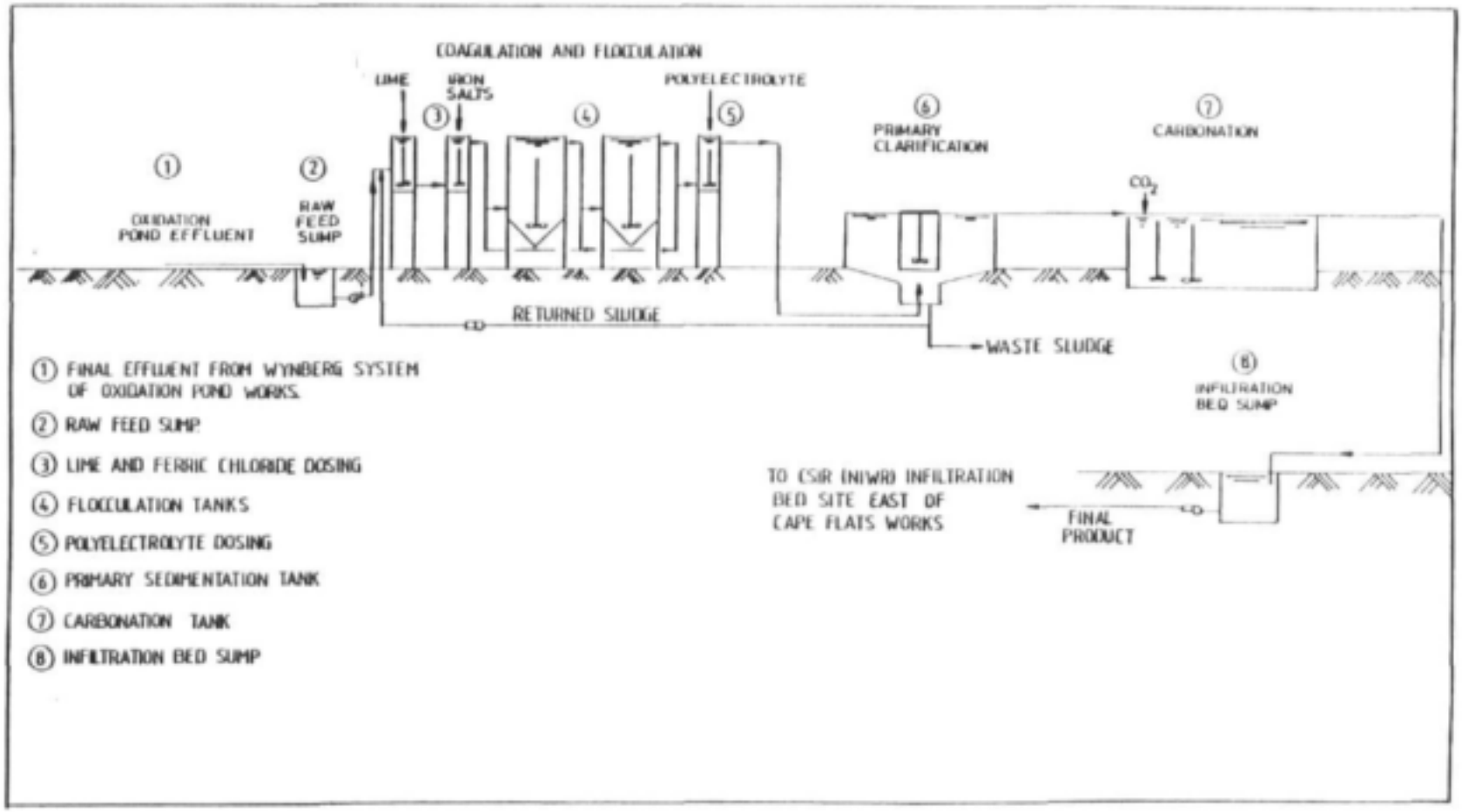


Fig 4.1 Configuration of the Cape Flats Reclamation Plant for phase I (not to scale)

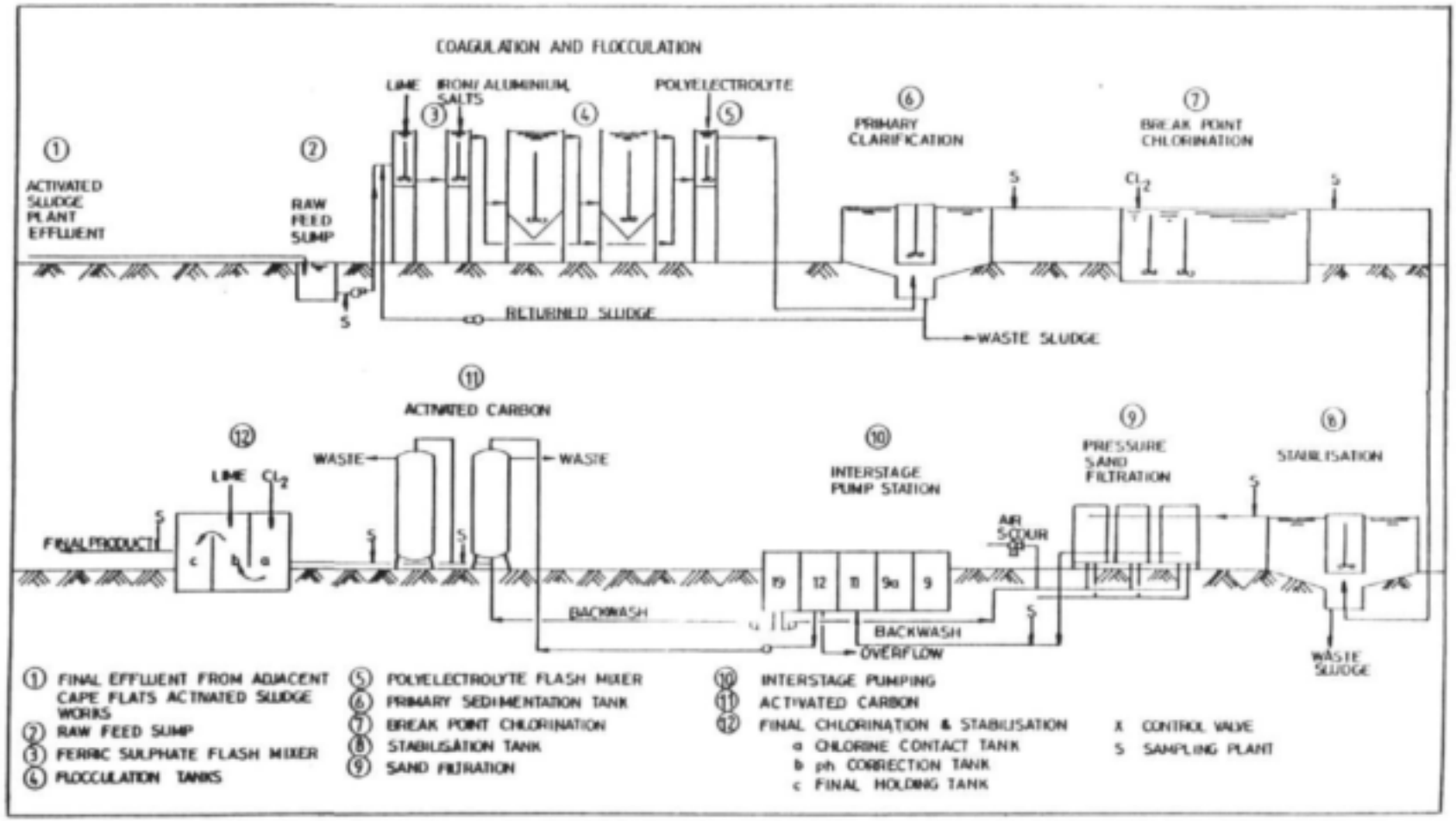


Fig 4.2 Configuration of the Cape Flats Reclamation Plant for phase II (not to scale)

4.3.2 Design problems

The major design problem encountered was the operation of the three pressure sand filters. The problems included improper design of the pipework, poor hydraulics, loss of sand from the filters through the poorly designed nozzles and uneven nozzle support plates and the operation of the pneumatic actuators and the butterfly valves.

Various improvements were tried which included changing the media, continuously servicing the pneumatic actuators and butterfly valves, modifying the nozzle seats by replacing the thin rubber seat with a thicker and larger version and finally replacing the nozzles with a more advanced type. Most of these remedies were unsuccessful and a decision was taken to replace the three pressure filters with two rapid gravity sand filters. These filters were constructed and commissioned during October 1984. Although these filters operated successfully from the start, a point of concern was that of relatively short filter runs. An intensive investigation indicated that by reducing the polyelectrolyte dose and installing a pipeline which increased the available head to the sand filters the filter runs could be lengthened from about 10 h to about 20 h.

Another problem area was the effect on the reclamation processes of the fluctuation in the feed water quality (the adjacent activated sludge works final effluent). It was frequently found that large diurnal variations in the ammonia, chemical oxygen demand, suspended solids and total phosphate concentrations created abnormal chemical dosing conditions on the reclamation plant. The most serious of these was the effect of the frequently high ammonia concentration on the disinfection process and the resulting trihalomethane concentrations which resulted from the very high chlorine doses.

An adjacent oxidation pond was converted into a quality equalisation and buffer pond for the reclamation plant feed water. An earth berm was constructed within the pond to eliminate short circuiting thereby ensuring that the theoretical retention time of about 16 days would be maintained. Furthermore this pond would permit the reclamation plant to continue operating for a limited period if the wastewater treatment works was shut down due to mechanical or operational failure. Fig 4.3 shows the flow pattern through the reclamation plant via the quality equalisation pond.

The disinfection process assumes a very important role when one is reclaiming a secondary treated sewage for potable reuse. It was felt that three stages would be more effective in placing an impenetrable barrier between the end user and any waterborne bacteriological or pathogenic contaminants than the two chlorine stages which were already provided. A decision was taken to incorporate ozonation between the sand filtration and activated carbon adsorption stages. An ozone generator was thus obtained from the WRC and after a lengthy period of restoration and installation was commissioned during July 1986.

Throughout the early years of operation of the plant problems were experienced with most of the control and measuring instruments, as they were unable to withstand the extreme climatic and corrosive conditions experienced at the plant. Certain instruments were replaced with a more suitable type whilst others were modified. Instrumentation modification, repairs and maintenance were an ongoing process.

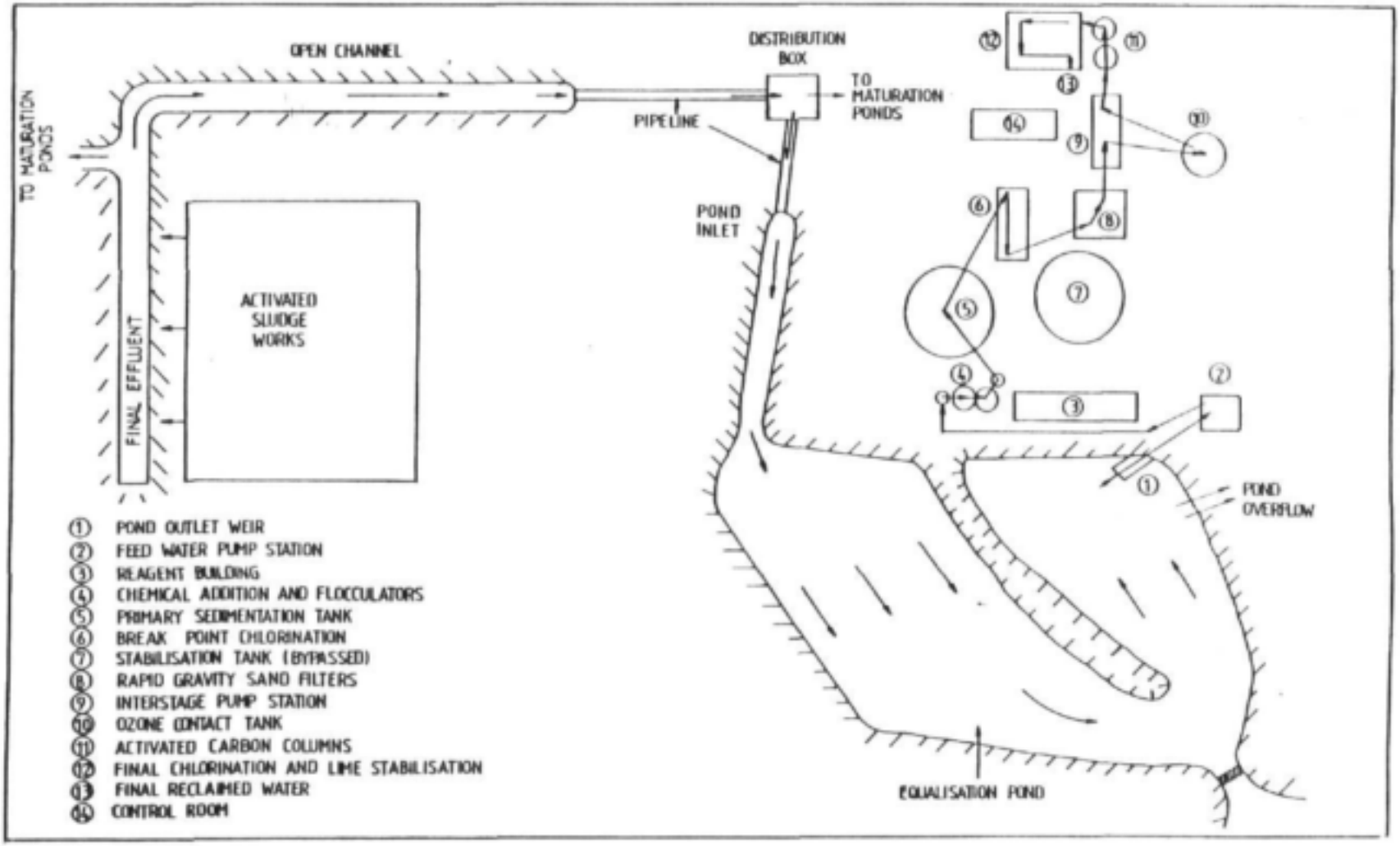


Fig 4.3 **Flow pattern through the Cape Flats Reclamation Plant via the quality equalisation pond** (not to scale)

Pumping of a calcium hydroxide slurry proved unsuitable. This facility was substituted by a manual dry feed system.

After implementation of these design modifications the process configuration was as follows: chemical flocculation, primary sedimentation, primary chlorination (primary disinfection), sand filtration, ozonation (secondary disinfection), activated carbon adsorption, final chlorination (tertiary disinfection) and final calcium hydroxide stabilisation. The final process flow sheet is given in Fig 4.4.

4.4 Process description

The choice of the unit process sequence was aimed at ensuring effective removal of all undesirable contaminants in order to produce a potable water. The overall control strategy therefore included the most effective and fail-safe procedures guaranteeing the attainment of the operating objectives set out for each unit process. A brief description of each stage is given below:

Feed water

The feed water used is a secondary effluent obtained from the adjacent five stage Bardenpho activated sludge wastewater treatment works. Before entering the reclamation plant the water passes through a quality equalisation and buffer pond which has a retention time of about two weeks. This pond evens out any fluctuations in the secondary effluent quality and provides additional but limited storage capacity in the event of the activated sludge plant being either shut down or being unable to provide an effluent of acceptable quality.

Chemical flocculation

The reclamation of water is possible using calcium hydroxide, Fe^{3+} solutions or Al^{3+} solutions as coagulants. In the reclamation of a secondary effluent containing high ammonia concentrations calcium hydroxide is usually considered the most suitable. At the Cape Flats plant where the ammonia values are generally low, ferric sulphate, ferric chloride or aluminium sulphate solutions can be used. However, for various reasons ferric sulphate was found to be most suitable and was thus used for most of the project. Jar tests are used to determine optimum chemical doses. After the coagulant addition the mixture passes through the flocculators where through a process of slow stirring, the sludge is formed into larger *floc* particles. A polyelectrolyte is generally added as a flocculation aid. Optimisation of the polyelectrolyte dose is critical as it was found that slightly high doses tend to shorten sand filter runs considerably.

Primary sedimentation

Sedimentation was effected in a circular clarifier with an inner four minute retention flocculation zone. The total retention time is approximately two and a half hours. Separation due to gravitational forces occurs in this unit between the liquid and the sludge. The clarified water is drawn off from the surface of the tank whilst the settled chemical sludge is withdrawn from the bottom. The thickened sludge is wasted and recirculated. Sludge is recycled to the feedwater in order to control the sludge density in the clarifier and to assist in the formation of a denser sludge blanket and to reduce flocculant requirements.

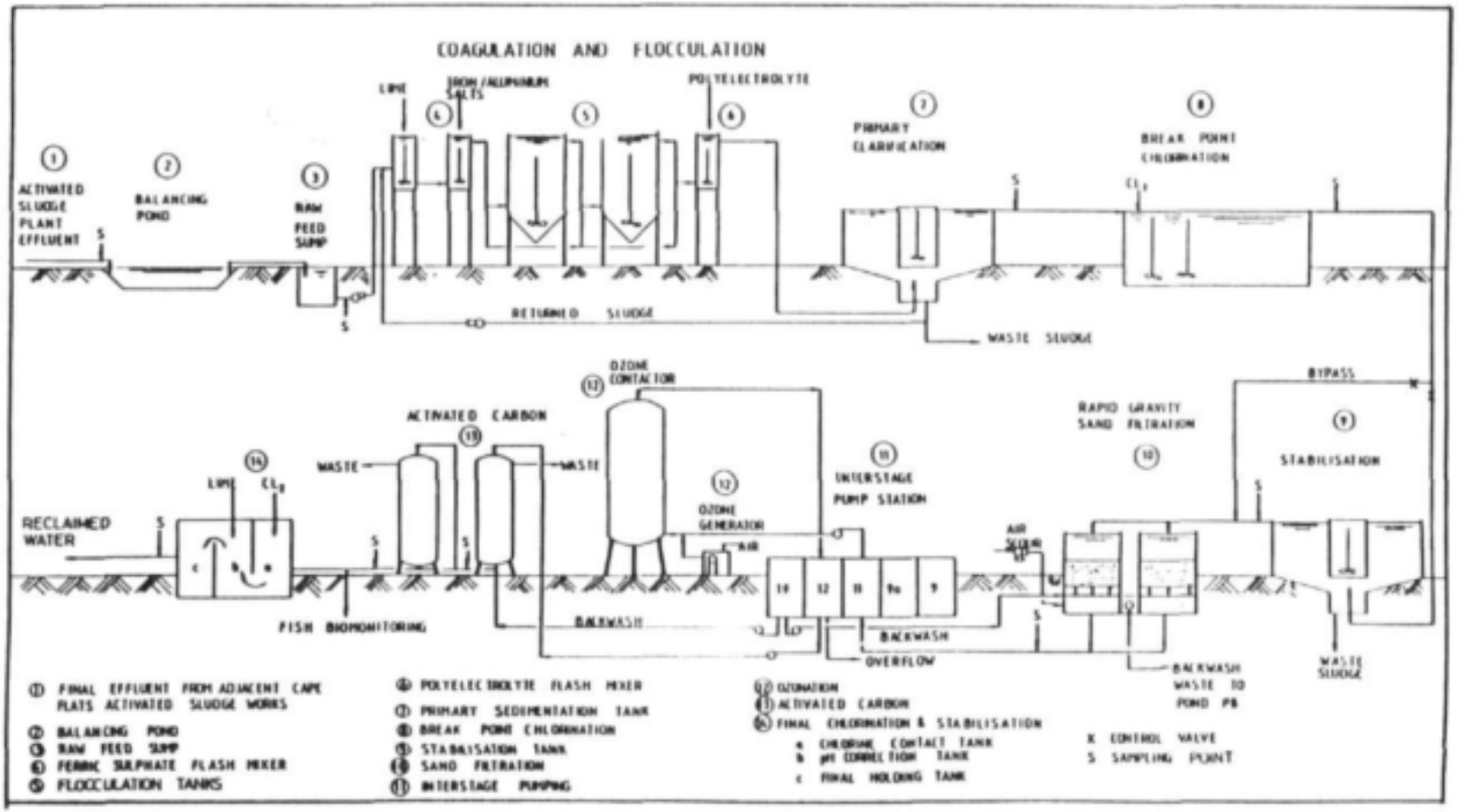


Fig 4.4 Final configuration of the Cape Flats Reclamation Plant (not to scale)

Chlorination

Chlorine is the disinfectant most commonly used in water treatment. In water reclamation the chlorine dose required is only to a minor extent determined by the type and quantity of microbes to be inactivated and depends primarily on the concentration of substances such as nitrogen compounds which are chiefly in the form of ammonia. Sufficient chlorine was added in order to maintain a low residual to prevent biological growth on the sand filters.

Sand filtration

Sand filtration is probably the most commonly applied unit process in water treatment practice. While filtration alone will not remove viruses, research has shown that in waters with turbidity of < 1 NTU, free chlorine residuals and acceptable contact times, viruses can be effectively inactivated. In water reclamation complete disinfection is secured through turbidity removal by filtration followed by disinfection. The mechanism of filtration is complex and is believed to consist of a number of different processes which effect the removal of suspended impurities in combination with one another. These processes varying in predominance are straining, sedimentation, flocculation, adsorption and biological activity. The Cape Flats plant has two rapid gravity sand filters which required backwashing approximately once a day. These filters replaced the pressure filters which proved unreliable.

Ozonation

In advanced water treatment ozonation is one of the most popular methods of disinfection. At the Cape Flats plant ozone was produced from air by electrical discharge using a Degremont type MB110 ozone generator and was injected into the filtered water before entering a contact tank with a 17 min retention time. Ozonation does not replace chlorination but is used in conjunction with it. Ozone was injected between the sand filtration and the activated carbon treatment stages and because of its powerful oxidation properties was able to lengthen the life of the activated carbon.

Activated carbon treatment

The primary function of the activated carbon columns is adsorption of both toxic and non-toxic dissolved organic compounds. Colour, taste, odour and a number of heavy metals such as mercury and cadmium are usually removed at the same time. The plant at Cape Flats has the option of using two sets of carbon columns. One set of three columns was capable of treating the full $1{,}6 \times 10^6$ m^3/a flow whilst the smaller set of two columns treats a maximum of $1{,}1 \times 10^5$ m^3/a. Due to the excessive cost of activated carbon the smaller columns were used. The smaller columns are of the fixed bed, downflow type and during operation each bed was backwashed regularly to prevent an excessive build up of pressure. These two columns were operated in series with the first being a roughing and the second a polishing column.

Final chlorination and calcium hydroxide stabilisation

All the free chlorine and free ozone in the water is removed during activated carbon treatment. This then permits bacteria to build up in the columns and can result in fairly high

bacterial counts in the effluent. Chlorine was added after the carbon columns to counteract this and to ensure a disinfected reclaimed water with sufficient residual to protect against contamination in the water distribution system. Chlorination results in a corrosive water and this is rectified by stabilisation with calcium hydroxide. The pH is set at a predetermined value which prevents corrosion as well as precipitation in the water distribution system.

CHAPTER 5

PLANT CONSTRUCTION

After the initial process configuration had been established it was agreed at an early technical sub-committee meeting that the CCC would be responsible for the necessary design and construction of the required additional units.

Certain units which were to be added to the process configuration had been supplied under the original contract but due to various circumstances had never been installed. As the original supplier was not prepared to install this equipment so long after delivery, it was proposed and agreed upon that the CCC would install this equipment.

The original design of Phase I of the project was carried out by the consultants, P G J Meiring and Partners, for the NIWR and the structural and hydraulic design of the additional units for phase II was carried out by consultants, A M Mendonca Inc for the CCC.

All the additional civil construction work comprising of the concrete settling tank, interstage pump station and the final water holding tank was carried out by the CCC. The installation of all the mechanical equipment as well as the construction and installation of all the interconnecting pipework was also carried out by the CCC. The supply and installation of all the mechanical work associated with the concrete settling tank was, however, carried out by Messrs R J Consani on contract to the CCC.

The electrical work which was carried out by Messrs Electron (Pty) Ltd comprised the supply and installation of all cabling, instrumentation panels, switchgear and the wiring of the mechanical equipment installed by the CCC.

The CCC installed all the instrumentation required to operate the plant.

The design, manufacture and commissioning of the microprocessing system was carried out by the Department of Chemical Engineering at UCT. This system received inputs from the instrumentation, updated the displayed information every 12 s and calculated an hourly average which was stored and printed out every 24 h.

The design and construction of the following was undertaken by the CCC:

- replacement rapid gravity sand filters
- interlinking walkways
- inlet screenings structure for feed water
- the building to house the ozone generator.

The refurbishing and installation of the ozone generator, which was obtained from the WRC, was carried out by the CCC.

The costs involved in the design and construction of all the additional process units and related equipment which included the new rapid gravity sand filters, walkways, inlet screenings structure and the ozone facility amounted to about R900 000. These costs were borne by the WRC.

CHAPTER 6

PLANT REQUIREMENTS

6.1 Staff requirements

Operation of the Cape Flats water reclamation plant requires that it be classified as per Schedule 1 of Section 26 (1985) of the Water Act (Act 54 of 1956) (Govt Printer, 1984a). The minimum number of suitably qualified persons required to be employed at this A-grade works as per schedule III (Govt Printer, 1984b) of the abovementioned act is:

1 x	Class	V	operator - Supervisor
1 x	Class	IV	operator
1 x	Class	III	operator
1 x	Class	II	operator
1 x	Class	I	operator
1 x	Trainee operator.		

Although the reclamation plant was not subject to this grading the minimum staff requirements were actually exceeded. The following lists the actual gradings of the operating personnel who were employed at the reclamation plant.

1 x	Class	V	operator - (Supervisor)
1 x	Class	IV	operator
3 x	Class	III	operator
1 x	Class	II	operator

The operating staff complement in conjunction with the total personnel input is given in Fig 6.1.

6.2 Maintenance requirements

The reclamation plant had its own mechanical maintenance team, which consisted of a mechanical fitter, a handyman and a workshop assistant. This small but efficient team operated out of an on site workshop and handled preventative maintenance as well unexpected mechanical failures. The maintenance fitter was also responsible for the running of the workshop, keeping a small store in which certain spare parts for all the mechanical equipment was kept as well as ensuring that accurate maintenance and history records were kept of the equipment and the maintenance or repairs that were carried out on them.

Electrical and instrumentational maintenance and repairs were carried out by staff who were available from the adjacent wastewater treatment facility.

All other routine maintenance with regard to the buildings, structures and grounds was also carried out by staff from the adjacent treatment works.

The maintenance personnel involved in the Cape Flats project is given in Fig 6.1 along with the total personnel input.

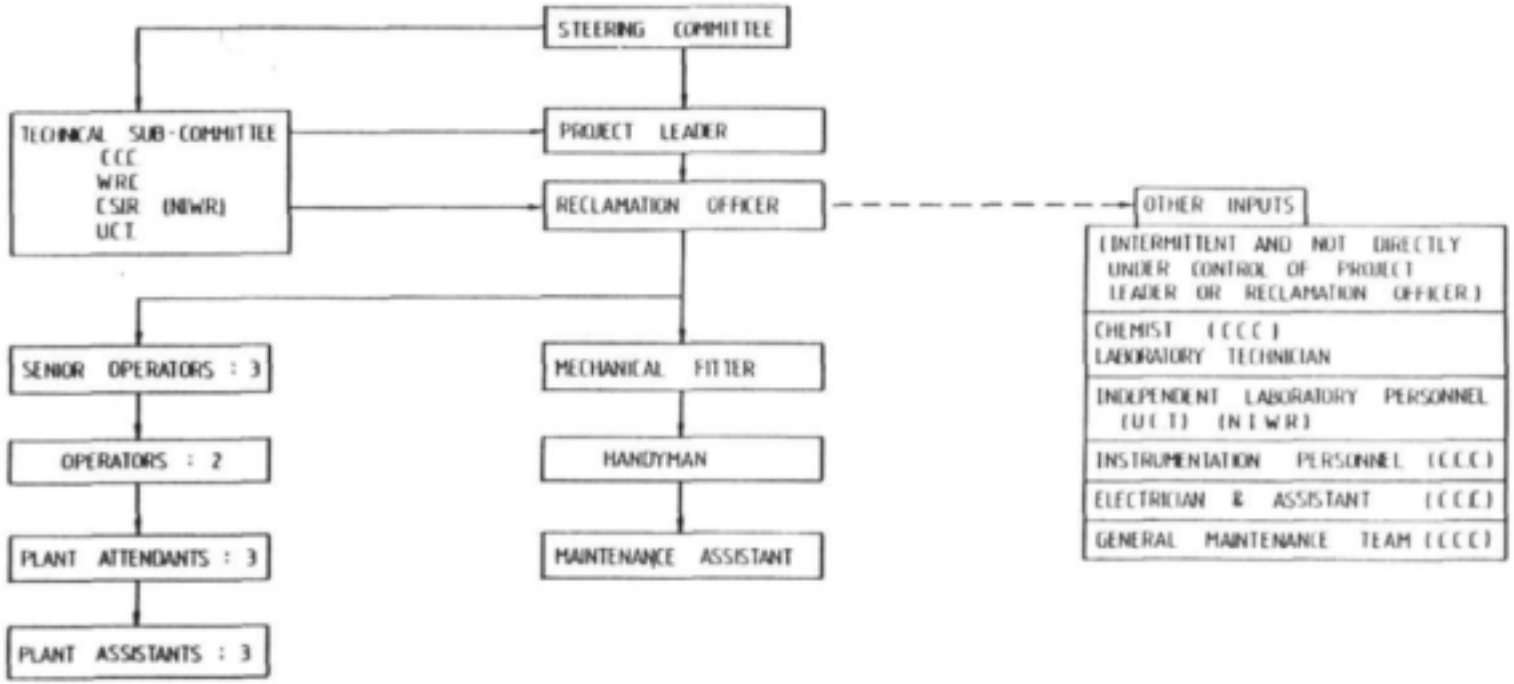


Fig 6.1 Personnel involved in the Cape Flats Water Reclamation Project

6.3 Surveillance requirements

The surveillance requirements of the process can be subdivided into three distinct groups: on site control analyses carried out by the operating staff, in depth control analyses carried out by a recognised laboratory and intermittent independent surveillance.

6.3.1 On site control analyses

The duty operator carried out a number of routine as well as intermittent laboratory analyses in order to control the operation of the various unit processes and to indicate whether previously determined process objectives were being achieved. This work was carried out on a 24 h basis in the on site control laboratory.

The operator was required to intermittently carry out jar tests to control the chemical addition and flocculation stages, i.e. to ensure that optimum doses of chemicals were used. These tests were carried out on the feed water to the reclamation plant and indicated whether the correct coagulant or polyelectrolyte was being used. In addition optimisation of the chemical doses, coagulation pH value, sludge recycle rates and other variables were determined.

The requirements for proper control of the disinfection process are that the concentrations of residual chlorine and chlorine derivatives are regularly measured. The residual chlorine content of the reclaimed water was measured automatically on a continuous basis. In addition to this the duty operator manually carried out various chlorine determinations every four hours. These tests comprised: residual chlorine (or free available residual), monochloramines, dichloramines, nitrogen trichloride and the total free chlorine determinations. These tests were carried out on the primary chlorination tank effluent and the reclaimed water.

Research has shown that viruses can effectively be inactivated in waters with a turbidity of <1 NTU, reasonable free chlorine residuals and adequate contact times (Van Vuuren, 1981). Turbidity measurements were carried out on the following samples : feed water, primary sedimentation tank effluent, breakpoint chlorination effluent, sand filtration effluent, activated carbon column effluent and the reclaimed water; in order to measure the efficacy of the unit processes.

Other important determinands which were carried out by the operating staff included pH, alkalinity, colour of water and sludge settlement tests.

Although these determinands do provide sufficient information for the satisfactory operation of the water reclamation plant, visual observation of each unit process, as well as general plant appearance, are equally important. The operator must be alert for changes in the physical appearance of a process and be able to relate these changes to its performance. Much can be learned from simple, but perceptive sensory observation of process features. By combining careful observation with experience, the operator can determine what is happening on the plant and make any adjustments that may be necessary. Observation can also direct him towards making more specific control tests that will indicate process demands and determine the type and extent of the control adjustments needed (Hart, 1981).

The plant should be equipped with various measuring devices to supplement these control procedures. These should include the on-line measurement of certain quality parameters as well as the measuring and recording of flows to the various unit processes. Table 6.1 lists all the on-line measurement equipment which was used on the plant

6.3.2 Control analyses by a recognised laboratory

An in depth quality surveillance programme, as carried out on any production line, is required on a water reclamation plant. In addition to the analyses carried out by the operating staff, a recognised laboratory should be available to measure the more complicated determinands or those where sophisticated and expensive equipment is necessary. The Scientific Services Branch of the CCC provided the staff and laboratory facilities to undertake these analyses.

At the Cape Flats plant the operating staff were responsible for all the sampling of the various unit processes, and these samples were then submitted to the Scientific Services Laboratory, for analysis. Most samples submitted for chemical analyses were 24 h composite samples and those submitted for bacteriological analyses were grab samples.

The following list of determinands should be undertaken by a laboratory for the proper control of a water reclamation plant. A description of the methods for these parameters, as well as the frequency of analyses, can be found in Appendix 6.

Sanitary analysis

Conductivity
pH
Alkalinity as ($CaCO_3$
Turbidity
Colour
COD-O
Na
K
Mg
Cl
SO_4
NO_3-N
NH_3-N
PO_4-P
Organic-N
Organic-P

Trace metals

Al
B
Cd
Co
Cr
Cu
Fe
Mn
Ni
Pb
Zn

Organic chemicals

Total halogens (THM)

Table 6.1

On-line surveillance and control equipment

Unit process	On-line equipment
Feed water	Flow meter and integrator Flow meter
Chemical addition and flocculators	pH-meter and recorder pH-control
Primary sedimentation	Waste sludge flow meter and integrator Waste sludge flow recorder Recycled sludge flow meter and integrator Recycled sludge flow recorder
Primary chlorination	pH-meter and recorder pH-control
Sand filtration	Flow meter and integrator Flow recorder Backwash flow meter and integrator Air scour flow meter Turbidimeter and recorder
Ozonation	Residual ozone analyzer
Activated carbon treatment	Inlet flow meter and integrator Inlet flow recorder Backwash flow meter and integrator Ultrasonic fish bio-surveillance system Dissolved organic carbon analyser
Reclaimed water	pH-meter and recorder pH-control Residual chlorine analyser
All units	Central microprocessor display and daily printout of selected parameters

Bacteriological analysis

Faecal coliforms

6.3.3 Intermittent independent surveillance

In the reclamation of a secondary effluent for potable reuse, a comprehensive independent surveillance programme is essential. This surveillance programme carried out by an unbiased third party will give the necessary assurance that the augmentation of the natural water supply with reclaimed water is in no way harmful to human health.

The independent surveillance programme for the Cape Flats project took the form of intermittent virological examination by UCT throughout the duration of the project and an intensive eleven week surveillance programme during the final months of the project by the following participating laboratories:

Cape Town City Council	-	Scientific Services Branch
UCT	-	Medical School Virological laboratories
CSIR	-	Watertek - Pretoria laboratories
CSIR	-	Watertek - Bellville laboratories

CHAPTER 7

PLANT OPERATION

7.1 Introduction

During the duration of the project many changes were introduced, both in the process configuration as well as in the types and doses of chemicals which were applied to the plant. A record was kept of all these changes and these are reflected in this chapter and appendix 7. The optimisation of all the chemicals used and certain unit processes is discussed in Chapter 8.

7.2 Summary of operational periods

All ferric sulphate and ferric chloride doses are in mg/l Fe^{3+} and chlorine in mg/l Cl_2.

7.2.1 May 1982 to July 1982

The plant was operated on an intermittent basis to locate and solve teething problems. Ferric chloride was used as coagulant and the following equipment and units were operated: feed water pump, ferric chloride dosing equipment, flocculators one and two, primary sedimentation tank (PST), waste sludge facility, and the stabilisation tank.

7.2.2 August 1982 to November 1982

The plant was operated as in the previous period but on a continuous basis. The optimisation of the flocculators took place between September and November resulting in the decision to use two flocculators (16 min retention) instead of one (eight min retention). The chemical surveillance programme started in earnest during September with the regular submission of samples to the CCC laboratory. The pilot carbon columns were operated intermittently during October and November facilitating the sampling of the effluent for virological examination by UCT.

7.2.3 December 1982 to January 1983

Jar flocculation tests indicated the optimum ferric chloride dose to be approximately 43 mg/l in the range of pH values from 5,0 to 5,5. As the calcium hydroxide equipment was undergoing maintenance very low pH values of about 2 were obtained and the ferric chloride dose was subsequently reduced to 19 mg/l. During December a sludge recycle of four per cent (v/v) was brought into operation as well as breakpoint chlorination at a dose of 8,0 mg/l. Two of the three pressure sand filters were in continuous operation during this period.

7.2.4 February 1983 to March 1983

Operation was as in the previous months with the exception that the sludge recycle was increased to eight per cent (v/v). Problems were experienced with the PST sludge withdrawal system. The pressure sand filters were taken out of operation on 1983-03-06.

The whole plant was shut down from 1983-03-15 to 1983-04-28 due to the depletion of ferric chloride supplies resulting from delays in delivering consignments.

7.2.5 April 1983 to June 1983

Operation using ferric chloride continued from 1983-04-28 and units in operation excluded the sand filtration and activated carbon treatment stages. A polyelectrolyte was introduced as a flocculant aid from 1983-05-23 and *Magnafloc 156* was dosed at a rate of 0,5 mg/*l*. Ferric chloride doses ranged from 17 to 29 mg/*l*. The whole plant was shut down on 1983-06-17 to effect repairs to the sludge withdrawal system, compressed air lines and the calcium hydroxide equipment.

7.2.6 July 1983 to September 1983

Ferric sulphate replaced ferric chloride as coagulant as from 1983-07-18. Initially a 14 day trial run was planned but due to encouraging results this was extended to a month and later indefinitely. Jar tests indicated the optimum dose to be between 53 and 64 mg/*l* within the range of pH values 5,0 to 6,0. Sand filtration was implemented from 1983-08-03 by making use of one recently refurbished pressure filter. The calcium hydroxide dosing equipment was used intermittently during this period and doses in the range of 90 mg/*l* were required. Breakpoint chlorination was implemented from the end of July.

7.2.7 October 1983 to June 1984

Ferric sulphate was used as coagulant and doses ranged from 17 to 47 mg/*l*. Polyelectrolytes were used to aid the flocculation process. *Magnafloc 156* was used up to 1984-03-06 with doses varying from 0,3 to 1,8 mg/*l* and *Magnafloc LT27* was introduced from 1984-03-07 with a constant dose of 0,5 mg/*l*. Between 5% and 10% (^{v}/v) of the sludge flow was recycled and 11% (^{v}/v) was wasted. Breakpoint chlorination was terminated during May due to unusually high ammonia values in the feed water. Calcium hydroxide was dosed from 1983-11-25 to facilitate pH correction prior to breakpoint chlorination. Sand filtration was still limited to one pressure filter.

7.2.8 July 1984 to October 1984

During this period aluminium sulphate was used as coagulant. The dose varied from 6 to 19 mg/*l* Al^{3+}. Results from jar tests indicated an optimum aluminium sulphate dose of about 16 mg/*l* and favourable plant results were obtained at doses higher than 13 mg/*l*. However, problems were encountered with the dosing equipment which was specifically designed to dose liquid ferric solutions. *Magnafloc LT27* was used at doses of 0,5 to 1,0 mg/*l*. Waste and recycled sludge volumes remained constant with flows of 11% and 5% (^{v}/v) respectively. There was no sand filtration during this period.

7.2.9 November 1984 to February 1985

Ferric sulphate was dosed at between 33 and 42 mg/*l*. Sand filtration was implemented from 1984-10-30 making use of the recently completed rapid gravity sand filters. The use of these filters resulted in favourable effluent turbidities being obtained almost immediately. Activated carbon treatment using the 1,1 x 10^5 m^3/a pilot columns was implemented on

1985-02-14 and produced favourable results.

7.2.10 March 1985 to June 1985

The plant was operated up to and including activated carbon treatment. The buffer or quality equalisation pond came into operation during April. Ferric sulphate was dosed at 42 mg/*l* and *Magnafloc LT27* was dosed at between 0,12 and 0,5 mg/*l*. Sludge was wasted and recycled at 10% and 5% (v/v) respectively. Chlorine was dosed to breakpoint with doses ranging from 5 to 18 mg/*l*. Calcium hydroxide was dosed to obtain a pH value of 7,0 for breakpoint chlorination. Rapid gravity sand filtration and activated carbon treatment were used throughout this period. Final calcium hydroxide dosing in order to stabilise the reclaimed water commenced during June 1985.

7.2.11 July 1985 to December 1985

The ferric sulphate dose was maintained at 42 mg/*l* and reduced to 38 mg/*l* on 1985-09-05. The *Magnafloc LT27* dose was maintained at 0,12 mg/*l*. Waste and recycled sludge rates were maintained as in the previous period and breakpoint chlorination required doses of 4 to 22 mg/*l*. Final chlorination commenced on 1985-07-01 and doses of 1,4 to 22 mg/*l* were recorded. The calcium hydroxide dose required for pH correction at the breakpoint chlorination stage as well as the reclaimed water stabilisation stage continued as in the previous period. During August 1985 the pilot activated carbon columns were refilled with *Norit Supra 0,8 ROW* activated carbon. The fish bio-surveillance system was operated from September to early December 1985 when, due to an electronic fault, the system was shut down. Activity counts of 1 000 to 1 500 /h were obtained during this period.

7.2.12 January 1986 to April 1986

Ferric sulphate and *Magnafloc LT27* were dosed at 38 mg/*l* and 0,12 mg/*l* respectively. Chlorine was dosed to breakpoint at doses of 4,2 to 25,4 mg/*l* and for reclaimed water disinfection at doses of 1,5 to 13,3 mg/*l*. Calcium hydroxide dosing prior to breakpoint was not required but doses giving a reclaimed water pH value of 8,5 to 9,5 were required. Sludge was wasted and recycled as before.

7.2.13 May 1986 to January 1987

The plant was run for the first time incorporating the full process configuration viz: activated sludge process, equalisation pond, coagulant addition, flocculation, polyelectrolyte addition, primary sedimentation, intermediate chlorination, sand filtration, ozonation, activated carbon treatment, final chlorination and final calcium hydroxide stabilisation. The ozonation stage was added to the process configuration during July. The 11 week intensive surveillance programme was carried out during this period.

These operational periods are described in full detail in Appendix 7.

CHAPTER 8

OPTIMISATION AND OPERATION OF THE INDIVIDUAL UNIT PROCESSES

8.1 Introduction

All the unit processes which were used at the Cape Flats plant were identical to or derivatives of previously tried and tested processes. Optimisation of these individual processes was a lengthy procedure and this chapter gives a description of these procedures as well as a brief outline of the mode of operation of each unit process.

8.2 Feed water

The quality of the feed water to the reclamation plant was generally good except for variable ammonia and nitrate concentrations on occasion. In an attempt to reduce these concentrations optimisation of the operation of the activated sludge process was carried out by the Civil Engineering Department of UCT between September 1983 and March 1984 (Ekama and Marais, 1984). Although the implementation of the findings of their report had a positive effect on the nitrification and denitrification processes, ammonia values, especially during the colder months remained high intermittently. Therefore an existing maturation pond adjacent to the reclamation plant was modified into a quality equalisation and buffer pond for the reclamation plant feed water. This pond was commissioned during April 1985 and remained in operation for the remainder of the project. The plant configuration is given in Fig 4.4. The influent to and effluent from the equalisation pond were chemically analysed to determine the pond's efficacy. These results and findings are presented in Chapter 10.

8.3 Chemical addition and primary coagulation stages

During the course of the project ferric chloride, ferric sulphate as well as aluminium sulphate were optimised as coagulants. The iron salts were cheaper than aluminium sulphate but had the disadvantage of their solutions being highly corrosive. Ferric sulphate, although similarly priced to ferric chloride, had the advantage of being available locally.

8.3.1 Ferric chloride

Ferric chloride was available in both the powdered and liquid form with the latter being used at Cape Flats. Ferric chloride solution is a dark brown, acidic aqueous liquid containing 15% Fe^{3+} ($^{m}/v$). Ferric chloride is not manufactured in the Western Cape area and thus had to be railed from the Transvaal. During the period that ferric chloride was used delays were experienced with deliveries which resulted in large quantities having to be stored on site to prevent plant shut downs.

Jar tests indicated the following average results (Fig 8.1):

Optimum dose:	about 43 mg/*l* Fe^{3+}
Optimum pH:	5,0 to 5,5
Polyelectrolyte:	0,3 to 0,5 mg/*l* (*Magnafloc 156*)

Generally, no significant turbidity reduction was obtained with increased ferric chloride doses, in fact, the turbidity values increased with increasing coagulant dose after the optimum concentration had been surpassed. The optimum pH value was found to be between 5,0 and 5,5, thus requiring an appropriate calcium hydroxide dose to counteract the depressed pH value. The low pH values resulted from the strong acidic nature of the ferric chloride.

Implementation of the optimum ferric chloride dose was not possible as it depressed the pH value to unacceptable levels of approximately 2,0. As the calcium hydroxide equipment was not in operation at this stage the plant was operated at a dose of 19 mg/*l* Fe^{3+}. This dose was later increased to 26 mg/*l* Fe^{3+} to counteract increased turbidities.

Although suitable clarification was obtained without the use of polyelectrolytes, a well formed floc with rapid settling characteristics was obtained with the introduction of *Magnafloc 156* at doses of between 0,3 and 0,5 mg/*l*. Even though the plant was operated well below the optimum dose, reductions in COD, turbidity and phosphate were obtained. To optimise the ferric chloride dose lower dosing rates of 17, 21, 26 and 29 mg/*l* were used. The average results are reflected in Table 8.1. A significant improvement with an increase in dose from 21 to 26 mg/*l* was obtained (Table 8.1). Therefore a dose of 26 mg/*l* was used since additional doses were not warranted.

8.3.2 Ferric sulphate

Ferric sulphate solution was used as coagulant after July 1983 and is a brown acidic solution containing between 10 and 12% Fe^{3+}.

A two week trial run, during which time AECI undertook to supply ferric sulphate free of charge, was initially planned. This period was not long enough to make a final decision even though favourable results were being obtained. The trial was then extended by another month, during which time the supplier undertook to supply the chemical at cost. After this six week period and taking into account the satisfactory results being obtained and the envisaged financial saving due to reduced transport costs it was decided to use ferric sulphate for an indefinite period. Numerous jar tests were carried out throughout this period and the following average results were obtained (Fig 8.1):

Optimum dose:	53 to 64 mg/*l* Fe^{3+}
Optimum pH:	5,0 to 6,0
Polyelectrolyte:	0,5 mg/*l* (*Magnafloc 156*)
	0,5 mg/*l* (*Magnafloc LT27*)

During the full scale operation ferric sulphate was optimised by applying the following doses 28, 31, 42, 48 and 56 mg/*l* Fe^{3+}. The average results of the feed water and the PST overflow quality at these doses are reflected in Table 8.2.

Optimum clarification of the water was obtained with a dose of ferric sulphate in the range of 42 to 48 mg/*l* (Table 8.2.). The plant was initially operated at a dose of approximately 42 mg/*l* but this was successfully reduced to and set at 38 mg/*l* from September 1985 until the end of December 1986.

Table 8.1

Optimisation of ferric chloride dose and its effects on the chemical quality of the overflow of the primary sedimentation tank (PST)

Determinand	Fe^{3+} dose	Feed water			PST overflow		
	mg//	number of analyses	mean	standard deviation	number of analyses	mean	standard deviation
COD	17	9	51	8.5	3	38	4
	21	5	69	19	2	45	6
	26	11	55	9	5	33	8
	29	11	44	6.5	4	35	4.7
Suspended solids	17	9	9	6.3	3	10	9
	21	4	10	3.6	2	14	0
	26	11	11	6	5	7	5
	29	11	13	7.9	4	9.5	5.4

Table 8.1 (continued)

Optimisation of ferric chloride dose and its effects on the chemical quality of the overflow of the primary sedimentation tank (PST)

Determinand	Fe^{3+} dose	Feed water			PST overflow		
	mg/l	number of analyses	mean	standard deviation	number of analyses	mean	standard deviation
Total P	17	3	6	0.9	3	1.7	2
	21	1	7	-	2	1.4	0.2
	26	3	6.3	1	3	0.7	0.6
	29	4	6.3	1.8	4	0.8	0.7
Turbidity	17	10	2.7	0.3	10	1.7	0.4
	21	6	2.6	0.2	4	2.3	0.5
	26	16	2.6	0.9	15	2.0	0.9
	29	15	2.9	1.9	11	2.3	0.7

Table 8.2

Optimisation of ferric sulphate dose and its effects on the chemical quality of the overflow of the primary sedimentation tank (PST)

Determinand	Fe^{3+} dose	Feed water			PST overflow		
	mg/l	number of analyses	mean	standard deviation	number of analyses	mean	standard deviation
COD	28	7	69	18	3	34	7.9
	42	31	70	14	13	25	3
	48	6	58	18	3	21	2.1
	56	7	71	6.2	3	25	8.5
Suspended solids	28	7	32	16	3	44	25
	42	31	18	9.5	13	6	3.7
	48	6	9	3.7	3	2.8	2.8
	56	7	18	11	3	24	19

Table 8.2 (continued)

Optimisation of ferric sulphate and its effects on the chemical quality of the primary sedimentation tank (PST) overflow

Determinand	Fe^{3+} dose	Feed water			PST overflow		
	mg/l	number of analyses	mean	standard deviation	number of analyses	mean	standard deviation
Total P	28	3	4.7	0.1	3	1.2	0.2
	42	13	5.8	1.5	13	0.26	0.1
	48	2	6.5	0	2	0.15	0,1
	56	3	5.3	0.8	3	0.57	0.4
Turbidity	28	8	8.9	3.8	8	8.4	4.3
	42	31	4.3	1.7	31	1.7	0.4
	48	13	2.7	0.3	13	1.8	0.9
	56	7	6.1	2.0	7	6.6	3.7

8.3.3 Aluminium sulphate

Aluminium sulphate (alum) was used as coagulant during July and October 1984. The change from ferric sulphate to aluminium sulphate was only implemented for a short period as a trial run. Once the trial run was completed operation using ferric sulphate continued.

Aluminium sulpnate was available in the lumped (kibbled) or powdered form. As no suitable facilities for making up the solutions were available, AECI undertook to supply an aluminium sulphate solution which was made up at the Somerset West factory at no extra expense to the CCC.

Jar tests which were carried out throughout the aluminium sulphate trial run indicated the following (Fig 8.1):

Optimum dose:	11 to 16 mg/*l* Al^{3+}
Optimum pH value:	about 6,5

Table 8.3 gives the quality comparison between the feed water and the PST overflow with varying alum dosages. Favourable plant results were obtained at a dose of 13 mg/*l* and higher (Table 8.3.)

The aluminium sulphate solution contained approximately 5% Al^{3+}. At the beginning of the trial run undiluted aluminium sulphate solution was dosed, but sediment in this solution resulted in blockages occurring in the dosing equipment. The solution was therefore diluted to one which contained approximately 2,5% Al^{3+}.

Aluminium sulphate dosing by gravity was not possible, and it was not considered economically viable at that late stage to effect the necessary changes to the existing equipment for the relatively short aluminium sulphate trial run. An active ingredient comparison is given in Table 8.4 with respect to ferric chloride, ferric sulphate and aluminium sulphate.

Examples of the type of optimisation graphs as obtained from the jar tests are given in Fig 8.1.

8.3.4 Polyelectrolytes

Polyelectrolytes are used to supplement coagulants (e.g. ferric sulphate) thereby promoting a well formed *floc* particle which settles well. These polyelectrolytes are available in both the powdered and liquid forms, although only the powdered form was used at the Cape Flats reclamation plant.

Jar tests were undertaken to determine the best type of polyelectrolyte which could be used to supplement ferric chloride or ferric sulphate. A large number of different types of polyelectrolytes were used, namely: *Zetag 57; Magnafloc 155, 156, 292, 351, E10, E24, and LT27. Magnafloc 156 and LT27* were the most suitable and both were used during the project. Once the quality equalisation pond was commissioned and the feed water quality improved it was found that *Magnafloc LT27* was most suitable.

Table 8.3

Optimisation of alumimium sulphate dose and its effects on the chemical quality of the primary sedimentation tank (PST) overflow

Determinand	Al^{3+} dose	Feed water			PST overflow		
	mg//	number of analyses	mean	standard deviation	number of analyses	mean	standard deviation
COD	6	13	59	7.2	5	34	8.8
	10	11	64	10	5	31	3.2
	11	4	87	25	2	25	3.7
	13	5	56	35	2	24	4.9
	16	5	61	35	3	22	2.5
	19	7	50	12	3	24	8.9
Suspended solids	6	10	10	4.9	4	10	2.5
	10	11	10	3.4	5	3	1.8
	11	3	44	23	2	3.5	2.1
	13	6	47	22	3	2	1
	16	6	16	14	3	4.7	0.6
	19	5	8	1.9	3	3.7	1.5

Table 8.3 (continued)

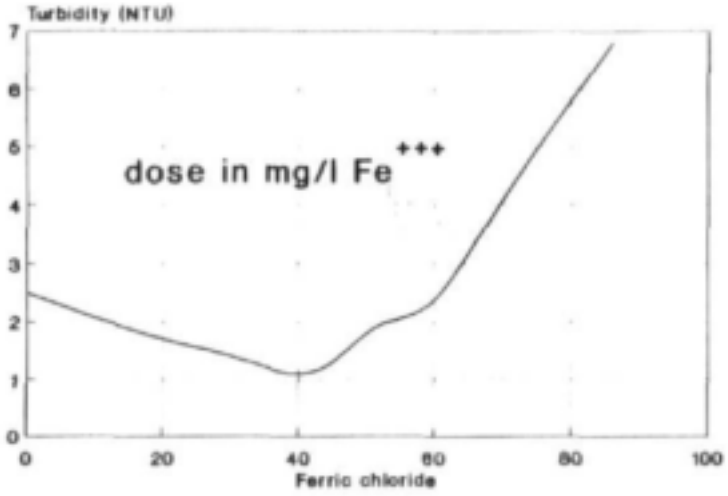
Optimisation of aluminium sulphate dose and its effects on the chemical quality of the primary sedimentation tank (PST) overflow

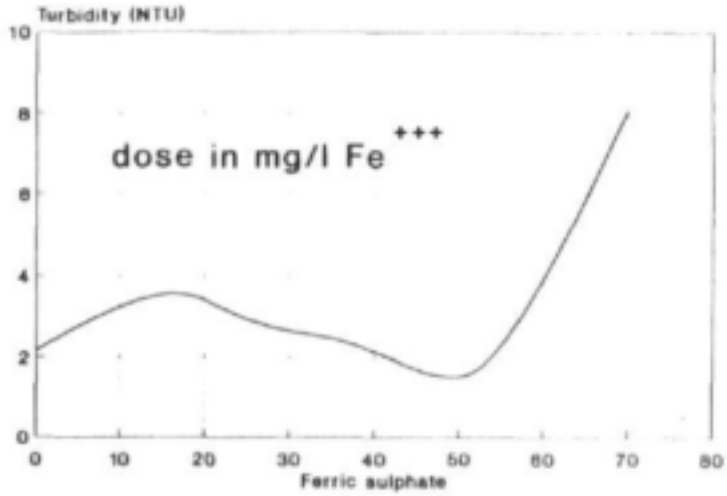
Determinand	Al^{3+} dose	Feed water			PST overflow		
	mg/l	number of analyses	mean	standard deviation	number of analyses	mean	standard deviation
Total P	6	5	5.8	1.0	5	1.3	0.6
	10	5	6.4	1.2	5	1.4	0.7
	11	2.1	-	-	2	0.4	0.3
	13	3	4.4	2.0	3	0.3	0.2
	16	3	2.1	1.7	3	0.07	0.06
	19	3	3.8	5.9	3	0.2	0.3
Turbidity	6	16	2.8	0.8	17	2.8	1.3
	10	14	3.2	0.7	14	1.3	0.3
	11	4	7.6	4.6	4	3.3	1.7
	13	8	9.2	4.4	7	1.5	0.4
	16	7	3.4	1.0	7	1.1	0.4
	19	6	2.8	0.5	6	1.8	0.3

Table 8.4

Active ingredient comparison

Flocculant	Units	Fe^{3+}	$Fe_2(SO)_4$	$FeCl_3$	Al^{3+}	Al_2O_3	Alum
Ferric sulphate	mg/l	49	175	-	-	-	-
Ferric chloride		43	-	125	-	-	-
Aluminium sulphate		-	-	-	16	30	190





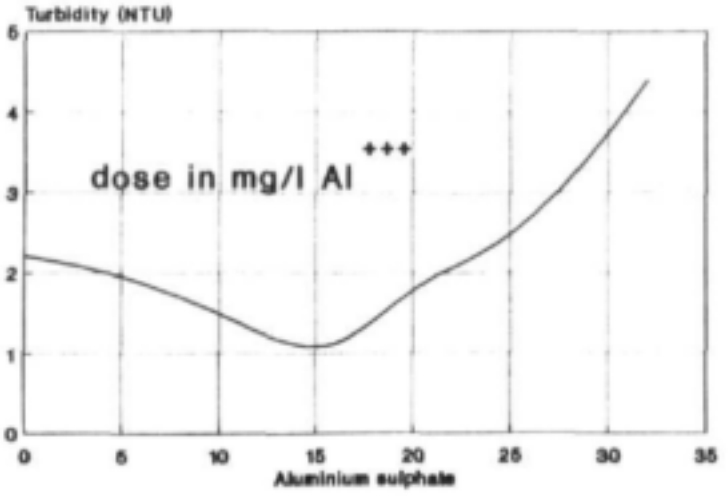


Fig 8.1 Optimisation of the flocculant (Fe and Al) dose

The LT27 grade of polyelectrolyte is of low toxicity and has been primarily developed for use in potable water treatment applications and as such is ideally suited to water reclamation.

The optimum dose of both the *Magnafloc 156 and LT27* was found to be about 0,3 to 1,0 mg/*l*. After commissioning the new rapid gravity sand filters problems were experienced with premature clogging of the filter beds which was attributed to the relatively high polyelectrolyte dose. This dose was subsequently reduced to 0,12 mg/*l* without any adverse affect on the PST overflow quality. However it was found on occasions that extremely high wind velocities stirred up the sludge blanket in the PST which resulted in high PST overflow turbidities.

8.3.5 Flocculators

The flocculators comprised of two eight minute retention cylindrical tanks each fitted with a slow stirrer. These units are situated between the coagulant and the polyelectrolyte dosing points.

The layout of these flocculator tanks provides for various process options. These options are:

- operation without the flocculator tanks - these tanks may be bypassed providing minimal retention time.

- operation using only one flocculator tank - (retention time of eight min).

- operation using two flocculator tanks in series - (retention time 16 min).

The optimisation of the use of these flocculators took place between September and November 1982. Use was made of visual observations and turbidity measurements of the PST overflow to determine flocculation efficiency. The results obtained from this optimisation exercise are presented in Table 8.5.

Operation using two tanks with a retention time of 16 min. was accepted as the optimum operating mode of the flocculators.

8.4 Primary sedimentation

Primary sedimentation was effected in a circular sedimentation tank which had an inner four min. retention flocculation zone with a stirrer and a total retention time of approximately 2,5 h. In this unit process, solid-liquid phase separation occurred. Sludge withdrawal was intermittent and could be either wasted, recirculated to the head of the process or used as a combination of the two.

Optimisation of the sludge handling processes proved to be difficult with visual observations being accepted as a rough indicator for the selection of the mode of operation. A summary of these visual observations is presented in Table 8.6.

Table 8.5

Optimisation of the flocculators and the effect on the chemical quality of the primary sedimentation tank (PST) overflow

Mode of operation	Retention (min)	Turbidity (NTU)					visual observation of floc paticles
		number of analyses	minimun value	maximun value	mean	standard deviation	
Both bypassed	minimal	11	1.2	11	4.1	3.8	Poor
One tank used	8	61	0.8	5.3	1.6	0.8	Good
Two tanks in series	16	22	0.9	3.6	1.6	0.6	Exellent

Table 8.6

Optimisation of the primary sedimentation tank (PST) sludge wasting and recycle rates

Recycle rate %	Wasting rate %	Visual observations
Nil	5	Satisfactory
Nil	10	Good
5	5	Satisfactory
10		
10	10	Good
5		
5	nil	Poor
10		

Based on these observations the plant was operated with a sludge recycle rate of 5% (v/v) and sludge wastage rate of 10% (v/v).

Throughout the exercise problems were experienced with the PST sludge withdrawal valves and the flow meter which measured the sludge wastage rate. In any full scale application dewatering of the waste sludge would have to be considered.

8.5 Breakpoint chlorination

Optimisation of the breakpoint chlorination facility, to achieve adequate breakpoint chlorination and satisfactory disinfection, was not carried out at all during the project as the following guidelines for this process have been proven and are well documented in various publications (Van Leeuwen, 1981a).

pH value	7
Cl_2 dose	ratio of Cl_2 to NH_3 of between 9 and 12 to 1
ammonia concentration	< 1 mg/*l*-N

If ammonia concentrations of greater than 1 mg/*l* as N are regularly experienced in the feed water to a reclamation plant, then ammonia stripping should be considered as an alternate process.

As a direct result of the high trihalomethane concentrations which were being experienced due to high chlorine doses, the chlorine dose in the breakpoint tank was reduced to well below breakpoint requirements and a residual chlorine level of 0,2 mg/*l* as Cl_2 was maintained. Any residual ammonia in the water then passed through the plant and was removed in the final chlorination stage. The advantage with this mode of operation was the reduced THM formation due to removal of organic compounds in the carbon columns prior to final chlorination.

8.6 Sand filtration

Two sets of sand filters were used during the course of the project. Initially three pressure filters were provided but proved unsatisfactory and were consequently replaced by the two rapid gravity filters which came into operation during October 1984 and which were used for the remainder of the project.

Each of the two rapid gravity filters was able to accommodate the full plant flow. Thus one filter would be in operation whilst the other filter was being backwashed and put on standby. The change-over to the standby filter comprised a gradual switch from the duty filter to the stand-by filter. The first quantity of filtered water from the clean filter would always be sent to waste as the first discharge of filtered water from a clean filter was usually contaminated. Although this water was wasted, in a full scale plant it would be redirected to the initial stages of the process.

During the initial stages of operation the rapid gravity filters only permitted short filter runs. These short runs necessitated backwashing the filters alternately every 7 to 8 h. The two main contributors to these short runs were found to be the relatively high polyelectrolyte dosage of 0,5 to 1,0 mg/*l* and the lack of sufficient operating head between

the stabilisation tank and the sand filter. These two problems were solved by:

- reducing the polyelectrolyte dose to 0,12 mg/*l*

- installing a bypass pipeline which linked the chlorination tank directly to the sand filters thereby increasing the available head between these units. The stabilisation tank previously situated between these units was thus taken out of operation.

As a result of the abovementioned changes the filter runs were lengthened to approximately 17 h. The backwash procedure was also subject to many changes during the initial periods of operation of the rapid gravity sand filters. The following was finally accepted as the optimum backwashing procedure:

Air scour plus water wash:	@ 72 m^3/h for 10 min
Air scour plus water wash:	@ 216 m^3/h for 10 min
Water wash only:	@ 432 m^3/h for 5 to 7 min
Air scour plus water wash:	@ 72 m^3/h for 5 to 7 min
Water wash only:	@ 432 m^3/h for 10 min

8.7 Ozonation

A Degremont type MB110 ozone generator was used to produce ozone from air. Ozonation was applied from July 1986 and 30 m^3/h (normal cubic metre per hour at standard temperature and pressure) of the ozone/air mixture was dosed into the sand filter effluent giving an effective dose of approximately 0,9 mg/*l* as ozone. Analysis of the ozone/air mixture showed that the production rate was approximately 5 g ozone/m^3 of air which was passed through the generating compartment at the setting of 30 m^3/h.

The ozone/air mixture was transferred from the generator to the 17 min retention contact tank via an unplasticised polyvinyl chloride (UPVC) flexible pipeline. Research has shown that the inclusion of ozonation into the process prior to activated carbon treatment has extended the effective life of the carbon. In European drinking water treatment plants, the adsorptive capacity of the active carbon has been increased about tenfold after preozonation and the operating life is reported to be increased by up to three years. It has also been found that the total cost of ozonation followed by activated carbon treatment could in some instances be lower than that of activated carbon adsorption alone (Van Leeuwen, 1981b and 1988).

8.8 Activated carbon adsorption

Two sets of activated carbon colums were installed at the plant, one set was capable of treating the full 1,6 x 10^6 m^3/a flow whilst the smaller pilot columns treated a maximum of 1,1 x 10^5 m^3/a. The smaller pilot columns were used throughout the project due to the extremely high cost of the activated carbon.

The pilot columns were of the fixed bed, downflow type and were operated in series, with the first column being the roughing column and the second column being the polishing column. While the columns were in operation the flow rates and pressure drop across the beds were recorded. The normal operating pressure drop was in the range between 15 and

50 kPa. When the pressure drop was equal to or above 50 kPa, the desired flow could not be easily maintained. At this stage the column would be taken out of operation and back-washed with reclaimed water.

Three batches of carbon were used during the course of the project and the type of carbon selected was limited to two brands, namely *Filtrasorb F300 and Norit supra 0,8 ROW.*

The amount of water treated by each fill is presented in Table 8.7 in terms of m^3 and bed volumes treated (one bed volume is equivalent to 6 m^3).

The chemical oxygen demand (COD) adsorption data was used to determine the remaining activity of the carbon fill. Fourteen-day moving averages of the COD were kept to measure the time taken to reach saturation. The carbon was to be replaced when the average COD in the effluent from the polishing column reached 15 mg/*l*. Figs 8.2, 8.3 and 8.4, show that moving COD averages reached a level of 15 mg/*l* long after the carbon expired. In fact this predetermined level was never reached by the polishing column throughout this project. A better way to detect saturation would possibly be to take the point at which the COD removal became approximately uniform i.e. points X and Y for the roughing and polishing columns respectively on Fig 8.3. In real terms this would represent a lifespan for the carbon of 3 to 4 months and approximately 4 550 to 6 100 bed volumes of water could be treated without pre-ozonation.

In an attempt to streamline the process of estimating the saturation, an on-line dissolved organic carbon (DOC) analyser was installed by Watertek. Although satisfactory results were obtained during the first few weeks of operation, the system as a whole was plagued with problems which resulted in erratic operation.

The positive effect of ozonation on the operation of the activated carbon columns can be seen by comparing Figs 8.3 and 8.4. Fig 8.3 represents the period prior to ozonation whilst Fig 8.4 the period whilst ozonation was in progress. A comparison in terms of equivalent volumes of water treated is given in Table 8.8.

There was a significant difference when ozone was used. There was an average increase in the carbon life of about 40% in the polishing column as shown in Fig 8.5. This strengthens other research findings in that, by using ozone in conjunction with activated carbon columns, the life of the carbon could be extended (Van Leeuwen, 1988).

8.9 Final chlorination

Chlorine was added to the process water just after the activated carbon stage to counteract the effects of the removal of residual chlorine and ozone on the carbon bed, ensuring a disinfected reclaimed water with sufficient chlorine residual to protect against contamination in the holding tank or in the envisaged water distribution system.

Sufficient chlorine was added to the reclaimed water to maintain a residual of approximately 1 mg/*l* Cl_2 after a 1 h retention period. The turbidity of the water during this period was always well below 1 NTU.

Table 8.7

Total volume of water treated in the activated carbon columns

Activated carbon type	Volume of water treated	
	$m^3 \times 10^4$	Bed volumes
Filtrasorb F300	5	8350
Norit Supra 0.8 ROW	9.3	15500
Norit Supra 0.8 ROW (not used to exhaustion)	5.5	8950

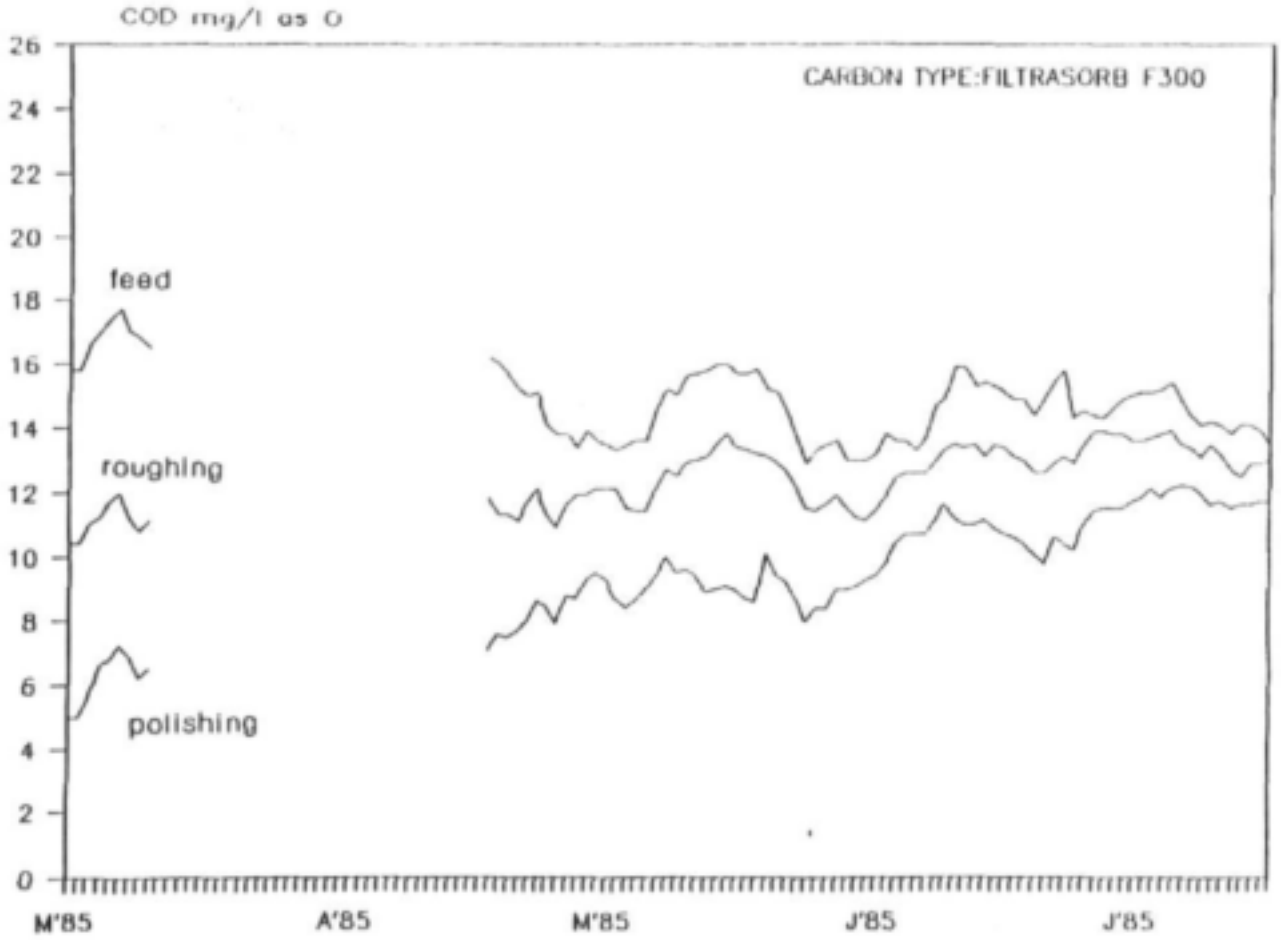


Fig 8.2 Activated carbon column loading data for *Filtrasorb F300* during March to July 1985.

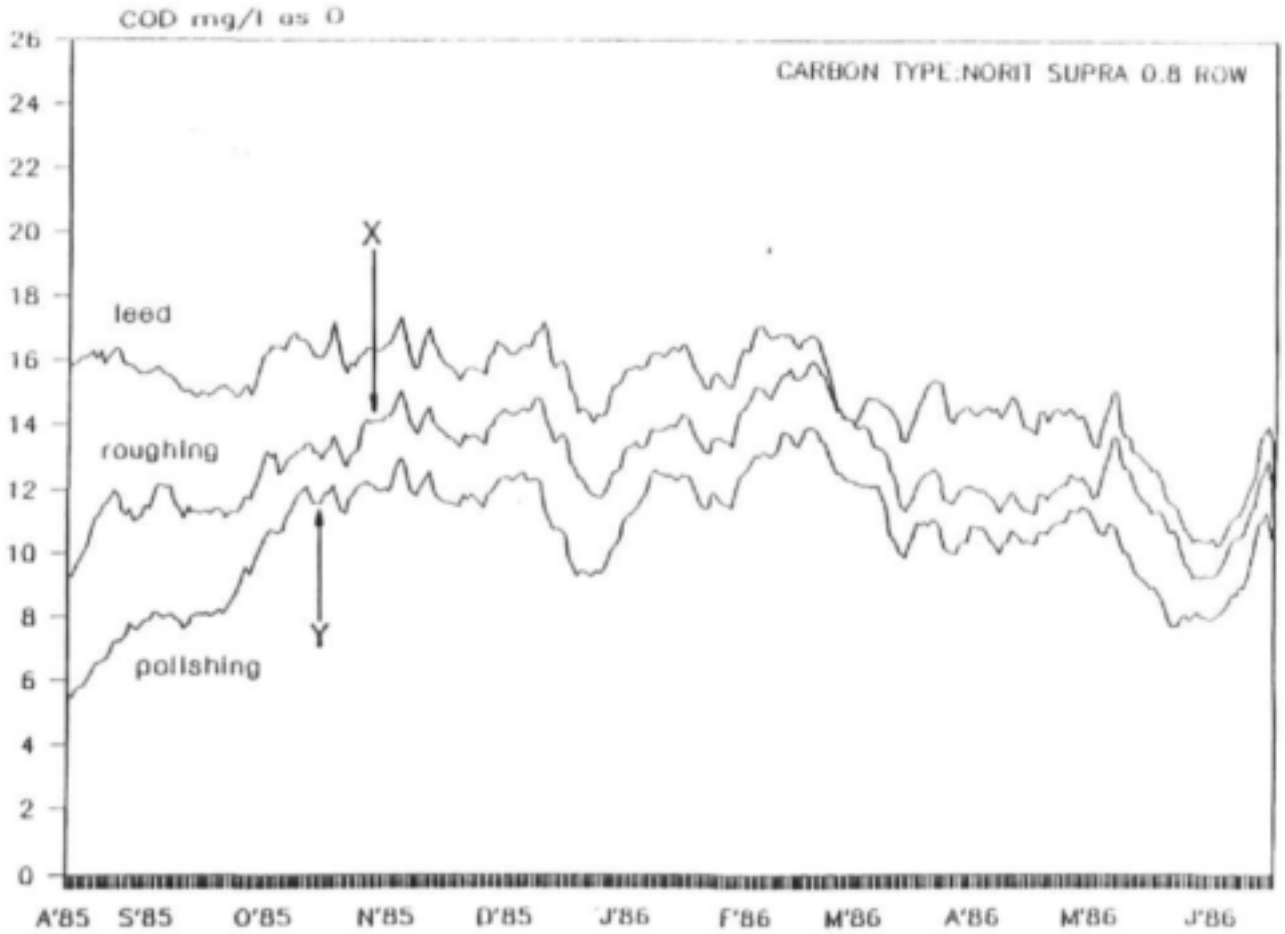


Fig 8.3 **Activated carbon column loading data for *Norit Supra 0.8 ROW* during August 1985 to June 1986.**

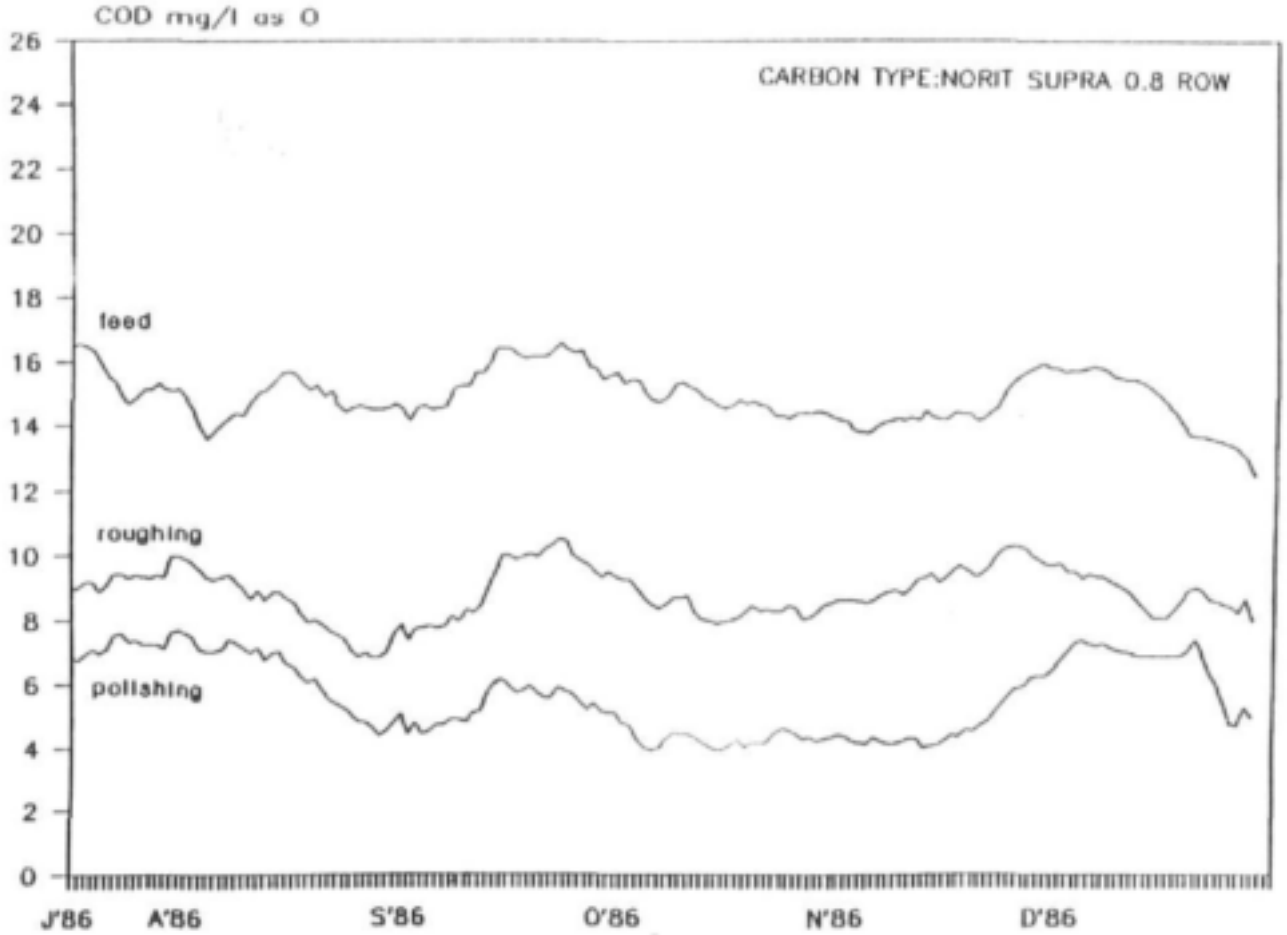


Fig 8.4 **Activated carbon column loading data for *Norit Supra 0.8 ROW* during July to December 1986.**

Table 8.8

14 day moving COD average (mg/l) comparison for Norit Supra 0.8 ROW with and without pre-ozonation

Bed volumes*	Roughing column COD		Polishing column COD	
	Without O_3	With O_3	Without O_3	With O_3
500	10.9	9.5	5.7	7.1
1000	10.9	9.5	7.3	8.1
2000	12.3	6.4	7.7	4.1
3000	14.2	10.6	11.4	6.4
4000	13.6	7.8	11.9	4.0
5000	13.7	8.6	11.3	4.7
6000	13.6	9.6	12.4	4.1
7000	11.8	12.8	9.9	7.2
8000	14.1	10.8	12.7	6.7

* *1 bed volume is about 6 m^3*

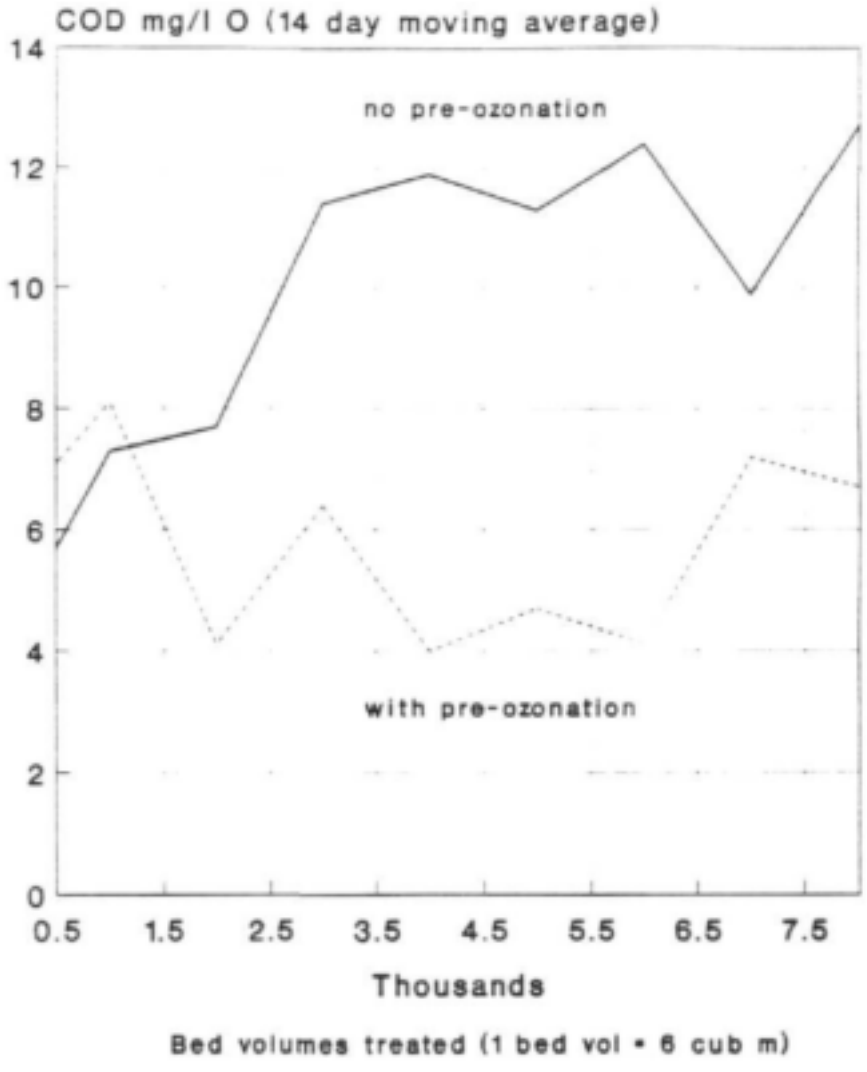


Fig 8.5 Effect of ozonation on COD removal by activated carbon

8.10 Calcium hydroxide stabilisation

The reclamation of a secondary effluent using ferric chloride or ferric sulphate produces an acidic and corrosive water.

Final chlorination produces a corrosive water with a pH value of about 5,8. This pH value is acceptable for disinfection but requires stabilisation with calcium hydroxide before the water is discharged into the distribution system.

In order to produce a water similar to the existing potable water supplies in the Western Cape the reclaimed water pH value was adjusted to within the range of 8,5 to 9,5 by using calcium hydroxide.

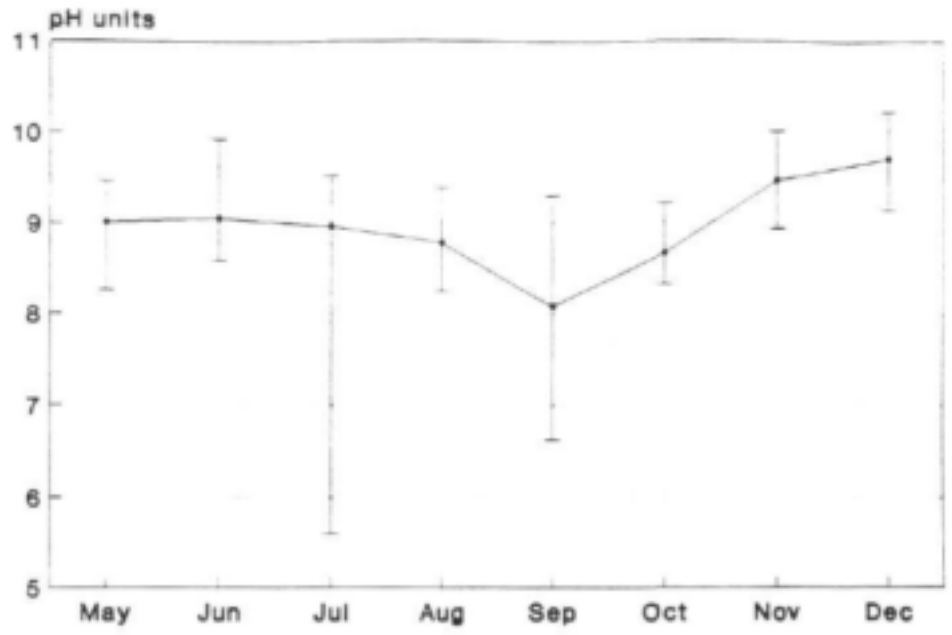
Initially this was carried out by making up a calcium hydroxide slurry in a stirred tank which could then be dosed in varying amounts in order to set the pH value at the predetermined level. A calcium hydroxide dose of between 50 and 70 mg/*l* was required giving a reclaimed water with an average pH value of about 9 and an alkalinity which ranged from 20 to 61 mg/*l* as $CaCO_3$. The pH and alkalinity results which were obtained on the reclaimed water for the final eight months of the project are presented in Fig 8.6.

An unexpected problem which was encountered with the calcium hydroxide stabilisation process was an increase in the turbidity of the reclaimed water from an average of 0,32 NTU to an average of 5,2 NTU. It is thought that the suspended solids in the reclaimed water was mainly due to the precipitation of excess calcium carbonate.

The calcium hydroxide dosing system was changed to a dry feed. The required pH value of about 9 was maintained with manual dosing into the final holding tank every 15 min. A stirrer was fitted to the calcium hydroxide dosing compartment to promote better mixing in the tank. An immediate improvement in the reclaimed water turbidity was noticed.

Although a vast improvement was noticed the average turbidity still exceeded that specified for potable water and an additional settling stage would be required to remove these excess suspended solids. A similar carry-over of suspended solids from the fresh water plants in the Western Cape area is also experienced intermittently. These solids eventually settle out in the water distribution system or in intermediate reservoirs both of which requires flushing out from time to time.

A list of criteria was published (Meiring, 1982) to which reclaimed water should comply if it is to be used for potable purposes. One of these criteria regards the stability of the water and it is suggested that the water be stable according to the Langelier and Ryznar indices. The Langelier saturation index is a qualitative measure and results are recorded as positive or negative only. A positive value indicates a tendency to precipitate $CaCO_3$ while a negative value is an indication that $CaCO_3$ may dissolve. Conversely the Ryznar stability index is a quantitative measure and the result indicates the degree of scaling or corrosion. A Ryznar index of less than or equal to six indicates scaling, an index of greater than seven indicates that scaling will not occur whilst indices of greater than 7,5 or greater than 10 indicate corrosive or very corrosive tendencies respectively (Wium & Coetzee, 1985). Both the Langelier and the Ryznar indices were calculated for the reclaimed water during the period from September to December 1986. These values are represented in Table 8.9.



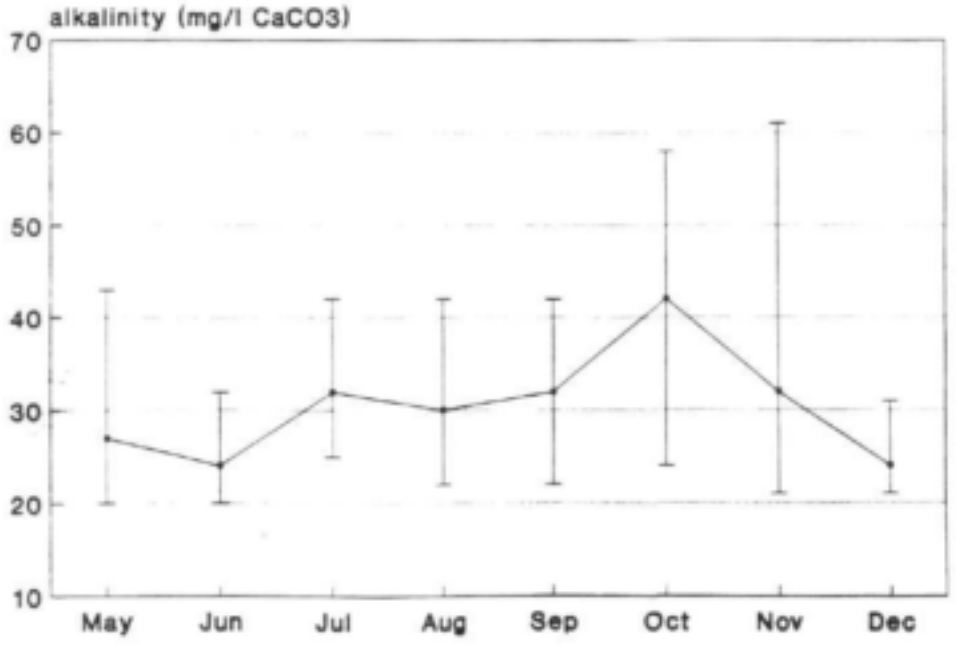


Fig 8.6 The mean, max and min pH and alkalinity values of the final water during May to December 1986

Table 8.9

Langelier and Ryznar indices of the reclaimed water between September and December 1986

Index	Date										
	09-29	10-06	10-13	10-20	10-27	11-03	11-10	11-17	11-24	12-01	12-08
Langelier	-	-	-	-	+	+	+	+	+	+	+
Ryznar	9.1	9.0	8.9	8.2	8.0	7.4	7.9	7.9	6.8	7.6	7.1
State of water	VC	VC	VC	C	C	OK	C	C	OK	OK	OK

VC = very corrosive
C = corrosive
OK = acceptable
- = negative
+ = positive

Conflicting results were obtained with the use of these indices (Table 8.9.). Loewenthal (1986) confirms the inadequacy of the Langelier and Ryznar indices. Previously calculation of the precipitation potential was tedious but this has been simplified with the development of conditioning diagrams and the STASOFT computer programme (Loewenthal *et al.*, 1986). On the whole the above results indicate a corrosive water with regard to the earlier samples and an acceptable water in the latter samples.

In a full scale application an in depth study into the reclaimed water treatment and stabilisation would have to be undertaken as variable calcium hydroxide requirements may necessitate the additional use of carbon dioxide.

CHAPTER 9

INTENSIVE SURVEILLANCE PROGRAMME

9.1 Introduction

The contract between the CCC and the WRC called for the surveillance of the quality of the water produced by the Cape Flats reclamation plant. A quality surveillance programme was drawn up by the WRC in collaboration with the CCC, the Technical Sub-Committee and the participating laboratories (Hattingh, 1986). The programme lasted for 11 consecutive weeks.

9.2 Summary of programme

9.2.1 Participating laboratories

The following laboratories participated in the surveillance programme.

- Scientific Services Branch (CCC)
- Medical School Virological Laboratories (UCT)
- CSIR - Watertek - Bellville
- CSIR - Watertek - Pretoria

9.2.2 Sampling points

The following sampling points were selected in order to gain an overall picture of the operation of the plant. Fig 9.1 indicates the position of these sampling points.

CR1 - Raw water inlet

CR2 - Sand filter outflow

CR3 - Ozone tank outflow

CR4 - Carbon column (polishing) outflow

CR5 - Reclaimed water.

9.2.3 Groups of analyses

The following groups of analyses were carried out

Group A - Sanitary analyses

conductivity	Cl
pH	SO_4

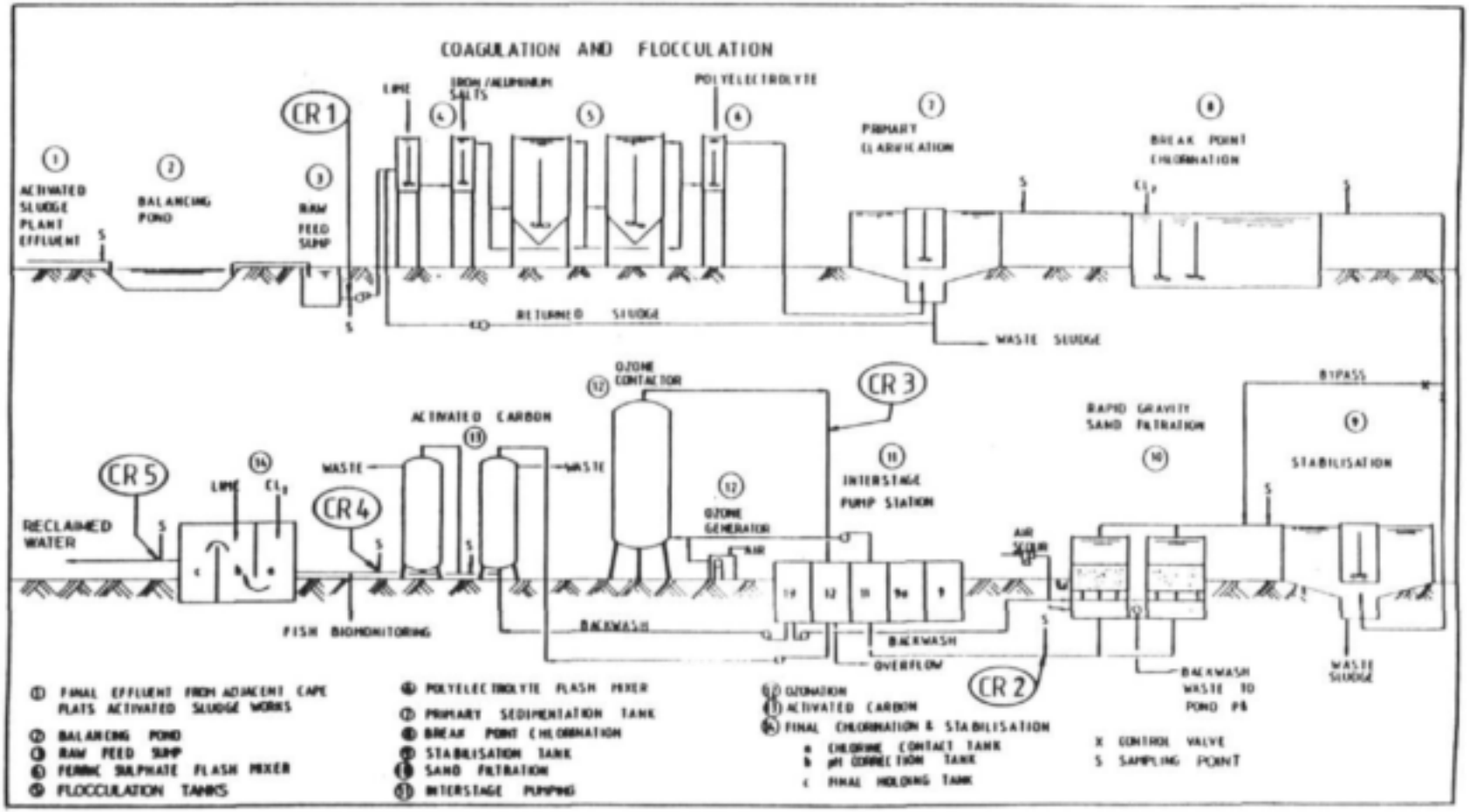


Fig 9.1 Sampling points for the intensive surveillance period

alkalinity $CaCO_3$	NO_3 - N
turbidity	NH_3 - N
colour	PO_4 - P
dissolved organic	organic - N
carbon (DOC)	COD - O
organic - P	Na
phenol	K
CN	Ca
F	Mg

Group B - Trace metals

Al	Fe
B	Mn
Ba	Ni
Be	Pb
Cd	Se
Co	Sr
Cr	Zn
Cu	As
Hg	

Group C - Bacteriological analyses

standard plate count	total coliforms
faecal coliforms	coliphage
acid fast bacilli	spore formers
faecal streptococci	

Group D - Enteric viruses

Group E - Organic chemicals

organic profile	total halogens (THM)
UV absorption (SCAN)	

Group F - Bio-assays

continuous fish bio-surveillance	ames test for carcinogenicity
enzyme analysis	luciferase test
daphnia bio-assay	

Group G - Control analyses

Routine analyses for control purposes e.g. chlorine content of the water.

9.2.4 Type of sample required

Group A	24 h composite
Group B	24 h composite
Group C	Grab
Group D	Grab
Group E	Grab
Group F	Grab/continuous
Group G	Grab/24 h composite

All the 24 h composite samples were taken on an hourly basis from 01:00 to 24:00 on the relevant day. During the 24 h period all the samples were stored in a refrigerator at approximately 4°C to minimise any deterioration of the determinands. The grab samples were taken at approximately 10:00 the following day and were submitted to the relevant laboratory immediately thereafter. Watertek (Bellville) sent the relevant samples via air freight to their Pretoria laboratories.

9.3 Results of quality surveillance programme

All the detailed results received from the participating laboratories for the intensive surveillance period have been included unabridged in appendices. Table 9.1 indicates the relevant appendix in which the various groups of results may be found.

The following paragraphs contain a summary of the findings as detailed in the aforementioned appendices.

9.3.1 Summary of results contained in appendix 1 (Groups A & B)

With the exception of DOC, Ba, Be, Se and Sr which were analysed by Watertek, all the analyses for Groups A and B were carried out by the CCC.

A statistical evaluation giving the minimum and maximum values, mean values and the standard deviations of all the results which were reported by the CCC are presented in Table 9.2. The statistical results for the analyses undertaken by Watertek are presented in Table 9.3.

Graphs of the COD, NH_3, NO_3, PO_4, turbidity, Ca, Mg and SO_4 concentration in the feed and reclaimed waters are presented in Figs 9.2 and 9.3.

9.3.2 Summary of results contained in appendix 2 (Group C)

The Bellville and Pretoria laboratories of Watertek carried out all the analyses for Group C. The results obtained by the Bellville laboratory are summarised in Table 9.4

Table 9.1

Key to the appendices containing the unabridged results for the intensive quality surveillance period

Appendix	Analyses group	Type of analyses	Analysed by
1	Group A	Sanitary analyses	CCC and Watertek
	Group B	Trace metals	
2	Group C	Bacteriological analyses	Watertek
3	Group D	Enteric viruses	UCT
4	Group E	Organic chemicals	Watertek
5	Group F	Bio-assays	Watertek

Table 9.2

Summary of results of 11 sets of analyses by the CCC for groups A and B

Determinand	Unit	Feed water (CR1)				Sand filter effluent (CR2)			
		min	max	mean	s	min	max	mean	s
pH		7,6	8,5	7,8	0,2	5,7	6,6	6,3	0,3
Conductivity	mS/m	88,0	97,0	90,1	2,5	89,0	93,0	91,5	1,2
Turbidity	NTU	2,40	9,50	4,56	2,47	0,24	0,56	0,38	0,10
Colour	Hazen	40,0	80,0	57,3	10,5	0,0	0,0	0,0	0,0
Alkalinity*	mg/l	100,0	224,0	122,4	33,2	7,0	40,0	20,1	9,9
COD-O	"	32,0	62,0	41,1	9,6	13,0	17,0	15,2	1,2
NO3-N	"	0,5	1,6	1,0	0,3	1,0	2,1	1,5	0,3
NH4-N	"	0,2	4,0	1,3	1,1	0,1	2,2	1,1	0,6
Organic-N	"	0,2	2,8	1,6	0,8	0,2	1,0	0,5	0,3
PO4-P	"	1,88	6,57	3,56	1,27	0,00	0,03	0,01	0,01
Organic-P	"	0,14	2,32	0,55	0,59	0,00	0,03	0,01	0,01
Na	"	117	143	126	8,7	114	141	123	8,8
K	"	14,5	17,9	16,0	1,1	14,0	17,4	15,5	1,2
Ca	"	39,5	46,9	43,6	2,6	39,0	45,5	42,8	1,9
Mg	"	7,7	8,9	8,5	0,4	7,8	9,3	8,4	0,4
SO4	"	78	95	87	5,2	163	192	180	8,9
Cl	"	141,0	188,0	154,3	16,2	140,0	196,0	151,0	15,3
F	"	0,10	0,19	0,12	0,03	0,09	0,14	0,11	0,02
Phenol	ug/l	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
CN	"	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
B	"	150	204	180	15,8	147	191	175	13,6
Cd	"	1,0	2,0	1,3	0,4	1,0	1,0	1,0	0,0
Co	"	5,0	7,0	6,1	0,7	4,0	8,0	5,8	1,1
Cr	"	2,0	16,0	6,3	3,9	0,0	4,0	1,5	1,2
Cu	"	5,0	12,0	6,5	2,1	2,0	12,0	4,6	2,5
Hg	"	0,0	0,0	0,0	0,0	0,0	1,0	0,3	0,4
Ni	"	6,0	12,0	9,4	1,7	8,0	12,0	9,4	1,4
Pb	"	8,0	18,0	12,7	2,6	5,0	14,0	10,5	2,5
Zn	"	14,0	92,0	28,8	21,2	7,0	25,0	16,7	5,0
As	"	0,0	2,0	0,6	0,6	0,0	1,0	0,1	0,3
Al	"	73	265	118	59,7	7	69	34	17,0
Fe	"	238	522	420	89,5	48	144	89	30,5
Mn	"	7	61	32	13,2	35	216	165	47,3

* as CaCO3

Table 9.2 - continued

Determinand	Unit	Ozone tank outflow (CR3)				Activated carbon outflow (CR4)			
		min	max	mean	s	min	max	mean	s
pH		5,9	6,9	6,5	0,3	5,7	6,7	6,2	0,4
Conductivity	mS/m	89,0	94,0	91,7	1,4	89,0	94,0	91,5	1,4
Turbidity	NTU	0,32	0,91	0,62	0,18	0,15	0,42	0,24	0,09
Colour	Hazen	0,0	20,0	1,8	5,7	0,0	0,0	0,0	0,0
Alkalinity*	mg/l	6,0	50,0	21,4	12,5	2,0	36,0	14,7	10,9
COD-O	"	12,0	16,0	13,5	1,4	2,0	7,0	4,5	1,4
NO3-N	"	1,1	2,2	1,5	0,3	1,2	2,7	1,9	0,4
NH4-N	"	0,2	2,1	1,1	0,7	0,1	0,9	0,4	0,2
Organic-N	"	0,2	0,8	0,4	0,2	0,0	0,3	0,2	0,1
PO4-P	"	0,00	0,03	0,02	0,01	0,01	0,11	0,03	0,03
Organic-P	"	0,00	0,05	0,02	0,01	0,00	0,03	0,02	0,01
Na	"	111	143	123	8,9	113	136	122	8,1
K	"	13,7	17,3	15,3	1,2	13,6	17,6	15,4	1,2
Ca	"	40,2	44,9	42,8	1,5	40,2	46,1	43,0	1,9
Mg	"	7,8	9,3	8,4	0,4	7,8	9,3	8,3	0,4
SO4	"	163	197	181	10,2	157	198	182	10,8
Cl	"	138,0	196,0	150,7	14,9	138,0	160,0	147,5	6,0
F	"	0,09	0,14	0,10	0,02	0,09	0,21	0,11	0,03
Phenol	ug/l	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
CN	"	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
B	"	140	274	181	31,7	98	219	178	35,0
Cd	"	1,0	1,0	1,0	0,0	1,0	2,0	1,1	0,3
Co	"	4,0	7,0	5,5	1,0	3,0	6,0	4,5	1,1
Cr	"	0,0	6,0	2,3	2,1	0,0	5,0	1,4	1,5
Cu	"	2,0	9,0	4,4	2,0	3,0	26,0	10,7	6,3
Hg	"	0,0	1,0	0,3	0,4	0,0	2,0	0,5	0,7
Ni	"	6,0	12,0	9,6	1,6	8,0	20,0	11,8	3,3
Pb	"	6,0	14,0	10,8	2,6	9,0	16,0	11,5	2,1
Zn	"	42,0	134,0	86,3	23,9	37,0	104,0	82,6	19,2
As	"	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Al	"	10	57	26	13,7	7	115	50	33,1
Fe	"	72	188	136	29,3	10	46	21	8,8
Mn	"	57	215	171	42,3	16	193	101	62,2

* as CaCO3

Table 9.2 - continued

Determinand	Unit	Reclaimed water (CR5)			
		min	max	mean	s
pH		7,3	9,5	8,5	0,8
Conductivity	mS/m	87,0	93,0	91,0	1,7
Turbidity	NTU	0,42	15,00	2,57	3,99
Colour	Hazen	0,0	0,0	0,0	0,0
Alkalinity*	mg/l	24,0	46,0	35,4	9,6
COD-O	"	2,0	7,0	3,8	1,5
NO3-N	"	0,7	2,1	1,7	0,4
NH4-N	"	0,1	0,5	0,2	0,1
Organic-N	"	0,1	0,5	0,2	0,1
PO4-P	"	0,01	0,04	0,01	0,01
Organic-P	"	0,00	0,04	0,01	0,01
Na	"	109	130	117	6,6
K	"	13,0	16,6	14,8	1,1
Ca	"	52,6	69,1	57,6	4,5
Mg	"	6,2	8,5	7,6	0,7
SO4	"	119	185	168	17,3
Cl	"	135,0	176,0	146,3	10,3
F	"	0,08	0,12	0,10	0,01
Phenol	ug/l	0,0	0,0	0,0	0,0
CN	"	0,0	0,0	0,0	0,0
B	"	140	213	180	19,8
Cd	"	1,0	2,0	1,1	0,3
Co	"	3,0	9,0	5,1	1,5
Cr	"	0,0	5,0	2,2	2,0
Cu	"	2,0	4,0	2,8	0,7
Hg	"	0,0	2,0	0,4	0,6
Ni	"	2,0	10,0	7,0	2,0
Pb	"	10,0	17,0	13,9	2,0
Zn	"	7,0	70,0	27,3	16,1
As	"	0,0	1,0	0,1	0,3
Al	"	54	132	93	24,7
Fe	"	28	60	46	10,7
Mn	"	10	125	36	30,3

as CaCO3

Table 9.3

Average analytical results obtained by Watertek of the CSIR for groups A and B

Sampling point	Statistic	Determinand				
		DOC	Be	Ba	Sr	Se
		mg/l	µg/l			
CR1	min	-	5	250	420	5
	max	-	-	-	450	-
	mean	12.6	5	250	440	5
	standard deviation	-	0	0	8.8	0
CR2	min	4.2	5	250	430	5
	max	20	-	-	450	-
	mean	6.9	5	250	440	5
	standard deviation	5.3	0	0	7.4	0
CR3	min	4.2	5	250	430	5
	max	7.2	-	-	450	-
	mean	5.4	5	250	440	5
	standard deviation	1.0	0	0	7.4	0

Table 9.3 (continued)

Average analytical results obtained by Watertek of the CSIR for groups A and B

Sampling point	Statistic	Determinand				
		DOC	Be	Ba	Sr	Se
		mg/l	µg/l			
CR4	min	1	5	250	430	5
	max	2.4	-	-	450	-
	mean	1.0	5	250	440	5
	standard deviation	1.0	0	0	7.0	0
CR5	min	1.0	5	250	430	5
	max	2.8	-	-	450	-
	mean	1.3	5	250	440	5
	standard deviation	0.9	0	0	6.7	0

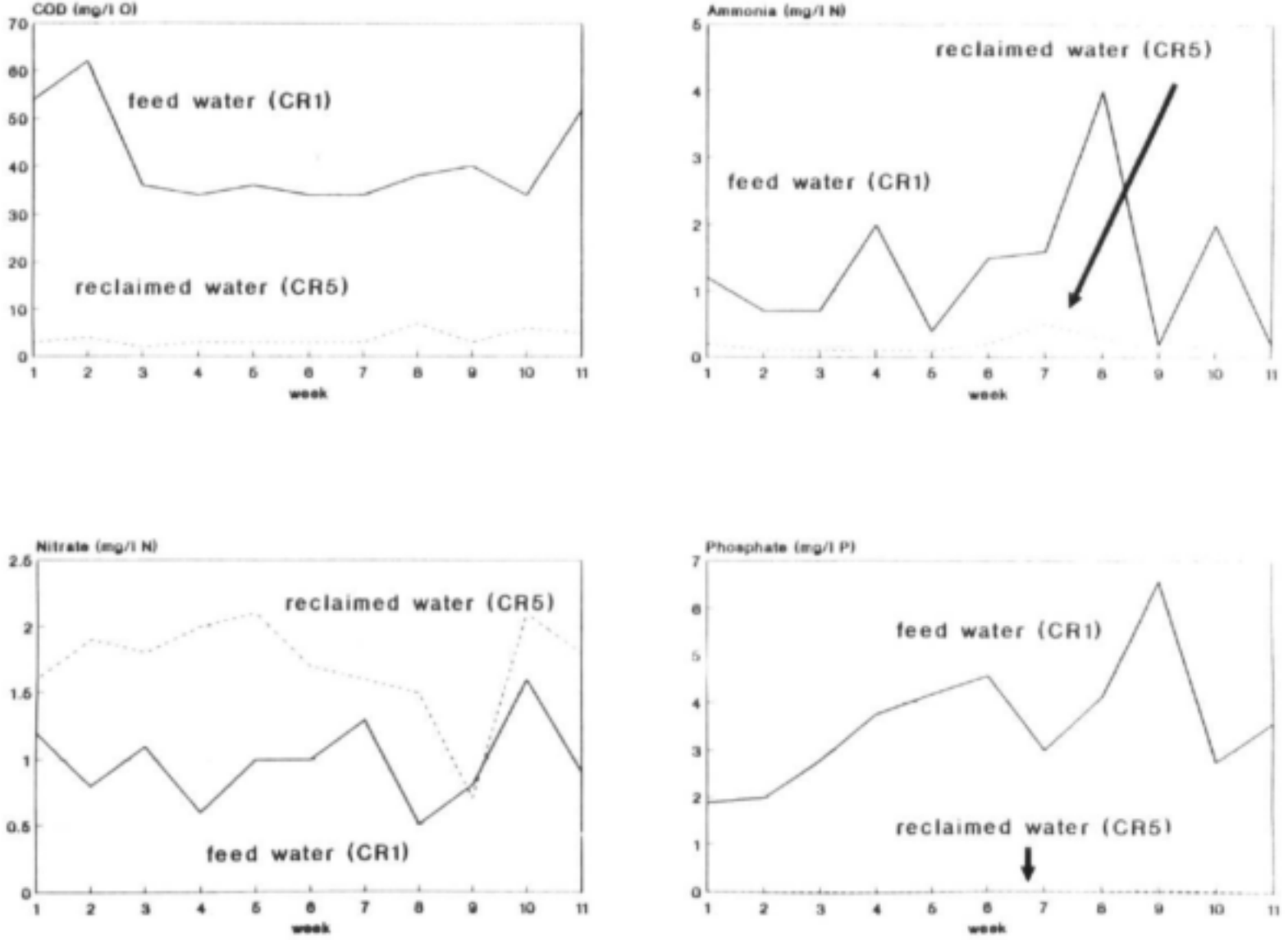


Fig 9.2 COD, ammonia, nitrate and phosphate change across the plant

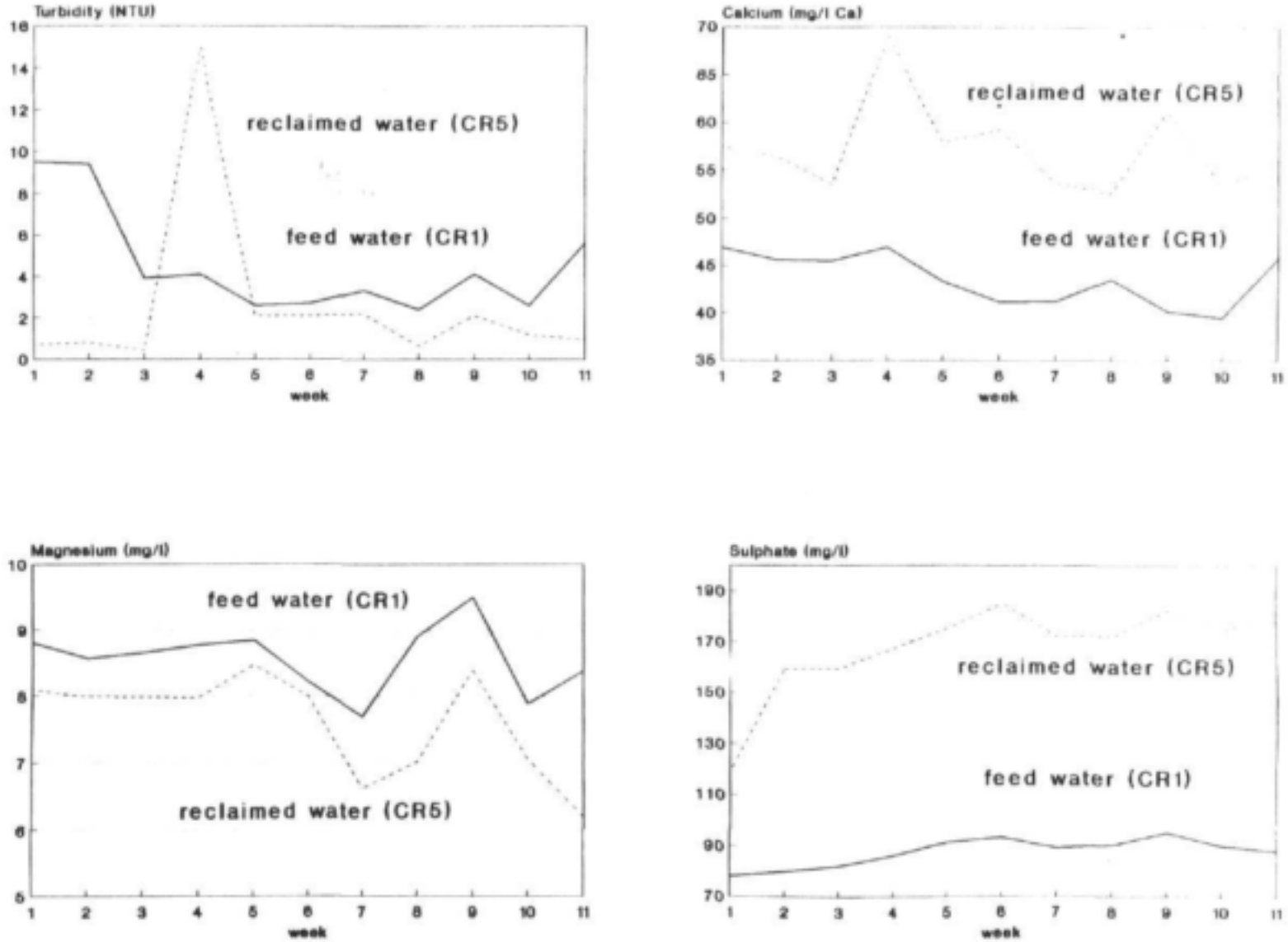


Fig 9.3 Turbidity, calcium, magnesium and sulphate change across the plant

Table 9.4

Average results obtained by the Bellville laboratories of Watertek of the CSIR

Sampling point	Determinand				
	Plate count*	Total coliforms**	Faecal coliforms**	Faecal streptococci**	Coliphage**
CR1	8071	4.9×10^5	5.6×10^4	10	10
CR2	28	3	2	0	0
CR3	1	1	1	0	0
CR4	49	161	3	0	0
CR5	1	0	0	0	0

* *count/ml*

** *count/100 ml*

The results which were obtained by the Pretoria laboratories are summarised in Table 9.5.

As a comparison of the quality of the reclaimed water a sample of Pretoria drinking water was analysed at the same time, these comparative results are given in Table 9.6.

9.3.3 Summary of results contained in appendix 3 (Group D)

These analyses were carried out for enteric virus by the Medical School virological laboratories, UCT.

The virological examinations were carried out only on the reclaimed water (CR5) and in all 12 weekly grab samples which were submitted no virus isolation was obtained.

All samples which were submitted contained a sandy deposit after being decanted. The standard plate count on this sandy deposit indicated counts of greater than 2 per 100 ml in most cases.

9.3.4 Summary of results contained in appendix 4 (Group E)

These analyses for organic chemicals were carried out by Watertek, Pretoria and a summary of the results which were obtained is presented in Table 9.7.

9.3.5 Summary of results contained in appendix 5 (Group F)

These bio-assays were carried out by Watertek, Pretoria.

All the results are presented in Tables 3 to 7 of appendix 5. In the Daphnia 24h lethality test it was found that the feed water (CR1) had no effect and that in most cases the carbon column effluent (CR4) also had no effect on the young Daphnia. However, the chlorinated final water (CR5) was lethal to the Daphnia in most cases. This is not cause for concern as it is well known that chlorine is lethal to aquatic organisms.

In the test showing the effect of the reclaimed water on the growth of *Pseudomonas putida* it was found that the feed water (CR1) had no effect in 62% of the samples and showed stimulation to varying degrees in 38% of the samples tested. The carbon column water (CR4) was found to have no effect on 50% of the samples, whilst stimulation was found in 25% of the samples and inhibition to growth in the remaining 25% of samples tested. The reclaimed water (CR5) showed inhibition to growth in 90% of the samples tested and had no effect on the growth rate in the remaining 10% of samples.

Similar results were obtained on the growth of *Pseudomonas putida* using a microassay, these results are presented in Table 5 of appendix 5.

The tests showing the effect of the reclaimed water on the growth of *Aeromonas punctata* showed inhibition to growth in 80% of samples tested and had no effect in the remaining 20% of samples using minimal medium. When a nutrient broth was used 70% of samples showed no effect whilst 30% of samples showed stimulation to varying degrees on the growth.

Table 9.5

Average microbiological quality as determined by the Pretoria laboratories of Watertek of the CSIR

Sampling point	Determinand		
	Clostridia*	Acid fast bacilli*	Bacterial toxins**
CR1			1334
CR2			37
CR3			26
CR4			39
CR5	0	0	12

** count/100 ml*

*** EU/ml*

Table 9.6

Comparison of microbiological quality of reclaimed water (CR5) and Pretoria drinking water

Sampling point	Determinand		
	Clostridia*	Acid fast bacilli*	Bacterial toxins**
CR5	0	0	12
Pretoria	0	5	31

* *count/100 ml*
** *EU/ml*

Table 9.7

Summary of results for group E analysis

Sampling point	Determinand		
	DOC mg/l	Total THM µg/l	UV absorbtion at 275 nm and 40 mm cell
CR1	12.6		
CR2	6.9	39.0	
CR3	5.4	40.5	
CR4	1.4	9.6	
CR5	1.6	67.7	0.02

The tests showing the effect of the reclaimed water (CR5) on the urease enzyme activity produced the following results.

- inhibition of activity obtained in 11% of samples
- no effect on activity obtained in 89% of samples

After aeration the samples showed no effect on activity in 100% of the reclaimed water (CR5) tests.

The average mutagenic activity of samples of the reclaimed water (CR5) as determined by the Ames *Salmonella* mutagenicity assay are presented in Table 9.8. The results are expressed in mutagenicity ratio (MR). The unabridged results of the mutagenic activity are given in Table 7 of appendix 2.

9.3.6 Results obtained from the ultrasonic fish bio-surveillance system

The hourly activity printouts, on the days coinciding with the samples for the surveillance period, have been averaged to give a daily average count per tank. These values as well as the minimum and maximum hourly value are presented in Table 9.9.

9.4 Discussion

All the results obtained during the intensive quality surveillance period indicate that, except for Watertek (Pretoria) standard plate count the quality of the reclaimed water (CR5) was well within the limits for potable water.

Conflicting results have been reported for the standard plate count in appendix 2. Engelbrecht (1989) reports that the Watertek, Pretoria results include both aerobic and anaerobic colonies whilst results reported by the Bellville laboratory include the anaerobic colonies only.
Although the high standard plate count in CR5 may not constitute a meaningful health risk, it does reflect occasional inadequate final disinfection.

Although viruses were isolated in samples prior to final disinfection the reclaimed water (CR5) was repeatedly shown to be completely free from viral contamination and is as clear as tap water. The failure to detect enteric viruses in the reclaimed water indicated that by virological standards this water is perfectly potable (Hodgkiss *et al.*, 1989).

Although the reclaimed water did not contain viruses or bacteria, a residual sandy deposit found in the bottom of certain of the sampling containers, when cultured by standard plate count for bacteria was shown to be variably, but sometimes significantly contaminated with viable bacteria. The species of bacteria isolated were commensals and no faecal coliforms were isolated.

Any in situ precipitate would trap bacteria from large volumes of water and the concentration detected by plate count cannot be extrapolated to a specific volume of water (Moodie, 1987).

Table 9.8

Average mutagenic activity as determined by the Ames Salmonella assay on reclaimed water (CR5)

Dilution	TA98						TA100					
	-S9			+S9			-S9			+S9		
	min	max	mean	min	max	mean	min	max	mean	min	max	mean
Nil	0.6	1.6	0.91	0.5	2.0	0.99	0.6	1.3	0.88	0.7	1.2	0.86
x 2	0.5	1.5	0.90	0.8	1.2	0.96	0.6	1.4	0.87	0.7	1.1	0.81
x 4	0.6	1.3	0.92	0.7	1.2	0.91	0.6	1.4	0.86	0.6	1.1	0.82

TA98 and TA100 - Salmonella
S9 - Rat liver microsome preparation for the inactivation of certain mutagens
x 2, x 4 - dilution by flash evaporation

Table 9.9

Activity counts by the fish in the bio-surveillance unit during the intensive surveillance period

Week	Tank number															Average		
	0			1			2			3			4					
	min	max	mean	min	max	mean	min	max	mean	min	max	mean	min	max	mean	min	max	mean
1	0	238	19	0	340	104	299	1384	1027	359	1260	933	10	819	387	0	1384	613
2	0	-	0	0	651	154	110	1140	640	139	1284	728	629	1012	940	0	1284	616
3	0	338	132	230	1151	665	611	1403	975	553	1213	982	555	1335	1007	230	1403	907
4	0	-	0	8	379	101	688	1622	1342	503	1341	1062	479	1539	1256	8	1539	940

The sandy deposit found is most probably due to the final calcium hydroxide dose which resulted in the observed increase in turbidity and suspended solids in the reclaimed water. This increase is due to the precipitation of calcium carbonate and does not reflect any faulty process on the reclamation plant. A further settling stage may have to be introduced to remove these solids.

Tap water from the domestic supply was also tested for viral purity on four occasions. No viruses were detected in these samples although the water contained more debris than the reclaimed product (Hodgkiss *et al.*, 1989).

CHAPTER 10

WATER QUALITY EVALUATION

10.1 Introduction

On site control analyses and routine control analyses by the CCC were carried out throughout the project. The results of the intensive surveillance period as reported in Chapter 9 are not part of the routine control programme and have therefore been dealt with separately.

The main objective of the routine control analyses was to initially measure the efficiency of the various unit processes in order to obtain an optimum mode of operation and thereafter to measure the performance of the units to ensure that the plant was operated correctly.

10.2 Selected results obtained from analyses of the individual unit processes

10.2.1 Quality equalisation and buffer pond

This stage was included to provide a feed water of consistent quality. A before and after evaluation of the pond was carried out from May 1985 up until the end of the project. The following determinands were measured: ammonia, nitrate. COD, total phosphate and faecal coliforms.

Table 10.1 gives a summary of the findings of this survey as well as the percentage removal of the relevant constituent.

The 16 day retention buffer pond proved fairly successful in the overall reduction of the concentrations of the determinands considered. If one considers the percentage removal of all the determinands which were tested one finds that the high reduction in faecal coliform counts of around 97% is as expected from a facultative type maturation pond whilst the average reduction in ammonia, COD, nitrate and total phosphate was low but acceptable. Fig 10.1 shows the reduction in faecal coliforms across the pond.

There was a significant overall buffering of the variation in quality during the period when the feed water to the reclamation plant was passed through the quality equalisation and buffer pond. Fig 10.2 shows the buffering and reduction in ammonia concentration across the pond.

10.2.2 Primary settling tank

The quality of the overflow from the PST was measured throughout the project. The following determinands were measured on a regular basis: pH, alkalinity, turbidity, COD, suspended solids, total phosphate, colour and faecal coliforms and are summarised in Tables 10.2 and 10.3.

The efficiency of the PST improved after the incorporation of the buffer pond into the system. The PST operated successfully throughout the project and the quality of the overflow

Table 10.1

The effect of the equalisation pond on the quality of the feed water between May 1985 and December 1986

Determinand	Pond inlet				Pond outlet				Removal %
	No of analyses	min	max	mean	No of analyses	min	max	mean	
NH_3-N	517	0.1	7.6	0.96	545	0.1	9.4	0.86	10
NO_3-N	517	0.5	9.9	4.2	546	0.5	7.3	3.1	26
COD-O	186	16	378	51	529	12	103	45	12
PO_4-P	167	0.93	11.0	5.29	207	0.46	10.0	4.68	12
Faecal coliforms*	51	9.4×10^3	1.1×10^6	1.6×10^5	51	80	4.1×10^4	4200	97

** counts/100 ml, other measurements in mg/l and pond outlet water is the feed (CR1) to the reclamation plant*

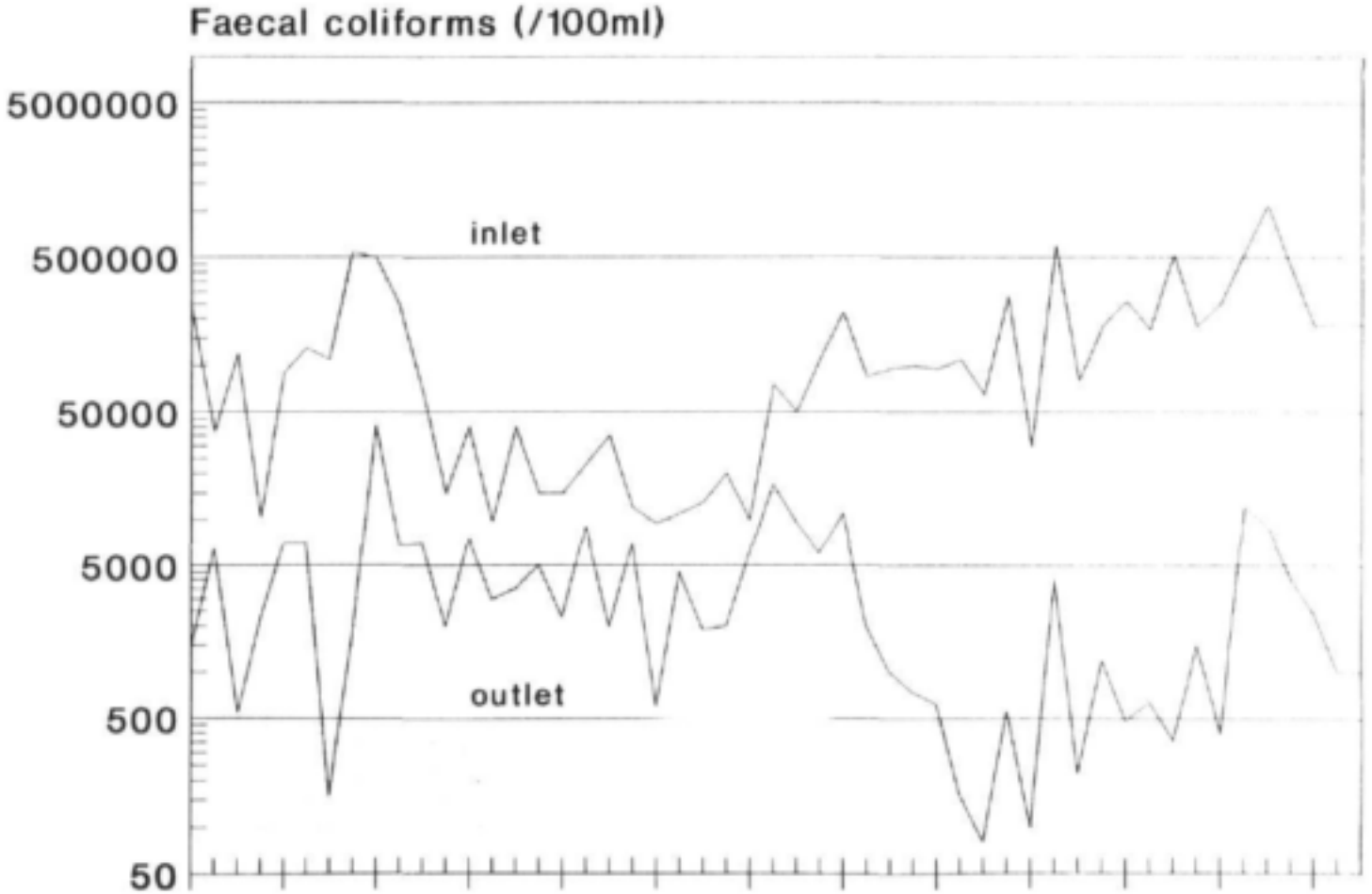
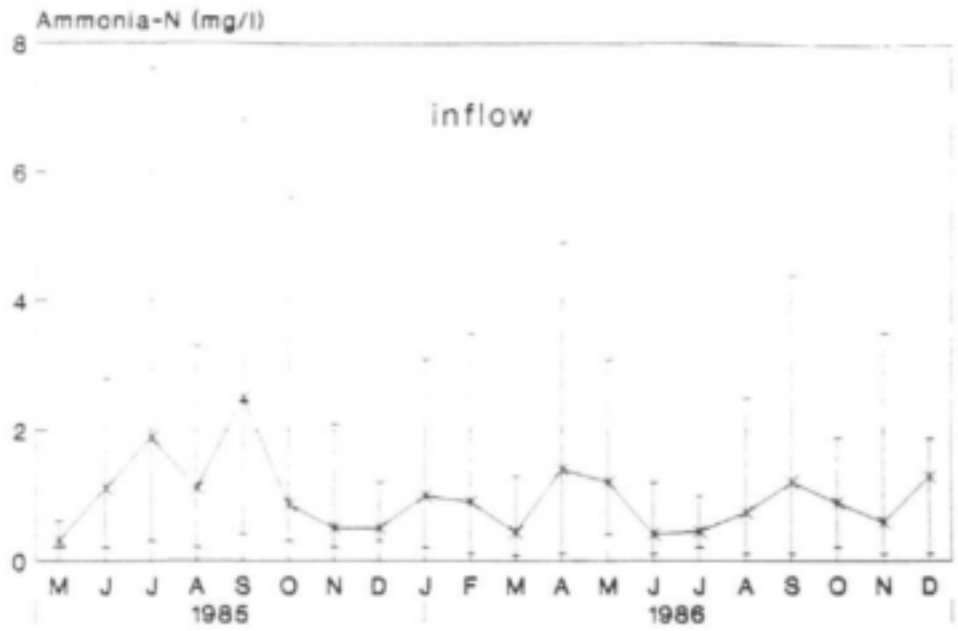


Fig 10.1 Faecal coliform reduction by pond between Apr and Dec 1986



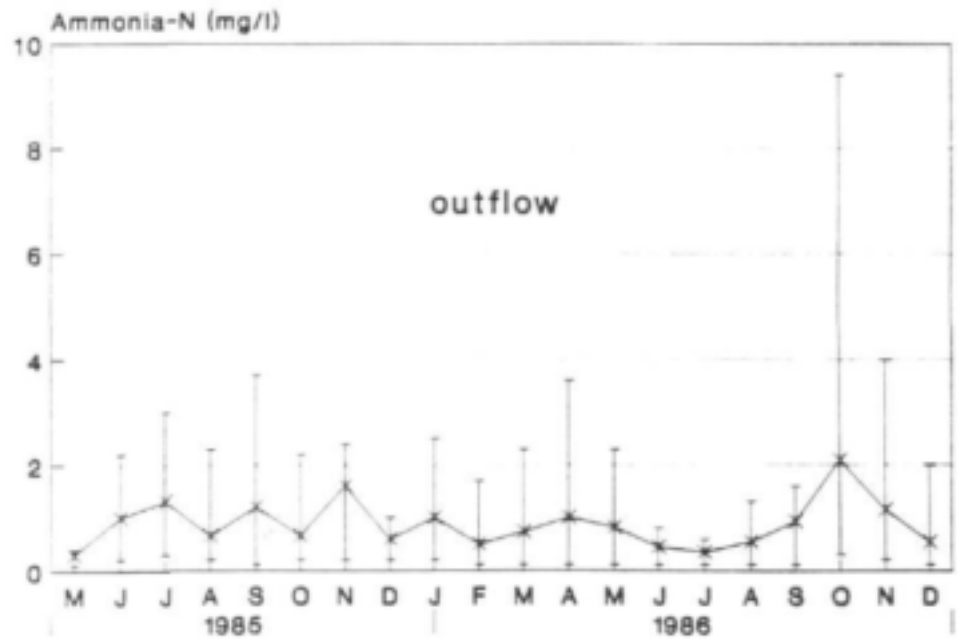


Fig 10.2 The effect of the equalisation pond on the ammonia content of water. The mean, max and min values are given.

Table 10.2

The quality of the primary sedimentation tank (PST) overflow between January 1983 and April 1985 (before the incorporation of the buffer pond)

Determinand	Units	Feed water (CR1)				PST overflow				Removal %
		n	min	max	mean	n	min	max	mean	
pH		690	6.52	7.57	6.93	690	3.23	8.45	5.78	
Alkalinity	mg/l $CaCO_3$	683	35	208	96	683	<1	123	35	
Turbidity	NTU	688	1.5	47	4.1	688	0.43	17.6	2.3	44
COD-O	mg/l	548	20	505	59	236	3	74	26	56
Suspended solids		525	<1	445	15	232	<1	88	7.1	53
PO_4-P		230	0.1	14	6.56	234	0.001	3.9	0.54	92
Colour	Hazen	60	40	100	57	59	5	50	14	75
Faecal coliforms	/100 ml	43	10×10^3	15×10^6	13×10^5	76	<200	10×10^7	14×10^5	nil

n = number of analyses

Table 10.3

The quality of the primary sedimentation tank (PST) overflow between May 1985 and December 1985 (after the incorporation of the buffer pond)

Determinand	Units	Feed water (CR1)				PST overflow				Removal %
		n	min	max	mean	n	min	max	mean	
pH		577	7.06	9.01	7.74	581	4.95	8.53	6.03	
Alkalinity	mg/l $CaCO_3$	577	70	141	109	581	3	226	28	
Turbidity	NTU	573	1.3	20	4.6	578	0.72	7.3	1.5	67
COD-O	mg/l	529	12	103	45	202	6	66	18	60
Suspended solids		515	1	51	14	194	1	27	4.3	69
PO_4-P		207	0.46	10	4.68	196	0.009	2.2	0.152	97
Colour	Hazen	195	40	140	66	194	5	70	11	83

n = number of analyses

water was acceptable and well within normally accepted PST performance objectives (Hart, 1981). Fig 10.3 show the reduction in COD, PO_4-P and turbidity concentrations between the feed water and the PST overflow for the period May 1985 to December 1986.

10.2.3 Primary chlorination

The objectives of this unit process are to effectively disinfect the water and to reduce the ammonia concentration to < 0,5 mg/*l*-N.

Throughout the project, the quality of the primary chlorination tank effluent was measured on a regular basis. The determinands measured included the ammonia, residual chlorine concentrations and faecal coliform counts and these are summarised in Table 10.4.

During the period between May 1985 and December 1986 (Table 10.4) results obtained on the breakpoint chlorination effluent gave faecal coliform counts of < 1/100 ml on 92 % of the samples tested. The reclaimed water faecal coliform counts were < 1 in all cases on the days when counts of > 1/100 ml were obtained in the breakpoint sample.

The removal of ammonia between the feed water and the chlorine tank effluent could have been improved from the 31 % average if consistently higher chlorine doses had been applied. High chlorine doses were avoided, especially during the period after July 1986, to counteract the formation of the undesirable trihalomethane compounds which result from the excessive use of chlorine in the presence of organic compounds. As a result a higher dose of chlorine was applied during the final disinfection stage.

10.2.4 Sand filtration

Sand filters are used in water treatment primarily to remove residual suspended matter which may have passed through the sedimentation stages. During the project two sets of sand filters were used; firstly pressure filters were operated but as these proved unsuccessful two new rapid gravity filters were designed and built.

The results obtained from analysis carried out on the pressure filters will be ignored in this section and only the results for the rapid gravity sand filters will be considered.

Table 10.5 contains a summary of results obtained from the analysis of the PST and sand filter effluents between May 1985 and December 1986. The determinands which were analysed include amongst others: turbidity, suspended solids, COD, total phosphate, colour, pH and alkalinity.

The removal in turbidity and suspended solids across the filter bed is a function of the efficacy of the PST process. Fig 10.3 shows the turbidity removal across the sand filter bed for the period May 1985 to December 1986.

The total phosphate and COD removal efficiencies observed is directly proportional to the amount of carry-over from the PST and does not reflect any significant soluble removal.

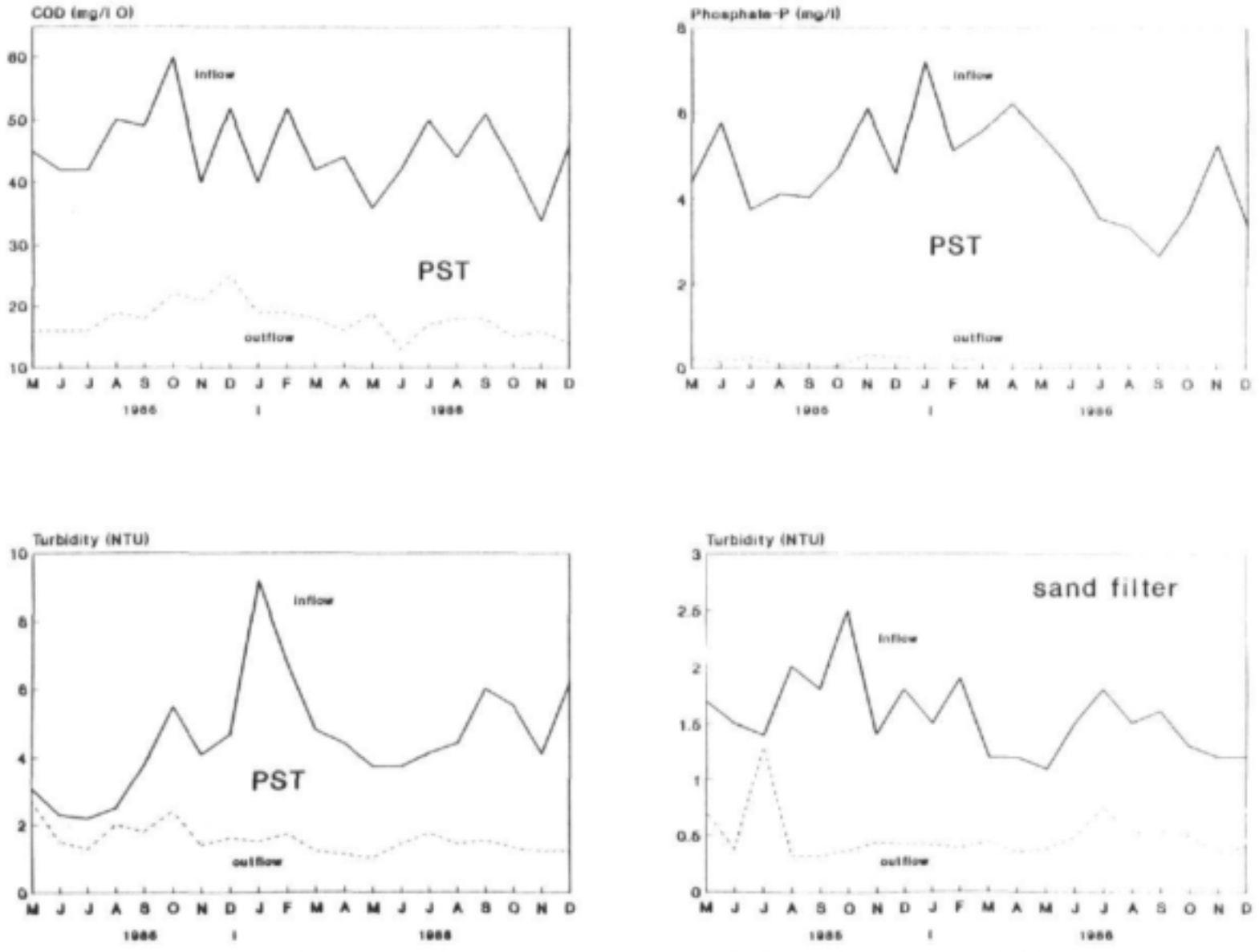


Fig 10.3 Removals by the primary settling tank (PST) and sand filter

Table 10.4

The quality of the water after breakpoint chlorination
between May 1985 and December 1985

Determinand	Units	Feed water (CR1)				Chlorine tank				Removal %
		n	min	max	mean	n	min	max	mean	
NH_3-N	mg/l	545	<1	9.4	0.86	207	<0.1	2.8	0.59	31
Residual chlorine	mg/l Cl_2	NS	-	-	-	542	0.1	6.5	1.6	-
Faecal coliforms	/100 ml	51	80	4.1×10^4	4200	144	<1	90*	<1	99.98

* *chlorinator faulty*

Table 10.5

Summary of the primary sedimentation tank (PST) and sand filter outflow qualities between May 1985 and December 1986

Determinand	Units	PST outflow				Sand filter outflow				Overall removal %
		n	min	max	mean	n	min	max	mean	
Turbidity	NTU	578	0.72	7.3	1.5	574	0.18	2.0	0.49	67
COD	mg/l	202	6	66	18	534	6	33	15	17
Suspended solids		194	<1	27	4.3	520	<1	11	<1	77
PO_4-P		196	0.009	2.2	0.152	199	0.001	0.253	0.043	72

n = number of analyses

10.2.5 Ozonation

Due to mechanical and electrical problems the ozone generator was only run for a relatively short period which coincided with the intensive surveillance programme.

10.2.6 Activated carbon treatment

Three batches of activated carbon were used during the course of the project. The types of carbon used as well as the amount of water treated in each case is presented in Table 8.7.

The average water quality data for the period from February to July 1985 whilst *Filtrasorb F300* was used is presented in Table 10.6.

The carbon columns were filled with a new batch of activated carbon, *Norit Supra 0,8 ROW*, during early August 1985. Table 10.7 gives the average carbon column influent and outflow data up until mid July 1986. The carbon columns were refilled with a new batch of *Norit Supra 0,8 ROW* during the 2nd half of July 1986 and operation continued up until the end of the project.

Table 10.8 indicates the average activated carbon column in and outflow quality whilst Norit Supra 0,8 ROW was in use during the period from July to December 1986. Graphs indicating moving COD averages of the feed water to the carbon columns, the outflow from the roughing column and the outflow from the polishing column are shown in Figs 8.2, 8.3 and 8.4 respectively.

Fig 10.4 gives the cumulative COD load removed as a function of cumulative COD applied for both the roughing and polishing activated carbon adsorption columns for all three batches of carbon used during the project.

10.2.7 Reclaimed water

Table 10.9 compares the quality of the reclaimed water to that of the feed water for the period May 1985 to December 1986. The overall percentage removal of the various constituents is also given. Although it is believed that adequate disinfection was achieved, it cannot be guaranteed that breakpoint chlorination was achieved at all times.

Table 10.10 gives a quality comparison between the reclaimed water, average analyses of local drinking waters and various local and international standards.

Table 10.6

The average quality of the feed to and the effluent from the activated carbon column between February and July 1985 whilst Filtrasorb F300 was used

Determinand	Units	Influent	Effluent		
			Jan/March	April/May	June/July
NH_3-N	mg/l	0.49	0.30	0.25	0.63
COD-O		15	5	10	11
PO_4-P		0.036	0.035	0.049	0.048
Turbidity	NTU	0.68	0.22	0.63	0.35

Table 10.7

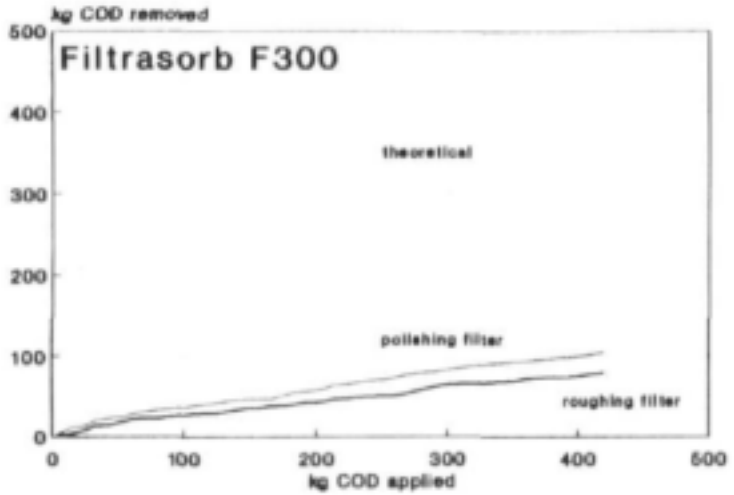
The average quality of the feed to and the effluent from the activated carbon column between August 1985 and July 1986 whilst Norit Supra 0.8 ROW was used

Determinand	Units	Influent	Effluent					
			1985		1986			
			Aug/Sept	Oct\Nov	Dec/Jan	Feb/Mar	Apr/May	Jun/Jul
NH_3-N	mg/l	0.52	0.73	1.0	0.30	0.33	0.32	0.25
COD-O		15	8	12	12	13	11	8
PO_4-P		0.044	0.026	0.026	0.045	0.032	0.027	0.021
Turbidity	NTU	0.42	0.26	0.33	0.41	0.40	0.30	0.50

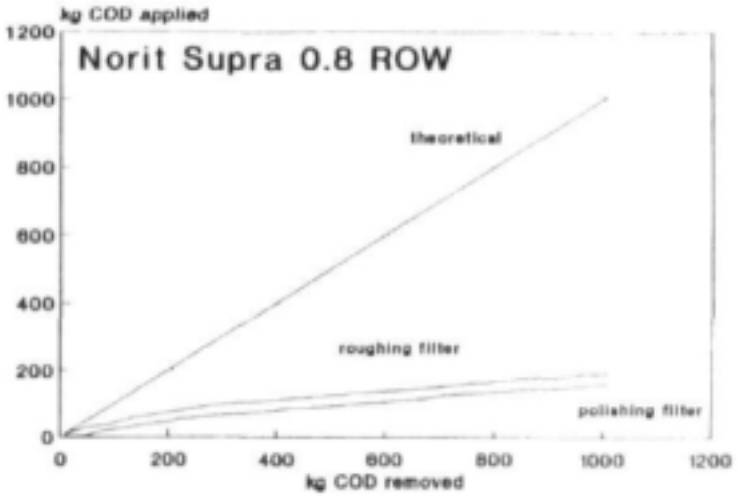
Table 10.8

The average quality of the feed to and the effluent from the activated carbon column between July and December 1986 whilst Norit Supra 0.8 ROW was used

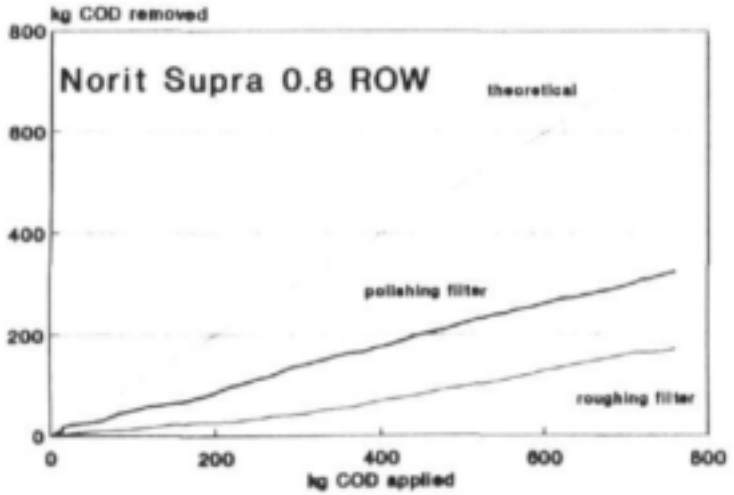
Determinand	Units	Influent	Effluent		
			Jul/Aug	Sep/Oct	Nov/Dec
NH_3-N	mg/l	0.69	0.38	0.75	0.28
COD-O		15	8	8	6
PO_4-P		0.033	0.019	0.023	0.052
Turbidity	NTU	0.51	0.46	0.26	0.18



Feb to August



August to June



July to December

Fig 10.4 Cumulative COD removed from Feb 1985 to Dec 1986

Table 10.9

Feed water and reclaimed water quality comparison
between May 1985 and December 1986

Determinand	Units	Feed water			Reclaimed water			Removal %
		Min	Max	Mean	Min	Max	Mean	
pH		7.06	9.01	7.74	5.54	10.55	8.90	-
NH_3-N	mg/l	<0.1	9.4	0.86	<0.1	2.2	0.24	72
Organic-N		0.1	3.9	2.0	0.1	2.1	0.41	80
NO_3-N		0.5	7.3	3.1	0.6	8.0	2.4	23
COD-O		12	103	45	1	21	7.7	83
Suspended solids		<1	51	14	<1	25	8.4*	40*
Dissolved solids		241	808	540	287	946	562	0
PO_4-P		0.46	10	4.68	0.001	0.44	0.028	99.4
Alkalinity	mg/l $CaCO_3$	70	141	109	8	75	31	-

** The relatively high suspended solids and turbidity results of the reclaimed water can be attributed to the final calcium hydroxide dosing. A detailed discussion of this aspect is included in chapter 8, section 8.10*

Table 10.9 (continued)

Feed water and reclaimed water quality comparison
between May 1985 and December 1986

Determinand	Units	Feed water			Reclaimed water			Removal
		Min	Max	Mean	Min	Max	Mean	%
Turbidity	NTU	1.3	20	4.6	0.45	12	3.8*	17
Colour	Hazen	40	140	66	<5	0	<5	>92
Cd		0	2.0	1.0	0	2.0	1	0
Co		4.0	10	6.5	2.0	9.0	6.2	5
Cr		1	16	5.3	0	5.0	1.3	75
Cu	µg/l	2.0	12	6.6	2.0	12	5.3	20
Fe		131	772	359	34	274	66	82
Mn		7.0	61	29	3.0	125	29	0
Ni		4.0	12	8.8	2.0	10	6.6	25

Table 10.9 (continued)

Feed water and reclaimed water quality comparison
between May 1985 and December 1986

Determinand	Units	Feed water			Reclaimed water			Removal %
		Min	Max	Mean	Min	Max	Mean	
Pb	µg/l	7.0	17	13	10	21	14	0
Zn		14	92	27	7.0	70	24	11
Total THM		0.3	6.8	3.0	19	353**	132**	0
Na	mg/l	68	143	110	58	126	101	8
K		13	19	16	13	17	14	12
Ca		26	52	40	34	69	51	0
Mg		5.4	10	7.9	4.2	12	6.9	13
Faecal coliforms	/100 ml	100	4.1×10^4	4200	<1	1	<1	99.9

*** Activated carbon spent during periods of individual process optimisation*

Table 10.10

Quality comparison

Determinand	Units	Cape Flats reclaimed water	SABS specification		Cape Town drinking water	Standards in	
		Mean	Max acceptable	Max allowable	1982/1983 mean	USA	United Kingdom
pH		8.9	6.0 to 9.0	5.5 to 9.5	9.1		
Conductivity	mS/m	90.6	70	300	14		
Alkalinity	mg/l $CaCO_3$	31			26		
Hardness		172			50		
Colour	Hazen	<5	20	<5	15		
Turbidity	NTU	3.8	1	5	0.6		
COD	mg/l	7.7			3.4		
Cl		146	250	600	18	250	
NO_3-N		2.4	6	10		10	10
NH_3-N		0.24			0.04		
Organic-N		0.41					

The results for the reclaimed water are the average results for the period May 1985 to December 1986.

Table 10.10 (continued)

Quality comparison

Determinand	Units	Cape Flats reclaimed water	SABS specification		Cape Town drinking water	Standards in	
		Mean	Max acceptable	Max allowable	1982/1983 mean	USA	United Kingdom
PO_4-P	mg/l	0.017			0.007		
Organic-P		0.011					
Na		101	100	400	9.3		
K		14			0.5		
Ca		51			17	80 to 100	
Mg		6.9	70	100	1.4	80 to 100	
SO_4		166	200	600	17	250	200 to 400
F		0.1	1.0	1.5	0.04	1.4 to 2.4	1.5
Phenol	µg/l	<5	5	10		1	
CN		<100	200	300		10 to 200	50
B		179					

The results for the reclaimed water are the average results for the period May 1985 to December 1986

Table 10.10 (continued)

Quality comparison

Determinand	Units	Cape Flats reclaimed water	SABS specification		Cape Town drinking water	Standards in	
		Mean	Max acceptable	Max allowable	1982/1983 mean	USA	United Kingdom
Cd	µg/l	1	10	20		10	10
Co		6					
Cr		1	50	50		50	
CN		5	500	1000		200 to 1000	
Hg		1	5	10		2	1
Ni		7					
Pb		14	50	100		50	100
Zn		24	1000	5000		5000	1500 to 5000
As		<1	100	300		50	50
Al		89			210		
Fe		66	100	1000	50	50 to 300	
Mn		29	50	1000		10 to 50	

The results for the reclaimed water are the average results for the period May 1985 to December 1986

CHAPTER 11

FINANCIAL EVALUATION

11.1 Introduction

The overall cost of water reclamation is a function of plant size, characteristics of the water to be treated and the sophistication of the process configuration. At the Cape Flats plant where water was reclaimed for human consumption it was expected that the reclaimed water would be significantly more expensive than the existing drinking water supplies.

The cost of chemicals, water, electricity, etc are directly proportional to plant size. However, maintenance costs and capital expenditure increase with plant size but not at a proportional rate. It is estimated that the six-tenths power factor is valid in this case (Hart, 1981). Staff and control and surveillance costs should remain relatively constant and are thus essentially independent of plant size.

11.2 Production costs

One of the important aspects of this project was to establish the actual operational costs which could be used to estimate the full scale plant production cost. During the course of the project a careful record was kept of all chemicals, fresh water and electricity that was consumed, as well as capital, maintenance and surveillance expenditure. From their average costs an estimate of the cost of producing potable reclaimed water has been made. The costs of all the associated services have been taken as a percentage of the actual annual costs whilst the cost reflected for capital (interest and redemption) sometimes called capital amortisation is a theoretically calculated value.

The costs/m^3 for the second half of 1986 are reflected in Table 11.1 and Fig 11.1 indicates the production cost composition per m^3 of water treated as at December 1986.

Similar cost calculations were carried out throughout the project for the various periods. A direct comparison of these costs can be deceiving because the full plant was not in operation throughout the project. For comparison purposes these costs have been adjusted theoretically to include the full process configuration required to produce a potable water. The unadjusted as well as adjusted production costs are presented in Table 11.2.

There was a significant cost increase over the duration of the project due partly to a significant rise in the purchase price of all the consumptive goods (Fig 11.2). However, the most significant price increase is that of the activated carbon. The progressive price increase of activated carbon, which is an imported consumable, is directly linked to the monetary exchange rate. Fig 11.3 indicates the approximate price increase per kilogram of activated carbon over the duration of the project as well as the exchange rate between the American dollar and the South African rand.

Table 11.1

Total cost of producing reclaimed water for the second half of 1986

Cost element	Item	Cost in c/m³		
		Cost	Sub totals	Total
Directly due to treatment	Flocculant - $Fe_2(SO_4)_3$	6.8	44.4	88.5
	Polyelectrolyte - Magnafloc LT27	0.1		
	Chlorine	1.4		
	Calcium hydroxide	0.6		
	Activated carbon	29.1		
	Electricity	4.8		
	Fresh water	0.2		
	Maintenance	1.4		
Fully or partially independent of size	Salaries, pensions etc.	9.1	15.2	
	Branch administration	1.4		
	Surveillance costs	4.3		
	Miscellaneous	0.4		
Capital amortisation (theoretical)			28.9	

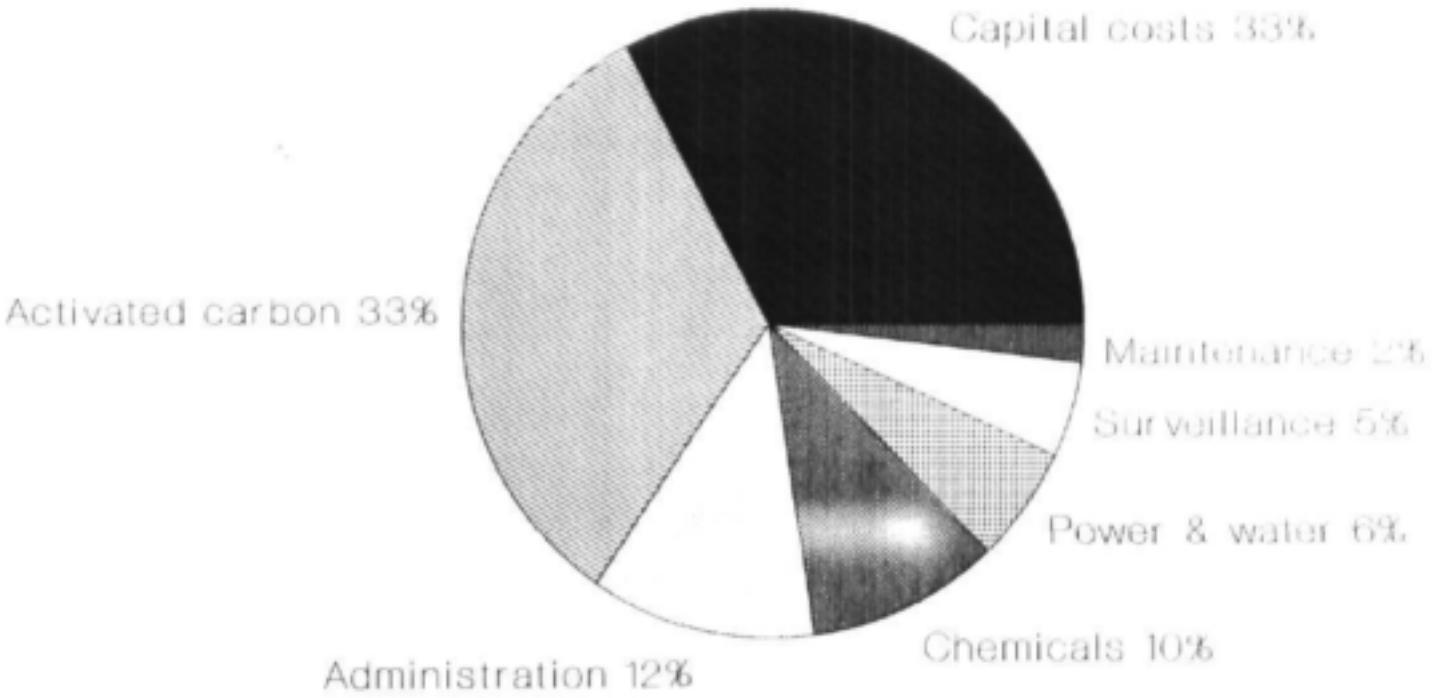


Fig 11.1 Production cost composition as at December 1986

Table 11.2

Cost comparison for the project giving adjusted and unadjusted production costs

Period	Costs in c/m³	
	Unadjusted	Adjusted
April to September 1983	16.6	61.8
October to December 1983	17.6	62.8
January to June 1984	17.7	62.9
July to October 1984	21.5	66.7
November 1984 to February 1985	20.6	65.8
March to June 1985	70.9	70.9*
July to September 1985	75.1	75.1*
October to December 1985	75.8	75.8*
January to April 1986	74.8	74.8*
May to December 1986	88.5	88.5*

* *no adjustment necessary*

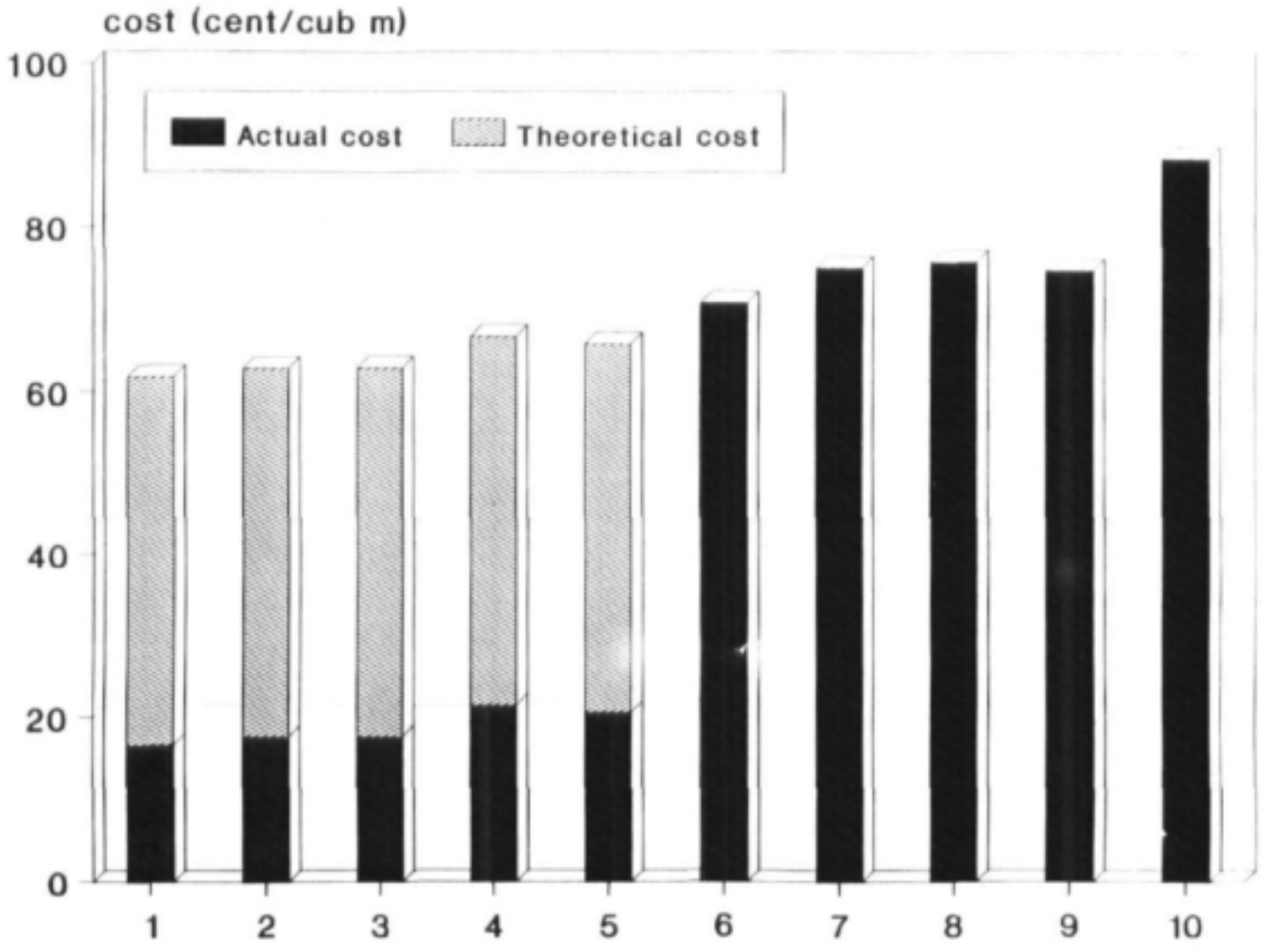


Fig 11.2 Production cost comparison (1983 to 1986)

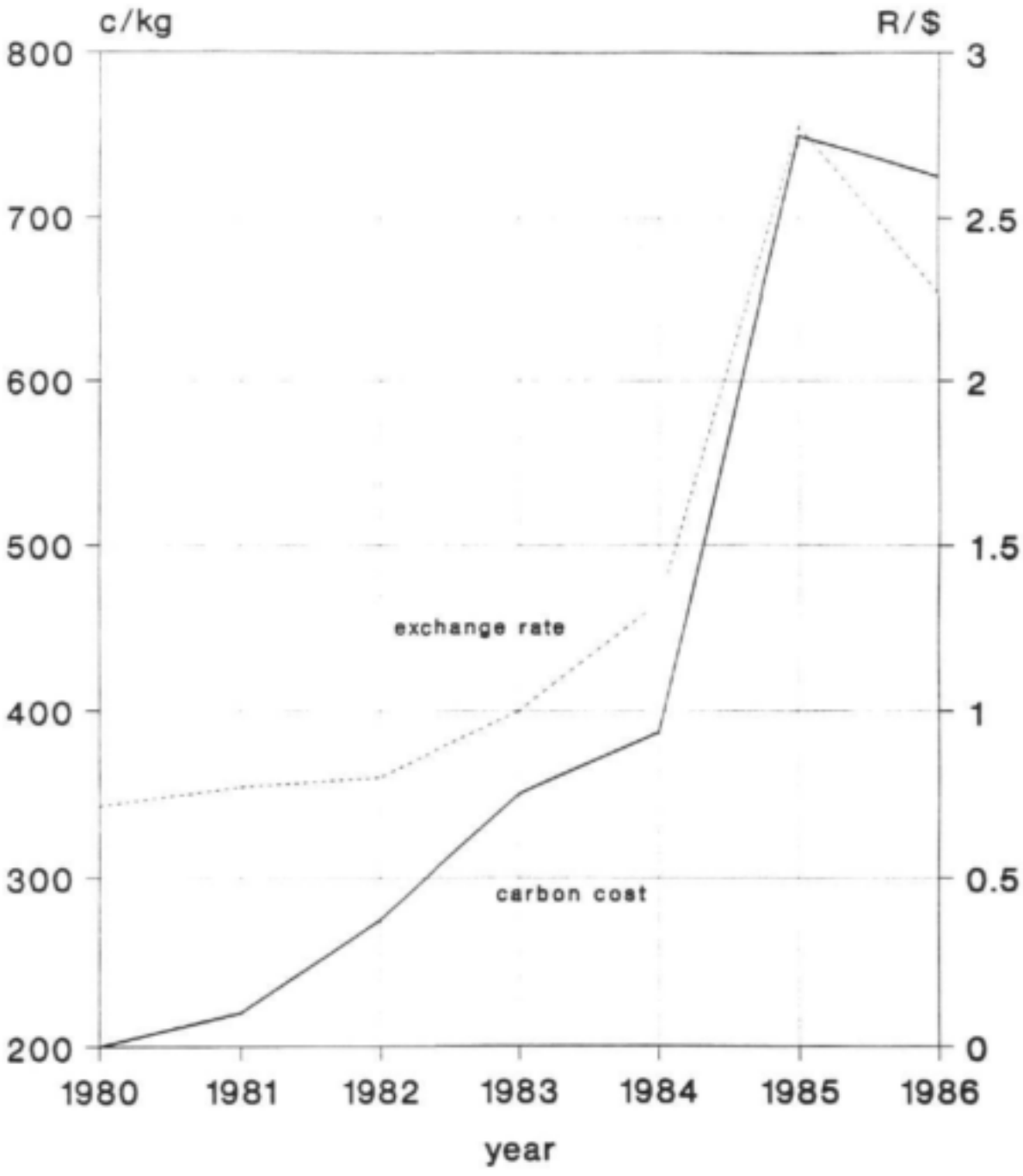


Fig 11.3 Activated carbon price increase vs exchange rate

11.3 Discussion

The overall production cost of reclaimed water for this prototype plant is about 88 c/m^3. Fifty per cent of this cost is plant size dependent and is much higher than the average production cost of potable water in the Cape Town area.

At present Cape Town's potable water supplies are from storage dams fed by mountain run-off making the treatment fairly simple and relatively cheap. The high cost element associated with the activated carbon treatment accounts for approximately 33 % of the production cost of reclaimed water. However, the practices of in line ozonation, which is reported to prolong the life of the carbon (van Leeuwen, 1988) as well as on site carbon regeneration could play a significant role in reducing these costs for a full scale application. Activated carbon treatment is the most expensive reclamation unit process but remains an absolute necessity for the production of potable water.

The cost element of 1,4c/m^3 related to ozonation is made up of electricity and fresh water consumption. This is lower than the reported 1,7c/m^3 at the Stander plant for electricity only (Hart, 1981). Significantly higher doses of ozone were used at the Pretoria plant which accounts for the higher electricity consumption.

The theoretical value associated with capital amortisation was obtained by estimating the plant replacement value at R2,49 million (1986 value) which would be repaid over 15 years at an interest rate of 17,5%. The following formula was used to calculate the annual or monthly premium.

$$P = Vi \{1 / 1 - (1+i)^{-n}\}$$

where V = capital outlay
P = payment per annum/per month
i = interest/100
n = number of years/months of loan duration.

CHAPTER 12

DISCUSSION AND CONCLUSIONS

1 Water reclamation, by the production of a potable water from an activated sludge plant effluent is a viable source for the supplementation of potable water supplies but should only be used when all other economical aspects of water supplementation have been explored and implemented.

2 The operational, maintenance and surveillance programmes proved conclusively that larger local authorities are capable of owning, maintaining and running a water reclamation plant which consistently produces a water of potable quality.

3 The total cost of producing reclaimed water at the Cape Flats reclamation plant was about 88 c/m^3 which is much higher than the cost of about 20 c/m^3 of producing fresh water in the Cape Town area (1986 costs). Approximately 33% of the total cost was associated with the activated carbon process. It is envisaged that ozonation prior to activated carbon treatment and on site carbon regeneration would significantly reduce the production cost of a full scale plant. The costs of fresh and reclaimed waters will tend to converge in future.

4 The wastewater treatment works supplying the feed water to the Cape Flats reclamation plant is a nutrient removal plant of the five stage Bardenpho type and the process configuration of the reclamation plant was specifically selected for this type of effluent. Pilot or prototype plant studies should be undertaken before full scale implementation of a water reclamation scheme.

5 It is essential that the wastewater treatment works supplying the feed water to the reclamation process is properly optimised, operated and controlled. This would ensure that the quality of the feed water to the reclamation process would be free from major fluctuations in quality and that the consistent supply of an acceptable feed water would always be available. During periods where the quality is unacceptable this feed water should bypass the reclamation process.

6 The inclusion of a feedwater quality equalisation and buffer pond is essential to prevent water of fluctuating quality from being supplied to the reclamation plant.

7 The provision of backup or standby mechanical equipment is essential to maintain the uninterrupted production of a potable water supply.

8 A comprehensive virological study of the reclaimed water was conducted during the surveillance period. All the samples examined during this time were clear and no viruses or coliphages were detected. By virological standards the reclaimed water is perfectly potable (Hodgkiss *et al.*, 1989).

9 The chemical quality of the reclaimed water, during the intensive surveillance period, conformed to the recommended limits for drinking water (Kempster and Smith, 1985).

10 Bacteriological examination of the reclaimed water during the intensive surveillance period indicated that, except for the standard plate count, the quality of the reclaimed water was well within generally accepted limits for drinking water. However, the occasional high standard plate count does not necessarily constitute a health risk but it does reflect occasional inadequate final disinfection.

11 The trihalomethane (THM) results obtained during the intensive surveillance period showed that the quality of the reclaimed water was well within the USEPA criterium of 100 $\mu g/l$ for drinking water. An increase in the THM values over the last three weeks of the surveillance period indicated that the activated carbon had become saturated with respect of the adsorption of THM's.

12 Consistently low dissolved organic carbon (DOC) concentrations were obtained on the reclaimed water throughout the intensive surveillance period.

13 The ongoing surveillance programmes which will be used in a full scale application will have to be intensive and will require more detailed analyses than for fresh water plants. It is essential that automatic surveillance equipment is provided.

14 Aluminium sulphate, ferric chloride and ferric sulphate were all successful as flocculants. Ferric sulphate however was used predominantly. Polyelectrolytes aided the flocculation process when added in low dosages.

15 The combined use of ferric sulphate and chlorine together with the poorly buffered feed water produced a corrosive water with a depressed pH value. Calcium hydroxide was used to stabilise this water to a pH value of about 9. This however resulted in the precipitation of relatively small quantities of calcium carbonate in the reclaimed water. This precipitate did not affect the final disinfection process as final chlorination preceded final stabilisation.

16 The use of ozonation prior to activated carbon treatment was found to increase the life of the carbon by about 40%. This concurs with other research findings (Van Leeuwen, 1988).

CHAPTER 13

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APPENDIX 1

Intensive surveillance programme

Chemical analyses of sample groups A and B by the CCC and Watertek

CAPE FLATS WATER RECLAMATION PLANT

INTENSIVE SURVEILLANCE PROGRAMME (86/09/29-86/12/08)

			WEEK NUMBER											STATISTICS			RECOMMENDE
PARAMETER	UNIT	SAMPLE	1	2	3	4	5	6	7	8	9	10	11	MIN	MAX	MEAN	S	LIMIT S
Conductivity	mS/m	CR1	88.0	88.0	88.0	91.0	90.0	97.0	88.0	91.0	90.0	90.0	90.0	88.0	97.0	90.1	2.5	
		CR2	90.0	91.0	89.0	93.0	92.0	93.0	91.0	92.0	92.0	92.0	92.0	89.0	93.0	91.5	1.2	
		CR3	90.0	91.0	89.0	92.0	92.0	94.0	91.0	93.0	92.0	93.0	92.0	89.0	94.0	91.7	1.4	
		CR4	90.0	91.0	89.0	91.0	91.0	93.0	91.0	93.0	92.0	94.0	91.0	89.0	94.0	91.5	1.4	
		CR5	92.0	91.0	89.0	91.0	90.0	92.0	91.0	93.0	92.0	93.0	87.0	87.0	93.0	91.0	1.7	70
pH		CR1	7.7	7.8	7.8	7.8	7.8	7.8	7.7	7.6	7.7	7.7	8.5	7.6	8.5	7.8	0.2	
		CR2	6.6	6.3	6.4	6.6	6.5	6.4	6.2	5.7	6.0	5.7	6.5	5.7	6.6	6.3	0.3	
		CR3	6.7	6.5	6.6	6.8	6.9	6.6	6.4	6.0	6.2	5.9	6.7	5.9	6.9	6.5	0.3	
		CR4	6.7	6.5	6.6	6.5	6.4	6.5	5.9	5.7	5.9	5.7	6.0	5.7	6.7	6.2	0.4	
		CR5	7.3	7.3	7.5	8.0	8.8	8.9	8.9	9.0	9.4	9.2	9.5	7.3	9.5	8.5	0.8	6 TO 9
Alkalinity	mg/l	CR1	114.0	112.0	111.0	132.0	112.0	224.0	100.0	120.0	104.0	105.0	112.0	100.0	224.0	122.4	33.2	
	as	CR2	26.0	18.0	25.0	31.0	24.0	40.0	12.0	10.0	8.0	7.0	20.0	7.0	40.0	20.1	9.9	
	CaCO3	CR3	28.0	21.0	26.0	32.0	26.0	50.0	12.0	8.0	8.0	6.0	18.0	6.0	50.0	21.4	12.5	
		CR4	22.0	24.0	24.0	20.0	16.0	36.0	2.0	4.0	2.0	4.0	8.0	2.0	36.0	14.7	10.9	
		CR5	42.0	46.0	43.0	40.0	24.0	46.0	24.0	24.0	46.0	24.0	30.0	24.0	46.0	35.4	9.6	
Colour	Hazen	CR1	60.0	50.0	50.0	50.0	60.0	60.0	70.0	60.0	40.0	50.0	80.0	40.0	80.0	57.3	10.5	
		CR2	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	0.0	0.0	0.0	0.0	
		CR3	<5	<5	<5	<5	<5	<5	<5	5	20.0	<5	<5	0.0	20.0	1.8	5.7	
		CR4	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	0.0	0.0	0.0	0.0	
		CR5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	0.0	0.0	0.0	0.0	
COD	mg/l	CR1	54.0	62.0	36.0	34.0	36.0	34.0	34.0	38.0	40.0	32.0	52.0	32.0	62.0	41.1	9.6	
	as O	CR2	15.0	16.0	16.0	17.0	15.0	14.0	15.0	15.0	13.0	17.0	14.0	13.0	17.0	15.2	1.2	
		CR3	12.0	15.0	12.0	14.0	12.0	12.0	14.0	16.0	13.0	14.0	15.0	12.0	16.0	13.5	1.4	
		CR4	6.0	3.0	7.0	5.0	4.0	3.0	5.0	5.0	2.0	6.0	4.0	2.0	7.0	4.5	1.4	
		CR5	3.0	4.0	2.0	3.0	3.0	3.0	3.0	7.0	3.0	6.0	5.0	2.0	7.0	3.8	1.5	
Chloride	mg/l	CR1	146.0	188.0	144.0	148.0	144.0	141.0	152.0	188.0	146.0	152.0	148.0	141.0	188.0	154.3	16.2	
	as Cl	CR2	146.0	152.0	142.0	144.0	140.0	140.0	145.0	196.0	150.0	160.0	146.0	140.0	196.0	151.0	15.3	
		CR3	146.0	148.0	144.0	144.0	140.0	138.0	152.0	196.0	150.0	152.0	148.0	138.0	196.0	150.7	14.9	
		CR4	146.0	148.0	142.0	144.0	140.0	138.0	152.0	160.0	150.0	152.0	150.0	138.0	160.0	147.5	6.0	
		CR5	144.0	144.0	142.0	144.0	136.0	135.0	148.0	176.0	144.0	148.0	148.0	135.0	176.0	146.3	10.3	250
Nitrate	mg/l	CR1	1.2	0.8	1.1	0.6	1.0	1.0	1.3	0.5	0.8	1.6	0.9	0.5	1.6	1.0	0.3	
	as N	CR2	1.7	1.9	1.6	1.1	1.0	1.4	1.7	1.2	1.3	2.1	1.1	1.0	2.1	1.5	0.3	
		CR3	1.8	1.8	1.7	1.1	1.3	1.4	1.4	1.1	1.3	2.2	1.1	1.1	2.2	1.5	0.3	
		CR4	1.6	1.9	2.0	2.5	2.7	2.1	1.2	1.5	1.7	2.0	2.1	1.2	2.7	1.9	0.4	
		CR5	1.6	1.9	1.8	2.0	2.1	1.7	1.6	1.5	0.7	2.1	1.8	0.7	2.1	1.7	0.4	6
Ammonia	mg/l	CR1	1.2	0.7	0.4	2.0	0.4	1.5	1.6	4.0	0.2	2.0	0.2	0.2	4.0	1.3	1.1	
	as N	CR2	0.7	0.4	0.6	2.0	1.6	1.4	1.0	2.2	0.8	0.8	0.1	0.1	2.2	1.1	0.6	
		CR3	0.6	0.5	0.7	2.0	1.6	1.4	2.1	2.1	0.7	0.7	0.2	0.2	2.1	1.1	0.7	
		CR4	0.4	0.2	0.3	0.4	0.1	0.9	0.6	0.6	0.2	0.2	0.1	0.1	0.9	0.4	0.2	
		CR5	0.2	0.1	0.1	0.1	0.1	0.2	0.5	0.3	0.1	0.2	0.1	0.1	0.5	0.2	0.1	1

CAPE FLATS WATER RECLAMATION PLANT

INTENSIVE SURVEILLANCE PROGRAMME (86/09/29-86/12/08)

PARAMETER	UNIT	SAMPLE	WEEK NUMBER 1	2	3	4	5	6	7	8	9	10	11	STATISTICS MIN	MAX	MEAN	S	RECOMMENDED LIMIT
Organic N	mg/l as N	CR1	1.4	2.4	1.7	1.4	2.8	1.4	1.0	0.9	2.4	0.2	2.4	0.2	2.8	1.6	0.8	
		CR2	0.2	0.5	0.5	0.2	0.6	0.6	0.3	0.4	0.9	0.3	1.0	0.2	1.0	0.5	0.3	
		CR3	0.2	0.5	0.4	0.2	0.6	0.6	0.3	0.3	0.2	0.7	0.8	0.2	0.8	0.4	0.2	
		CR4	0.1	0.0	0.2	0.2	0.2	0.3	0.1	0.2	0.2	0.3	0.3	0.0	0.3	0.2	0.1	
		CR5	0.1	0.2	0.3	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.5	0.1	0.5	0.2	0.1	
Ortho PO4	mg/l as P	CR1	1.88	2.00	2.79	3.75	4.17	4.57	3.00	4.14	6.57	2.75	3.57	1.88	6.57	3.56	1.27	
		CR2	0.01	0.02	0.02	0.01	0.01	0.01	<0.01	0.01	0.01	0.02	0.03	0.00	0.03	0.01	0.01	
		CR3	0.02	0.02	0.02	0.01	0.01	0.02	<0.01	0.01	0.03	0.02	0.01	0.00	0.03	0.02	0.01	
		CR4	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.11	0.06	0.06	0.01	0.11	0.03	0.03	
		CR5	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.04	0.02	0.01	0.01	0.04	0.01	0.01	
Organic PO4	mg/l as P	CR1	0.56	0.65	0.32	0.28	0.14	0.14	0.43	0.71	0.40	0.15	2.32	0.14	2.32	0.55	0.59	
		CR2	0.03	0.01	0.03	0.02	<0.01	0.01	0.01	0.01	0.01	0.01	<0.01	0.00	0.03	0.01	0.01	
		CR3	0.03	0.02	0.02	0.02	<0.01	<0.01	0.01	0.01	0.05	0.01	0.01	0.00	0.05	0.02	0.01	
		CR4	0.03	0.02	<0.01	0.01	0.01	<0.01	0.03	0.03	0.01	0.01	0.02	0.00	0.03	0.02	0.01	
		CR5	0.04	<0.01	<0.01	0.01	<0.01	<0.01	0.01	0.01	<0.01	0.01	<0.01	0.00	0.04	0.01	0.01	
Turbidity	NTU	CR1	9.50	9.40	3.90	4.10	2.60	2.70	3.30	2.49	4.10	2.60	5.60	2.40	9.50	4.56	2.47	
		CR2	0.56	0.53	0.40	0.31	0.37	0.46	0.37	0.26	0.33	0.24	0.38	0.24	0.56	0.38	0.10	
		CR3	0.58	0.91	0.45	0.50	0.32	0.55	0.55	0.87	0.80	0.76	0.53	0.32	0.91	0.62	0.18	
		CR4	0.18	0.16	0.15	0.20	0.26	0.19	0.25	0.25	0.34	0.18	0.42	0.15	0.42	0.24	0.09	
		CR5	0.70	0.82	0.42	15.00	2.10	2.10	2.20	0.63	2.10	1.20	0.95	0.42	15.00	2.57	3.99	1
Sodium	mg/l as Na	CR1	117	127	117	121	126	120	119	143	125	135	140	117	143	126	8.7	
		CR2	115	118	114	117	125	117	118	141	128	126	138	114	141	123	8.8	
		CR3	111	120	116	115	126	117	119	143	125	125	135	111	143	123	8.9	
		CR4	113	117	114	114	123	119	117	136	126	128	136	113	136	122	8.1	
		CR5	109	116	110	110	118	114	112	130	119	122	126	109	130	117	6.6	100
Potassium	mg/l as K	CR1	14.5	15.1	14.6	15.8	15.8	17.3	15.9	17.6	16.5	15.2	17.9	14.5	17.9	16.0	1.1	
		CR2	14.0	14.3	14.5	14.6	15.2	17.1	15.5	17.0	16.2	14.6	17.4	14.0	17.4	15.5	1.2	
		CR3	13.7	13.7	14.3	14.9	14.9	16.6	15.5	17.2	16.1	14.6	17.3	13.7	17.3	15.3	1.2	
		CR4	13.8	13.6	14.3	14.9	15.3	17.6	15.6	16.4	16.0	14.8	17.2	13.6	17.6	15.4	1.2	
		CR5	13.6	13.0	13.7	14.0	15.0	16.4	15.2	15.6	15.2	14.3	16.6	13.0	16.6	14.8	1.1	200
Calcium	mg/l as Ca	CR1	46.9	45.6	45.5	46.9	43.3	41.1	41.2	43.5	40.2	39.5	45.8	39.5	46.9	43.6	2.6	
		CR2	44.3	45.2	43.2	44.0	42.2	42.1	40.7	43.8	40.9	39.0	45.5	39.0	45.5	42.8	1.9	
		CR3	43.6	43.5	42.7	44.9	44.7	42.7	40.2	43.0	40.9	40.6	44.0	40.2	44.9	42.8	1.5	
		CR4	43.2	44.3	44.2	44.2	46.1	43.9	40.7	44.2	40.7	40.2	41.0	40.2	46.1	43.0	1.9	
		CR5	57.4	56.6	53.6	69.1	57.9	59.2	53.7	52.6	61.2	53.3	59.0	52.6	69.1	57.6	4.5	150
Magnesium	mg/l as Mg	CR1	8.8	8.6	8.7	8.8	8.8	8.2	7.7	8.9	8.5	7.9	8.4	7.7	8.9	8.5	0.4	
		CR2	8.7	8.4	8.4	8.8	8.5	8.4	8.0	8.6	9.3	7.8	8.1	7.8	9.3	8.4	0.4	
		CR3	8.3	8.3	8.3	8.6	8.8	8.3	7.9	8.6	9.3	7.8	8.1	7.8	9.3	8.4	0.4	
		CR4	8.3	8.1	8.3	8.5	8.5	8.4	7.8	8.6	9.3	7.8	7.8	7.8	9.3	8.3	0.4	
		CR5	8.1	8.0	8.0	8.0	8.5	8.0	6.6	7.0	8.4	7.1	6.2	6.2	8.5	7.6	0.7	70

CAPE FLATS WATER RECLAMATION PLANT

INTENSIVE SURVEILLANCE PROGRAMME (86/09/29-86/12/08)

			WEEK NUMBER											STATISTICS			RECOMMENDED
PARAMETER	UNIT	SAMPLE	1	2	3	4	5	6	7	8	9	10	11	MIN	MAX	MEAN	S	LIMIT #
Sulphate	mg/l	CR1	78	80	82	86	91	93	89	90	95	90	88	78	95	87	5.2	
	as SO4	CR2	163	172	170	177	180	191	176	192	190	184	183	163	192	180	8.9	
		CR3	163	172	168	174	185	194	181	197	189	185	182	163	197	181	10.2	
		CR4	157	169	187	175	181	183	192	198	188	184	185	157	198	182	10.8	
		CR5	119	159	159	167	175	185	172	172	182	177	178	119	185	168	17.3	200
Flouride	mg/l	CR1	0.11	0.12	0.14	0.12	0.14	0.10	0.13	0.10	0.10	0.19	0.12	0.10	0.19	0.12	0.03	
	as F	CR2	0.10	0.09	0.12	0.13	0.10	0.10	0.10	0.14	0.10	0.14	0.10	0.09	0.14	0.11	0.02	
		CR3	0.10	0.14	0.11	0.10	0.11	0.10	0.09	0.09	0.11	0.13	0.10	0.09	0.14	0.10	0.02	
		CR4	0.09	0.11	0.12	0.10	0.10	0.11	0.21	0.11	0.11	0.12	0.10	0.09	0.21	0.11	0.03	
		CR5	0.09	0.09	0.11	0.09	0.09	0.10	0.12	0.08	0.11	0.10	0.10	0.08	0.12	0.10	0.01	1
Phenol	ug/l	CR1	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	0.0	0.0	0.0	0.0	
	as	CR2	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	0.0	0.0	0.0	0.0	
	C6H5OH	CR3	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	0.0	0.0	0.0	0.0	
		CR4	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	0.0	0.0	0.0	0.0	
		CR5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	0.0	0.0	0.0	0.0	5
Cyanide	ug/l	CR1	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	0.0	0.0	0.0	0.0	
	as Cn	CR2	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	0.0	0.0	0.0	0.0	
		CR3	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	0.0	0.0	0.0	0.0	
		CR4	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	0.0	0.0	0.0	0.0	
		CR5	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	0.0	0.0	0.0	0.0	200
Boron	ug/l	CR1	165	158	150	177	204	177	197	189	189	189	180	150	204	180	15.8	
	as B	CR2	186	158	147	167	186	173	191	189	173	189	171	147	191	175	13.6	
		CR3	178	176	140	163	181	173	274	182	174	186	167	140	274	181	31.7	
		CR4	219	183	98	162	209	178	207	198	188	189	126	98	219	178	35.0	
		CR5	213	182	140	177	196	173	192	188	189	178	148	140	213	180	19.8	500
Cadmium	ug/l	CR1	2.0	2.0	1.0	1.0	2.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.0	1.3	0.4	
	as Cd	CR2	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.0	
		CR3	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.0	
		CR4	1.0	1.0	1.0	1.0	1.0	1.0	2.0	1.0	1.0	1.0	1.0	1.0	2.0	1.1	0.3	
		CR5	1.0	2.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.0	1.1	0.3	10
Cobolt	ug/l	CR1	6.0	6.0	6.0	6.0	7.0	6.0	7.0	5.0	5.0	6.0	7.0	5.0	7.0	6.1	0.7	
	as Co	CR2	6.0	5.0	4.0	6.0	5.0	7.0	8.0	7.0	5.0	5.0	6.0	4.0	8.0	5.8	1.1	
		CR3	6.0	6.0	4.0	6.0	6.0	7.0	6.0	4.0	6.0	6.0	4.0	4.0	7.0	5.5	1.0	
		CR4	5.0	4.0	3.0	5.0	4.0	3.0	6.0	5.0	5.0	6.0	3.0	3.0	6.0	4.5	1.1	
		CR5	4.0	5.0	6.0	5.0	3.0	4.0	9.0	6.0	5.0	4.0	5.0	3.0	9.0	5.1	1.5	250
Chromium	ug/l	CR1	2.0	16.0	7.0	6.0	2.0	10.0	8.0	3.0	4.0	7.0	4.0	2.0	16.0	6.3	3.9	
	as Cr	CR2	<1	1.0	4.0	1.0	2.0	1.0	3.0	1.0	1.0	2.0	<1	0.0	4.0	1.5	1.2	
		CR3	<1	<1	6.0	1.0	1.0	5.0	<1	2.0	3.0	2.0	5.0	0.0	6.0	2.3	2.1	
		CR4	1.0	<1	2.0	<1	<1	1.0	<1	1.0	2.0	3.0	5.0	0.0	5.0	1.4	1.5	
		CR5	<1	<1	1.0	3.0	<1	5.0	5.0	3.0	<1	5.0	2.0	0.0	5.0	2.2	2.0	100

CAPE FLATS WATER RECLAMATION PLANT

INTENSIVE SURVEILLANCE PROGRAMME (86/09/29-86/12/08)

			WEEK NUMBER											STATISTICS			RECOMMENDE
PARAMETER	UNIT	SAMPLE	1	2	3	4	5	6	7	8	9	10	11	MIN	MAX	MEAN	S	LIMIT #
Copper	ug/l	CR1	9.0	12.0	5.0	5.0	6.0	5.0	5.0	5.0	8.0	6.0	6.0	5.0	12.0	6.5	2.1	
	as Cu	CR2	2.0	3.0	3.0	2.0	2.0	3.0	4.0	3.0	3.0	3.0	2.0	2.0	12.0	4.6	2.5	
		CR3	7.0	7.0	5.0	6.0	6.0	5.0	5.0	6.0	9.0	7.0	4.0	2.0	9.0	6.4	2.0	
		CR4	9.0	8.0	12.0	4.0	3.0	5.0	26.0	9.0	17.0	13.0	12.0	3.0	26.0	10.7	6.3	
		CR5	4.0	3.0	3.0	3.0	2.0	3.0	2.0	2.0	4.0	3.0	2.0	2.0	4.0	2.8	0.7	500
Mercury	ug/l	CR1	n/r	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	0.0	0.0	0.0	0.0	
	as Hg	CR2	n/r	<1	<1	<1	1.0	<1	1.0	<1	1.0	<1	<1	0.0	1.0	0.3	0.4	
		CR3	n/r	<1	<1	<1	<1	<1	1.0	<1	1.0	1.0	<1	0.0	1.0	0.3	0.4	
		CR4	n/r	1.0	2.0	1.0	1.0	<1	<1	<1	<1	<1	<1	0.0	2.0	0.5	0.7	
		CR5	n/r	2.0	1.0	<1	<1	<1	<1	<1	<1	1.0	<1	0.0	2.0	0.4	0.6	5
Nickel	ug/l	CR1	9.0	10.0	7.0	6.0	9.0	10.0	10.0	12.0	12.0	9.0	9.0	6.0	12.0	9.4	1.7	
	as Ni	CR2	8.0	8.0	10.0	8.0	9.0	8.0	11.0	11.0	12.0	9.0	9.0	8.0	12.0	9.4	1.4	
		CR3	9.0	6.0	10.0	11.0	9.0	10.0	10.0	12.0	10.0	11.0	8.0	6.0	12.0	9.6	1.6	
		CR4	8.0	11.0	9.0	8.0	11.0	13.0	13.0	14.0	20.0	10.0	13.0	8.0	20.0	11.8	3.3	
		CR5	8.0	7.0	7.0	10.0	9.0	7.0	7.0	8.0	7.0	2.0	8.0	2.0	10.0	7.0	2.0	250
Lead	ug/l	CR1	11.0	14.0	13.0	11.0	11.0	16.0	8.0	13.0	14.0	11.0	18.0	8.0	18.0	12.7	2.6	
	as Pb	CR2	8.0	10.0	14.0	10.0	10.0	9.0	5.0	12.0	13.0	13.0	11.0	5.0	14.0	10.5	2.5	
		CR3	12.0	13.0	14.0	9.0	7.0	6.0	12.0	14.0	9.0	12.0	11.0	6.0	14.0	10.8	2.6	
		CR4	12.0	10.0	13.0	12.0	9.0	9.0	11.0	16.0	9.0	11.0	14.0	9.0	16.0	11.5	2.1	
		CR5	15.0	15.0	10.0	13.0	14.0	13.0	11.0	16.0	17.0	15.0	14.0	10.0	17.0	13.9	2.0	50
Zinc	ug/l	CR1	31.0	38.0	14.0	18.0	27.0	19.0	92.0	17.0	23.0	14.0	24.0	14.0	92.0	28.8	21.2	
	as Zn	CR2	16.0	25.0	17.0	15.0	15.0	20.0	25.0	16.0	16.0	12.0	7.0	7.0	25.0	16.7	5.0	
		CR3	90.0	134.0	90.0	100.0	72.0	73.0	113.0	97.0	67.0	71.0	42.0	42.0	134.0	86.3	23.9	
		CR4	95.0	89.0	92.0	84.0	86.0	71.0	96.0	104.0	98.0	57.0	37.0	37.0	104.0	82.6	19.2	
		CR5	70.0	28.0	26.0	31.0	31.0	22.0	20.0	22.0	36.0	7.0	7.0	7.0	70.0	27.3	16.1	1000
Arsenic	ug/l	CR1	<1	1.0	<1	<1	1.0	2.0	1.0	<1	<1	1.0	1.0	0.0	2.0	0.6	0.6	
	as As	CR2	<1	<1	<1	<1	<1	1.0	<1	<1	<1	<1	<1	0.0	1.0	0.1	0.3	
		CR3	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	0.0	0.0	0.0	0.0	
		CR4	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	0.0	0.0	0.0	0.0	
		CR5	<1	<1	<1	<1	<1	1.0	<1	<1	<1	<1	<1	0.0	1.0	0.1	0.3	100
Aluminium	ug/l	CR1	265	208	73	77	128	90	76	78	113	80	109	73	265	118	59.7	
	as Al	CR2	69	53	45	31	24	18	25	33	43	19	7	7	69	34	17.0	
		CR3	57	28	29	36	11	10	14	29	37	20	12	10	57	26	13.7	
		CR4	57	20	26	7	22	28	81	97	115	46	54	7	115	50	33.1	
		CR5	88	132	115	120	103	85	80	73	115	58	54	54	132	93	24.7	150
Iron	ug/l	CR1	492	490	238	522	486	454	382	406	490	274	386	238	522	420	89.5	
	as Fe	CR2	144	130	114	86	48	82	88	48	100	52	90	48	144	89	30.5	
		CR3	146	188	148	164	72	108	140	126	144	114	148	72	188	136	29.3	
		CR4	16	22	20	22	18	26	16	20	16	10	46	10	46	21	8.8	
		CR5	58	60	52	58	34	34	42	48	52	28	38	28	60	46	10.7	100

CAPE FLATS WATER RECLAMATION PLANT

INTENSIVE SURVEILLANCE PROGRAMME (86/09/29-86/12/08)

			WEEK NUMBER											STATISTICS			RECOMMENDE
PARAMETER	UNIT	SAMPLE	1	2	3	4	5	6	7	8	9	10	11	MIN	MAX	MEAN	S	LIMIT *
Manganese	ug/l	CR1	42	39	32	61	7	34	38	29	21	21	33	7	61	32	13.2	
	as Mn	CR2	166	153	144	209	203	216	172	147	191	174	35	35	216	165	47.3	
		CR3	154	177	132	215	195	191	183	210	186	176	57	57	215	171	42.3	
		CR4	52	24	16	53	191	178	193	104	122	117	63	16	193	101	62.2	
		CR5	44	22	21	26	33	29	49	15	125	20	10	10	125	36	30.3	50

NOTES :1. SAMPLING POINTS .....CR1 - FEED WATER
CR2 - SAND FILTER EFFLUENT
CR3 - OZONE TANK EFFLUENT
CR4 - CARBON COLUMN EFFLUENT
CR5 - FINAL RECLAIMED WATER

2. * - RECOMMENDED LIMIT as given by KEMPSTER and SMITH (CSIR report number 628)

3. All the above mentioned results were reported by THE SCIENTIFIC SERVICES BRANCH of the CCC.

APPENDIX 2

Intensive surveillance programme

Microbiological analyses of sample group C by Watertek

COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

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W.9/23/1/42

CAPE FLATS WATER RECLAMATION PLANT : MICROBIOLOGICAL ANALYSES

(Period: 3 September to 2 December 1986)

b y

W O K Grabow and R Kfir

for

Water Quality Division

INTRODUCTION

Water samples from the following treatment stages were flown to Pretoria and analysed within 24 h:

CR 1 = Raw water intake
CR 2 = After sand filtration
CR 3 = Before carbon filtration
CR 4 = After carbon filtration
CR 5 = After final chlorination

Analyses for conventional indicators such as coliform bacteria and coliphages were carried out by the NIWR Branch Laboratory in Bellville. Tests for enteric viruses were carried out by Prof. J W Moodie of the University of Cape Town.

RESULTS

Results are listed in Tables 1 to 7.

DISCUSSION

Clostridia. These anaerobic, Gram-positive spore-formers are indicators of faecal pollution. Since their spores are more resistant to unfavourable environmental conditions, including disinfection processes, than most pathogenic bacteria or viruses, their absence is strong evidence of microbiologically safe water. The absence of clostridia from all samples of CR 5 does, therefore, indicate efficient treatment. The occasional detection of clostridia in Pretoria tapwater (Table 6) indicates that the reclaimed water was of a better quality.

Acid-fast bacteria. These bacteria are not specific for faecal pollution. They occur in large numbers in polluted water and can multiply in sandfilters and activated carbon columns. They are useful indicators of the efficiency of disinfection processes because they are exceptionally resistant due to a protective mucopeptide layer. Their absence from all samples of CR 5 does, therefore, indicate efficient disinfection. The occasional detection of these organisms in Pretoria tapwater (Table 6) may be due to aftergrowth in the distribution system.

Legionella bacteria. These bacteria cause legionellosis (Legionnaires' disease) which is a lung disease resembling pneumonia. Infection is generally caused by the inhalation of contaminated water in the form of aerosols such as those generated by showers, cooling towers, sprinklers and air-conditioning systems. The bacteria are more resistant to chlorination than coliform bacteria, and can multiply in certain water environments. Tests for legionellas were included in

this study because information on their growth requirements indicates that they may multiply in carbon filters.

The results in Tables 3 to 5 show a significantly higher incidence of legionellas in the water after carbon filtration than before, which implies multiplication in the carbon columns. The occasional detection in CR 5 indicates that their numbers were reduced by chlorination, but the bacteria were not completely inactivated. This is an important finding because the absence of indicators such as clostridia, acid-fast bacteria, coliphages and coliform bacteria is generally considered as reliable evidence of sufficient disinfection. Quality guidelines for *Legionella* bacteria in water supplies have not yet been formulated, and there is no evidence that the levels detected in CR 5 may constitute a significant health risk. These observations add another pathogen to the list of health-related micro-organisms which proliferate in activated carbon columns, and emphasize the importance of efficient post-disinfection.

Bacterial endotoxins. These are degradation products of bacterial cell walls which cause endotoxic shock when administered intravenously as in cases of therapeutic treatment or kidney dialysis. There are also indications that they may cause gastro-intestinal disorders. Tests for endotoxins were mainly included because there is reason to believe that levels may increase during activated carbon filtration due to bacterial growth on the carbon. The results in Tables 1 to 6 show extensive removal during early treatment stages followed by some increase during carbon filtration. Final chlorination reduced levels considerably, but not completely. The levels of endotoxins in CR 5 (average 12 EU/mℓ) were lower than those in Pretoria tapwater (average 31 EU/mℓ) and Windhoek reclaimed water (average 71 EU/mℓ). There are no quality guidelines for endotoxins in water supplies, but available information indicates that it is most unlikely that the very low levels detected in CR 5 may constitute a meaningful health risk.

Ames *Salmonella* mutagenicity assay. The assay detects mutagenic compounds, about 90% of which are carcinogenic. Mutagens in water are generally organic compounds, particularly chlorinated hydrocarbons, but may also include inorganic compounds and certain metals. The results in Table 7 are expressed in mutagenicity ratios (MR). An MR value of 2,0 or more is considered as a statistically significant indication of mutagenic activity. The very low MR values for CR 5, except for the sample of 2 December 1986, indicate that there is no reason for concern. These values are lower than those recorded for conventional drinking water supplies.

CONCLUSIONS

The results of analyses carried out in this investigation indicate that, except for the standard plate count and *Legionella* bacteria, the quality of the final reclaimed water was well within generally accepted limits for drinking water. Although the high standard plate count and occasional presence of *Legionella* bacteria in CR 5 may not constitute a meaningful health risk, it does reflect inadequate final disinfection.

- - - o 0 o - - -

PRETORIA.
9 March 1987
WOKG/dr.

NATIONAL INSTITUTE FOR WATER RESEARCH

WATER QUALITY DIVISION

RESULTS OF MICROBIOLOGICAL ANALYSES

TABLE: 1 SAMPLE: CR 1 : Cape Flats Water Reclamation Plant, raw water intake

Date 1986	09-30	10-07	10-14	10-21	10-28	11-04	11-11	11-18	11-25	12-02		Average
Standard plate count per mℓ												
Total coliforms per 100 mℓ												
Faecal coliforms per 100 mℓ												
Faecal streptococci per 100 mℓ												
Clostridia/100 mℓ												
Acid-fast bacteria/ 100 mℓ												
Legionella bacteria/ 500 mℓ Microscopy Cultivation												
Bacterial endotoxins = EU/mℓ	1 800	1 840	1 440	1 205	860	870	1 400	1 260	ND	ND		1 334
Coliphages												
Enteric viruses/10 ℓ Type												

ND = not done

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WATER QUALITY DIVISION

RESULTS OF MICROBIOLOGICAL ANALYSES

TABLE: 2 SAMPLE: CR 2 : Cape Flats Water Reclamation Plant, after sandfiltration

Date 1986	09-30	10-07	10-14	10-21	10-28	11-04	11-11	11-18	11-25	12-02		Average
Standard plate count per mℓ												
Total coliforms per 100 mℓ												
Faecal *coliforms* per 100 mℓ												
Faecal streptococci per 100 mℓ												
Clostridia/100 mℓ												
Acid-fast bacteria/ 100 mℓ												
Legionella bacteria/ 500 mℓ Microscopy Cultivation												
Bacterial endotoxins = EU/mℓ	84	52	37	25	33	30	25	12	ND	ND		37
Coliphages												
Enteric viruses/10 ℓ Type												

ND = not done

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WATER QUALITY DIVISION

RESULTS OF MICROBIOLOGICAL ANALYSES

TABLE: 3 SAMPLE: CR 3 : Cape Flats Water Reclamation Plant, before carbon filtration

Date 1986	09-30	10-07	10-14	10-21	10-28	11-04	11-11	11-18	11-25	12-02		Average
Standard plate count per mℓ			5	4	46	10				7		15
Total coliforms per 100 mℓ			0	0	39	0				0		8
Faecal coliforms per 100 mℓ			0	0	0	0				0		0
Faecal streptococci per 100 mℓ			0	0	0	0				0		0
Clostridia/100 mℓ												
Acid-fast bacteria/ 100 mℓ												
Legionella bacteria/ 500 mℓ												
Microscopy	-	-	-	-	-	-	-	-	-	+		10% +
Cultivation	-	-	-	-	-	-	-	-	-	-		0% +
Bacterial endotoxins - EU/mℓ	42	38	32	10	35	27	13	10	25	• ND		26
Coliphages												
Enteric viruses/10 ℓ Type												

ND = not done

A2.8

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RESULTS OF MICROBIOLOGICAL ANALYSES

TABLE: 4 SAMPLE: CR 4 : Cape Flats Water Reclamation Plant, after carbon filtration

Date 1986	09-30	10-07	10-14	10-21	10-28	11-04	11-11	11-18	11-25	12-02		Average
Standard plate count per mℓ			9 600	1 720	1 320	3 370				5 170		4 240
Total coliforms per 100 mℓ			14	7	10	24				0		11
Faecal coliforms per 100 mℓ			0	0	0	0				0		0
Faecal streptococci per 100 mℓ			0	0	0	0				0		0
Clostridia/100 mℓ												
Acid-fast bacteria/ 100 mℓ												
Legionella bacteria/ 500 mℓ												
Microscopy	+	+	+	+	+	++	-	-	-	+		70% +
Cultivation	+	++	-	-	+++	+++	-	+	+	+		70% +
Bacterial endotoxins = EU/mℓ	82	75	26	25	33	32	29	19	28	ND		39
Coliphages												
Enteric viruses/10 ℓ Type												

ND = not done

12.9

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RESULTS OF MICROBIOLOGICAL ANALYSES

TABLE: 5 SAMPLE: CR 5 : Cape Flats Water Reclamation Plant, after final chlorination

Date 1986	09-30	10-07	10-14	10-21	10-28	11-04	11-11	11-18	11-25	12-02		Average
Standard plate count per mℓ				440	5 000	820				910		1 790
Total coliforms per 100 mℓ				0	0	0				2		0
Faecal coliforms per 100 mℓ				0	0	0				0		0
Faecal streptococci per 100 mℓ				0	0	0				0		0
Clostridia/100 mℓ	0	0	0	0	0	0	0	0	0	ND		0
Acid-fast bacteria/ 100 mℓ	1	0	0	1	0	0	0	0	ND	ND		0
Legionella bacteria/ 500 mℓ												
Microscopy	ND	ND	ND	-	+	-	-	-	-	-		14% +
Cultivation	ND	ND	ND	-	++	-	-	-	-	+		29% +
Bacterial endotoxins = EU/mℓ	32	13	11	5	16	12	5	3	12	ND		12
Coliphages												
Enteric viruses/10 ℓ Type												

ND = not done

R2.10

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RESULTS OF MICROBIOLOGICAL ANALYSES

TABLE: 6 SAMPLE: Pretoria tapwater

Date 1986	09-30	10-07	10-14	10-21	10-28	11-04	11-11	11-18	11-25	12-02		Average
Standard plate count per ml												
Total coliforms per 100 ml												
Faecal coliforms per 100 ml												
Faecal streptococci per 100 ml												
Clostridia/100 ml	0	0	1	0	0	0	0	2	0	ND		0
Acid-fast bacteria/ 100 ml	0	3	0	1	4	1	1	32	ND	ND		5
Legionella bacteria/ 500 ml Microscopy Cultivation												
Bacterial endotoxins = EU/ml	ND	29	33	39	ND	17	ND	38	30	ND		31
Coliphages												
Enteric viruses/10 l Type												

ND = not done

TABLE 7: Mutagenic activity of samples of the final reclaimed water (CR5) as determined by the Ames *Salmonella* mutagenicity assay. Results expressed in mutagenicity ratio (MR)

SAMPLE	DATE	TA 98		TA 100	
		-S9	+S9	-S9	+S9
CR5 x 1	86.09.30	1,1	N.R	1,3	N.R
x 2	"	1,0	N.R	1,4	N.R
x 4	"	1,1	N.R	1,4	N.R
CR5 x 1	86.10.07	0,7	0,8	0,8	0,7
x 2	"	1,0	0,8	0,9	0,8
x 4	"	1,2	0,8	1,0	0,7
CR5 x 1	86.10.14	0,8	0,5	0,9	0,8
x 2	"	0,5	0,8	0,6	0,5
x 4	"	0,7	0,7	0,7	0,6
CR5 x 1	86.10.21	0,6	1,1	1,1	1,2
x 2	"	0,8	1,2	1,1	1,1
x 4	"	0,7	1,2	1,1	1,1
CR5 x 1	86.10.28	1,1	1,0	0,6	0,8
x 2	"	1,2	0,8	0,7	0,8
x 4	"	1,1	0,9	0,7	0,9
CR5 x 1	86.11.04	1,6	0,7	1,1	1,0
x 2	"	1,5	0,8	1,0	0,9
x 4	"	1,3	0,9	0,9	1,0
CR5 x 1	86.11.11	0,9	1,1	0,6	0,9
x 2	"	1,0	0,9	0,7	1,0
x 4	"	1,0	0,8	0,7	1,0
CR5 x 1	86.11.18	0,7	0,8	0,6	0,7
x 2	"	0,7	1,2	0,6	0,7
x 4	"	0,6	1,1	0,6	0,7
CR5 x 1	86.11.25	0,7	0,9	N.R.	N.R.
x 2	"	0,6	1,0	N.R.	N.R.
x 4	"	0,7	0,9	N.R.	N.R.
CR5 x 1	86.12.02	0,9	2,0	0,9	0,8
x 2	"	0,7	1,1	0,8	0,7
x 4	"	0,8	0,9	0,6	0,6

N.R. = no result
x 1 = unconcentrated sample
x 2 = sample concentrated two-fold by flash evaporation
x 4 = sample concentrated four-fold by flash evaporation
S9 = Rat liver microsome preparation for the activation of certain mutagens
TA98 and TA100 = *Salmonella* tester strains

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WNNR

Verw. 6/703/1

9 Augustus 1989

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Aandag: Mnr P H Novella

Geagte heer,

VERSKILLE IN STANDAARDPLAATTELLING RESULTATE

Ons telefoniese gesprek ten opsigte van die verskille in die standaardplaattelling resultate by die Kaapse Vlakte watersuiweringswerke verwys.

Na konsultasie met prof W O K Grabow blyk dit dat daar 'n verskil in interpretasie van die standaardplaattelling was. Die resultate van prof Grabow sluit aërobiese en anaërobiese kolonies in, terwyl my resultate slegs die anaërobiese kolonies insluit. Die resultate van prof Grabow ten opsigte van die Standaardplaattelling is dus meer korrek.

Ek hoop dit los jou probleem op.

Die uwe,

J F P Engelbrecht
Mikrobioloog

WETENSKAPLIKE EN NYWERHEIDNAVORSINGSRAAD

NASIONALE INSTITUUT VIR WATERNAVORSING

BELLVILLE

6/703/1

KAAPSE VLAKTE WATERHERWINNINGSWERKE

MIKROBIOLOGIESE ONTLEDINGS - 3 SEPTEMBER - 2 DESEMBER 1986

deur

J F P Engelbrecht

INLEIDING

Watermonsters is binne vier ure ontleed nadat dit by die volgende punte geneem is:

CR 1 = Invoerwater

CR 2 = Na sandfiltrasie

CR 3 = Voor koolstoffiltrasie

CR 4 = Na koolstoffiltrasie

CR 5 = Finale water

Die volgende indikators organismes is bepaal:

Standaardplaattelling

Totale kolivorme

Fekale kolivorme

Kolifage

Fekale streptococci.

RESULTATE

Die resultate wat gedurende die toetsperiode verkry is word in table 1 - 5 weergegee.

BESPREKING

Al die indikator organismes waarvoor daar getoets is, was altyd teenwoordig in die invoerwater (tabel 1).

Kolonie vormende eenhede, totale en fekale kolivorme wat gereeld in monster CR 4 (tabel 4) gevind is, is heelwaarskynlik die gevolg van mikrobiologiese groei op die koolstoffilter.

-2/.....

Al die monsters wat op 28 Oktober 1986 geneem is, toon die teenwoordigheid van organismes. Selfs die finale water (tabel 5) het kolonie vormende eenhede bevat. Hierdie verskynsel dui op 'n foutiewe proses op die betrokke dag.

GEVOLGTREKKING

Resultate toon dat die finale water (CR 5) altyd aan die standaard vir drinkwater voldoen het. In die enkele geval waar organismes wel in die finale water voorgekom het, was die konsentrasie binne die perke van die standaard.

oooOooo

JFP/sjh

NASIONALE INSTITUUT VIR WATERNAVORSING

BELLVILLE

RESULTATE VAN MIKROBIOLOGIESE ONTLEDINGS

TABEL: 1 MONSTER: CR1: Invoerwater

Datum 1986	09-30	10-07	10-14	10-21	10-28	11-04	11-11	11-18	11-25	12-02
Standaardplaat-telling per ml	42000	26500	8268	616	500	592	368	514	560	796
Totale kolivorme per 100 ml	$2,5x10^6$	$2,0x10^6$	$3,6x10^5$	1450	3600	700	2200	300	11300	17600
Fekale kolivorme per 100 ml	$1,4x10^5$	$2,4x10^5$	$1,8x10^5$	150	400	200	300	40	2160	1730
Fekale streptococci per 100 ml	0	52	4	0	8	12	0	0	16	8
Kolifage per 10 ml	20	4	18	16	4	6	2	6	18	0

NASIONALE INSTITUUT VIR WATERNAVORSING

BELLVILLE

RESULTATE VAN MIKROBIOLOGIESE ONTLEDINGS

TABEL: 2 MONSTER: CR 2 : Na sandfiltrasie

Datum 1986	09-30	10-07	10-14	10-21	10-28	11-04	11-11	11-18	11-25	12-02
Standaardplaat-telling per ml	0	0	0	0	280	0	0	0	0	0
Totale kolivorme per 100 ml	0	0	0	0	28	0	0	0	0	0
Fekale kolivorme per 100 ml	0	0	0	0	24	0	0	0	0	0
Fekale streptococci per 100 ml	0	0	0	0	0	0	0	0	0	0
Kolifage per 10 ml	0	0	0	0	0	0	0	0	0	0

NASIONALE INSTITUUT VIR WATERNAVORSING

BELLVILLE

RESULTATE VAN MIKROBIOLOGIESE ONTLEDINGS

TABEL: 3 MONSTER: CR 3: Voor koolstoffiltrasie

Datum 1986	09-30	10-07	10-14	10-21	10-28	11-04	11-11	11-18	11-25	12-02
Standaardplaat-telling per ml	0	0	0	0	1	7	0	0	0	0
Totale kolivorme per 100 ml	0	0	0	0	6	0	0	0	0	0
Fekale kolivorme per 100 ml	0	0	0	0	2	0	0	0	0	0
Fekale streptococci per 100 ml	0	0	0	0	0	0	0	0	0	0
Kolifage per 10 ml	0	0	0	0	0	0	0	0	0	0

NASIONALE INSTITUUT VIR WATERNAVORSING

BELLVILLE

RESULTATE VAN MIKROBIOLOGIESE ONTLEDINGS

TABEL: 4 MONSTER: CR 4 : Na koolstoffiltrasie

Datum 1986	09-30	10-07	10-14	10-21	10-28	11-04	11-11	11-18	11-25	12-02
Standaardplaat-telling per ml	100	90	30	14	18	64	44	52	60	16
Totale kolivorme per 100 ml	160	1300	84	4	60	4	0	0	0	0
Fekale kolivorme per 100 ml	0	0	24	2	2	4	0	0	0	0
Fekale streptococci per 100 ml	0	0	0	0	0	0	0	0	0	0
Kolifage per 10 ml	0	0	0	0	0	0	0	0	0	0

NASIONALE INSTITUUT VIR WATERNAVORSING

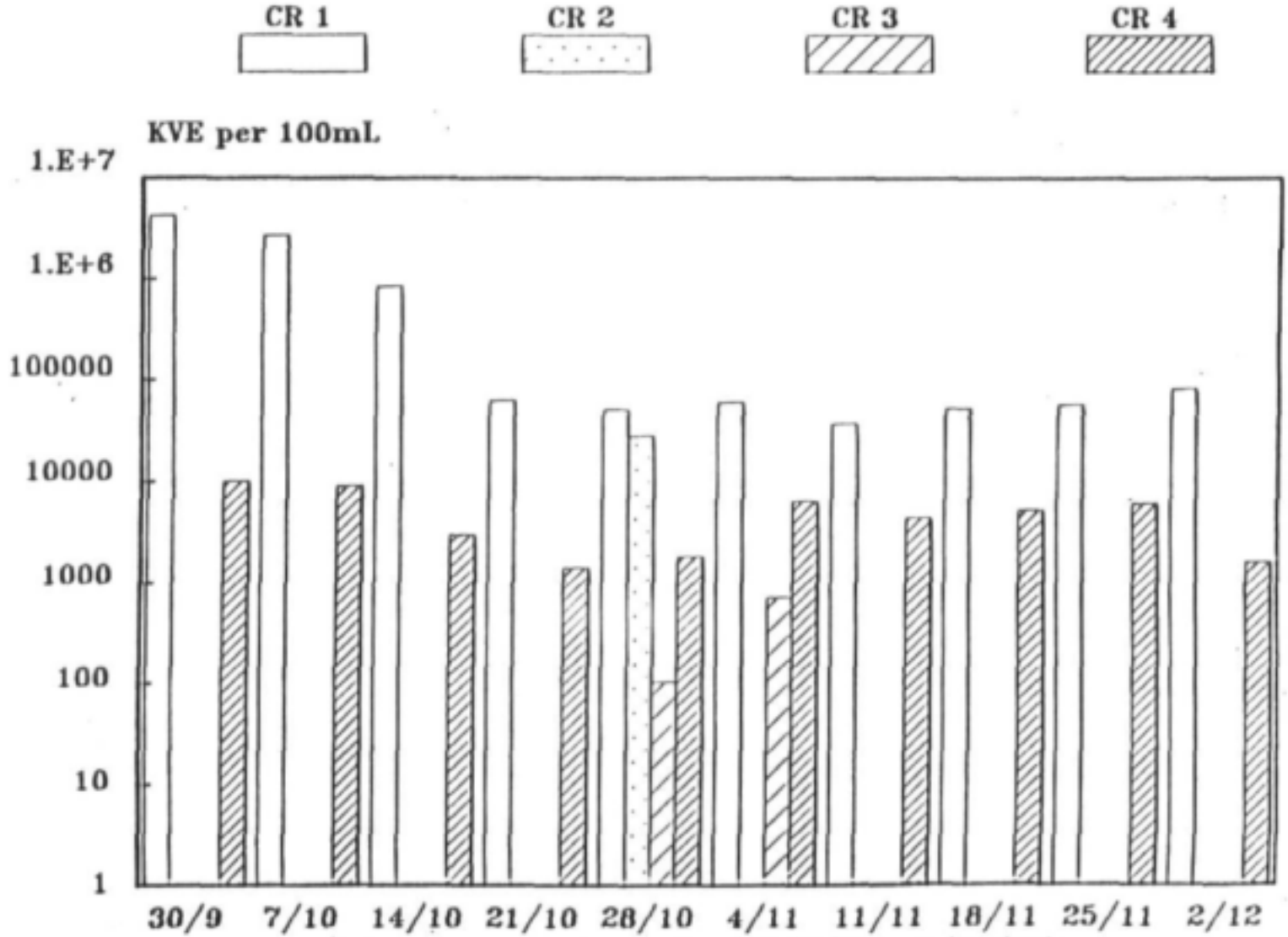
BELLVILLE

RESULTATE VAN MIKROBIOLOGIESE ONTLEDINGS

TABEL: 5 MONSTER: CR 5 : Finale Water

Datum 1986	09-30	10-07	10-14	10-21	10-28	11-04	11-11	11-18	11-25	12-02
Standaardplaat-telling per ml	0	0	0	0	5	0	0	0	0	0
Totale kolivorme per 100 ml	0	0	0	0	0	0	0	0	0	0
Fekale kolivorme per 100 ml	0	0	0	0	0	0	0	0	0	0
Fekale streptococci per 100 ml	0	0	0	0	0	0	0	0	0	0
Kolifage per 10 ml	0	0	0	0	0	0	0	0	0	0

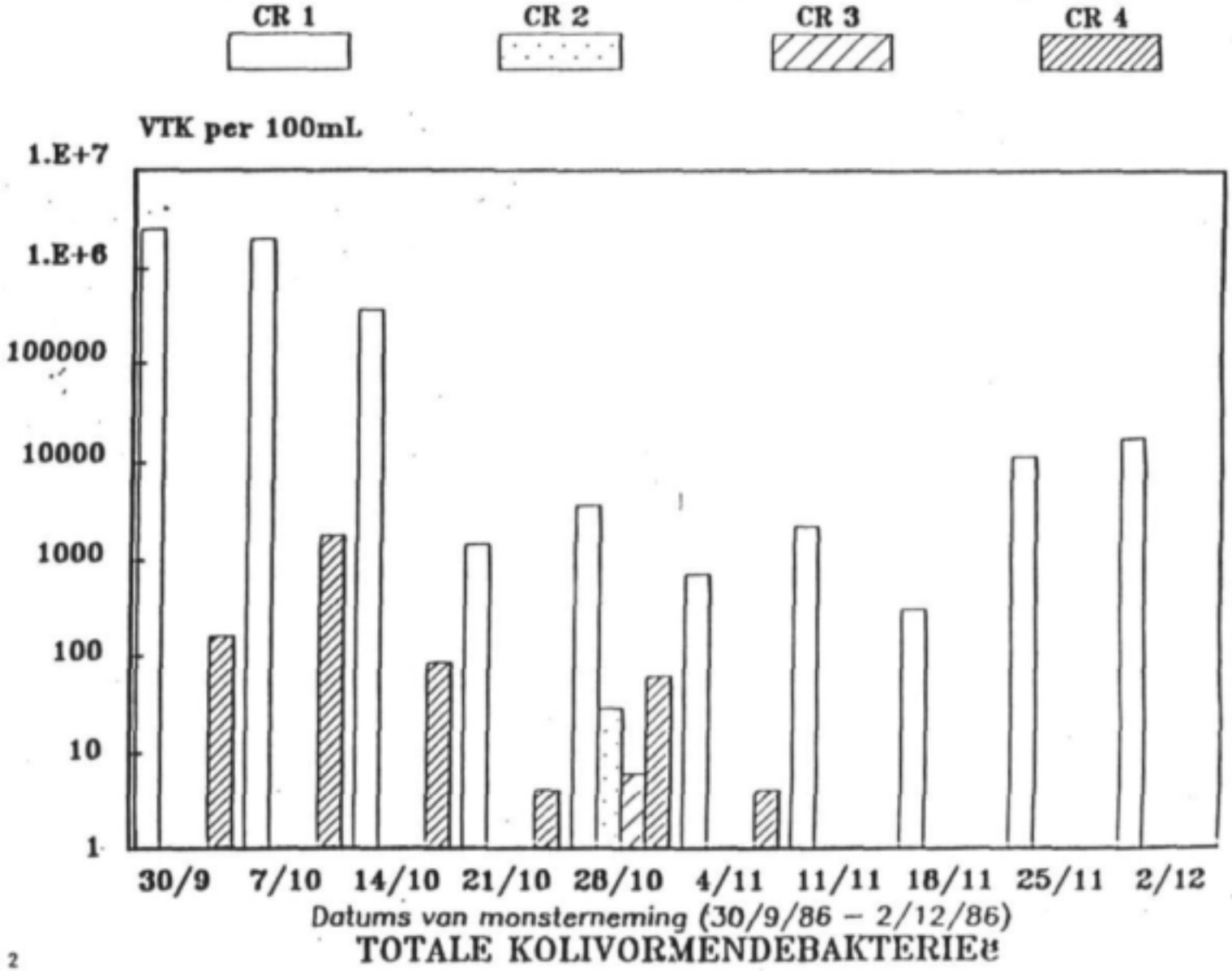
Kaapse Vlakte Waterherwinningswerke



STANDAARDPLAATTELLING

FIGUUR 1

Kaapse Vlakte Waterherwinningswerke

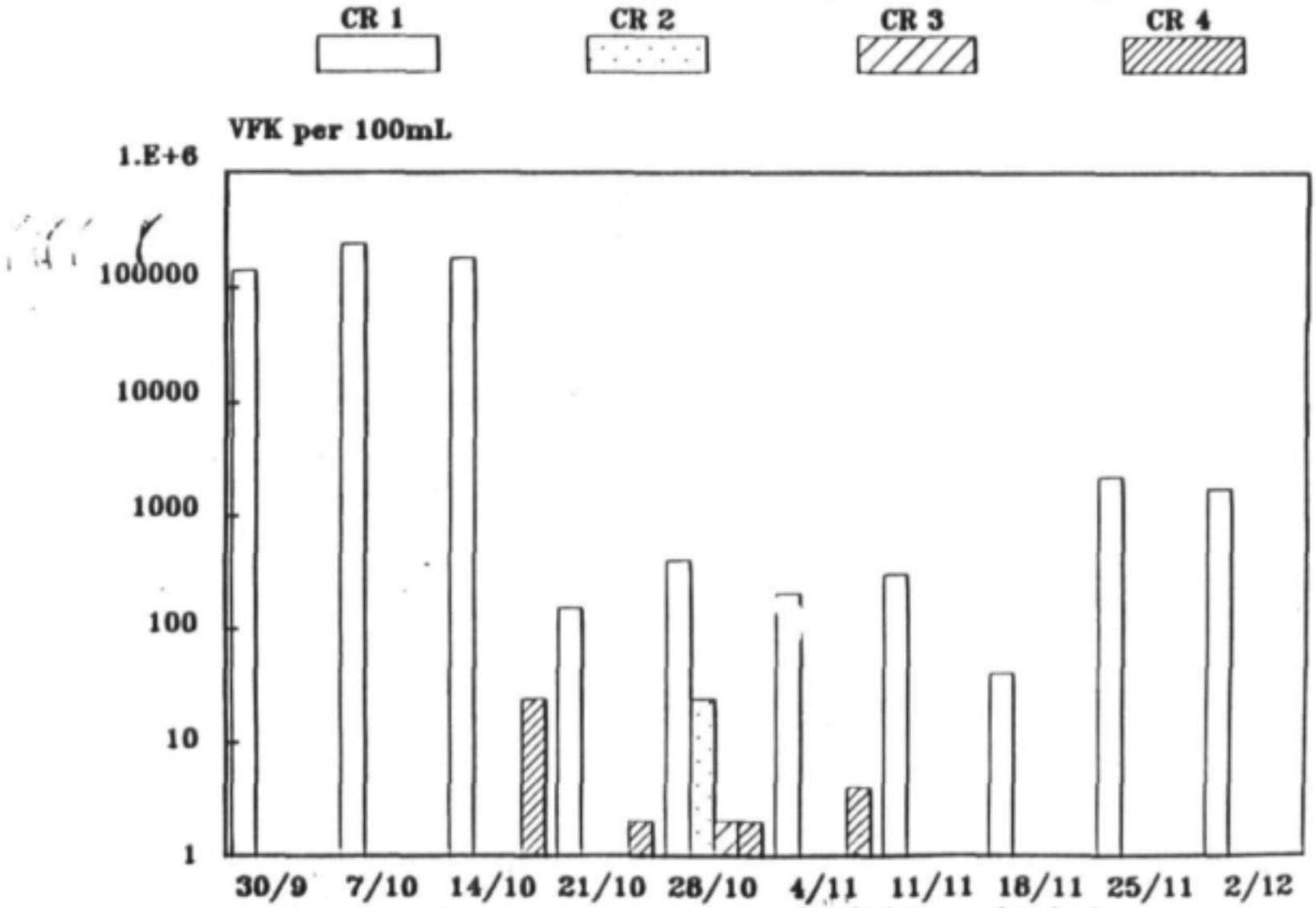


TOTALE KOLIVORMENDEBAKTERIE

FIGUUR 2

A2.22

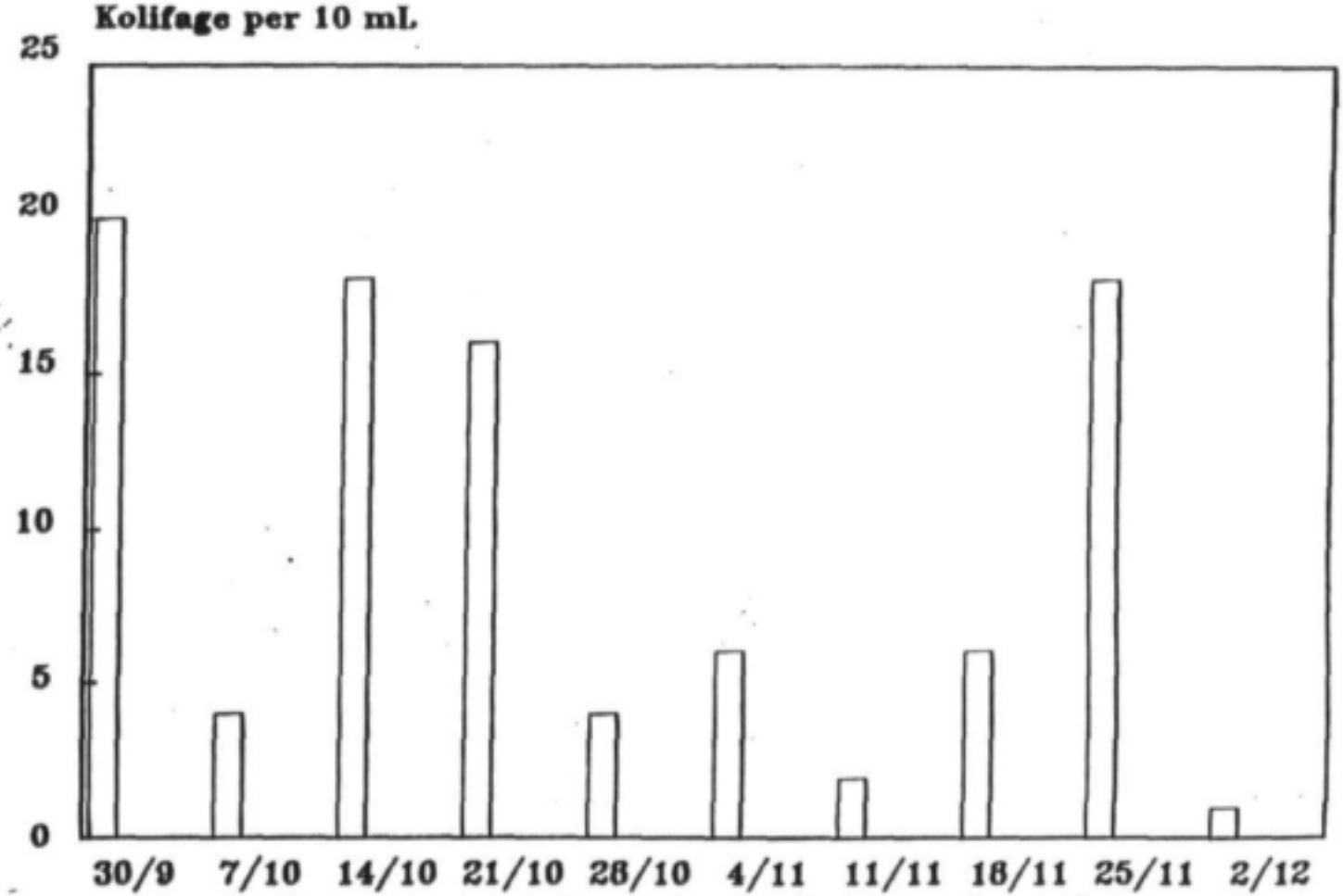
Kaapse Vlakte Waterherwinningswerke



FIGUUR 3

FEKALE KOLIVORMENDEBAKTERIEë

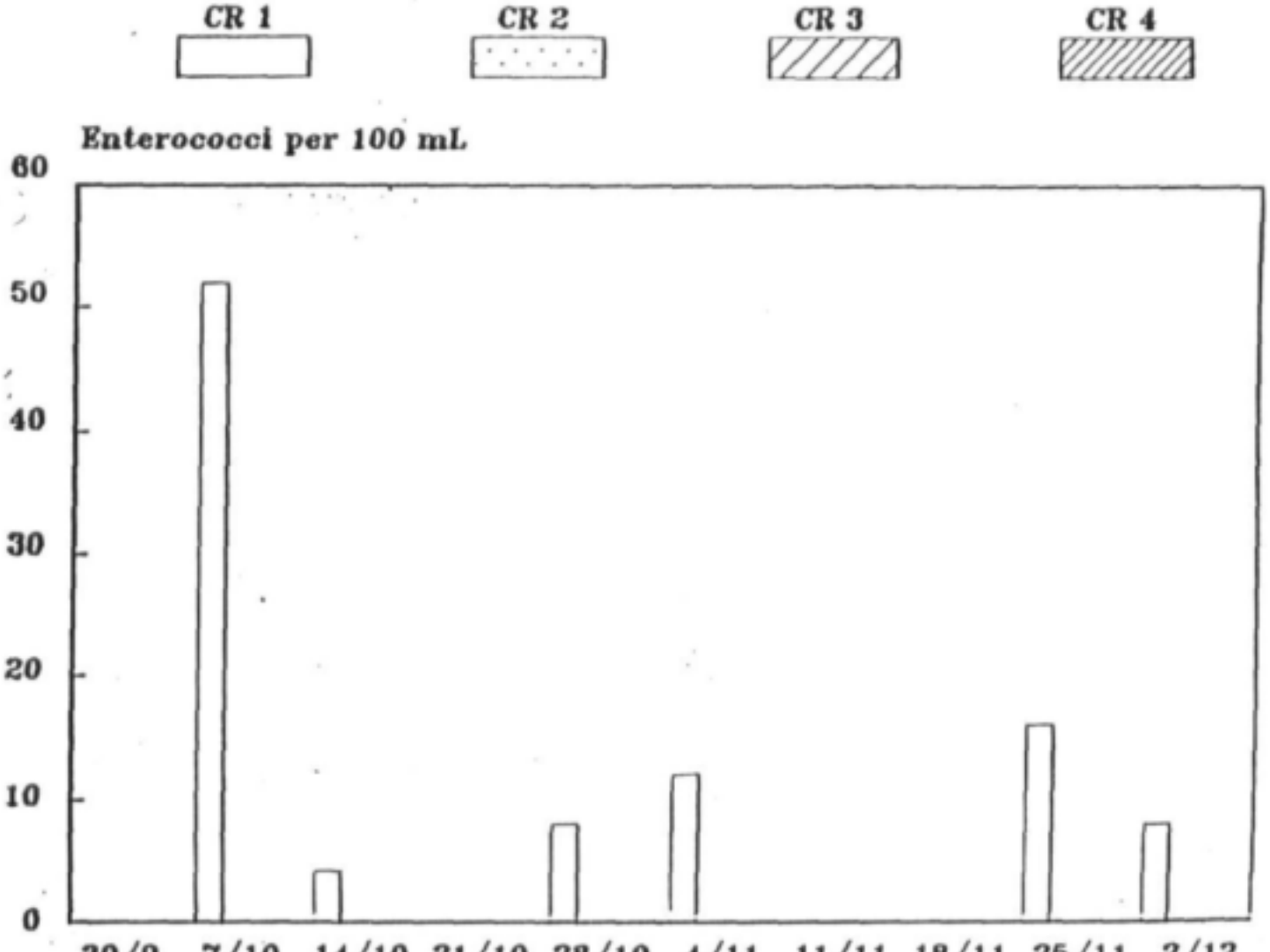
Kaapse Vlakte Waterherwinningswerke



KOLIFAGE

FIGUUR 4

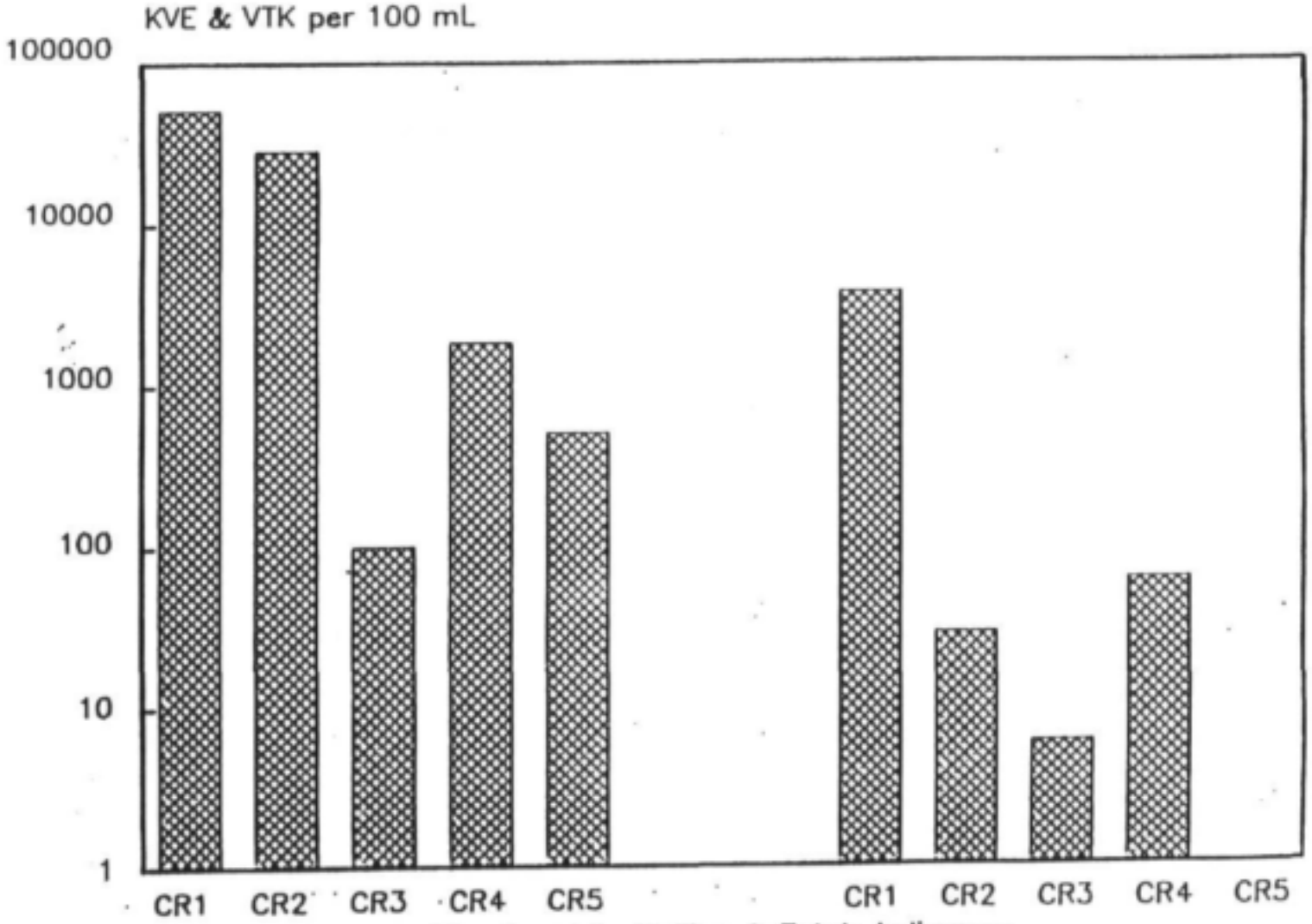
Kaapse Vlakte Waterherwinningswerke



FIGUUR 5

ENTEROCOCCI

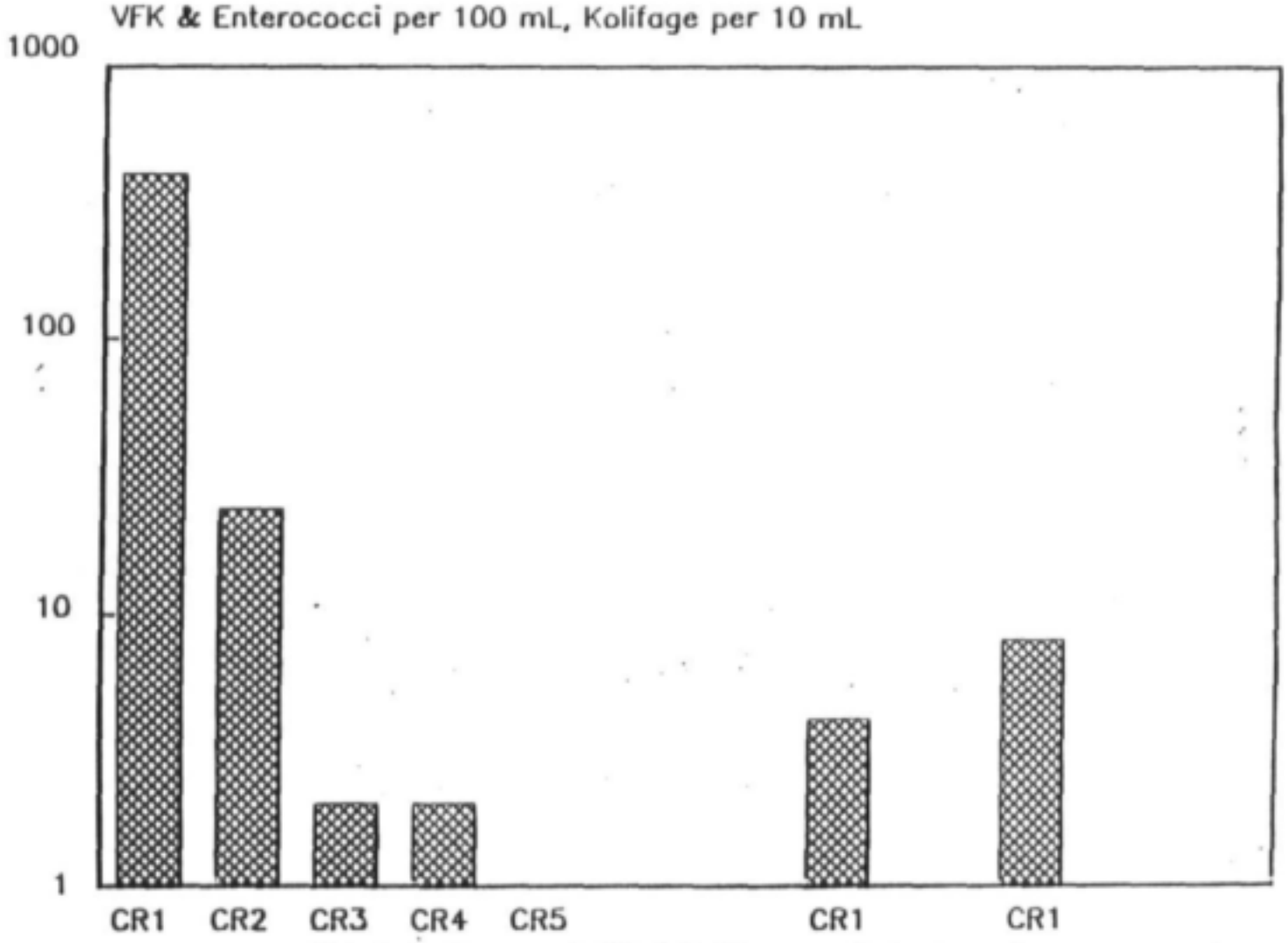
Kaapse Vlakte Waterherwinningswerke



MIKROBIOLOGIESE ONTLEDINGS OP 28/10/86

FIGUUR 6

A2.26



FIGUUR 7

MIKROBIOLOGIESE ONTLEDINGS OP 28/10/86

APPENDIX 3

Intensive surveillance programme

Virological analyses of sample group D by UCT

UNIVERSITY OF CAPE TOWN

Department of Medical Microbiology

Medical School, Observatory, Cape, 7925 South Africa. Telephone 47-1250
Head of the Department: A.A. Forder M.Med. (Path.)
Head of Clinical Virology: Professor J.W. Moodie, M.D.

17 July 1987

The City Engineer
City Engineer's Department
P O Box 1694
CAPE TOWN 8000

Attention: Mr Fawcett

Dear Sir

CAPE FLATS PROTOTYPE WATER RECLAMATION PLANT

I enclose summary sheets of all data relating to the virological assay performed. Included is the tap water study referred to in Item 5.1 of your Minutes of 8 March 1987. The requested comment on the domestic tap water and the bacteria present in the sandy deposit present in water (CR5) from the reclamation plant between SEptember 1987 - January 1987 is as follows:

Although the supernatant water was not found to contain viruses or bacteria, a residual sandy deposit, when cultured by standard plate count for bacteria was shown to be variably, but sometimes significantly, contaminated with viable bacteria. The species of bacteria isolated were commensals and no faecal coliforms were isolated. Any in situ precipitate would trap bacteria from large volumes of water and the concentration detected by plate count cannot be extrapolated to a specific volume of water.

Yours sincerely

J W MOODIE

SUMMARY OF RESULTS OF VIRAL STUDIES OF DOMESTIC TAPWATER

CODE	DATE	SAMPLE	TOTAL COLIFORMS /100 ml	STANDARD PLATE COUNT - /100 ml	COLIPHAGES /100 ml	VIRUS ISOLATION
W4/82	20.9.82	Tapwater	ND	Gram Neg Bacilli Present	ND	None
FPS/86	30.1.86	Tapwater Florent Primary School	<2	$4x10^2$ NLF 3 Flavo Sp	<2	None
TW1/86	29.7.86	Tapwater	<2	<2	<2	None
TW1/87	21.5.87	Tapwater	<2	<2	<2	None

SUMMARY OF RESULTS OF WATER FROM THE CAPE FLATS RECLAMATION PLANT FROM JUNE 1982 - MARCH 1985

CODE	DATE	SAMPLE	VIRUS ISOLATION	VIRUS TITRE/LITRE
W1/82	23.6.82	C.Col eff. No Cl.	Reovirus Poliovirus 2 Rotavirus	$10^{4.8}$
W2/82	6.7.82	C.Col eff. No Cl.	Reovirus Coxsackie B5	10^{2}
W3/82	7.9.82	C.Col eff. No Cl.	-	
W6/82	28.10.82	C.Col eff. No Cl.	Reovirus	20
W7/82	2.11.82	C.Col eff. No Cl.	-	
W8/82	9.11.82	C.Col eff. No Cl.	-	
W9/82	16.11.82	C.Col eff. No Cl.	-	
W10/82(1)	18.11.82	(1)Feed No Cl	Reovirus	$>2x10^{4}$
W10/82(2)	18.11.82	(2)Br. pt Cl	Reovirus	$>2x10^{4}$
W10/82(3)	18.11.82	(3)Stab. No Cl	Reovirus	$>2x10^{4}$
W10/82(4)	18.11.82	(4)Sa. Fil No Cl	Reovirus	7
W10/82(5)	18.11.82	(5)C. Col	-	
W11/82(1)	7.12.82	(1) Feed No Cl	Reovirus	$2x10^{3.75}$
W11/82(2)	7.12.82	(2) Br.Pt No Cl	Reovirus	$2x10^{2}$
W11/82(3)	7.12.82	(3) Stab. No Cl	Reovirus	2x10
W11/82(4)	7.12.82	(4) Sa. Fil.	Reovirus	< 2
W11/82(5)	7.12.82	(5) C.Col No Cl	Reovirus 2nd Pass.	< 2

SPECIAL MONITORING PROGRAMME OF THE CAPE FLATS WATER RECLAMATION PLANT VIRAL STUDIES FROM SEPTEMBER '86 - JANUARY '87

CODE	DATE	SAMPLE	TOTAL COLIFORMS /100 ml	STANDARD PLATE COUNT /100 ml	STANDARD PLATE COUNT SANDY DEPOSIT /100 ml	COLIPHAGES /100 ml	VIRUS ISOLATION /10 L
CR5 1/86	30.9.86	CFRP Final Product	<2	<2	<2	<2	None
CR5 2/86	7.10.86	"	<2	<2	>2x10 Bac. Sp	<2	"
CR5 3/86	14.10.86	"	<2	<2	<2	<2	"
CR5 4/86	21.10.86	"	<2	<2	$>2x10^2$ NLFs $>10^5$ diptheroids	<2	"
CR5 5/86	28.10.86	"	<2	<2	>2x10 Bac. Sp >2x10 NLFs	<2	"
CR5 6/86	4.11.86	"	<2	<2	>2x10 Bac. Sp $>2x10^2$ NLFs	<2	"
CR5 7/86	11.11.86	"	<2	<2	<2	<2	"
CR5 8/86	18.11.86	"	<2	<2	>2x10 Bac. Sp >2x10 NLFs	<2	"
CR5 9/86	25.11.86	"	<2	<2	>2x10 Bac. Sp $>2x10^2$ NLFs	<2	"
CR5 10/86	2.12.86	"	<2	<2	>2x10 Bac. Sp $>2x10^2$ NLFs	<2	"
CR5 11/86	9.12.86	"	<2	<2	>2x10 Bac. Sp $>2x10^2$ NLFs	<2	"
CR5 1/87	6.1.87	"	<2	<2	>2x10 Bac. Sp $>2x10^2$ NLFs	<2	"

CODE	DATE	SAMPLE	VIRUS ISOLATION	VIRUS TITRE/LITRE
W8/84	19/3/84	Feed Water	Reovirus III	1.1×10^4
W9/84	2.4.84	Feed Water	Reovirus III	2×10^3
W10/84	28.11.84	Sa. Fil.	Reovirus III	
W1/85	23.1.85	Sa. Fil.	None	
W2/85	30.1.85	Sa. Fil.	"	
W3/85	6.2.85	Sa. Fil.	"	
W4/85	13.2.85	Sa. Fil.	"	
W5/85	20.2.85	Sa. Fil.	"	
W6/85	27.2.85	Sa. Fil.	"	
W7/85	12.3.85	Sa. Fil.	"	

C.Col. = Carbon Column

Feed = Feed Water

Br. pt. Cl. = Breakpoint Chlorination Tank

Stab. = Stabilisation Tank

Sa. Fil. = Sand Filter effluent

Int. Cl. = Intermediate Chlorination

No Cl. = No Chlorination

CODE	DATE	SAMPLE	VIRUS ISOLATION	VIRUS TITRE/LITRE
W1/83	11.1.83	C.Col eff. Int. Cl	None	
W2/83(1)	18.1.83	(1)Post stab. Pre C	"	
(2)	18.1.83	(2)Stab. Post Cl	"	
W3/83	25.1.83	C.Col eff. Int. Cl	"	
W4/83	1.2.83	C.Col eff. Int. Cl	"	
W5/83	8.2.83	C.Col eff. Int. Cl	"	
W6/83	16.2.83	C.Col eff. Int. Cl	"	
W7/83	2.3.83	C.Col eff. Int.Cl	"	
W8/83	9.3.83	C.Col eff. Int. Cl	"	
W9/83	16.3.83	C.Col eff. Int. Cl	"	
W10/83	24.10.83	Sa. Fil.	"	
W11/83	31.10.83	Sa. Fil.	"	
W12/83	7.11.83	Sa. Fil.	"	
W13/83	14.11.83	Sa. Fil.	"	
W14/83	21.11.83	Sa. Fil.	"	
W1/84	9.1.84	Sa. Fil.	"	
W2/84	16.1.84	Sa. Fil.	"	
W3/84	23.1.84	Sa. Fil.	"	
W4/84	30.1.84	Sa. Fil.	"	
W5/84	6.2.84	Sa. Fil.	"	
W6/84	20.2.84	W9 Pond	Reovirus III	6.3×10^2
W7/84	5.3.84	Feed Water	Reovirus III	4.2×10^3

UNIVERSITY OF CAPE TOWN

DEPARTMENT OF MEDICAL MICROBIOLOGY

Sample: ...Tap Water..... Code: W4/82

Date: .....20.9.82..... Date of Report: ..6.7.87....

Date of Receipt: 20.9.82.....

Tissue Culture

No virus isolated

Microscopic Examination

No virus detected
Gram negative bacilli present by EM

Test for Rotavirus

Rotazyme negative

Bacteriology

Gram negative bacilli

Remarks

Signature: .....

pp A. SHERSBY

UNIVERSITY OF CAPE TOWN

DEPARTMENT OF MEDICAL MICROBIOLOGY

Sample: Drinking Water - Floreat Primary School Code: FPS/86.

Date: ....30.1.86..... Date of Report: ..10.3.86....

Date of Receipt: 31.1.86.....

Tissue Culture

No virus isolated from 10ℓ of water

Microscopic Examination

Electron microscopy showed many fibres

Test for Rotavirus

Rotascreen test negative

Bacteriology

4×10^2 gram negative
Non-lactose fermenting bacilli/100 ml water

3 Flavobacterium Sp/100 ml water

Remarks

There was a heavy discoloured deposit on the filter membrane

UNIVERSITY OF CAPE TOWN

DEPARTMENT OF MEDICAL MICROBIOLOGY

Sample: ....Tap water..... Code: TW1/86.

Date: ....29.7.86..... Date of Report: 6.7.87....

Date of Receipt: 29.7.86.....

Tissue Culture

No virus isolated

Microscopic Examination

No virus detected

Test for Rotavirus

Rotalex negative

Bacteriology

<2 Coliform/100 ml
<2 Coliphage/100 ml
SPC <2/100 ml

Remarks

Signature: .....

UNIVERSITY OF CAPE TOWN

DEPARTMENT OF MEDICAL MICROBIOLOGY

Sample: Tap Water ..... Code: TW1/87

Date: 21.5.87 ..... Date of Report: 6.7.87 .....

Date of Receipt: 21.7.87.....

Tissue Culture

No virus isolated

Microscopic Examination

No virus detected

Test for Rotavirus

Rotalex negative

Bacteriology

<2 Coliform/100ml
<2 Coliform/100 ml
SPC <2/100 ml

Remarks

Signature: .....

VIROLOGICAL ASSAY OF WATER SAMPLES
WATER RESEARCH UNIT, DEPARTMENT OF MEDICAL MICROBIOLOGY, UCT

SOURCE:CFRP Feed Water

DATE:07.12.82
CODE:W11/1/82

APPEARANCE:Turbidity 1.1

VOLUME:5 l

CONCENTRATION TIME:16 h
PRESSURE:200 kpa
ULTRAFILTRATION MEMBRANE: XM 50

ELUTION VOLUME: 20 ml MEM
DECONTAMINATION: 3.0 ml Chloro

INOCULATION

TISSUE CULTURE CELLS:
BATCH NO.
FLASKS:
ROLLER TUBES 1ST PASSAGE: 0.4ml eluate /4 tubes
2ND PASSAGE:

MICROSCOPY: Reo-like
VIRAL ISOLATION: Reovirus
TITRE OF VIRUS: $2 \times 10^{3.7}$

ROTAVIRUS

LATEX TEST: negative
ELECTRONMICROSCOPY:
IMMUNOFLUORESCENCE: negative

ISOLATE IDENTIFICATION

CYTOPATHOLOGY:
IMMUNOFLUORESCENCE:
MICE:
HAEMAGGLUTINATION:
POLYACRYLAMIDE GEL ELECTROPHORESIS:

BACTERIOLOGY

COLIPHAGES:
TOTAL COLIFORM COUNT:
STANDARD PLATE COUNT:

FINAL RESULT: Reovirus isolated $2 \times 10^{3.7}$ /litre

VIROLOGICAL ASSAY OF WATER SAMPLES
WATER RESEARCH UNIT, DEPARTMENT OF MEDICAL MICROBIOLOGY, UCT

SOURCE:CFRP Breakpoint Chlorination T

DATE:07.12.82
CODE:W11/2/82

APPEARANCE:Turbidity 0.75

VOLUME:51

CONCENTRATION TIME:16 h
PRESSURE:200 kpa
ULTRAFILTRATION MEMBRANE: XM 50

ELUTION VOLUME: 20 ml MEM
DECONTAMINATION: 3.0 ml Chloro

INOCULATION

TISSUE CULTURE CELLS:
BATCH NO.
FLASKS: 15 ml eluate in 1 Roux bottle
ROLLER TUBES 1ST PASSAGE: 0.1 ml eluate /4 tubes
2ND PASSAGE: 0.2 ml (bottle) in 2 tubes

MICROSCOPY: Reo-like
VIRAL ISOLATION: Reovirus
TITRE OF VIRUS: $2x10^2$/litre

ROTAVIRUS

LATEX TEST: negative
ELECTRONMICROSCOPY:
IMMUNOFLUORESCENCE:

ISOLATE IDENTIFICATION

CYTOPATHOLOGY:
IMMUNOFLUORESCENCE:
MICE:
HAEMAGGLUTINATION:
POLYACRYLAMIDE GEL ELECTROPHORESIS:

BACTERIOLOGY

COLIPHAGES:
TOTAL COLIFORM COUNT:
STANDARD PLATE COUNT:

FINAL RESULT: Reovirus isolated $2x10^2$/litre

VIROLOGICAL ASSAY OF WATER SAMPLES
WATER RESEARCH UNIT, DEPARTMENT OF MEDICAL MICROBIOLOGY, UCT

SOURCE:CFRP Stabilisation tank No C1

DATE:07.12.82
CODE:W11/3/82

APPEARANCE:Turbidity 0.95

VOLUME:5 l

CONCENTRATION TIME:16 h
PRESSURE:200 kpa
ULTRAFILTRATION MEMBRANE: XM 50

ELUTION VOLUME: 20 ml MEM
DECONTAMINATION: 3.0 ml Chloro

INOCULATION

TISSUE CULTURE CELLS:
BATCH NO.
FLASKS: 15 ml eluate in 1 Roux bottle
ROLLER TUBES 1ST PASSAGE: titrated in 4 tubes/sample
2ND PASSAGE: 0.2 ml (bottle) in 2 tubes

MICROSCOPY: Reo-like
VIRAL ISOLATION: Reovirus
TITRE OF VIRUS: 2x10 /litre

ROTAVIRUS

LATEX TEST: negative
ELECTRONMICROSCOPY:
IMMUNOFLUORESCENCE:

ISOLATE IDENTIFICATION

CYTOPATHOLOGY:
IMMUNOFLUORESCENCE:
MICE:
HAEMAGGLUTINATION:
POLYACRYLAMIDE GEL ELECTROPHORESIS:

BACTERIOLOGY

COLIPHAGES:
TOTAL COLIFORM COUNT:
STANDARD PLATE COUNT:

FINAL RESULT: Reovirus Type I isolated 2x10 /litre

VIROLOGICAL ASSAY OF WATER SAMPLES
WATER RESEARCH UNIT, DEPARTMENT OF MEDICAL MICROBIOLOGY, UCT

SOURCE:CFRP Sand Filter Effluent

DATE:07.12.82
CODE:W11/4/82

APPEARANCE:Turbidity 0.61

VOLUME:5 l

CONCENTRATION TIME:16 h
PRESSURE:200 kpa
ULTRAFILTRATION MEMBRANE: XM 50

ELUTION VOLUME: 20,ml MEM
DECONTAMINATION: 3.0 ml Chloro

INOCULATION

TISSUE CULTURE CELLS:
BATCH NO.
FLASKS: 15 ml eluate in 1 Roux bottle
ROLLER TUBES 1ST PASSAGE: 0.1 ml eluate / 4 tubes
2ND PASSAGE: 0.2 ml (bottle) in 2 tubes

MICROSCOPY: Reo-like
VIRAL ISOLATION: Reovirus
TITRE OF VIRUS: < 2x10 /litre

ROTAVIRUS

LATEX TEST: negative
ELECTRONMICROSCOPY:
IMMUNOFLUORESCENCE:

ISOLATE IDENTIFICATION

CYTOPATHOLOGY:
IMMUNOFLUORESCENCE:
MICE:
HAEMAGGLUTINATION:
POLYACRYLAMIDE GEL ELECTROPHORESIS:

BACTERIOLOGY

COLIPHAGES:
TOTAL COLIFORM COUNT:
STANDARD PLATE COUNT:

FINAL RESULT: Reovirus isolated < 2x10 / litre

VIROLOGICAL ASSAY OF WATER SAMPLES
WATER RESEARCE UNIT, DEPARTMENT OF MEDICAL MICROBIOLOGY, UCT

SOURCE:CFRP Carbon Column Effluent

DATE:07.12.82
CODE:W11/5/82

APPEARANCE:Turbidity 0.30

VOLUME:5 l

CONCENTRATION TIME:16 h
PRESSURE:200 kpa
ULTRAFILTRATION MEMBRANE: XM 50

ELUTION VOLUME: 20 ml MEM
DECONTAMINATION: 3.0 ml Chloro

INOCULATION

TISSUE CULTURE CELLS:
BATCE NO.
FLASKS: 15 ml elaute in 1 Roux bottle
ROLLER TUBES 1ST PASSAGE: 0.1ml eluate in 4 tubes
2ND PASSAGE: 0.2 ml (bottle) in 2 tubes

MICROSCOPY: Reo-like
VIRAL ISOLATION: Reovirus
TITRE OF VIRUS: < 2x10 /litre

ROTAVIRUS

LATEX TEST: negative
ELECTRONMICROSCOPY:
IMMUNOFLUORESCENCE:

ISOLATE IDENTIFICATION

CYTOPATHOLOGY:
IMMUNOFLUORESCENCE:
MICE:
HAEMAGGLUTINATION:
POLYACRYLAMIDE GEL ELECTROPHORESIS:

BACTERIOLOGY

COLIPHAGES:
TOTAL COLIFORM COUNT:
STANDARD PLATE COUNT:

FINAL RESULT: Reovirus isolated on 2nd passage < 2x10 /litre

VIROLOGICAL ASSAY OF WATER SAMPLES
WATER RESEARCE UNIT, DEPARTMENT OF MEDICAL MICROBIOLOGY, UCT

SOURCE:CFRP Carbon Column Effluent

DATE:11.01.83
CODE:W1 /83

APPEARANCE:Clear

VOLUME:10 l

CONCENTRATION TIME:16 h
PRESSURE:200 kpa
ULTRAFILTRATION MEMBRANE: XM 50

ELUTION VOLUME: 20 ml MEM
DECONTAMINATION: 3.0 ml Chloro

INOCULATION

TISSUE CULTURE CELLS: PMK
BATCH NO. 060183
FLASKS: 15ml eluate in 1 Roux bottle
ROLLER TUBES 1ST PASSAGE: 0.4 ml eluate /4 tubes
2ND PASSAGE:

MICROSCOPY: negative
VIRAL ISOLATION: none
TITRE OF VIRUS:

ROTAVIRUS

LATEX TEST: negative
ELECTRONMICROSCOPY:
IMMUNOFLUORESCENCE:

ISOLATE IDENTIFICATION

CYTOPATHOLOGY:
IMMUNOFLUORESCENCE:
MICE:
HAEMAGGLUTINATION:
POLYACRYLAMIDE GEL ELECTROPHORESIS:

BACTERIOLOGY

COLIPHAGES:
TOTAL COLIFORM COUNT:
STANDARD PLATE COUNT:

FINAL RESULT: No virus detected.

VIROLOGICAL ASSAY OF WATER SAMPLES
WATER RESEARCH UNIT, DEPARTMENT OF MEDICAL MICROBIOLOGY, UCT

SOURCE:CFRP Primary settling tank

DATE:18.01.82
CODE:W2/83 1

APPEARANCE:

VOLUME:10 l

CONCENTRATION TIME:16 h
PRESSURE:200 kpa
ULTRAFILTRATION MEMBRANE: XM 50

ELUTION VOLUME: 20 ml MEM
DECONTAMINATION: 3t0 ml Chloro

INOCULATION

TISSUE CULTURE CELLS: PMK1
BATCH NO. 120182
FLASKS: 18 ml eluate in 1 Roux
ROLLER TUBES 1ST PASSAGE: 0.4 ml eluate in 4 tubes
2ND PASSAGE: 0.8 ml (bottle) in 4 tubes

MICROSCOPY: negative
VIRAL ISOLATION: none
TITRE OF VIRUS:

ROTAVIRUS

LATEX TEST:
ELECTRONMICROSCOPY:
IMMUNOFLUORESCENCE:

ISOLATE IDENTIFICATION

CYTOPATHOLOGY:
IMMUNOFLUORESCENCE:
MICE:
HAEMAGGLUTINATION:
POLYACRYLAMIDE GEL ELECTROPHORESIS:

BACTERIOLOGY

COLIPHAGES:
TOTAL COLIFORM COUNT:
STANDARD PLATE COUNT:

FINAL RESULT: No virus detected.

VIROLOGICAL ASSAY OF WATER SAMPLES
WATER RESEARCH UNIT, DEPARTMENT OF MEDICAL MICROBIOLOGY, UCT

SOURCE:CPRP Stabilization tank
Post Chlorination

DATE:18.01.83
CODE:W2 83(2)

APPEARANCE:

VOLUME:10 l

CONCENTRATION TIME:20 h
PRESSURE:200 kpa
ULTRAFILTRATION MEMBRANE: XM 50

ELUTION VOLUME: 20 ml MEM
DECONTAMINATION: 3.0ml Chloro

INOCULATION

TISSUE CULTURE CELLS: PMK
BATCH NO. 05.01.83
FLASKS: 18ml in 1 Roux bottle
ROLLER TUBES 1ST PASSAGE: 0.4ml eluate /4 tubes
2ND PASSAGE: 0.8ml (bottle) 4 tubes/sample

MICROSCOPY: negative
VIRAL ISOLATION: none
TITRE OF VIRUS:

ROTAVIRUS

LATEX TEST: negative
ELECTRONMICROSCOPY:
IMMUNOFLUORESCENCE:

ISOLATE IDENTIFICATION

CYTOPATHOLOGY:
IMMUNOFLUORESCENCE:
MICE:
HAEMAGGLUTINATION:
POLYACRYLAMIDE GEL ELECTROPHORESIS:

BACTERIOLOGY

COLIPHAGES:
TOTAL COLIFORM COUNT:
STANDARD PLATE COUNT:

FINAL RESULT: No virus detected.

VIROLOGICAL ASSAY OF WATER SAMPLES
WATER RESEARCH UNIT, DEPARTMENT OF MEDICAL MICROBIOLOGY, UCT

SOURCE:Carbon Column Effluent

DATE: 25.01.83
CODE:W3/83

APPEARANCE: Clear

VOLUME: 10 l

CONCENTRATION TIME:16 h
PRESSURE:200 kpa
ULTRAFILTRATION MEMBRANE: XM 50

ELUTION VOLUME: 20 ml MEM
DECONTAMINATION: 3.0 ml Chloro

INOCULATION

TISSUE CULTURE CELLS: PMK1
BATCH NO. 1201 !3
FLASKS: 15 ml eluate in 1 Roux
ROLLER TUBES 1ST PASSAGE: 0.8 ml eluate in 4 tubes
2ND PASSAGE: 0.8 ml (bottle) in 4 tubes

MICROSCOPY: negative
VIRAL ISOLATION: none
TITRE OF VIRUS:

ROTAVIRUS

LATEX TEST:
ELECTRONMICROSCOPY:
IMMUNOFLUORESCENCE:

ISOLATE IDENTIFICATION

CYTOPATHOLOGY:
IMMUNOFLUORESCENCE:
MICE:
HAEMAGGLUTINATION:
POLYACRYLAMIDE GEL ELECTROPHORESIS:

BACTERIOLOGY

COLIPHAGES:
TOTAL COLIFORM COUNT:
STANDARD PLATE COUNT:

FINAL RESULT: No virus detected.

VIROLOGICAL ASSAY OF WATER SAMPLES
WATER RESEARCE UNIT, DEPARTMENT OF MEDICAL MICROBIOLOGY, UCT

SOURCE:CFRP Carbon Column Effluent

DATE:01.02.83
CODE:W4 /83

APPEARANCE:Clear

VOLUME:10 l

CONCENTRATION TIME:16 h
PRESSURE:200 kpa
ULTRAFILTRATION MEMBRANE: XM 50

ELUTION VOLUME: 20ml MEM
DECONTAMINATION: 3.0ml Chloro

INOCULATION

TISSUE CULTURE CELLS: PMK
BATCH NO. 26.01.83
FLASKS: 17ml eluate in 1 Roux bottle
ROLLER TUBES 1ST PASSAGE: 0.8ml eluate /4 tubes
2ND PASSAGE: 0.8ml (bottle)

MICROSCOPY: negative
VIRAL ISOLATION: none
TITRE OF VIRUS:

ROTAVIRUS

LATEX TEST: negative
ELECTRONMICROSCOPY:
IMMUNOFLUORESCENCE:

ISOLATE IDENTIFICATION

CYTOPATHOLOGY:
IMMUNOFLUORESCENCE:
MICE:
HAEMAGGLUTINATION:
POLYACRYLAMIDE GEL ELECTROPHORESIS:

BACTERIOLOGY

COLIPHAGES:
TOTAL COLIFORM COUNT:
STANDARD PLATE COUNT:

FINAL RESULT: No virus detected.

VIROLOGICAL ASSAY OF WATER SAMPLES
WATER RESEARCH UNIT, DEPARTMENT OF MEDICAL MICROBIOLOGY, UCT

SOURCE:CFRP Carbon Column Effluent

DATE:08.02.83
CODE:W5 /83

APPEARANCE:Clear

VOLUME:10 l

CONCENTRATION TIME:20 h
PRESSURE:200 kpa
ULTRAFILTRATION MEMBRANE: XM 50

ELUTION VOLUME: 20 ml MEM
DECONTAMINATION: 3.0 ml Chloro

INOCULATION

TISSUE CULTURE CELLS: PMK
BATCH NO. 260183
FLASKS: 17ml eluate in 1 Roux bottle
ROLLER TUBES 1ST PASSAGE: 0.8ml /4 tubes
2ND PASSAGE: 0.8ml (bottle)

MICROSCOPY: negative
VIRAL ISOLATION: none
TITRE OF VIRUS:

ROTAVIRUS

LATEX TEST: negative
ELECTRONMICROSCOPY:
IMMUNOFLUORESCENCE: negative

ISOLATE IDENTIFICATION

CYTOPATHOLOGY:
IMMUNOFLUORESCENCE:
MICE:
HAEMAGGLUTINATION:
POLYACRYLAMIDE GEL ELECTROPHORESIS:

BACTERIOLOGY

COLIPHAGES:
TOTAL COLIFORM COUNT:
STANDARD PLATE COUNT:

FINAL RESULT: No virus detected.

VIROLOGICAL ASSAY OF WATER SAMPLES
WATER RESEARCH UNIT, DEPARTMENT OF MEDICAL MICROBIOLOGY, UCT

SOURCE:CFRP Carbon Column Effluent

DATE:16.02.83
CODE:W6 /83

APPEARANCE:Clear

VOLUME:10 l

CONCENTRATION TIME:16 h
PRESSURE:200 kpa
ULTRAFILTRATION MEMBRANE: XM 50

ELUTION VOLUME: 20ml MEM
DECONTAMINATION: 3.0 ml Chloro

INOCULATION

TISSUE CULTURE CELLS: PMK
BATCH NO. 260183
FLASKS: 18ml eluate in 1 Roux bottle
ROLLER TUBES 1ST PASSAGE: 0.8ml eluate in 4 tubes
2ND PASSAGE: 0.8ml (bottle) + tubes

MICROSCOPY: negative
VIRAL ISOLATION: none
TITRE OF VIRUS:

ROTAVIRUS

LATEX TEST: negative
ELECTRONMICROSCOPY:
IMMUNOFLUORESCENCE: negative

ISOLATE IDENTIFICATION

CYTOPATHOLOGY:
IMMUNOFLUORESCENCE:
MICE:
EAEMAGGLUTINATION:
POLYACRYLAMIDE GEL ELECTROPHORESIS:

BACTERIOLOGY

COLIPHAGES:
TOTAL COLIFORM COUNT:
STANDARD PLATE COUNT:

FINAL RESULT: No virus detected.

VIROLOGICAL ASSAY OF WATER SAMPLES
WATER RESEARCH UNIT, DEPARTMENT OF MEDICAL MICROBIOLOGY, UCT

SOURCE:CFRP Carbon Column Effluent

DATE:02.03.83
CODE:W7 /83

APPEARANCE:Clear

VOLUME:10 l

CONCENTRATION TIME:16 h
PRESSURE:75 kpa
ULTRAFILTRATION MEMBRANE: XM 50

ELUTION VOLUME: 20 ml MEM
DECONTAMINATION: 3.0 ml Chloro

INOCULATION

TISSUE CULTURE CELLS: PMK
BATCH NO. 160283
FLASKS: 17ml eluate in 1 Roux bottle
ROLLER TUBES 1ST PASSAGE: 0.8ml eluate in 4 tubes
2ND PASSAGE: 0.8ml (bottle) + 0.8 eluate

MICROSCOPY: negative
VIRAL ISOLATION: none
TITRE OF VIRUS:

ROTAVIRUS

LATEX TEST: negative
ELECTRONMICROSCOPY:
IMMUNOFLUORESCENCE: negative

ISOLATE IDENTIFICATION

CYTOPATHOLOGY:
IMMUNOFLUORESCENCE:
MICE:
HAEMAGGLUTINATION:
POLYACRYLAMIDE GEL ELECTROPHORESIS:

BACTERIOLOGY

COLIPHAGES:
TOTAL COLIFORM COUNT:
STANDARD PLATE COUNT:

FINAL RESULT: No virus detected.

VIROLOGICAL ASSAY OF WATER SAMPLES
WATER RESEARCH UNIT, DEPARTMENT OF MEDICAL MICROBIOLOGY, UCT

SOURCE:CFRP Carbon Column Effluent

DATE:01.01.83
CODE:W8 /83

APPEARANCE:Clear

VOLUME: 10 l

CONCENTRATION TIME:16 h
PRESSURE:150 kpa
ULTRAFILTRATION MEMBRANE: XM 50

ELUTION VOLUME: 20ml MEM
DECONTAMINATION: 3.0ml Chloro

INOCULATION

TISSUE CULTURE CELLS: PMK
BATCH NO. 16.02.83
FLASKS: 18ml eluate in 2 Med. Flasks
ROLLER TUBES 1ST PASSAGE: 0.8ml eluate /4 tubes
2ND PASSAGE: 0.8ml (bottle) in 4 tubes

MICROSCOPY: negative
VIRAL ISOLATION: none
TITRE OF VIRUS:

ROTAVIRUS

LATEX TEST: negative
ELECTRONMICROSCOPY:
IMMUNOFLUORESCENCE:

ISOLATE IDENTIFICATION

CYTOPATHOLOGY:
IMMUNOFLUORESCENCE:
MICE:
HAEMAGGLUTINATION:
POLYACRYLAMIDE GEL ELECTROPHORESIS:

BACTERIOLOGY

COLIPHAGES:
TOTAL COLIFORM COUNT:
STANDARD PLATE COUNT:

FINAL RESULT: No virus detected.

VIROLOGICAL ASSAY OF WATER SAMPLES
WATER RESEARCH UNIT, DEPARTMENT OF MEDICAL MICROBIOLOGY, UCT

SOURCE:CFRP Carbon Column Effluent

DATE:16.03.83
CODE:W9 /83

APPEARANCE:Clear

VOLUME:10 l

CONCENTRATION TIME:16 h
PRESSURE:140 kpa
ULTRAFILTRATION MEMBRANE: XM 50

ELUTION VOLUME: 20ml MEM
DECONTAMINATION: 3.0ml Chloro

INOCULATION

TISSUE CULTURE CELLS: PMK
BATCH NO. 230283
FLASKS: 18ml eluate in 1 Roux bottle
ROLLER TUBES 1ST PASSAGE: 0.8ml eluate /4 tubes
2ND PASSAGE: 0.8ml (bottle) + 4 tubes

MICROSCOPY: negative
VIRAL ISOLATION: none
TITRE OF VIRUS:

ROTAVIRUS

LATEX TEST: negative
ELECTRONMICROSCOPY:
IMMUNOFLUORESCENCE: negative

ISOLATE IDENTIFICATION

CYTOPATHOLOGY:
IMMUNOFLUORESCENCE:
MICE:
HAEMAGGLUTINATION:
POLYACRYLAMIDE GEL ELECTROPHORESIS:

BACTERIOLOGY

COLIPHAGES:
TOTAL COLIFORM COUNT:
STANDARD PLATE COUNT:

FINAL RESULT: No virus detected.

VIROLOGICAL ASSAY OF WATER SAMPLES
WATER RESEARCH UNIT, DEPARTMENT OF MEDICAL MICROBIOLOGY, UCT

SOURCE:CFRP Sand Filter Effluent

DATE:24.10.83
CODE:W10/83

APPEARANCE:Clear

VOLUME:10 l

CONCENTRATION TIME:16 h
PRESSURE:150 kpa
ULTRAFILTRATION MEMBRANE: XM 50

ELUTION VOLUME: 20 ml MEM
DECONTAMINATION: 3.0ml Chloro

INOCULATION

TISSUE CULTURE CELLS: PMK
BATCH NO. 210983
FLASKS: 16ml eluate in 2 Med. Flasks
ROLLER TUBES 1ST PASSAGE: 0.8ml eluate /4tubes
2ND PASSAGE: 8 ml (flask)/ 1 PMK Bottle

MICROSCOPY: negative
VIRAL ISOLATION: none
TITRE OF VIRUS:

ROTAVIRUS

LATEX TEST: negative
ELECTRONMICROSCOPY:
IMMUNOFLUORESCENCE:

ISOLATE IDENTIFICATION

CYTOPATHOLOGY:
IMMUNOFLUORESCENCE:
MICE:
HAEMAGGLUTINATION:
POLYACRYLAMIDE GEL ELECTROPHORESIS:

BACTERIOLOGY

COLIPHAGES:
TOTAL COLIFORM COUNT:
STANDARD PLATE COUNT:

FINAL RESULT: No virus detected.

VIROLOGICAL ASSAY OF WATER SAMPLES
WATER RESEARCH UNIT, DEPARTMENT OF MEDICAL MICROBIOLOGY, UCT

SOURCE:CFRP Sand Filter Effluent

DATE:31.10.83
CODE:W11/83

APPEARANCE:Clear

VOLUME:10 l

CONCENTRATION TIME:16 h
PRESSURE:150 kpa
ULTRAFILTRATION MEMBRANE: XM 50

ELUTION VOLUME: 20 ml MEM
DECONTAMINATION: 3.0 ml Chloro

INOCULATION

TISSUE CULTURE CELLS: M104
BATCH NO. P119
FLASKS: 18ml eluate in 2 Med. Flasks
ROLLER TUBES 1ST PASSAGE: 0.8ml eluate /4 tubes
2ND PASSAGE:

MICROSCOPY: negative
VIRAL ISOLATION: none
TITRE OF VIRUS:

ROTAVIRUS

LATEX TEST: negative
ELECTRONMICROSCOPY:
IMMUNOFLUORESCENCE:

ISOLATE IDENTIFICATION

CYTOPATHOLOGY:
IMMUNOFLUORESCENCE:
MICE:
HAEMAGGLUTINATION:
POLYACRYLAMIDE GEL ELECTROPHORESIS:

BACTERIOLOGY

COLIPHAGES:
TOTAL COLIFORM COUNT:
STANDARD PLATE COUNT:

FINAL RESULT: No virus detected.

VIROLOGICAL ASSAY OF WATER SAMPLES
WATER RESEARCH UNIT, DEPARTMENT OF MEDICAL MICROBIOLOGY, UCT

SOURCE:CFRP Sand Filter Effluent

DATE:07.11.83
CODE:W12/83

APPEARANCE:Turbidity 2.0

VOLUME:10 l

CONCENTRATION TIME:16 h
PRESSURE:140 kpa
ULTRAFILTRATION MEMBRANE: XM 50

ELUTION VOLUME: 20ml MEM
DECONTAMINATION: 3.0ml Chloro

INOCULATION

TISSUE CULTURE CELLS: M104
BATCH NO. P120
FLASKS: 18ml eluate in 2 Med. Flasks
ROLLER TUBES 1ST PASSAGE: 0.8ml eluate /4 tubes
2ND PASSAGE:

MICROSCOPY: negative
VIRAL ISOLATION: none
TITRE OF VIRUS:

ROTAVIRUS

LATEX TEST: negative
ELECTRONMICROSCOPY:
IMMUNOFLUORESCENCE:

ISOLATE IDENTIFICATION

CYTOPATHOLOGY:
IMMUNOFLUORESCENCE:
MICE:
HAEMAGGLUTINATION:
POLYACRYLAMIDE GEL ELECTROPHORESIS:

BACTERIOLOGY

COLIPHAGES:
TOTAL COLIFORM COUNT:
STANDARD PLATE COUNT:

FINAL RESULT: No virus detected.

VIROLOGICAL ASSAY OF WATER SAMPLES

WATER RESEARCE UNIT, DEPARTMENT OF MEDICAL MICROBIOLOGY, UCT

SOURCE:CFRP Sand Filter Effluent

DATE:09.01.84
CODE:W1/84

APPEARANCE:Clear

VOLUME:10 l

CONCENTRATION TIME:16 h
PRESSURE:140 kpa
ULTRAFILTRATION MEMBRANE: XM 50

ELUTION VOLUME: 20 ml MEM
DECONTAMINATION: 3.0 ml Chloro

INOCULATION

TISSUE CULTURE CELLS: PMK
BATCH NO. 151284
FLASKS: 16.5 ml eluate in Roux Bottle
ROLLER TUBES 1ST PASSAGE: 0.8 ml eluate /4 tubes
2ND PASSAGE: 0.8ml (bottle)+ 0.8 eluate

MICROSCOPY: Negative
VIRAL ISOLATION: None
TITRE OF VIRUS:

ROTAVIRUS

LATEX TEST: negative
ELECTRONMICROSCOPY:
IMMUNOFLUORESCENCE:

ISOLATE IDENTIFICATION

CYTOPATEOLOGY:
IMMUNOFLUORESCENCE:
MICE:
HAEMAGGLUTINATION:
POLYACRYLAMIDE GEL ELECTROPHORESIS:

BACTERIOLOGY

COLIPHAGES:
TOTAL COLIFORM COUNT:
STANDARD PLATE COUNT:

FINAL RESULT: No virus detected

VIROLOGICAL ASSAY OF WATER SAMPLES
WATER RESEARCH UNIT, DEPARTMENT OF MEDICAL MICROBIOLOGY, UCT

SOURCE:CFRP Sand Filter Effluent

DATE:16.01.84
CODE:W2/84

APPEARANCE:Clear

VOLUME:10 l

CONCENTRATION TIME:16 h
PRESSURE:130 kpa
ULTRAFILTRATION MEMBRANE: XM 50

ELUTION VOLUME: 20 ml MEM
DECONTAMINATION: 3.0 ml Chloro

INOCULATION

TISSUE CULTURE CELLS: PMK
BATCH NO. 281284
FLASKS: 17 ml eluate in 1 Roux Bottle
ROLLER TUBES 1ST PASSAGE: 0.8 ml eluate /4 tubes
2ND PASSAGE: 0.8ml (bottle)+ 0.8 eluate

MICROSCOPY: Negative
VIRAL ISOLATION: None
TITRE OF VIRUS:

ROTAVIRUS

LATEX TEST: negative
ELECTRONMICROSCOPY:
IMMUNOFLUORESCENCE:

ISOLATE IDENTIFICATION

CYTOPATHOLOGY:
IMMUNOFLUORESCENCE:
MICE:
HAEMAGGLUTINATION:
POLYACRYLAMIDE GEL ELECTROPHORESIS:

BACTERIOLOGY

COLIPHAGES:
TOTAL COLIFORM COUNT:
STANDARD PLATE COUNT:

FINAL RESULT: No virus detected

VIROLOGICAL ASSAY OF WATER SAMPLES
WATER RESEARCH UNIT, DEPARTMENT OF MEDICAL MICROBIOLOGY, UCT

SOURCE:CFRP Sand Filter Effluent

DATE:23.01.84
CODE:W3/84

APPEARANCE:Clear

VOLUME:10 l

CONCENTRATION TIME:16 h
PRESSURE:150 kpa
ULTRAFILTRATION MEMBRANE: XM 50

ELUTION VOLUME: 20 ml MEM
DECONTAMINATION: 3.0 ml Chloro

INOCULATION

TISSUE CULTURE CELLS: PMK
BATCH NO. 110184
FLASKS: 17.5 ml eluate in Roux Bottle
ROLLER TUBES 1ST PASSAGE: 0.8 ml eluate /4 tubes
2ND PASSAGE: 0.8ml (bottle)+ 0.8 eluate

MICROSCOPY: Negative
VIRAL ISOLATION: None
TITRE OF VIRUS:

ROTAVIRUS

LATEX TEST: negative
ELECTRONMICROSCOPY:
IMMUNOFLUORESCENCE:

ISOLATE IDENTIFICATION

CYTOPATHOLOGY:
IMMUNOFLUORESCENCE:
MICE:
HAEMAGGLUTINATION:
POLYACRYLAMIDE GEL ELECTROPHORESIS:

BACTERIOLOGY

COLIPHAGES:
TOTAL COLIFORM COUNT:
STANDARD PLATE COUNT:

FINAL RESULT: No virus detected

VIROLOGICAL ASSAY OF WATER SAMPLES
WATER RESEARCH UNIT, DEPARTMENT OF MEDICAL MICROBIOLOGY, UCT

SOURCE:CFRP Sand Filter Effluent

DATE:06.02.84
CODE:W5/84

APPEARANCE:Clear

VOLUME:10 L

CONCENTRATION TIME:16 h
PRESSURE:200 kpa
ULTRAFILTRATION MEMBRANE: XM 50

ELUTION VOLUME: 20 ml MEM
DECONTAMINATION: 3.0 ml Chloro

INOCULATION

TISSUE CULTURE CELLS: PMK
BATCH NO. 250184
FLASKS: 16.5ml eluate in Roux - 21 day
ROLLER TUBES 1ST PASSAGE: 0.8 ml eluate /4 tubes
2ND PASSAGE:

MICROSCOPY: negative
VIRAL ISOLATION: none
TITRE OF VIRUS:

ROTAVIRUS

LATEX TEST: negative
ELECTRONMICROSCOPY:
IMMUNOFLUORESCENCE:

ISOLATE IDENTIFICATION

CYTOPATHOLOGY:
IMMUNOFLUORESCENCE:
MICE:
HAEMAGGLUTINATION:
POLYACRYLAMIDE GEL ELECTROPHORESIS:

BACTERIOLOGY

COLIPHAGES:
TOTAL COLIFORM COUNT:
STANDARD PLATE COUNT:

FINAL RESULT: No virus detected.

VIROLOGICAL ASSAY OF WATER SAMPLES
WATER RESEARCH UNIT, DEPARTMENT OF MEDICAL MICROBIOLOGY, UCT

SOURCE:CFRP Pond W9

DATE:20.02.84
CODE:W6/84

APPEARANCE:Turbid

VOLUME:5 l

CONCENTRATION TIME:16 h
PRESSURE:100 kpa
ULTRAFILTRATION MEMBRANE: XM 50

ELUTION VOLUME: 20 ml MEM
DECONTAMINATION: 3.0 ml Chloro

INOCULATION

TISSUE CULTURE CELLS: PMK
BATCH NO. 080284
FLASKS: 16 ml eluate in 1 Roux Bottle
ROLLER TUBES 1ST PASSAGE: 0.8 ml eluate /4 tubes
2ND PASSAGE:

MICROSCOPY: Reovirus
VIRAL ISOLATION: Reovirus Type III
TITRE OF VIRUS: $10^{1\cdot 5} = 6.3 \times 10^{1}$/litre

ROTAVIRUS

LATEX TEST: negative
ELECTRONMICROSCOPY:
IMMUNOFLUORESCENCE: negative

ISOLATE IDENTIFICATION

CYTOPATHOLOGY:
IMMUNOFLUORESCENCE:
MICE:
HAEMAGGLUTINATION: Reovirus III
POLYACRYLAMIDE GEL ELECTROPHORESIS: Reovirus Type III

BACTERIOLOGY

COLIPHAGES:
TOTAL COLIFORM COUNT:
STANDARD PLATE COUNT:

FINAL RESULT: 6.3×10^{1}. Reovirus Type III/litre

VIROLOGICAL ASSAY OF WATER SAMPLES
WATER RESEARCH UNIT, DEPARTMENT OF MEDICAL MICROBIOLOGY, UCT

SOURCE:CFRP Feed Water

DATE:05.03.84
CODE:W7/84

APPEARANCE:Turbid

VOLUME:5 l

CONCENTRATION TIME:16 h
PRESSURE:80 kpa
ULTRAFILTRATION MEMBRANE: XM 50

ELUTION VOLUME: 20 ml MEM
DECONTAMINATION: 3.0 ml Chloro

INOCULATION

TISSUE CULTURE CELLS: PMK
BATCH NO. 220284
FLASKS: 16 ml eluate in 1 Roux Bottle
ROLLER TUBES 1ST PASSAGE: 0.8 ml eluate /4 tubes
2ND PASSAGE:

MICROSCOPY: Reovirus
VIRAL ISOLATION: Reovirus Type III
TITRE OF VIRUS: $10^{-2.3}$ - 4.2×10^{3}/litre

ROTAVIRUS

LATEX TEST: negative
ELECTRONMICROSCOPY:
IMMUNOFLUORESCENCE: negative

ISOLATE IDENTIFICATION

CYTOPATHOLOGY:
IMMUNOFLUORESCENCE:
MICE:
HAEMAGGLUTINATION: Reovirus III
POLYACRYLAMIDE GEL ELECTROPHORESIS: Reovirus Type III

BACTERIOLOGY

COLIPHAGES:
TOTAL COLIFORM COUNT:
STANDARD PLATE COUNT:

FINAL RESULT: 4.2×10^{3}. Reovirus Type III/litre

VIROLOGICAL ASSAY OF WATER SAMPLES
WATER RESEARCH UNIT, DEPARTMENT OF MEDICAL MICROBIOLOGY, UCT

SOURCE:CFRP Feed Water

DATE:19.03.84
CODE:W8/84

APPEARANCE:Turbid

VOLUME:5 l

CONCENTRATION TIME:16 h
PRESSURE:200 kpa
ULTRAFILTRATION MEMBRANE: XM 50

ELUTION VOLUME: 20 ml MEM
DECONTAMINATION: 3.0 ml Chloro

INOCULATION

TISSUE CULTURE CELLS: PMK
BATCH NO. 070384
FLASKS: 16 ml eluate in 1 Roux Bottle
ROLLER TUBES 1ST PASSAGE: 0.8 ml eluate /4 tubes
2ND PASSAGE:

MICROSCOPY: Reovirus
VIRAL ISOLATION: Reovirus Type III
TITRE OF VIRUS: $10^{-3.7}$ - 1.1×10^{4}/litre

ROTAVIRUS

LATEX TEST: negative
ELECTRONMICROSCOPY:
IMMUNOFLUORESCENCE: negative

ISOLATE IDENTIFICATION

CYTOPATHOLOGY:
IMMUNOFLUORESCENCE:
MICE:
HAEMAGGLUTINATION: Reovirus III
POLYACRYLAMIDE GEL ELECTROPHORESIS: Reovirus Type III

BACTERIOLOGY

COLIPHAGES:
TOTAL COLIFORM COUNT:
STANDARD PLATE COUNT:

FINAL RESULT: 1.1×10^{4} Reovirus Type III/litre

VIROLOGICAL ASSAY OF WATER SAMPLES

WATER RESEARCH UNIT, DEPARTMENT OF MEDICAL MICROBIOLOGY, UCT

SOURCE:CFRP Feed Water

DATE:02.04.84
CODE:W9/84

APPEARANCE:Turbid

VOLUME:5 l

CONCENTRATION TIME:16 h
PRESSURE:200 kpa
ULTRAFILTRATION MEMBRANE: XM 50

ELUTION VOLUME: 20 ml MEM
DECONTAMINATION: 3.0 ml Chloro

INOCULATION

TISSUE CULTURE CELLS: E6
BATCH NO. P46
FLASKS: 17 ml eluate in 1 Roux Bottle
ROLLER TUBES 1ST PASSAGE: 0.8 ml eluate /4 tubes
2ND PASSAGE:

MICROSCOPY: Reovirus
VIRAL ISOLATION: Reovirus Type III
TITRE OF VIRUS: 10^{-2} - $2x10^{3}$/litre

ROTAVIRUS

LATEX TEST: negative
ELECTRONMICROSCOPY:
IMMUNOFLUORESCENCE: negative

ISOLATE IDENTIFICATION

CYTOPATEOLOGY:
IMMUNOFLUORESCENCE:
MICE:
HAEMAGGLUTINATION: Reovirus III
POLYACRYLAMIDE GEL ELECTROPHORESIS: Reovirus Type III

BACTERIOLOGY

COLIPHAGES:
TOTAL COLIFORM COUNT:
STANDARD PLATE COUNT:

FINAL RESULT: $2x10^{3}$ Reovirus Type III per litre

VIROLOGICAL ASSAY OF WATER SAMPLES
WATER RESEARCH UNIT, DEPARTMENT OF MEDICAL MICROBIOLOGY, UCT

SOURCE:CFRP Sand Filter Effluent

DATE:28.11.84
CODE:W10/84

APPEARANCE:Clear

VOLUME:10 l

CONCENTRATION TIME:16 h
PRESSURE:140 kpa
ULTRAFILTRATION MEMBRANE: XM 50

ELUTION VOLUME: 20 ml MEM
DECONTAMINATION: 3.0 ml Chloro

INOCULATION

TISSUE CULTURE CELLS: BGM
BATCH NO. P192
FLASKS: 17.5 ml eluate in Roux Bottle
ROLLER TUBES 1ST PASSAGE: 0.8 ml eluate /4 tubes
2ND PASSAGE: 0.8 ml (bottle)/ 4 tubes

MICROSCOPY: Negative
VIRAL ISOLATION: None
TITRE OF VIRUS:

ROTAVIRUS

LATEX TEST: negative
ELECTRONMICROSCOPY:
IMMUNOFLUORESCENCE:

ISOLATE IDENTIFICATION

CYTOPATHOLOGY:
IMMUNOFLUORESCENCE:
MICE:
HAEMAGGLUTINATION:
POLYACRYLAMIDE GEL ELECTROPHORESIS:

BACTERIOLOGY

COLIPHAGES:
TOTAL COLIFORM COUNT:
STANDARD PLATE COUNT:

FINAL RESULT: No virus detected

VIROLOGICAL ASSAY OF WATER SAMPLES
WATER RESEARCH UNIT, DEPARTMENT OF MEDICAL MICROBIOLOGY, UCT

SOURCE:CFRP Sand Filter Effluent

DATE:23.01.85
CODE:W1 /85

APPEARANCE:Clear

VOLUME:10 l

CONCENTRATION TIME:16 h
PRESSURE:100 kpa
ULTRAFILTRATION MEMBRANE: XM 50

ELUTION VOLUME: 20ml MEM
DECONTAMINATION: 3.0ml Chloro

INOCULATION

TISSUE CULTURE CELLS: PMK
BATCH NO. 240185
FLASKS: 16.5ml eluate in 1 Roux bottle
ROLLER TUBES 1ST PASSAGE: 0.8ml eluate /4 tubes
2ND PASSAGE: 10ml (bottle) + 0.8 eluate

MICROSCOPY: negative
VIRAL ISOLATION: none
TITRE OF VIRUS:

ROTAVIRUS

LATEX TEST: negative
ELECTRONMICROSCOPY:
IMMUNOFLUORESCENCE:

ISOLATE IDENTIFICATION

CYTOPATHOLOGY:
IMMUNOFLUORESCENCE:
MICE:
HAEMAGGLUTINATION:
POLYACRYLAMIDE GEL ELECTROPHORESIS:

BACTERIOLOGY

COLIPHAGES:
TOTAL COLIFORM COUNT:
STANDARD PLATE COUNT:

FINAL RESULT: No virus detected.

VIROLOGICAL ASSAY OF WATER SAMPLES
WATER RESEARCH UNIT, DEPARTMENT OF MEDICAL MICROBIOLOGY, UCT

SOURCE:CFRP Sand Filter Effluent

DATE:30.01.85
CODE:W2 /85

APPEARANCE:Clear

VOLUME:10 l

CONCENTRATION TIME:16 h
PRESSURE:100 kpa
ULTRAFILTRATION MEMBRANE: XM 50

ELUTION VOLUME: 20 ml MEM
DECONTAMINATION: 3.0 ml Chloro

INOCULATION

TISSUE CULTURE CELLS: PMK
BATCH NO. 240185
FLASKS: 16ml eluate in 1 Roux bottle
ROLLER TUBES 1ST PASSAGE: 0.8ml eluate /4 tubes
2ND PASSAGE: 10ml (bottle) in Falcon Flask

MICROSCOPY: negative
VIRAL ISOLATION: none
TITRE OF VIRUS:

ROTAVIRUS

LATEX TEST: negative
ELECTRONMICROSCOPY:
IMMUNOFLUORESCENCE:

ISOLATE IDENTIFICATION

CYTOPATHOLOGY:
IMMUNOFLUORESCENCE:
MICE:
HAEMAGGLUTINATION:
POLYACRYLAMIDE GEL ELECTROPHORESIS:

BACTERIOLOGY

COLIPHAGES:
TOTAL COLIFORM COUNT:
STANDARD PLATE COUNT:

FINAL RESULT: No virus detected.

VIROLOGICAL ASSAY OF WATER SAMPLES
WATER RESEARCH UNIT, DEPARTMENT OF MEDICAL MICROBIOLOGY, UCT

SOURCE:CFRP Sand Filter Effluent

DATE:06.02.85
CODE:W3 /85

APPEARANCE:Clear

VOLUME:10 l

CONCENTRATION TIME:16 h
PRESSURE:100 kpa
ULTRAFILTRATION MEMBRANE: XM 50

ELUTION VOLUME: 20ml MEM
DECONTAMINATION: 3.0ml Chloro

INOCULATION

TISSUE CULTURE CELLS: PMK
BATCH NO. 240185
FLASKS: 16ml eluate in 1 Roux Bottle
ROLLER TUBES 1ST PASSAGE: 0.8 ml eluate /4 tubes
2ND PASSAGE: 10ml (Roux) in Falcon Flask

MICROSCOPY: negative
VIRAL ISOLATION: none
TITRE OF VIRUS:

ROTAVIRUS

LATEX TEST: negative
ELECTRONMICROSCOPY:
IMMUNOFLUORESCENCE:

ISOLATE IDENTIFICATION

CYTOPATHOLOGY:
IMMUNOFLUORESCENCE:
MICE:
HAEMAGGLUTINATION:
POLYACRYLAMIDE GEL ELECTROPHORESIS:

BACTERIOLOGY

COLIPHAGES:
TOTAL COLIFORM COUNT:
STANDARD PLATE COUNT:

FINAL RESULT: No virus detected.

VIROLOGICAL ASSAY OF WATER SAMPLES
WATER RESEARCH UNIT, DEPARTMENT OF MEDICAL MICROBIOLOGY, UCT

SOURCE:CFRP Sand Filter Effluent

DATE:13.02.85
CODE:W4/85

APPEARANCE:Clear

VOLUME:10 l

CONCENTRATION TIME:16 h
PRESSURE:50 kpa
ULTRAFILTRATION MEMBRANE: XM 50

ELUTION VOLUME: 20 ml MEM
DECONTAMINATION: 3.0 ml Chloro

INOCULATION

TISSUE CULTURE CELLS: PMK
BATCH NO. 240185
FLASKS: 16.5ml eluate in 3 Med Bottles
ROLLER TUBES 1ST PASSAGE: 0.8 ml eluate /4 tubes
2ND PASSAGE: 0.8ml (bottle) + 0.8 eluate

MICROSCOPY: negative
VIRAL ISOLATION: none
TITRE OF VIRUS:

ROTAVIRUS

LATEX TEST: negative
ELECTRONMICROSCOPY:
IMMUNOFLUORESCENCE:

ISOLATE IDENTIFICATION

CYTOPATHOLOGY:
IMMUNOFLUORESCENCE:
MICE:
HAEMAGGLUTINATION:
POLYACRYLAMIDE GEL ELECTROPHORESIS:

BACTERIOLOGY

COLIPHAGES:
TOTAL COLIFORM COUNT:
STANDARD PLATE COUNT:

FINAL RESULT: No virus detected

VIROLOGICAL ASSAY OF WATER SAMPLES
WATER RESEARCH UNIT, DEPARTMENT OF MEDICAL MICROBIOLOGY, UCT

SOURCE:CFRP Sand Filter Effluent

DATE:26.02.85
CODE:WS/85

APPEARANCE:Clear

VOLUME:10 l

CONCENTRATION TIME:16 h
PRESSURE:80 kpa
ULTRAFILTRATION MEMBRANE: XM 50

ELUTION VOLUME: 20 ml MEM
DECONTAMINATION: 3.0 ml Chloro

INOCULATION

TISSUE CULTURE CELLS: PMK
BATCH NO. 130285
FLASKS: 15ml eluate in 2 Falcon Flasks
ROLLER TUBES 1ST PASSAGE: 0.8 ml eluate /4 tubes
2ND PASSAGE: 0.8ml (bottle) + 0.8 eluate

MICROSCOPY: negative
VIRAL ISOLATION: none
TITRE OF VIRUS:

ROTAVIRUS

LATEX TEST: negative
ELECTRONMICROSCOPY:
IMMUNOFLUORESCENCE:

ISOLATE IDENTIFICATION

CYTOPATHOLOGY:
IMMUNOFLUORESCENCE:
MICE:
HAEMAGGLUTINATION:
POLYACRYLAMIDE GEL ELECTROPHORESIS:

BACTERIOLOGY

COLIPHAGES:
TOTAL COLIFORM COUNT:
STANDARD PLATE COUNT:

FINAL RESULT: No virus detected

VIROLOGICAL ASSAY OF WATER SAMPLES
WATER RESEARCH UNIT, DEPARTMENT OF MEDICAL MICROBIOLOGY, UCT

SOURCE:CFRP Sand Filter Effluent

DATE:27.02.85
CODE:W6/85

APPEARANCE:Clear

VOLUME:10 l

CONCENTRATION TIME:16 h
PRESSURE:80 kpa
ULTRAFILTRATION MEMBRANE: XM 50

ELUTION VOLUME: 20 ml MEM
DECONTAMINATION: 3.0 ml Chloro

INOCULATION

TISSUE CULTURE CELLS: PMK
BATCH NO. 130285
FLASKS: 14ml eluate in 2 Falcon Flasks
ROLLER TUBES 1ST PASSAGE: 0.8 ml eluate /4 tubes
2ND PASSAGE: 0.8ml (bottle) + 0.8 eluate

MICROSCOPY: negative
VIRAL ISOLATION: none
TITRE OF VIRUS:

ROTAVIRUS

LATEX TEST: negative
ELECTRONMICROSCOPY:
IMMUNOFLUORESCENCE:

ISOLATE IDENTIFICATION

CYTOPATHOLOGY:
IMMUNOFLUORESCENCE:
MICE:
HAEMAGGLUTINATION:
POLYACRYLAMIDE GEL ELECTROPHORESIS:

BACTERIOLOGY

COLIPHAGES:
TOTAL COLIFORM COUNT:
STANDARD PLATE COUNT:

FINAL RESULT: No virus detected

VIROLOGICAL ASSAY OF WATER SAMPLES
WATER RESEARCH UNIT, DEPARTMENT OF MEDICAL MICROBIOLOGY, UCT

SOURCE:CPRP Sand Filter Effluent

DATE:12.03.85
CODE:W7/85

APPEARANCE:Clear

VOLUME:10 l

CONCENTRATION TIME:16 h
PRESSURE:50 kpa
ULTRAFILTRATION MEMBRANE: XM 50

ELUTION VOLUME: 20 ml MEM
DECONTAMINATION: 3.0 ml Chloro

INOCULATION

TISSUE CULTURE CELLS: PMK
BATCH NO. 270285
FLASKS: 17ml eluate in 2 Falcon Flasks
ROLLER TUBES 1ST PASSAGE: 0.8 ml eluate /4 tubes
2ND PASSAGE: 0.8ml (bottle) + 0.8 eluate

MICROSCOPY: negative
VIRAL ISOLATION: none
TITRE OF VIRUS:

ROTAVIRUS

LATEX TEST: negative
ELECTRONMICROSCOPY:
IMMUNOFLUORESCENCE:

ISOLATE IDENTIFICATION

CYTOPATHOLOGY:
IMMUNOFLUORESCENCE:
MICE:
HAEMAGGLUTINATION:
POLYACRYLAMIDE GEL ELECTROPHORESIS:

BACTERIOLOGY

COLIPHAGES:
TOTAL COLIFORM COUNT:
STANDARD PLATE COUNT:

FINAL RESULT: No virus detected

APPENDIX 4

Intensive surveillance programme

Organic chemical analyses of sample group E by Watertek

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ORGANIC CHEMICAL RESULTS OF THE CAPE FLATS WATER RECLAMATION PLANT FOR THE PERIOD 2 OCTOBER TO 2 DECEMBER 1986

ANALYTICAL METHODS

Dissolved Organic Carbon (DOC)

The method is based on the oxidation of the organic compounds in a water sample followed by infrared detection of the carbon dioxide liberated (Van Steenderen and Lin, 1981).

Total Organohalogen Potential Value (TOHp)

Samples were chlorinated to contain a free chlorine residual of 60 mg/l and left at room temperature in a closed container for 48 h. Samples were then extracted with petroleum ether and subjected to microcoulometric analysis as described by Van Steenderen 1980.

Ultraviolet Absorption Measurements

Samples were filtered through a glass fibre filter, placed in a 40 mm quartz cuvette and read at 275 nm on a Zeiss spectrometer.

Trihalomethanes (THM's)

Samples were extracted the day they were received, that is, two days after actual sampling. Analysis was by means of gas chromatography as described by Van Rensburg and Hassett, 1982.

DISCUSSION OF AVERAGE DOC, TOHp AND UV ABS RESULTS (TABLE 1)

1. There was a 45 per cent reduction in DOC after flocculation and another 45 per cent after GAC adsorption (a total of 90 per cent removal). This removal r ate was maintained throughout the sampling period.

2. Flocculation reduced the TOHp value by 22 per cent.

3. After ozonation the precursor concentration increased to a value higher than that of the intake water (CR1).

4. GAC removed 65 per cent of the TOHp concentration.

5. pH correction and post chlorination (CR5) had no further effect on the DOC and precursor concentration.

6. The consistently low DOC values obtained for sampling point CR5 coincide with the extremely low UV absorption values and it is not possible to derive a correlation from the values tabled.

DISCUSSION OF THM RESULTS (TABLE 2)

All results are terminal values. It was only towards the end of the experimental run that the THM values approached the 100 µg/l level used by the US Environmental Protection Agency (EPA) as an acceptable level in drinking-waters. If one can assume that the raw water (CR1) contained THM concentrations of less than 10 µg/l then prechlorination resulted in a four fold escallation of THM's at CR2. Ozone treatment (CR3) did not have a noticeable effect on the THM's already formed. With the exception of sample point CR4, the bromo containing components were predominant at all the other sampling points and made up 82% of the THM concentration at CR5.

TABLE 1: Dissolved organic carbon (DOC), the organohalogen potential (TOHp) and ultraviolet absorption measurements of the Cape Flats Water Reclamation Plant for the period 2 October to 2 December 1986

Date	Sample points										
	CR1		CR2		CR3		CR4		CR5		
	DOC	TOHp	DOC	TOHp	DOC	TOHp	DOC	TOHp	DOC	TOHp	UV
86-10-02	12,6	1200	*	*	5,0	1917	<1,0	1444	<1,0	751	0,01
86-10-14	-	-	4,1	350	4,2	428	<1,0	144	<1,0	177	0,04
86-10-23	-	-	4,8	746	7,1	526	1,6	287	1,8	249	0,03
86-10-28	-	-	4,8	*	4,6	*	<1,0	*	1,8	*	0,02
86-11-04	-	-	5,0	1702	6,6	1490	1,8	255	1,2	338	0,01
86-11-11	-	-	5,8	515	5,4	1283	1,8	409	1,4	1521	0,03
86-11-18	-	-	20,3	1614	4,6	1821	<1,0	246	2,8	313	0,01
86-11-25	-	-	5,2	881	5,6	2257	1,4	260	2,4	342	0,01
86-12-02	-	-	5,2	768	5,0	1252	2,4	102	1,4	123	0,01
AVERAGES	12,6	1200	6,9	942	5,4	1373	1,4	418	1,6	476	0,02

DOC concentrations in mg/l carbon
TOHp concentrations in µg/l (as $CHCl_3$)
UV absorption readings at 275 nm, 40 mm cell
* sample not taken, received container broken or not enough sample received due to leakage during transport.

REFERENCES

1. VAN STEENDEREN, R A and LIN, J S (1981) Determination of dissolved organic carbon in *Water Anal. Chem.* 53, 2157-8.

2. VAN STEENDEREN, R A (1980) The construction of a total organohalogen analyser system. *Laboratory Practice* 29(4), 380-385.

3. VAN RENSBURG, J F J and HASSETT, A J (1982) A low volume liquid-liquid extraction technique. Journal of High Resolution Chromatograpy and Chromatography Communications 5, 574-6.

PRETORIA
March 1987
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TABLE 2. TRIHALOMETHANE CONCENTRATIONS IN THE CAPE FLATS WATER RECLAMATION PLANT FOR THE PERIOD 86-10-02 TO 86-12-02

Determinand	Sample	86-10-02	86-10-14	86-10-21	86-10-28	86-11-04	86-11-11	86-11-18	86-11-25	86-12-02	Min	Max	$\bar{x}$	η
$CH Cl_3$				16,1	17,0	23,7	10,9	16,4	18,0	10,2	10,2	23,7	16,0	
$CH Br Cl_2$				6,0	3,8	5,8	2,0	4,6	9,6	2,0	2,0	9,6	4,8	
$CH Br_2 Cl$	CR 2			10,8	12,6	20,0	15,1	21,2	14,0	0,8	0,8	21,2	13,5	7
$CH Br_3$				4,8	4,0	10,0	1,6	3,2	7,4	1,7	1,6	10,0	4,7	
TOTAL				37,7	37,4	59,5	29,6	45,4	49,0	14,7	14,7	59,5	39,0	
$CH Cl_3$		17,1		14,0	18,6	18,0	8,0	20,4	22,6	8,6	8,0	22,6	15,9	
$CH Br Cl_2$		3,0		5,6	4,0	3,8	1,6	6,0	10,0	3,7	1,6	10,0	4,7	
$CH Br_2 Cl$	CR 3	12,7		11,8	9,3	19,0	12,3	12,9	12,3	1,2	1,2	19,0	11,4	8
$CH Br_3$		7,4		3,0	5,0	11,2	22,9	6,0	9,1	2,8	2,8	22,9	8,4	
TOTAL		40,2		34,4	36,9	52,0	44,8	45,3	54,0	16,3	16,3	54,0	40,5	
$CH Cl_3$		4,1		8,6	2,4	3,9	2,7	6,1	10,7	11,1	2,4	11,1	6,2	
$CH Br Cl_2$		1,4		3,1	1,0	0,5	0,5	1,2	4,1	3,6	0,5	4,1	1,9	
$CH Br_2 Cl$	CR 4	1,1		1,1	0,7	0,6	0,5	0,4	0,6	0,9	0,4	1,1	0,7	8
$CH Br_3$		0,6		0,7	0,7	0,4	0,6	0,4	0,9	2,0	0,4	2,0	0,8	
TOTAL		7,2		13,5	4,8	5,4	4,3	8,1	16,3	17,6	4,3	17,6	9,6	
$CH Cl_3$		12,8	14,3	11,3	10,7	9,7	8,4	11,6	13,7	16,1	8,4	14,3	12,1	
$CH Br Cl_2$		13,6	10,1	6,4	8,8	6,3	8,0	8,1	10,4	17,3	6,3	17,3	9,9	
$CH Br_2 Cl$	CR 5	20,9	20,7	14,2	19,0	18,9	14,0	20,9	29,8	34,0	14,0	34,0	21,4	9
$CH Br_3$		10,4	30,8	8,9	20,7	16,4	24,1	32,3	40,4	35,6	8,9	40,4	24,4	
TOTAL		57,7	75,9	40,8	59,2	51,3	54,5	72,9	94,3	103,0	40,8	103,0	67,7	

Sample:
CR 2 after sand filtration
CR 3 after ozonation
CR 4 after granular activated carbon treatment
CR 5 final reclaimed water

Results:
Concentrations in µg/ℓ
All results are terminal values
η = number of samples

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CAPE FLATS PROTOTYPE WATER RECLAMATION PLANT: INORGANIC ANALYSIS BY NIWR WATER QUALITY DIVISION, 30 SEPTEMBER TO 2 DECEMBER 1986

Ten sets of weekly samples from CR1, 2, 3, 4, 5 were analysed for beryllium,, barium, strontium, and selenium. In all cases, beryllium, barium and selenium results were below the detection limits of 5, 250, and 5 µg/l respectively. Strontium results were in the range of 420 to 450 µg/l Sr, with an average of 440 µg/l, for all sampling points, indicating that little of no strontium removal took place. Recommended and maximum allowable (µg/l) limits for drinking-water suggested by Kempster and Smith (1985) for these determinands are shown in the following table (no contaminant levels set for strontium):

Determinand	Recommended limit	Maximum allowable limit
Be	2	5
Ba	500	1 000
Sr	-	-
Se	20	50

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March 1987

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CAPE FLATS PROTOTYPE WATER RECLAMATION PLANT : INORGANIC ANALYSIS BY NIWR WATER QUALITY DIVISION, PRETORIA, 1986

DETERMINAND	WEEK NO. / SPLE NO.	1	2	3	4	5	6	7	8	9	10	MEAN VALUES
Beryllium	CR1	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
(µg/ℓ Be)	CR2	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
	CR3	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
	CR4	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
	CR5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Barium	CR1	<250	<250	<250	<250	<250	<250	<250	<250	<250	<250	<250
(µg/ℓ Ba)	CR2	<250	<250	<250	<250	<250	<250	<250	<250	<250	<250	<250
	CR3	<250	<250	<250	<250	<250	<250	<250	<250	<250	<250	<250
	CR4	<250	<250	<250	<250	<250	<250	<250	<250	<250	<250	<250
	CR5	<250	<250	<250	<250	<250	<250	<250	<250	<250	<250	<250
Strontium	CR1	450	440	450	420	440	450	440	440	440	440	440
(µg/ℓ Sr)	CR2	450	440	450	430	440	450	440	430	440	440	440
	CR3	450	440	450	440	440	450	440	430	430	440	440
	CR4	450	440	450	430	440	450	450	440	440	450	440
	CR4	450	440	450	430	440	440	440	430	440	440	440
Selenium	CR1	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
(µg/ℓ Se)	CR2	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
	CR3	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
	CR4	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
	CR5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5

Sampling Points

CR1: Feedwater to reclamation plant
CR2: After sand filtration
CR3: After ozonation
CR4: After carbon filtration
CR5: Final water

APPENDIX 5

Intensive surveillance programme

Bio-surveillance of sample group F by Watertek

COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

NATIONAL INSTITUTE FOR WATER RESEARCH

EVALUATION OF THE QUALITY OF CAPE FLATS RECALIMED WATER IN TERMS OF TOXICITY USING VARIOUS BIOLOGICAL ASSAYS

(PERIOD: 30 SEPTEMBER TO 2 DECEMBER 1906)

by

J.L. Slabbert

1. INTRODUCTION

A variety of biological assays have been established for the detection of toxic chemicals in water. Some of these tests have been applied in research on the quality of Cape Flats reclaimed water. This report presents a brief description of toxicity tests and a summary of the results.

2. TOXICITY TESTS

2.1 *Daphnia* 24 h-lethality test

Daphnia 24 h or less in age (neonates or first instars) were used in toxicity tests. To obtain the necessary number of young for a test, adult females bearing embryos in their brood pouches were removed from the stock cultures 24 h preceding the initiation of a test and placed in 400 ml beakers containing 300 ml of water (Table 1) and 0,5 ml of food suspension (trout chow, alfalfa and yeast). One beaker containing 10 adults supplied enough neonates for one toxicity test. *Daphnia* test conditions are summarized in Table 2. The neonates were transferred to a small intermediary holding beaker and from there to the test beakers, using a firepolished 2 mm Pasteur pipette.

Table 1 Moderately hard reconstituted water *

Reagent added ** (mg/l)	$NaHCO_3$	96,0
	$CaSO_4.2H_2O$	60,0
	$MgSO_4$	60,0
	KCl	4,0
	pH	7,4 - 7,8 (8,2)
Nominal water quality range***	Hardness****	80 - 100 (89)
	Alkalinity	60 - 70 (59)

* EPA (1985)

** Prepared with deionized water

*** Measured value in parenthesis

**** As mg/l $CaCO_3$

2.1 *Pseudomonas putida* growth test

A culture of *P. putida* strain W, grown overnight at 27 °C, was diluted with fresh minimal medium (1,05 g K_2HPO_4, 0,45 g KH_2PO_4, 0,047 g Na-citrate.$2H_2O$, 0,1 g $(NH_4)_2SO_4$, 0,01 g $MgSO_4.7H_2O$ and 0,25 g glucose /1 deionized water) to a density with an absorption of 0,8, measured spectrophotometrically at 600 nm (4 cm cuvette), 30 min before inoculation. This supension was added at a ratio of 1 to 4 to a 12,5-times concentrate of minimal medium, and used as 5 ml volumes for inoculation of 45 ml test sample (decontaminated by filtration through a 0,45 µm membrane) (Slabbert 1986). Sterile deionized water (autoclaved at 121 °C for 15 min) was used for control tests. Each test was carried out in triplicate. Cultures were incubated at 27 °C for 6 h. Growth was measured spectrophotometrically. Toxic effects were expressed as percentage inhibition, determined in relation to control results. Inhibition > 10% was ascribed to toxicity, and stimulation > 10% to the presence of nutrients in test samples.

Table 2 *Daphnia* bioassay test conditions *

Temperature	20 °C
Light quality	Ambient laboratory illumination
Photoperiod	±13 h day light/24 h
Feeding regime	No feeding
Oxygen concentration	Dissolved oxygen remained above the recommended 40% of saturation aeration therefore not necessary.
pH	As obtained
Size of test beaker	50 ml
Volume of test sample **	25 ml
Number of organisms/beaker	5
Number of replicate beakers	4
Total number of organisms/test	20
Control water	Moderately hard reconstituted water
Test duration	24 h (static test)
Effect measured	Mortality (no movement of body or appendages on gentle prodding)
Interpretation of results	Mortality in test sample >10% indicated acute toxicity (if control mortality <10%)

* In agreement with the EPA's recommendations (EPA, 1985)

** Water filter sterilized (0,45 µm membrane)

2.3 Bacterial microassays

For toxicity tests bacteria were subcultured in 25 ml growth medium (minimal growth medium or 1 g/l nutrient broth) in 50 ml medical flats. *P. putida* was incubated at 27 °C and *Aeromonas punctata* at 35 °C for 16 to 10 h (overnight). Cultures were diluted with fresh medium to an O.D. of approximately 0,09, 30 min before inoculation of test samples. Density measurements were carried out at 620 nm with a vertical light path, filter photometer (Titertek Multiskan MC). Bacterial suspensions were added to 12,5-times concentrated media at a ratio of 1 to 4, and used as 30 µl volumes for inoculation of 270 µl test sample (decontaminated by filtration through a 0,45 µm membrane). Disposable sterile flat-bottomed 96-well microplates were used for testing (Slabbert, 1907). Sterile deionized water (autoclaved at 121 °C for 15 min) was used for control testing. Water samples were tested in duplicate. Reference test and control samples (duplicate samples) received 30 µl medium without bacteria. Plates were covered with lids and incubated at 27 °C (*Pseudomonas*) or 35 °C (*Aeromonas*) for 6 h. Growth was determined by subtracting reference readings from test and control readings. The effect of test solutions on growth was expressed as percentage inhibition (or stimulation), calculated in relation to control results. Effects > 30% were considered significant.

2.4 Urease enzyme inhibition test

The following reagents were used:

Enzyme: 2 mg urease/ml buffer

1 mg urease/ml buffer

0,5 mg urease/ml buffer

Buffer: 0,025 M TRIS-buffer (pH: 7,6)

Urea: 1,5% (w/v) in deionized water

Phenolphtalein (ØØ) : 0,1% (w/v) in 50% (v/v) ethanol-water solution

400 µl of a decontaminated water sample (0,45 µm filtration) was added to 100 µl enzyme. Each water sample was tested in triplicate using three different urease concentrations. Deionized water was used as control. Thirty minutes was allowed for inhibition of the enzyme. 100 µl urea was then added and 15 to 20 min allowed for the enzyme-substrate complex to form. The test was concluded by the addition of 50 µl ØØ. Control (and non-toxic) solutions developed a dark pink colour, while highly toxic solutions remained colourless. Inhibition of 0,5 mg/ml urease indicated the presence of an individual heavy metal or groups of metals at recommended levels for drinking water and inhibition of 2,0 mg/ml urease, the presence of heavy metals at critical levels.

3. RESULTS AND DISCUSSION

Results are presented in Tables 3 to 7. The effect of CR5 water samples and preparations thereof on the test organisms used in bioassays should not be alarming. These samples were taken after final chlorination, and it is known that chlorine is toxic to aquatic organisms (EPA, 1972). Although free chlorine is toxic in itself, combinations with ammonia, cyanide and organic compounds, such as phenols and amines, may even be more toxic (EPA, 1972). Chlorine tests carried out in the NTWR laboratory on the CR5 water collected on 06-11-04 showed free chlorine at levels above 2 mg/l, which is considerably higher than the reported lethal concentrations (Dickson *et al.*, 1977) for fish, and concentrations required to kill bacteria. Although not tested it is expected that chlorine was also present at toxic concentrations in other CR5 samples.

TABLE 3 Effect of the feed water to the reclamation plant (CR1), water after carbon filtration (CR4) and the final water (CR5) on *Daphnia pulex*

Date	Effect					
	CR1	CR4	CR5	CR5 aerated	CR5**** 2x	CR5**** 4x
86-09-30	no effect (≤10%)	no effect (≤10%)	lethal (65%)	***	no effect (≤10%)	no effect (≤10%)
86-10-07	*	*	no effect (≤10%)	lethal (100%)	no effect (≤10%)	lethal (20%)
86-10-14	no effect (≤10%)	no effect (≤10%)	lethal (15%)	no effect (≤10%)	no effect (≤10%)	no effect (≤10%)
86-10-21	no effect (≤10%)	lethal (100%)	lethal (100%)	lethal (100%)	no effect (≤10%)	no effect (≤10%)
86-10-28	no effect (≤10%)	no effect (≤10%)	lethal (100%)	no effect (≤10%)	no effect (≤10%)	no effect (≤10%)
86-11-04	no effect (≤10%)	no effect (≤10%)	no effect (≤10%)	no effect (≤10%)	lethal (100%)	lethal (100%)
86-11-11	no effect (≤10%)	no effect (≤10%)	lethal (100%)	lethal (100%)	lethal (100%)	lethal (100%)
86-11-18	no effect (≤10%)	no effect (≤10%)	no effect (≤10%)	no effect (≤10%)	no effect (≤10%)	no effect (≤10%)
86-11-25	*	*	lethal (100%)	no effect (≤10%)	lethal (100%)	lethal (100%)
86-12-02	no effect (≤10%)	no effect (≤10%)	no effect (≤10%)	no effect (≤10%)	**	**

* No samples received
** Accidentally discarded before tested
*** Not tested
**** Samples concentrated

TABLE 4 Effect of the feed water to the reclamation plant (CR1), water after carbon filtration (CR4) and the final water (CR5) on the growth of *Pseudomonas putida*

Date	Effect			
	CR1	CR4	CR5	CR5 aerated
86-09-30	no effect (≤10%)	no effect (≤10%)	inhibition (17%)	**
86-10-07	*	*	inhibition (23%)	inhibition (92%)
86-10-14	no effect (≤10%)	no effect (≤10%)	inhibition (20%)	inhibition (57%)
86-10-21	no effect (≤10%)	inhibition (94%)	inhibition (98%)	inhibition (98%)
86-10-28	stimulation (27%)	inhibition (22%)	inhibition (95%)	no effect (≤10%)
86-11-04	no effect (≤10%)	no effect (≤10%)	inhibition (97%)	inhibition (25%)
86-11-11	stimulation (16%)	stimulation (13%)	inhibition (94%)	inhibition (13%)
86-11-18	stimulation (40%)	stimulation (11%)	no effect (≤10%)	inhibition (58%)
86-11-25	*	*	inhibition (22%)	inhibition (13%)
86-12-02	no effect (≤10%)	no effect (≤10%)	inhibition (15%)	no effect (≤10%)

* No samples received

** Not tested

TABLE 5 Effect of the feed water to the reclamation plant (CR1), water after carbon filtration (CR4) and the final water (CR5) on the growth of *P. putida* using a microassay

Date	Effect							
	CR1		CR4		CR5		CR5 aerated	
	minimal medium	nutrient broth	minimal medium	nutrient broth	minimal medium	nutrient broth	minimial medium	nutrient broth
86-09-30	stimulation (53%)	stimulation (37%)	no effect (≤30%)	no effect (≤30%)	inhibition (56%)	no effect (≤30%)	**	**
86-10-07	*	*	*	*	inhibition (32%)	no effect (≤30%)	inhibition (86%)	no effect (≤30%)
86-10-14	no effect (≤30%)	no effect (≤30%)	no effect (≤30%)	no effect (≤30%)	no effect (≤30%)	inhibition (36%)	inhibition (56%)	inhibition (72%)
86-10-21	no effect (≤30%)	no effect (≤30%)	inhibition (54%)	inhibition (53%)	inhibition (81%)	inhibition (80%)	inhibition (88%)	no effect (≤30%)
86-10-28	stimulation (35%)	no effect (≤30%)	inhibition (40%)	no effect (≤30%)	inhibition (92%)	inhibition (95%)	no effect (≤30%)	no effect (≤30%)
86-11-04	no effect (≤30%)	stimulation (47%)	no effect (≤30%)	stimulation (69%)	inhibition (90%)	stimulation (56%)	no effect (≤30%)	no effect (≤30%)
86-11-11	no effect (≤30%)	no effect (≤30%)	no effect (≤30%)	stimulation (47%)	inhibition (90%)	no effect (≤30%)	no effect (≤30%)	no effect (≤30%)
86-11-18	no effect (≤30%)	stimulation (55%)	no effect (≤30%)	stimulation (43%)	no effect (≤30%)	stimulation (40%)	inhibition (53%)	stimulation (55%)
86-11-25	*	*	*	*	stimulation (50%)	no effect (≤30%)	no effect (≤30%)	no effect (≤30%)
86-12-02	no effect (≤30%)	stimulation (80%)	no effect (≤30%)	stimulation (93%)	no effect (≤30%)	stimulation (83%)	stimulation (74%)	no effect (≤30%)

* No sample received
** Not tested

TABLE 6 Effect of the feed water to the reclamation plant (CR1), water after carbon filtration (CR4) and the final water (CR5) on the growth of *Aeromonas punctata* using a microassay

Date	Effect							
	CR1		CR4		CR5		CR5 aerated	
	minimal medium	nutrient broth	minimal medium	nutrient broth	minimal medium	nutrient broth	minimal medium	nutrient broth
86-09-30	stimulation (37%)	no effect (≤30%)	no effect (≤30%)	no effect (≤30%)	inhibition (73%)	no effect (≤30%)	**	**
86-10-07	*	*	*	*	inhibition (66%)	no effect (≤30%)	inhibition (80%)	no effect (≤30%)
86-10-14	stimulation (61%)	no effect (≤30%)	no effect (≤30%)	no effect (≤30%)	inhibition (70%)	no effect (≤30%)	inhibition (76%)	no effect (≤30%)
86-10-21	stimulation (93%)	no effect (≤30%)	inhibition (91%)	no effect (≤30%)	inhibition (91%)	no effect (≤30%)	inhibition (86%)	no effect (≤30%)
86-10-28	no effect (≤30%)	no effect (≤30%)	stimulation (34%)	no effect (≤30%)	inhibition (93%)	no effect (≤30%)	stimulation (41%)	stimulation (39%)
86-11-04	no effect (≤30%)	stimulation (56%)	no effect (≤30%)	stimulation (44%)	inhibition (71%)	stimulation (56%)	no effect (≤30%)	no effect (≤30%)
86-11-11	no effect (≤30%)	no effect (≤30%)	no effect (≤30%)	no effect (≤30%)	inhibition (93%)	no effect (≤30%)	inhibition (61%)	inhibition (80%)
86-11-18	no effect (≤30%)	no effect (≤30%)	no effect (≤30%)	no effect (≤30%)	no effect (≤30%)	no effect (≤30%)	inhibition (66%)	inhibition (58%)
86-11-25	*	*	*	*	inhibition (46%)	stimulation (60%)	no effect (≤30%)	stimulation (75%)
86-12-02	no effect (≤30%)	stimulation (34%)	no effect (≤30%)	stimulation (34%)	no effect (≤30%)	stimulation (43%)	inhibition (50%)	stimulation (61%)

* No samples received
** Not tested

TABLE 7 Effect of the feed water to the reclamation plant (CR1), water after carbon filtration (CR4) and the final water (CR5) on urease (u) enzyme activity

Date	Effect					
	CR1	CR4	CR5	CR5 aerated	CR5**** 2x	CR5**** 4x
86-09-30	no effect	no effect	no effect	***	no effect	inhibition (0,5 mg/ml u)
86-10-07	*	*	no effect	no effect	no effect	no effect
86-10-14	no effect	no effect	no effect	no effect	no effect	no effect
86-10-21	no effect	no effect	inhibition (0,5 mg/ml u)	no effect	inhibition (0,5mg/ml u)	inhibition (0,5mg/ml u)
86-10-20	no effect	no effect	no effect	no effect	no effect	no effect
86-11-04	no effect	no effect	no effect	no effect	no effect	total inhibition (1,0 mg/ml u)
86-11-11	no effect	no effect	no effect	no effect	no effect	no effect
86-11-25	*	*	no effect	no effect	no effect	no effect
86-12-02	no effect	no effect	no effect	no effect	**	**

* No samples received
** Accidentally discarded before tested
*** Not tested
**** Samples concentrated

Six out of the ten CR5 samples tested were lethal to *Daphnia* (Table 3) and nine inhibited the growth of *P. putida* (Table 4). Microassays detected toxicity in some six to eight CR5 samples when using minimal medium (Tables 5 and 6), but in a maximum of only three when using nutrient broth for culturing. Nutrient broth is known to reduce toxicity (Slabbert, 1906). In some instances toxicity was removed when samples were aerated, but in others toxicity was enhanced. The reason for the increase in toxicity is not known, but it could have been due to the formation of oxidation by-products which might have been more toxic than free chlorine. Some of the 2- and 4-times concentrated CR5 samples were lethal to *Daphnia* (Table 3). Concentrated samples were not tested with bacterial assays because of precipitation when media were added. The sensitivity of the *Daphnia* lethality test and bacterial growth tests to a number chemicals is given in Table 8.

Only one of the CR5 samples (06-10-21) showed urease enzyme inhibition (Table 7), and only when using the 0,5 mg/ml enzyme concentration. This indicated the presence of a heavy metal or a group of metals at the recommended limit for drinking-water. Heavy metals were below this limit in other CR5 samples. Concentration limits for a number of urease-inhibiting heavy metals are given in Table 9. Two of the ten concentrated CR5 samples inhibited urease activity at the 0,5 mg/ml concentration, indicating the presence of heavy metals at recommended limits for drinking-water. Only one concentrated sample (4-times concentrated inhibited the enzyme at the 1,0 mg/ml concentration, indicating a heavy metal concentration at the miximum permissible limit.

Feed water samples (CR1) never showed any toxicity. Stimulation of bacterial growth was sometimes observed, which indicated the presence of growth promoters which probably consisted of organic compounds and sources of energy.

Toxicity was detected in two of the ten CR4 water samples. The sample of 06-10-21 was toxic to *Daphnia* and the bacteria (Tables 3 to 6) and that of

TABLE 8 Sensitivity of the various biological tests to a number of individual chemicals

Chemical	*P. putida* growth inhibition test	*Pseudomonas* microassay (EC50) mg/l		*Aeromonas* microassay (EC50) mg/l		*D. pulex* lethality test
	(EC10) mg/l	minimal medium	nutrient broth	minimal medium	nutrient broth	(LC50) mg/l
Copper	0,1	1,66	6,13	0,18	2,59	*
Cadium	0,00	1,12	0,65	1,00	0,90	0,14
Zinc	0,15	0,30	1,24	2,40	1,07	*
Mercury	0,025** 0,05***	0,02** 0,05**	0,07** 0,12***	0,02** 0,05***	0,13** 0,31***	0,003
Cyanide	0,010	0,56	1,07	0,07	0,43	*
Phenol	15,1	*	*	*	*	*
Acetone	594	*	*	*	*	0000

* Not available
** EC0
*** EC100

TABLE 9 Concentration limits for the urease-inhibiting heavy metals****

Metal	Recommended* limit (µg/l)	Maximum permissible limit (µg/l	Critical*** limit (µg/l
Mercury	5	10	20
Silver	20	50	100
Cadium	10	20	40
Lead	50	100	200
Copper	500	1000	2000
Zinc	1000	5000	10000
Cobalt	250	500	1000
Nickel	250	500	1000
Manganese	50	1000	2000

* Detected by 0,5 mg/ml urease

** Detected by 1,0 mg/ml urease

*** Detected by 2,0 mg/ml urease

**** Kempster and Smith (1905)

06-10-20 toxic to only *P. putida* (Table 4 and 5). Enzyme activity was never affected by any of the CR4 samples (Table 3), indicating heavy metal concentrations below the recommended limit for drinking-water. The toxicity of the CR4 water could have been due to chlorination by-products formed after breakpoint chlorination at CR3. The toxicity could also have been due to metals at concentrations not dectable by the usrease enzyme system (*viz.* copper and zinc) (Tables 8 and 9), or other chemicals. Bacterial growth was sometimes stimulated by CR4 water (Tables 4 and 6). This was due to the presence of nutrients in the water, possibly organic matter released from the carbon columns. There is no indication that stimulation could have been due to toxicity.

4. REFERENCES

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APPENDIX 6

Routine surveillance

APPENDIX 6

ROUTINE SURVEILLANCE

A6.1 Introduction

There is evidence that water can transmit substances and bacteria which can affect the health of the consumer (Scarpino, 1971). As the level of pollution in feed waters increases, surveillance becomes more important. If a secondary effluent is used as opposed to a natural river feeding a reservoir, then surveillance becomes far more critical.

In the reclamation of sewage effluents for potable and other reuse, intensive and sophisticated means of measuring the effectiveness of the treatment system become essential.

The surveillance undertaken took the form of chemical and bacteriological analysis as well as on-line bio-surveillance. The determinands considered were the result of a research programme, carried out under the auspices of the WRC, on the effect, if any, on the health of the consumer of water reclaimed from secondary effluents (Hattingh, 1981).

A6.2 Sampling procedure and frequency of sampling

A6.2.1 Sampling Procedure

An appropriate sampling procedure is fundamental to obtaining precise and accurate results from laboratory analyses.

Apart from the regular hourly grab samples for chemical analysis and the trihalomethane (THM) and trace metals samples, all samples taken for chemical analysis were of the 24 h composite variety i.e. the result of the analyses would be an average value of the quality of the water over a 24 h period.

All composite samples were refrigerated during the entire sampling period until they were delivered to the laboratory, so as to prevent deterioration of the sample before analysis.

The samples for THM and trace metals were grab samples i.e. the result of the analyses indicates the quality of the water at the specific time of sampling. In the case of trace metals, the sample was acidified with nitric acid on sampling, whilst in the case of THM a chlorine suppressing agent was added at the time of sampling to prevent further formation of THM's, this result is then termed the instantaneous value (THMm).

All bacteriological as well as virological samples were also of the grab variety. The bacteriological samples were taken in specially prepared sterilised bottles. Sample bottles for samples containing residual chlorine always contained a Cl_2 suppressing agent. Flaming of sample taps was carried out prior to sampling and where taps were not provided the samples were taken directly from the process units. All the bacteriological samples were submitted to the laboratory immediately after sampling.

The virological samples were collected in special 5 l containers which were prepared and provided by UCT. The taps were sterilised by flaming and 10 l of water was sampled. These samples were delivered within an hour of sampling to the UCT laboratories.

The sampling procedure for the 11 week intensive surveillance programme is covered in Chapter 9.

A6.2.2 Sampling frequency

The sampling frequency varied considerably throughout the project, and was dependent on which unit processes were in operation at that specific time.

During the periods of full operation (i.e. when a potable water was produced) the sampling frequency was as is given in Table A6.1.

TABLE A6.1: Sampling frequency

Determinand		Frequency
chlorine determinations	-	every two hours
bacteriological sampling	-	twice weekly
virological sampling	-	weekly when required
pH, alk, turbidity	-	every two hours
NH_3-N, NO_3-N, COD & suspended solids	-	daily on feed and reclaimed waters and three times a week on remaining samples
organic N, dissolved solids, PO_4-P, colour	-	three times a week on all units
trace metals	-	monthly
trihalomethane	-	monthly or weekly when required

During periods when the full plant was not operated the final unit process in operation was sampled and analysed as if it was the reclaimed water sample.

A6.3 Description of methods

All determinands used for the surveillance of the water quality and for the control of the various unit processes were determined according to Standard Methods for the Examination of Water and Wastewater (Anon, 1985). The exceptions were colifages (Grabow, 1978) and THM (Van Rensburg et al, 1978).

A6.4 Biological surveillance using fish

The NIWR in collaboration with the National Electrical Engineering Research Unit (NEERI) of the CSIR have designed a biological surveillance system which can detect toxic substances in the reclaimed water.

One such system was installed on the reclaimed water prior to the final chlorination stage. This system is capable of detecting abnormal fish behaviour in the water and provides advance warning

of possible undesirable toxic substances in the reclaimed water.

The system comprises a number of parallel fish tanks, one being a control tank and the others each containing a single male guppy (POECILIA reticulata). The behaviour patterns of these freshwater fish are measured on a continuous basis. Research has shown that the presence of even minute quantities of toxins cause a marked deviation in the rhythm of gill movement, heart rate and relative activity of the fish. This system which was developed by KÜhn and Morgan makes use of ultrasonic echoes to measure the activity of the fish (Anon, 1982). Each tank or sensor chamber is fitted with an ultrasonic transmitter and receiver. The signal which is returned from the sensor chamber comprises the sum of the various reflected sound waves coming off the body of the fish as it swims around. These returned signals are processed and recorded by the activity counters. Whenever three (or any preset number) of the five sensor chambers exceeds the predetermined threshold then an audible alarm is generated. The data obtained from each chamber were recorded on an hourly basis by means of a printout.

Although equipment failure limited the success of this system (see Chapter 10), similar installations have functioned adequately and proved highly successful in both the water reclamation and industrial effluent fields at the Windhoek water reclamation plant in Namibia and at the Sappi Kraft (Tugela Mill) Limited factory in Natal (Morgan et al, 1982).

It is envisaged that an on-line fish bio-surveillance installation would be an integral part of any future full scale water reclamation plant.

A6.5 Quality criteria

Safeguarding public health is one of the most important aspects to be considered when drawing up quality criteria to which the reclaimed water should conform to make it acceptable as a potable water.

The quality criteria have been investigated by the WRC taking into account the results obtained from the Windhoek and Stander Water

Reclamation Plants as well as the requirements of the World Health Organization (WHO) and certain United States (EPA) regulations. A list of criteria was prepared for the WRC (Meiring et al, 1982). These suggestions are outlined in Table A6.2.

TABLE A6.2: Proposed criteria for potable reclaimed water (Meiring et al, 1982)

Determinand	Objective (criterion)
pH	final effluent pH to obtain stability with respect to colour, carbonate and corrosion.
Chemical oxygen demand	15 mgl^{-1}
Ammonia (NH_3-N) and chloramines	0,5 mgl^{-1}
Nitrate nitrogen (NO_3-N)	10 mgl^{-1} *
Total phosphorus (PO_4-P)	0,5 mgl^{-1}
Heavy metals & trace elements	to comply with local drinking water standards or with WHO standards.
Total organic carbon	3,0 mgl^{-1}
Volatile halogenated hydrocarbons (VHH)	0,1 mgl^{-1}
Turbidity	0,4 NTU (JTU)
Total dissolved solids	500 mgl^{-1} above that of the potable water supply from which the reclaimed water initially originated.
Stability	Water must be stable according to Langelier, Ryznar and corrosivity indices.
Microbiological quality	free chlorine residual of 0,5 mgl^{-1} (0,3 to 0,7) at point of discharge into potable water supply plus compliance with the following:
Total plate count	not greater than 100/ml
Total coliforms	0/100 ml
Total enteric viruses	0/ 10 l
Total coliphages	0/ 10 l

* If the reclaimed water is to be blended with potable supplies the NO_3-N can be higher than 10 mgl^{-1} provided that the net value is 10 mgl^{-1}.

The South African Bureau of Standards (SABS) have revised their specification for potable water (SABS, 1984) and these have also been used in the assessment of the quality of the reclaimed water produced by the plant. Table A6.3 gives a list of selected determinands and the quality criteria as laid down by the SABS, (SABS, 1984).

TABLE A6.3 - Quality criteria as laid down in SABS 241-1984

Determinand	Limit	
	recommended	maximum allowable
Turbidity (NTU)	1	5
Colour (mgl^{-1} of pt)	20	-
pH	6,0 to 9,0	5,5 to 9,5
Conductivity (mSm^{-1})	70	300
Total hardness (mgl^{-1} as $CaCO_3$)	20 - 300	650
Magnesium (mgl^{-1} as Mg)	70	100
Sodium (mgl^{-1} as Na)	100	400
Chloride (mgl^{-1} as Cl)	250	600
Sulphate (mgl^{-1} as SO_4)	200	600
Nitrate + Nitrite (mgl^{-1} as N)	6	10
Flouride (mgl^{-1} as F)	1,0	1,5
Zinc (mgl^{-1} as Zn)	1,0	5,0
Arsenic (ugl^{-1} as As)	100	300
Cadmium (ugl^{-1} as Cd)	10	20
Copper (ugl^{-1} as Cu)	500	1 000
Cyanide (ugl^{-1} as CN)	200	300
Iron (ugl^{-1} as Fe)	100	1 000
Lead (ugl^{-1} as Pb)	50	100
Manganese (ugl^{-1} as Mn)	50	1 000
Mercury (ugl^{-1} as Hg)	5	10
Phenolic compounds (ugl^{-1} as phenol)	5	10
Selenium (ugl^{-1} as Se)	20	50
Total coliform bacteria (per 100 ml)	nil *	5
Faecal coliform bacteria (per 100 ml)	nil	nil
Standard plate count (per ml)	100	N.S.

* If any coliform bacteria are found in a sample, a second sample must be taken immediately after the tests on the first sample have been completed; this must be free of coliform bacteria, and not more than 5% of the total number of water samples (from any one reticulation system) tested per year may contain coliform bacteria.

The CSIR (NIWR) have published specific provisional criteria for aesthetic, physical and inorganic determinands in drinking water for use in the Republic of South Africa (Kempster and Smith, 1985). The criteria are specified in three types of limits, these are:

- the recommended or working limit is the limit which should ideally not be exceeded. This limit has a built in safety factor, and thus no immediate danger exists where this limit is exceeded, provided the maximum permissible limit is not exceeded.

- the maximum permissible limit is still safe, but should not be exceeded. Where the concentration of a particular determinand exceeds this limit, then planning/action to reduce the concentration of this pollutant should be instituted without delay.

- the crisis limit is twice the maximum permissible limit and exceptions to this rule are dissolved oxygen, pH, temperature, colour and free residual chlorine. Once the crisis limit is exceeded extreme action needs to be taken. This limit, however, should be treated as a tentative guideline only.

Table A6.4 gives a list of the CSIR criteria as set out by Kempster and Smith (1985).

TABLE A6.4 Quality criteria as published by the CSIR (Kempster and Smith, 1985)

Determinand	Unit	Recommended limit	Maximum permissible limit	Crisis limit
Colour	mgl^{-1} Pt	20	NS	NS
Electrical conductivity	mSm^{-1}(25°C)	70	300	400
Odour	TON	1	5	10
Dissolved oxygen	% saturation	70% min	30% min	10% min
pH	pH unit	6,0 - 9,0	5,5 - 9,5	`4,0 or ``11,0
Taste	TTN	1	5	10
Temperature	°C	25°C max	30°C max	40°C max
Turbidity	NTU	1,0	5,0	10,0
Chloride	$mgl^{-1}Cl$	250	600	1200
Free residual chlorine	$mgl^{-1}Cl$	0,2 - 5,0	`0,2 or ``5,0	NS
Sulphate	$mgl^{-1}SO_4$	200	600	1200
DOC	$mgl^{-1}C$	5,0	10,0	20,0
Cu	ugl^{-1}	500	1000	2000
H_2S	ugl^{-1}	100	300	600
Fe	ugl^{-1}	100	1000	2000
Mn	ugl^{-1}	50	1000	2000
Determinand	Unit	Recommended limit	Maximum permissible limit	Crisis limit
Phenols	ugl^{-1}	5	10	40
Zn	ugl^{-1}	1000	5000	10000
NH_3-N	mgl^{-1}	1,0	2,0	4,0
Ca	mgl^{-1}	150	200	400

F	mgl^{-1}	1,0	1,5	3,0
Total hardness	$mgl^{-1} CaCO_3$	20 min 300 max	NS min 650 max	NS min 1300 max
Li	mgl^{-1}	2,5	5,0	10,0
Mg	mgl^{-1}	70	100	200
NO_3-N	mgl^{-1}	6,0	10,0	20
K	mgl^{-1}	200	400	800
Na	mgl^{-1}	100	400	800
Al	ugl^{-1}	150	500	1000
Sb	ugl^{-1}	50	100	200
As	ugl^{-1}	100	300	600
Ba	ugl^{-1}	500	1000	2000
Be	ugl^{-1}	2	5	10
Bi	ugl^{-1}	250	500	1000
B	ugl^{-1}	500	2000	4000
Br	ugl^{-1}	1000	3000	6000
Cd	ugl^{-1}	10	20	40
Ce	ugl^{-1}	1000	2000	4000
Cr	ugl^{-1}	100	200	400
Co	ugl^{-1}	250	500	1000
Free CN	ugl^{-1}	200	300	600
Au	ugl^{-1}	2	5	10
Iodide	ugl^{-1}	500	1000	2000
Pb	ugl^{-1}	50	100	200
Hg	ugl^{-1}	5	10	20
Mo	ugl^{-1}	50	100	200
Ni	ugl^{-1}	250	500	1000
Se	ugl^{-1}	20	50	100
Ag	ugl^{-1}	20	50	100
Te	ugl^{-1}	2	5	10
Tl	ugl^{-1}	5	10	20
Sn	ugl^{-1}	100	200	400
Ti	ugl^{-1}	100	500	1000
W	ugl^{-1}	100	500	1000
U	ugl^{-1}	1000	4000	8000
V	ugl^{-1}	250	500	1000

Note: NS - not specified
TON - threshold odour number
TTN - threshold taste number

APPENDIX 7

Operation periods in detail

APPENDIX 7

OPERATIONAL PERIODS IN DETAIL

A7.1 May 1982 to July 1982

The plant was operated on an intermittent basis to overcome the teething problems which were being experienced with certain items of equipment. Initially all items of plant were operated so that all the mechanical equipment such as stirrers, pumps and scraper mechanisms could be checked and adjusted where necessary. However, due to problems experienced with the actuators and valves on the pressure sand filters, the plant was operated up to but excluding the sand filtration stage.

The feed water into the reclamation plant was of a consistently poor quality during this period with high ammonia, COD and suspended solids concentrations.

Ferric chloride was used as coagulant at a dose of 27 mgl^{-1}. The operating staff measured the pH and alkalinity every two hours on the following samples: feed water, flocculated water, PST effluent and breakpoint chlorine tank effluent (even though chlorination was not carried out). Although turbidity was not measured visual inspections of the PST indicated that good flocculation and subsequent settling of the floc particles was being achieved producing a fairly clear and acceptable PST effluent.

As a result of prolonged problems concerning the sand filter actuators dosing of chemicals was stopped from early June 1982.

However, operation continued up to the sand filtration stage, to obtain a "trouble free" period of operation of the mechanical equipment. Ferric chloride dosing recommenced on 1982-06-21 and the plant operated intermittently until the end of July.

A7.2 August 1982 to November 1982

The plant was operated on a continuous basis up to and including the sand filtration stage. Operation of the activated carbon columns continued intermittently during October and November to provide samples for virological analysis by UCT. Although chlorination was not carried out, four out of five carbon column effluent samples indicated negative virus isolation. However, all the sand filter effluent samples indicated positive virus isolation.

Optimisation of the two flocculators took place between September and November. As a result of visual observations and turbidity measurements, the decision was taken to operate both flocculation tanks to provide a retention time of 16 min. During the period when both flocculators were by-passed an average turbidity of 4,1 NTU was obtained and the visual appearance of the PST effluent was poor. During the periods when one or both tanks were in operation the turbidity averaged 1,6 NTU and the visual appearance of the effluent of the PST ranged from good with one flocculator to very good with two flocculators in operation.

The chemical surveillance programme started in earnest from September, with the regular submission of samples to the CCC laboratories. The quality of the treated water was fairly consistent during this period with PST and sand filter effluent

COD's being generally between 15 and 25 mgl^{-1} and the carbon column effluent COD's being generally well below 15 mgl^{-1}. The adjacent activated sludge plant operated more successfully than in the previous period and generally ammonia concentrations were `1 mgl^{-1} as N and the COD and suspended solids concentrations were less than the General Standard limits of 75 mgl^{-1} and 25 mgl^{-1} respectively.

A7.3 December 1982 to January 1983

Numerous jar flocculation tests indicated the optimum ferric chloride dose to be between 41 and 44 mgl^{-1} in the pH range of 5,0 to 5,5. Implementation of this dose at plant scale reduced the pH to the unacceptable level of about 2. As the calcium hydroxide equipment was receiving attention at the time, and pH adjustment was not possible, the dose was reduced to 19 mgl^{-1}. It was noted that the PST overflow turbidities were maintained at between 0,8 and 1,5 NTU after this reduction. Towards the end of December the dose was increased to 26 mgl^{-1} to counteract an increase in turbidity. During December the PST sludge recycle was set at four per cent (v/v).

Chlorine was dosed into the breakpoint tank at about 8,0 mgl^{-1}. Throughout this period problems were experienced with the chlorinator and this resulted in faecal coliforms being detected in the post chlorination samples. Four out of the five samples of the carbon column effluent which were submitted to UCT for virological examination showed negative virus isolation. In the sample of carbon column effluent taken during December, before chlorination commenced, Reovirus was isolated on the 2nd passage.

During this period the feed water from the adjacent activated sludge plant was of an acceptable quality and the chemical quality of the water from the various unit processes on the reclamation plant was satisfactory.

Sand filtration was limited to two pressure filters throughout this period and the carbon columns continued to be operated on an intermittent basis.

A7.4 February to March 1983

Operation of the plant was as in the previous period and the following units were in operation: feed water pumping, chemical (ferric chloride) addition and flocculation using 2 flocculators, primary sedimentation, breakpoint chlorination, stabilisation tank, pressure sand filtration using two filters and activated carbon treatment on an intermittent basis.

The sludge recycle was increased to eight per cent (v/v). Towards the end of February problems were experienced with the PST sludge withdrawal system which required subsequent repairs.

Ferric chloride doses ranged from 15 to 26 mgl^{-1}. Numerous jar tests were carried out on various flocculants with the following average results being obtained.

Ferric chloride : 41 to 44 mgl^{-1} as Fe^{3+}

Ferric sulphate : 37 to 42 mgl^{-1} as Fe^{3+}

Aluminium sulphate : 8 to 15 mgl^{-1} as Al^{3+}

The carbon columns continued to be operated on an intermittent basis to facilitate virological sampling. The results of the six samples of water that were submitted yielded negative virus isolation.

Operation of the breakpoint chlorinator proved unsatisfactory with positive faecal coliform counts being obtained in certain samples from the post chlorination stages of the process.

The pressure sand filters were plagued with problems and they were shut down from 1983-03-06 pending the result of an investigation into their replacement with rapid gravity sand filters.

The chemical quality of the feed water as well as the water produced from the various stages was of an acceptable quality throughout this period.

A7.5 April 1983 to June 1983

The plant was temporarily shut down between 1983-03-06 and 1983-04-28 as a result of delays experienced in the delivery of ferric chloride. Operation using ferric chloride continued from 1983-04-28 and all units up to but excluding the sand filtration (pressure filters) stage were used. Magnafloc 156 was introduced as a coagulant aid from 1983-05-23. The chemicals used were dosed as follows:

Ferric chloride

83-04-01 to 83-04-27	26 mgl^{-1} as Fe^{3+}
83-04-27 to 83-05-02	21 " " "

83-05-02 to 83-05-16	29	"	"	"
83-05-16 to 83-06-06	26	"	"	"
83-06-06 to 83-06-17	17	"	"	"

Magnafloc 156

83-05-23 to 83-06-17 0,5 mgl^{-1}

The plant was shut down between 1983-06-17 and 1983-07-18 to effect repairs to the PST sludge withdrawal system, compressed air lines and the calcium hydroxide dosing equipment.

A7.6 July 1983 to September 1983

During May 1983, it was decided to investigate the possible use of ferric sulphate as an alternative to ferric chloride as the coagulant. It was envisaged that if plant scale experiments proved acceptable, the project would benefit from the locally available product.

Ferric sulphate thus replaced ferric chloride as coagulant from 1983-07-18. Initially a 14 day trial run was planned, during which time AECI undertook to supply a free batch of ferric sulphate. Due to the favourable results obtained, it was decided to extend the period by approximately one month, during which time AECI supplied the chemical at cost. After the six week trial period it was decided that ferric sulphate be used indefinitely.

Jar tests indicated the optimum dose of ferric sulphate to be between 53 and 64 mgl^{-1} in the pH range of 5,0 to 6,0.

Ferric sulphate and Magnafloc 156 were dosed as follows:

Ferric sulphate

1983-07-18 to 1983-07-19	31 mgl^{-1}	as Fe^{3+}
1983-07-19 to 1983-07-21	56 "	"
1983-07-21 to 1983-07-25	28 "	"
1983-07-25 to 1983-08-01	56 "	"
1983-08-01 to 1983-09-17	42 "	"
1983-09-17 to 1983-09-30	48 "	"

Magnafloc 156

1983-07-23 to 1983-07-27	0,5 mgl^{-1}

Sand filtration was implemented as from 1983-08-03 by making use of only one pressure filter with a reuduced flow. This filter had been repaired during June 1983, by replacing the existing nozzles with modified ones. Flow through the filter was maintained at 1730 m^3d^{-1} and the backwash procedure was implemented approximately every 48 h.

The calcium hydroxide equipment was used between 1983-07-25 and 1983-08-03 to facilitate pH correction before coagulation. The pH value was maintained at approximately 5,5 which required intermittent calcium hydroxide doses in the region of 90 mgl^{-1}. During the early part of August, as a direct result of the reduction in ferric sulphate dose from 56 to 42 mgl^{-1}, calcium hydroxide dosing was terminated.

Chlorination prior to sand filtration commenced from the end of July at a dose of 8 mgl^{-1}. Although this was satisfactory for disinfection purposes higher doses were required for the oxidation

of ammonia. The quality of the activated sludge works' final effluent was poor during this period due to incomplete nitrification and with ammonia concentrations as high as 6,5 mgl^{-1} as N being observed. The use of chlorine to oxidise such high ammonia values is not recommended and ammonia stripping using a high calcium hydroxide process should be used. Chlorine was therefore not dosed to breakpoint.

Weekly samples from the pre- and post-chlorination units were submitted for bacteriological examination. Faecal coliform values in the order of 5×10^3 counts per 100 ml were observed in the pre-chlorination samples from the PST and counts of `2 per 100 ml were observed in the post chlorination samples from the stabilisation tank in 75% of the samples submitted.

The carbon columns were not operated at all during this period and as a result no samples were submitted to UCT for virological examination.

A7.7 October 1983 to June 1984

The plant was operated during this period using ferric sulphate at the following doses:

1983-10-01 to 1983-11-06	48 mgl^{-1}	as Fe^{3+}
1983-11-07 to 1983-12-06	39 "	"
1983-12-07 to 1983-12-11	34 "	"
1983-12-15 to 1983-12-19	17 "	"
1983-12-20 to 1984-01-05	21 "	"
1984-01-06 to 1984-01-30	25 "	"

1984-01-31 to 1984-02-07	29	" "
1984-02-08 to 1984-02-14	34	" "
1984-02-15 to 1984-02-22	38	" "
1984-02-23 to 1984-03-04	42	" "
1984-03-05 to 1984-06-25	34	" "

Flocculation was aided throughout this period with various types of polyelectrolytes at the following doses:

1983-10-01 to 1983-11-06	Magnafloc 156	0,5 mgl^{-1}
1983-11-07 to 1983-11-26	" "	0,7 "
1983-11-27 to 1983-12-05	" "	0,3 "
1983-12-06 to 1983-12-11	" "	1,8 "
1983-12-15 to 1984-03-06	" "	1,8 mgl^{-1}
1984-03-07 to 1984-06-24	Magnafloc LT27	0,5 "

Sludge was wasted and recycled at the following rates:

Period	Waste sludge	Recycled sludge
1983-10-01 to 1983-11-09	11% (v/v)	5% (v/v)
1983-11-10 to 1983-12-11	11% "	10% "
1983-12-15 to 1984-03-04	11% "	10% "
1983-03-05 to 1984-06-25	11% "	5% "

Chlorine was dosed to breakpoint from 1983-10-01 to 1984-05-18 at doses of between 5 mgl^{-1} and 20 mgl^{-1}. Chlorination was discontinued during May and June due to unacceptably high ammonia concentrations in the feed water, which resulted from incomplete nitrification on the adjacent activated sludge treatment works.

Samples were submitted throughout this period for bacteriological analysis. Faecal coliform counts of $7,6 \times 10^3$ per 100 ml were obtained on the pre-chlorination sample from the PST and these counts were reduced to `2 on 69% of the post-chlorination samples taken from the stabilisation tank.

Calcium hydroxide was dosed between 1983-11-25 and 1984-03-02 to facilitate pH correction prior to breakpoint chlorination. The pH value was maintained at about 7 by intermittent calcium hydroxide doses of about 110 mgl^{-1}. This dosing was terminated due to precipitation of a mixture of calcium sulphate and calcium carbonate in the chlorination tank.

Sand filtration was stopped from 1984-03-26 to facilitate the construction of the new rapid gravity sand filters.

A7.8 July 1984 to October 1984

The plant was operated during this period using aluminium sulphate (alum) as coagulant. The alum was obtained from the supplier in a liquid state, diluted on site and dosed in the same manner as the ferric solutions. Problems were experienced with blockages forming in the dosing pipe lines, pumps and ball valves due to an accumulation of sediment. The low capacity of the chemical dosing pumps prevented weaker alum solutions from being used. The ideal set up of a gravity chemical dosing system was not possible with the existing system and it was considered uneconomical to effect the necessary changes purely for experimental purposes.

Results obtained from jar tests indicated optimum alum dosages in the order of 16 mgl^{-1} and favourable plant results were obtained at doses upwards of 13 mgl^{-1}.

The following alum dosages were applied to the plant:

1984-06-27 to 1984-07-18	6 mgl^{-1}	as Al^{3+}
1984-07-19 to 1984-08-06	10 "	" "
1984-10-04 to 1984-10-07	11 "	" "
1984-10-08 to 1984-10-14	13 "	" "
1984-10-15 to 1984-10-20	16 "	" "
1984-10-21 to 1984-10-27	19 "	" "

Magnafloc LT27 was used from 1984-07-12 with doses of 0,5 to 1,0 mgl^{-1}.

The plant was operated up to and including the stabilisation tank, and the following units were in operation: feed water pumping, chemical addition (alum) and flocculation, primary sedimentation, break-point chlorination and the stabilisation tank.

Construction on the new rapid gravity sand filters continued throughout this period.

The quality of the feed and stabilisation tank overflow was of a high standard throughout this period and the average results are indicated in Table A7.1.

Table A7.1 - Quality of feed water and stabilisation tank overflow during the alum trial run

		Feed water	Stabilisation tank overflow
NH_3-N	mgl^{-1}	0,4	0,35
COD-O	mgl^{-1}	63	26
Suspended solids	mgl^{-1}	20	5
PO_4-P	mgl^{-1}	5,2	0,7

A7.9 November 1984 to February 1985

The plant was operated during this period with ferric sulphate at the following doses:

1984-10-29 to 1985-01-09	34 mgl^{-1}	as Fe^{3+}
1985-01-10 to 1985-02-07	42 "	"
1985-02-08 to 1985-02-19	38 "	"
1985-02-19 to 1985-02-28	34 "	"

Magnafloc 156 was dosed throughout this period at 0,5 to 1,0 mgl^{-1}.

Sand filtration was implemented on 1984-10-30 making use of the recently constructed rapid gravity sand filters. Favourable filtrate turbidities of around 0,5 NTU were obtained almost immediately. The activated carbon columns were put back into operation on 1985-02-14 and produced encouraging results. The average results for this period are presented in Table A7.2.

TABLE A7.2: Quality profile across the plant after the inclusion of the rapid gravity sand filters.

	Feed water	Stabilisation tank	Sand filter	Carbon Columns
NH_3-N mgl^{-1}	1,0	0,3	0,5	0,2
COD-O mgl^{-1}	58	18	17	2
Suspended solids mgl^{-1}	14	3	1,6	1
PO_4-P mgl^{-1}	5,6	`0,1	`0,1	`0,1
Turbidity NTU	4,3	1,3	0,5	0,4

The following average faecal coliform results were obtained: $2,5 \times 10^4$ counts per 100 ml for the pre-chlorination sample from the PST and `2 counts per 100 ml on 86% of the samples examined for the post-chlorination sample from the stabilisation tank.

The submission of samples to UCT for virological examination recommenced during January 1985. A total of six samples of sand filter effluent were submitted and in all cases no viruses were isolated.

A7.10 March 1985 to June 1985

Use of ferric sulphate and Magnafloc LT27 continued as in the previous period. The dose of ferric sulphate was maintained at about 42 mgl^{-1} whilst the following doses of LT27 were applied:

1985-03-01 to 1985-06-05 0,5 mgl^{-1}

1985-06-06 to 1985-06-11 0,25 mgl^{-1}

1985-06-12 to 1985-06-30 0,12 mgl^{-1}

Premature clogging of the sand filters and shorter filter runs were overcome by implementing two changes. Firstly the dose of Magnafloc LT27 was reduced from 0,5 to 0,12 mgl^{-1} and secondly the available head to the filters was increased by bypassing the stabilisation tank.

The quality equalisation pond was brought into operation during April 1985 and its merits are discussed fully in chapter eight.

Average faecal coliform results for this period are indicated in Table A7.3.

TABLE A7.3: Average faecal coliform counts on pre and postchlorination samples between March to June 1985.

	Faecal coliforms per 100 ml
Feed water	$4,7 \times 10^5$
Primary sedimentation tank	$1,5 \times 10^4$
Sand filter	`1 (95% of Samples tested)
Carbon column	`1 (91% of Samples tested)

One sand filter effluent sample was submitted for virological examination during this period and no viruses were isolated. As a result of the consistent negative virus isolation on samples of the sand filter effluent during the period October

1983 to April 1985 virological studies were suspended until the intensive surveillance programme had commenced.

Average results showing the quality profile of the water through the plant are presented in Table A7.4

TABLE A7.4: Quality profile of the water through the plant between March and June 1985.

	Feed water	Stabilisation tank	Sand filter	Carbon columns
NH_3-N mgl^{-1}	0,5	0,5		0,3
COD-O "	46	16	14	9
Suspended solids mgl^{-1}	22	3	1	`1
PO_4-P mgl^{-1}	5,6	0,096	0,063	0,049
Turbidity NTU	3,4	1,8	0,5	0,4

A7.11 July 1985 to December 1985

The plant was operated throughout this period using ferric sulphate and Magnafloc LT27 at the following doses.

Ferric Sulphate:

1985-07-01 to 1985-09-04 42 mgl^{-1} as Fe^{3+}

1985-09-05 to 1985-12-31 38 " " "

Magnafloc LT27

1985-07-01 to 1985-12-31 0,12 mgl^{-1}

The sludge wastage and recycle flows remained constant at the settings which had been successfully applied since June

1984, namely about 10% (v/v) and 5% (v/v) respectively.

Calcium hydroxide was added throughout this period to facilitate pH correction prior to breakpoint chlorination. The pH value was maintained between 6 and 6,5 and intermittent calcium hydroxide doses in the region of 65 mgl^{-1} were required.

The calcium hydroxide equipment for the reclaimed water pH adjustment was brought into operation at the end of June 1985 and was used throughout this period. The pH value of the reclaimed water was maintained between 8,5 and 9,5 by intermittent calcium hydroxide doses in the region of 135 mgl^{-1} thus providing an alkalinity of about 33 mgl^{-1} as $CaCO_3$.

Final chlorination of the activated carbon column effluent was introduced from July 1985. Chlorine doses into the breakpoint tank and reclaimed water were as follows:

Breakpoint	4 mgl^{-1} to 26 mgl^{-1}
Reclaimed water	1,4 mgl^{-1} to 22 mgl^{-1}

Average faecal coliform results are presented in Table A7.5.

TABLE A7.5: Average Faecal coliform counts for the period July to December 1985.

	Faecal coliform counts per 100 ml
Feed water	$1,3 \times 10^5$
Sand filter	`1 (94% of samples tested)
Carbon column	`1 (100% of samples tested)
Reclaimed water	`1 (100% of samples tested)

During August the pilot carbon columns were taken out of operation and refilled with a new charge of Norit Supra 0,8 ROW activated carbon. After commissioning, favourable COD removal was obtained. The length of operation of the previous filling (Filtrasorb F300) was 5,6 months and 50100 m^3 of water (8350 bed volumes) was processed during this period.

The average results showing the quality profile through the plant are presented in Table A7.6.

TABLE A7.6: Average results showing quality profile through the plant for the period July to December 1985.

	Feed	Sand filter	Activated carbon columns	Reclaimed water
NH_3-N mgl^{-1}	1,0		0,8	0,3
COD-O "	49	16	10	8
Suspended solids mgl^{-1}	13	`1	`1	9
Dissolved Solids "	540		612	576
PO_4-P mgl^{-1}	4,5	0,068	0,064	0,040
pH	7,8	5,7	5,8	9,0
Turbidity NTU	3,8	0,5	0,3	3,7
THM ugl^{-1}	2,7	40	43	150

The fish biosurveillance system was operated until early December 1985 when, due to an electronic fault, the system was shut down. Counts averaging 1 000 to 1 500 per h were obtained throughout this period, reflecting a good quality water which can be used for potable purposes.

A7.12 January to April 1986

During this period of operation the sequential process configuration was: quality equalisation, feed water pumping, coagulant addition, flocculation, polyelectrolyte addition, primary sedimentation, breakpoint chlorination, sand filtration, activated carbon treatment, final chlorination and final calcium hydroxide stabilisation.

Ferric sulphate, Magnafloc LT27, calcium hydroxide and chlorine were dosed throughout this period at the following rates (Table A7.7).

TABLE A7.7: Chemical usage between January and April 1986.

Chemical type	Setting	Dosage	
		Average	Range
Ferric Sulphate	900 ml min $^{-1}$	135 mgl^{-1}	Constant
Magnafloc - LT27		0,12 mgl^{-1}	Constant
Chlorine - breakpoint	0,7 to 4,3 kghr^{-1}	8,9 mgl^{-1}	4,2 to 25,4 mgl^{-1}
Chlorine - final	5,2 to 46,6 mgsec^{-1}	5,7 mgl^{-1}	1,5 to 13,3 mgl^{-1}
Calcium hydroxide - breakpoint	pH - 5,8 to 6,3	not required	
Calcium hydroxide - final	pH - 8,5 to 9,5	about 140 mgl^{-1}	Intermittent

Work continued throughout this period on the refurbishing and installation of the ozone generator which was obtained from the WRC.

Problems were experienced in obtaining permission to operate the system as valid certificates of manufacture or testing for the pressure vessels were not available. The pressure caused by the head of water in the contacting tower resulted in the maximum requirement for optimum and safe production of ozone to be exceeded. This resulted in the design and manufacture of a venturi injector.

High ammonia values in the feed water to the plant resulted in unusually high doses of chlorine being required in both the breakpoint and final holding tanks.

Table A7.8 gives the average faecal coliform results which were obtained on samples submitted to the CCC.

TABLE A7.8: Average faecal coliform results between January and April 1986.

	Faecal coliform counts per 100 ml
Feed water	$2,0 \times 10^4$
Sand filter	`1 (100% of samples tested)
Carbon column	`1 (90% of samples tested)
Reclaimed water	`1 (93% of samples tested)

Table A7.9 gives the overall plant performance with respect to removal of various determinands between January and April 1986.

TABLE A7.9: Overall plant performance between January and April 1986.

Determinands	Units	Feed water	Reclaimed water	Removal %
NH_3-N	mgl^{-1}	0,8	0,2	75
NO_3-N	"	3,0	3,0	Nil
COD-O	"	44	10	77
Suspended solids	"	17	7,5	56
Dissolved solids	"	496	511	-
Colour	Hazen	72	`5	"93
PO_4-P	mgl^{-1}	6,0	0,024	99,6
Faecal coliforms	No. per 100 ml	$2,0 \times 10^4$	`1	"99,99
THM	ugl^{-1}	2,8	248	-

The high THM results obtained during this period and from July to December 1985 was cause for concern. The use of chlorine to counteract high ammonia values from the adjacent activated sludge plant, compounds the problem. Activated carbon is successful in removing the THM although the saturation point of the carbon is low with respect to THM.

The intermediate chlorine dose was reduced to below the breakpoint requirements and the residual concentration after the chlorination tank was maintained at approximately 0,2 mgl^{-1}. This change was implemented from July 1986.

A7.13 May 1986 to January 1987

During this period the plant was operated for the first time incorporating the full configuration, which sequentially was as follows:

the activated sludge process, quality equalisation pond, coagulant addition, flocculation, polyelectrolyte addition, primary sedimentation, intermediate chlorination, sand filtration, ozonation, activated carbon adsorption, final chlorination and final calcium hydroxide stabilisation.

Ferric sulphate and Magnafloc LT27 were dosed at constant rates of 38 mgl^{-1} and 0,12 mgl^{-1} respectively. Chlorine was dosed into both the chlorination tank and the reclaimed water and calcium hydroxide was used to stabilize the reclaimed water to a pH value of about 9.

The ozonation stage was incorporated into the configuration between the sand filtration and activated carbon stages on 1987-07-24 and 30 m^3hr^{-1} of the ozone air mixture was dosed providing an effective dose of approximately 0,9 mgl^{-1}. The ozone generator produced approximately 5 g ozone per m^3 of air and the ozonated water passed through a 17 min contact reactor tank before being pumped to the pilot carbon columns.

The pilot carbon columns were emptied and refilled with a new charge of "Norit Supra 0,8 ROW" activated carbon during July. A total of 8950 bed volumes of water were treated until shut down during January 1987. (1 bed volume = $6m^3$ of water.)

Table A7.10 gives a breakdown of all the chemicals used as well as the doses which were recorded.

TABLE A7.10: Chemical usage between May 1986 and January 1987.

Chemical	Setting	Dose Average	Dose Range
Ferric sulphate	900 ml min^{-1}	135 mgl^{-1}	Constant
Magnafloc LT27		0,12 mgl^{-1}	"
Chlorine intermediate	0,1 to 3,9 kgh^{-1}	5,2 mgl^{-1}	0,6 to 23,4 mgl^{-1}
Chlorine final	2,4 to 87 $mgsec^{-1}$	4,1 mgl^{-1}	0,7 to 25,1 mgl^{-1}
Calcium hydroxide final	pH 8,5 to 9,5	56 mgl^{-1}	Intermittent
Ozone	30 m^3 h^{-1}	0,9 mgl^{-1}	Constant

Sludge was wasted at 10% (v/v) and recycled at 5% (v/v) throughout this period.

Once again the fluctuation in the ammonia concentration of the plant feed water of between 0,1 and 9,4 mgl^{-1} N from the adjacent activated sludge plant was cause for concern and resulted in the final effluent from the activated sludge works being diverted from the quality equalisation pond on occasions.

The average results as presented in Table A7.11 for faecal coliforms, indicate the performance of the disinfection stages. Problems were experienced with the pre-sand filtration chlorinator during July, October and December as is indicated by the reduction in the percentage of samples in which `1 count per 100 ml was detected on the sand filter sample. The quality equalisation pond sample has been added to indicate the effect the pond has on reducing the faecal coliform count.

TABLE A7.11: Average faecal coliform results between May and December 1986.

Process water	Faecal coliform counts per 100 ml
Quality equalisation pond inlet	$1,6 \times 10^5$
Feed water	$4,3 \times 10^3$
Sand filter	`1 (84% of samples tested)
Carbon column	`1 (92% of samples tested)
Reclaimed water	`1 (96% of samples tested)

Table A7.12 gives the overall plant performance with respect to removal of selected determinands between May and December 1986.

TABLE A7.12: Overall plant performance of selected determinands between May and December 1986.

Determinand	Unit	Feed water	Reclaimed water	Removal %
NH_3-N	mgl^{-1}	0,84	0,19	77,4
NO_3-N	"	3,4	2,4	29,4
COD-O	"	43	5,8	86,5
Suspended solids	"	14	8,5	39,3
Dissolved solids	"	541	549	-
Colour	Hazen	68	`5	"92
PO_4-P	mgl^{-1}	4,01	0,026	99,4
Faecal coliforms	No. per 100 ml	$4,3 \times 10^3$	`1	"99,98
THM (total)	ugl^{-1}	3,3	48	-

In accordance with the contract agreement between the CCC and WRC, an intensive surveillance programme was initiated from 1986-09-29 and ran for eleven consecutive weeks. An in depth look at this surveillance programme as well as the presentation of the results is covered in detail in Chapter 9.

The plant was shut down during January 1987 after the successful completion of 5 years of operation.