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Environmental Assessment, Regarding Nutrients and Oxygen Demanding Substances, of the Keiskammahoek Community on the Keiskamma River, South Africa

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Abstract

This report evaluates the environmental impact of the Keiskammahoek community on the Keiskamma River. The study area is situated in the Eastern Cape Province of South Africa. The Keiskammahoek TLC consists of 12,000 people of which about 5,000 are connected to the treatment works which is constructed as an aerobic/anaerobic pond system. The treatment works was constructed for a population of about 1,000 people, which means that it now suffers from overloading. Other potential polluters of the river have also been identified.

A measurement campaign was carried out for three weeks during November 1999 in both the Keiskamma river and in the treatment works. Measured parameters were pH, conductivity, chemical oxygen demand (COD), phosphorus, ammonia and nitrate. The results show that the effluent from the treatment works exceeds the legislative limits many times for several parameters. The river is also affected by this effluent with increased concentrations downstream of the treatment works. Recommendations include continuing the measurement campaign and to investigate the possible use of wetland technique, together with the treatment ponds, to meet legislative requirements.

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Preface

This study has been carried out within the framework of the Minor Field Study (MFS) Scholarship Programme, which is funded by the Swedish International Development Agency (SIDA).

The MFS Scholarship Programme offers Swedish students an opportunity to carry out two months' fieldwork in a Third World country on a basis of a Master's dissertation or a similar in-depth study. These studies are preliminary conducted within areas that are important for development and in a country supported by the Swedish programme for development assistance.

The main purpose of the MFS programme is to increase the interest in developing countries and to enhance Swedish university students' knowledge and understanding of these countries and their problems. An MFS should provide the student with initial experience of conditions in such a country. A further purpose is to widen the Swedish personnel resources for recruitment into international development co-operation.

Acknowledgements

This Minor Field Study is a result of a co-operation between Professor Greg Morrison, Chalmers University of Technology (CTH) and Professor Olalekan Fatoki, University of Fort Hare (UFH), through which two Swedish students were given the opportunity to perform the field work of their Master's Theses in South Africa.

I would like to start this report by thanking some of the people who made this project possible.

First of all I would like to thank Professor Greg Morrison and Professor Olalekan Fatoki for believing in us and for all their help with applications and during my Master's Thesis work.
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Lennart Persson
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Glossary

Aerobic-	Living or taking place only in the presence of oxygen
Anaerobic-	living or taking place in the absence of oxygen, especially not requiring oxygen for metabolism
Anions -	Negatively charged particles
Black water –	Water that contains human excreta
Cations -	Positively charged particles
COD –	Chemical Oxygen Demand
Drop and store-	Sanitation system which uses *e.g.* the bucket system, septic tanks or pit latrines *etc.*
Flush and discharge-	Waterborne sanitation system
French drain -	Underground pipe with drilled holes, allowing water to penetrate or be discharged from it
Greywater –	Washingwater and householdwater excluding water that contains human excreta
Ground water –	Water held underground in soil or permeable rock, often Feeding springs and wells
KWWTW-	Keiskammahoek Waste Water Treatment Works
Nutrients –	Any substance that provides nourishment
Sanitation –	The disposal of human excreta and household refuse, "Good sanitation is a state of cleanliness and a healthy environment, free from contamination. Sanitation is the process of creating and maintaining these conditions" (WHO/Collaborative Council Working Group on Sanitation Promotion, 1995)
Septic tank -	Tank for holding human waste
Sida –	Swedish International Development Cooperation Agency
TLC-	Transitional Local Council, works as a municipality.
Urine –	A fluid produced by the kidneys and periodically discharged
WHO –	World Health Organisation
VIP-latrines –	Ventilated, improved pit latrines

1. Introduction

1.1 Background

This report evaluates the environmental impact of the community Keiskammahoek on the Keiskamma River. The area is situated in the Eastern Cape Province of South Africa. Although the problems of the present sanitation system have been known for a long time, they has been thought of as secondary to other more pressing matter, *e.g.* education, unemployment, poverty *etc.*

"The domestic water-supply of the villages comes mostly from the streams which, owing to the lack of proper sanitary precautions, are often polluted", wrote [1] Hobart Houghton (1955) concerning the village of Keiskammahoek.

The problems escalated in 1997 when 443 RDP-housing units were connected to the wastewater treatments works without any re-construction of the works. Problems with bypassing, due to overflows, have occurred regularly since then.[2] (Ms Precious, 14th Oct, 1999)

The present treatment works is built as an anaerobic/aerobic pond system, which is a form of treatment works which has been popular in the past, but is nowadays considered as inadequate[3] (Viessman Jr W, 1988). This fact, added to the problem with too many connections, may result in poor purification and consequent pollution of the recipient.

The recipient is the Keiskamma River that runs up in the Amatola Mountain Range and then makes its way through Keiskammahoek on its way to the Indian Ocean. The population throughout the area uses this river for different purposes such as a freshwater resource, for fishing, swimming and other recreational activities. It is therefore of great concern that the river remains healthy. Another fact that needs to be pinpointed is the location of Sandile Dam downstream of Keiskammahoek, which is used as a freshwater resource. Pollution of the Keiskamma River will, without a doubt, lead to an increased use of treatment chemicals in the purification works.

This report concentrates on the nutrient load and oxygen demanding substances that affect the Keiskamma River. A measurement campaign was designed in co-operation with Olalekan Fatoki, Professor in Analytical Chemistry at the University of Fort Hare and Greg Morrison, Professor in Sanitary Engineering at Chalmers University of Technology.

The measurement campaign was conducted for three weeks in November 1999.

Stemele, Bosch & Associates (SBA) performed in January 1999 an environmental scoping investigation for the transport, treatment and disposal of wastewater in the town of Keiskammahoek on behalf of the municipality of Keiskammahoek. Their report has been used as a source of information, and for comparison with the results of the measurement campaign.

1.2 Aims

The major aim of this report is to evaluate the impacts of the Keiskammahoek Wastewater Treatment Works (KWWTW) and to a certain extent other sources within the Keiskamma TLC, regarding nutrient loads and oxygen demanding substances affecting the Keiskamma River. This aim have been subdivided into:

- Plan and conduct a measurement campaign in the area of Keiskammahoek TLC.
- Describe the area and identify potential problems affecting the Keiskamma River in the vicinity of Keiskammahoek TLC,
- Present the measurement campaign, its quality assurance and describe the measurement points,
- Present the results of the measurement campaign,
- Evaluate the results through comparison with current legislation and with theory,
- Discuss wetland techniques,
- Suggest further studies.

2. Background

2.1 South Africa

"The world in one country" is the way that South Africa markets itself, and it is truly a magnificent country with its ability to fulfil virtually every desire one might have. The ability to see beautiful scenery, wildlife, culture and activities seems endless. Although the main cities have one of the highest crime rates in the world, the open countryside still offers hospitable, friendly people.

Figure 1: Map over South Africa

South Africa is located on the southern tip of the African continent and it is bordered by the Indian and the Atlantic Ocean. There are three major geographical areas, plateau, mountains and the coastal belt, where the mountain ranges rise steeply from the coastal belt to form a plateau on the top.

Climate

The climate in South Africa is quite pleasant with mild temperatures and a lot of sunshine. Seasons are clearly defined between summer and winter, however the rainy season varies with which region one is situated in. The Cape Town region has winter rains (May to September) which can last for days, whilst the eastern parts of South Africa have summer rains (November to March) characterised by short, but fierce thunderstorms.

People

South Africa's population is about 43 million (1997), according to WHO's Epidemiological Fact Sheet.[4] (southafrica.pdf, visited 28th Feb, 2000) Approximately three-quarters of the population are African, whilst the remaining are white, Asian (most of Indian descent) or *coloured.* This demographic grouping was used for registration purposes during the apartheid era. Among the Africans, there are 2 major groups: the Xhosa (18%) and the Zulu (22%). The ethnic and political rivalry between these two groups has had a defining impact on African politics. The Xhosa now make up the most powerful party (ANC), and the Zulus have the third most powerful party, the Inkatha Freedom Party (IFP).[5] (Warner T A, 1999, p72)

Demography

South Africans live in nine different provinces of which KwaZulu-Natal is the most populous one. According to WHO statistics 51% of the population was urbanised in 1996. Over 90% of all whites live in urban areas. This is explained by the segregation between whites and blacks until 1991. The black population lived in townships (an urban settlement planned for black people only, usually implying inferior facilities and services)[6] (*Encarta® World English Dictionary, 1999)* set up on the outskirts of the cities. Estimated life expectancy at birth is 65 years (78 years in Sweden) but this has now decreased and is expected to be as low as 45 years in a few years, this is the result of a recent increase of HIV-AIDS.

Language
Due to its extraordinary diversity, South Africa has no less than eleven official languages. In addition to English and Afrikaans (origins from Dutch), there are nine African languages that correspond to the nine different tribal groupings. (Warner T A, 1999, p73)

Religion
There is no official religion in South Africa, but about two-thirds of the population are Christian. (Warner T A, 1999, p73)

2.2 Eastern Cape

The Province
One of South Africa's nine provinces is the Eastern Cape, which has been central to the history of the Xhosa people. The area around King William's Town has long been a centre for black political thought and action. The UFH, which was considered the best black university during the apartheid era, has made the Eastern Cape famous. The apartheid government put up two homelands in the Eastern Cape, the Ciskei and the Transkei. Due to mismanagement during the apartheid era the area is currently the second poorest province in the country. In some cities the unemployment is as high as 80%, and schools are constantly in crisis. (Warner T A, 1999, p171)

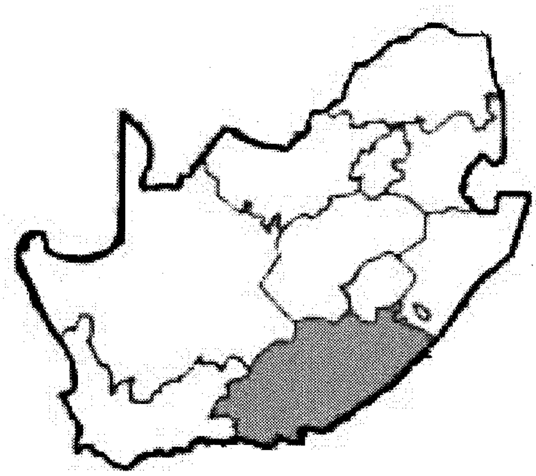

Figure 2: Eastern Cape province

Keiskammahoek
The study area of this report is the town Keiskammahoek, which is situated in the former Ciskei, now in the Eastern Cape Province. Below follows a description of the history of the area and the present situation regarding unemployment and education.

Historical Background
In the eighteenth century, the area of Keiskammahoek was occupied by Khoikhoi. They were driven away by Xhosa people, expanding from the east, who in their turn were defeated by the British army and in 1853 the settlement of Keiskammahoek was established as a military post. The name Keiskamma originates from Khoikhoi, and probably means "glistening or sparkling water or river". A number of villages were also established by both black (Mfengu) and white (mainly German) inhabitants. Over time, a number of Xhosa, together with members of other Cape Nguni groupings, drifted back into the area. A small coloured population also grew up in the area.[7] (de Wett C, 1999, p2)

Keiskammahoek developed as an administrative and commercial centre over the years. In 1936 after the implementation of the Native Trust and Land Act, the region became a part of Ciskei, a artificially created homeland for Xhosa, and it remained like this until the reunification of South Africa in 1994. The Native Trust and Land Act forced white farmers to sell their farms to the government, which converted them into Trust settlements for blacks. This resulted in a decline of the white population in the area. (de Wett C, 1999, p3-13)

From the 1950's and onwards, involvement with the wider economical and political setting was to be intensified as a result of the apartheid (literally meaning "the state of being apart") policy. Tribal authorities were formed as local government in the late 1950's. Self-government and the formation of political parties came in the 1970's, with homeland style "independence" in 1981. Pensions were granted to blacks in rural areas in the 1960's, and wages in the mining and manufacturing sectors rose markedly in the 1970's. In later days there has been an economic decline and a rising unemployment in the area. (ibid, p3-13)

The educational levels have suffered from the Bantu Education Act, implemented in 1953. This law meant that black people were only allowed to study basic skills necessary for menial labour. A network of hospitals, clinics and village health workers has been created. Although South Africa is now a re-unified country, the past will continue to influence the present for a long time. (ibid, p3-13)

Education and unemployment in the area of Keiskammahoek

The education level in the area of Keiskammahoek is low, 11% have progressed beyond the Junior Secondary level of education[8] (SBA, 1999, p43), and this is a result of many factors. During the years of apartheid the state took over the provision of education for black children. The per capita spending on black education was always a fraction of that spent on white education in South Africa and the mind-set of the architects of Apartheid ensured that the quality of the black education kept them segregated in society. Education is and has never been compulsory for black pupils and the remains from the past are still very evident in the education of the children in Keiskammahoek. (de Wett, 1999 p179).

The educational problem of Keiskammahoek are a result of many different factors such as, local teachers with low educational levels, lack of classrooms, laboratories, libraries *etc.* These issues are more or less a question of money, but there are also wider issues that need to be taken into consideration, including the problem of poverty in the community. Principals feel that some parents do not care about their children's education. Some parents see the school as a childminding institution and since many parents have a low or non-existing education, their children lose respect of them when they pass their educational level. Since some parents do not have the authority, the will or an understanding of the importance of education, children drop out of school. (de Wett, p172).

The environmental education is low or non-existing. Sean Coughlan writes that even the teachers have any idea of what it might involve. The majority of the teachers think that it is related to Geography and/or Nature studies. (de Wett, p178)

One of the most crucial questions in South Africa today concerns the regional policy of the future. Like other developing countries, South Africa is still a rural society with an urbanised population of about 51%. (southafrica.pdf, visited 28th Feb, 2000) A third of the population falls within the economically active group and 56% of the population is under the age of 19. Unemployment figures vary, but are at a high level. Approximately 65% of the economically active population is unemployed. The largest work supplier is the government sector, followed by significantly smaller opportunities in private business and domestic work.[9] (SETPLAN, 1996)

2.3 The sanitation problem and its impact

Access to basic infrastructure services, such as water supply and sanitation, are important steps to a sustainable future on our earth. Poverty has been said to be one of the greatest threats to our common future and it is a fact that poor people are they ones that lack access to the services mentioned above. Furthermore, it is a fact that adequate water supply and sanitation is an important contributor to health, well being and economic productivity of our society. Yet this quite obvious facts seems to be difficult to translate and implement in today's developing countries, although a lot of effort is put into this work.[10] (national_sanitation_policy.htm, visited 14th Nov, 1999)

According to the WHO, 53% of the South Africans do not have access to adequate sanitation facilities, for example the bucket system or the unimproved pit latrines. Poorly designed water-borne wastewater systems are constantly being built throughout the country and this is and will continue to create serious environmental problems. Inadequate excreta disposal facilities combined with unhygienic practices describe South Africa's sanitation problem. Often the unhygienic practices are related to:

- a lack of access to health and hygiene education;
- inadequate water supplies;
- poor facilities for the safe disposal of water and other domestic waste; and inadequate toilet facilities.

The effects of the sanitation problem are three-fold:

- health impacts - the impact of inadequate sanitation on the health of the poor is significant in terms of the quality of life and the education and development potential of communities,
- economical impacts - poor health keeps families in a cycle of poverty and lost income. The national cost of lost productivity, reduced educational potential and curative health care is substantial, and
- environmental effects - inadequate sanitation leads to dispersed pollution of water resources. This in turn increases the cost of downstream water treatment, as well as the risk of disease for communities who use untreated water.

(national_sanitation_policy.htm, visited 14th Nov, 1999)

3. Theory

3.1 Sanitation systems

There are two main groups of sanitation practises used in the society of today, "drop and store" and "flush and discharge". Over the past hundred years "flush and discharge" has been considered as the best solution, especially in urban areas. Many communities in developing countries are now implementing this model, where it is theoretically possible to achieve an acceptable treatment of wastewater. One problem, though, is that many of these countries do not have the resources to maintain such a system with its demand for water, money and institutional capacity (Winblad U, 1998). This results in the discharging of wastewater into the environment without adequate treatment.[11] (UNCSD, 1997)

3.2 Systems for collection of waste- and stormwater

The design of waste- and stormwater systems from urban, rural and industrial sites poses a different approach from the design of freshwater supply systems. A comparison shows a number of differences *e.g.* the transportation of wastewater must be as quick as possible in order to prevent septic conditions (but not so fast that erosion occurs), suspended solids need to remain in solution, the wastewater can contain chemicals which create selection criteria for the materials chosen for the wastewater pipes. In addition, flow fluctuations needs to be taken into consideration, mainly due to precipitation and evapotranspiration differences and other seasonal variations. The situation in urban areas is even more complicated, due to impermeable surfaces or *urban runoff* as it is often called. (Viessman Jr W, 1988, p324)

There are two main groups of wastewater systems:

- Separate systems, this means that black and grey water are separated from stormwater.
- Combined sewers, designed to receive both stormwater and domestic wastewater.

From these systems there are a number of different combinations, *e.g.* the industry can have their own treatment works or they can do their own pre-treatment before discharge into the wastewater system. (Viessman Jr W, 1988, p324)

3.3 Treatment of wastewater

The main purpose of municipal wastewater treatment is to prevent the discharge of pollutants into watercourses. Examples of such pollutants are heavy metals, iron, manganese, and *E.coli* bacteria. Nowadays, the discharge of nutrients, mainly phosphorus and nitrate, are thought of as pollutants. (Viessman Jr W, 1988, p 8)

There are a lot of different processes available for wastewater treatment and each treatment works need to be constructed individually, depending on the local situation, *e.g.* population, estimated population growth, population density, access to water, climate, and recipient. (Viessman Jr W, 1988, p 8, 194)

The main topics that needs to be considered and evaluated in the construction of a new treatment works are:

1. What kind of existing sewer collection system there is or what kind of system that needs to be built.
2. The recipient needs to be investigated in order to find out to which extent the wastewater needs to be treated. If the recipient is used for recreation (fishing, swimming, picnicking *etc.*) or as a water supply there is a greater demand for treatment.

3.4 Wetlands

During the past 20 years, considerable interest has existed of the potential use of different natural biological systems to help purify water in a controlled way. These natural biological treatment systems include various forms of ponds and wetland systems.

Constructed wetland treatment systems are engineered systems, designed to use natural processes in *e.g.* wetland vegetation and soil, and to utilise the micro-organisms present to assist in treating wastewater. Some of these systems have been designed with only one purpose: treating wastewater, whilst other constructed wetlands have been implemented with multiple-use objectives in mind. One example is the use of treated wastewater effluent as a water source for the creation and restoration of wetland habitat for wildlife use and environmental enhancement.

Constructed wetlands treatment systems generally fall into one of two general categories:

- *Subsurface Flow Systems* and
- *Free Water Surface Systems.*

Subsurface Flow Systems are designed to create a subsurface flow through a permeable medium, keeping the water being treated below the surface, thereby helping to avoid the development of odours and other nuisance problems. Such systems have also been referred to as *root-zone systems*. The media used, whether it be soil, sand gravel *etc.,* greatly influence the hydraulics of the system. *Free Water Surface Systems*, on the other hand, are designed to simulate natural wetlands, with the water flowing over the soil surface at shallow depths. Both types of wetlands treatment systems are typically constructed in basins or channels with a natural or constructed subsurface barrier to limit seepage.

Generally, wetlands remove dissolved biodegradable material with the help of micro-organisms, which are live on the exposed surfaces of the aquatic plants and soils. Aquatic plants play an important role in supporting the purification through pumping atmospheric oxygen into their submerged stems, roots, and tubers. Micro-organisms then use this oxygen in their decomposing processes. Plants also play an active role in the up-taking of nitrogen, phosphorus, and other compounds from the wastewater.[12] (Allen, G.H., 1988) Many studies conducted on treatment wetlands show that they can effectively remove a wide variety of pollutants from water, such as suspended solids, nitrogen, phosphate, ammonium, organic chemicals, metals, and bacteria.[13] (water-sc.htm, visited 25th Apr, 2000)
However, it should be stated that wetlands are not self-managing system. To the contrary, they must be monitored carefully. Pollutants can accumulate and reach levels that can poison the wildlife there. Industrial wastewater containing *e.g.* heavy metals, may be ingested by animals, either thought their direct drinking of the wastewater, or through their consumption of plants which have absorbed the wastewater. Even small levels can be very dangerous, since these forms of pollutants accumulate in the body, slowly poisoning the animal. It is also important to remember that wetlands do have a maximum capacity. At a certain point, the wetland system is not able to handle any more waste. (Allen, G.H., 1988)

3.5 Measured parameters

pH

pH is technically defined as the negative base 10 logarithm of the effective hydrogen ion concentration in gram equivalents per litre.[14] (H2Oquality.html#nitra, visited 991114) The greater the hydrogen ion concentration, the lower the pH and the more acidic the water. A high pH indicates a low hydrogen ion concentration and a low acidity. A measure of 7 indicates neutrality. A pH from 1 to less than 7 is acidic while values from greater than 7 to 14 are basic. Most water bodies have a pH range between 6 (slightly acidic) and 9 (slightly basic).[15] (page22.htm, visited 14th Nov, 1999)

Conductivity

Conductivity is the capacity of water to carry an electrical current. This property is related to both the total concentrations of ionised substances in the water and the temperature at which the measurement is made.[16] (page21.htm, visited 14th Nov, 1999)

COD

A prerequisite for aquatic life is dissolved oxygen, although the concentration of O_2-saturation are low in natural waters, usually between 7-14 mg/l.[17] (vatten, 1998) Dissolved oxygen is necessary for the respiration of most aquatic organisms. The distribution of oxygen in a water body is balanced between the inputs from the atmosphere and photosynthesis, and the losses due to chemical and biological oxidation. Oxygen distribution is essential to many organisms and affects the solubility and availability of many nutrients. It is therefore central to the productivity of aquatic ecosystems. (page24.htm, visited 14th Nov, 1999)) The solubility of oxygen in water is inversely proportional to temperature and salt content. As temperatures or salt content increase, oxygen solubility decreases.[18] (page24.htm, visited 14th Nov, 1999)

COD is a key parameter for process control and the routine monitoring of effluent quality in wastewater. (Vatten, 1998). An assessment of the amount of oxygen demanding substances in the aquatic environment can be estimated using the Chemical Oxygen Demand or COD value.[19] (Morrison G, 1992)

Phosphorus (P)

Phosphorus, usually found in aquatic systems as phosphate (PO_4^{3-}), is often the limiting factor for growth in freshwater environments. This is due to the fact that plants need it to grow and it is often present in low concentrations. The problem with phosphorus has become evident since untreated wastewater began to be discharged into water bodies.[20] (aquatic4.html, visited 14th Nov, 1999) When phosphorus is in excess in a system, algae blooms occurs at the surface leading to high oxygen production. When the algae dies, it sinks and while being decomposed, oxygen is used, often leading to low oxygen concentrations in these regions. Sources of phosphorus are many *e.g.* washing powder, fertilisers, and wastewater sludge but also wet and dry deposition. (Morrison G, 1992) The algae bloom also leads to lower visibility and light penetration, affecting plant life at the bottom. (aquatic4.html, visited 14th Nov, 1999)

Ammonia (NH_4^+)

Ammonia is released into aquatic environments from many industries and human activities. Release of wastewater effluents from municipalities is often the largest non-industrial source of ammonia. Toxicity problems may arise when ammonia accumulates in sediments from municipal wastewater outfalls. Other sources of ammonia are agriculture and the animal husbandry sector (*i.e.*, ranching, dairies, poultry, and other animal-raising practices).[21] (ammonia_summary.htm, visited 20th Mar, 2000)

Ammonia may become toxic to plants and animals at elevated pH levels when ammonium hydroxide forms. On fish, it tends to block oxygen transfer from the gills to the blood and can cause both immediate and long-term gill damage.[22] (H2Oquality.html#nitra visited 14th Nov, 1999)

However, if ammonia is present in sufficient concentrations it is the preferred form for plants, since the utilisation of nitrate requires additional energy as well as the presence of the enzyme nitrate reductase (an enzyme that catalyses the reduction of an organic compound). Ammonia concentrations are usually low in aerobic waters because of its utilisation by plants.[23] (page28.htm, visited 14th Nov, 1999)

Aquatic plants seem to be immune to the toxic actions of ammonia in typical water concentrations. Actually it is quite the opposite, ammonia at typical wastewater effluent concentrations is a nutrient for aquatic plants. In some aquatic systems the alterations to ecosystems through excess stimulation of plant growth is the most likely form of disturbance. (ammonia_summary.htm, visited 20th Mar, 2000)

Nitrogen (N)

Nitrogen is a very important constituent of living material, both in plants and animals. It has a range of species in water including nitrate (NO_3^-), ammonium (NH_4^+) and nitrite (NO_2^-). There are a number of sources that contribute to nitrogen in surface and groundwater *e.g.* wastewater treatment plants, agriculture and the burning of fossil fuels.

Nitrogen is a major nutrient that affects the productivity of freshwater ecosystems and is occasionally present in such low quantities that plant growth is limited. Relatively small quantities exist in the combined forms of ammonia, nitrite, nitrate and a large number of organic compounds (*e.g.* amino acids, amines, nucleotides, proteins).[24] (page27.htm visited 14th Nov, 1999)

Where ammonia and nitrite is toxic to fish, Nitrate is essentially harmless. This form of nitrogen is also the end product of the nitrification cycle and is very important to plants.[25] (H2Oquality.html#nitra, visited 14th Nov, 1999)

Animals excrete nitrogenous waste primarily in the form of ammonia. Other organic wastes, like uneaten food, dead fish and plants are also transformed to ammonia via demineralisation and mineralisation. In the presence of acidic water, ammonia utilises free hydrogen ions and forms ammonium, which is partly used by plants as a fertiliser. These ammonia compounds are also the first step in the nitrification process. In the presence of oxygen, ammonia is oxidised to nitrite. In the second step of the process, which is aerobic, nitrite is oxidised to nitrate. Some of the nitrate is utilised by water plants and algae as a fertiliser. The remaining nitrate may be removed from the water body through denitrification, which is an anaerobic process where nitrate is turned into nitrogen gas (N_2).[26] (page29.htm, visited 14th Nov, 1999).

4. Study area

4.1 Location

The town of Keiskammahoek falls beautifully into the Amatola mountain range, which is situated in the Eastern Cape Province. Geograpically, it is located 45 km north-west of King Williams Town (KWT), 34 km south-west of Stutterheim, 18 km north of Dimbaza and 43 km north-east of Alice and the University of Fort Hare, see Figure 3. (SBA, 1999)

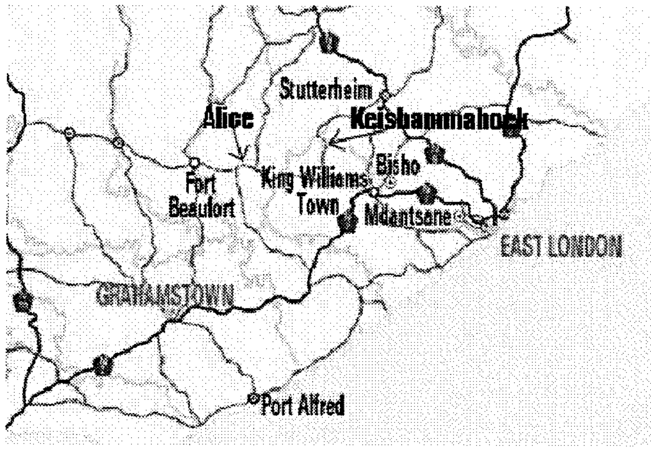

Figure 3: Location of Keiskammahoek

4.2 Topography

The village is at an altitude of 620-660 m above sea level. The topography varies from steep slopes to moderate slopes and low-lying areas. The altitude of the entire area varies by more than 1000 m within a distance of 30 km.[7] The topography predisposes soil erosion and this together with overgrazing leads to a low productivity in the area.[27] (Oosthuysen L, 1989) Immigration and natural population growth have extended the pressures on the available land even further.[28] (Doni T M, 1997)

4.3 Climate

The village of Keiskammahoek lies within the summer rainfall region of South Africa. This means that close to 70% of the annual precipitation occurs in a period of six months, October to March. (Doni T M, 1997). The mean annual rainfall in the area is 650-700 mm. [29] (Austin M N, 1989) Average evaporation rates vary between 96,5 – 259 mm/month throughout the region, with peak values in November and December [30] (Weather Bureau, 1998).

4.4 Villages and population

The Keiskammahoek TLC consists of the town of Keiskammahoek and seven surrounding villages. In total, there are 12 000 people living within the TLC, and of them 5 000 are connected to the treatment works in Keiskammahoek (KWWTW). There are two different ways of collecting and transporting the wastewater to the treatment works, the "flush and discharge" and "drop and store" systems. (Ms Precious, 14th Oct, 1999)

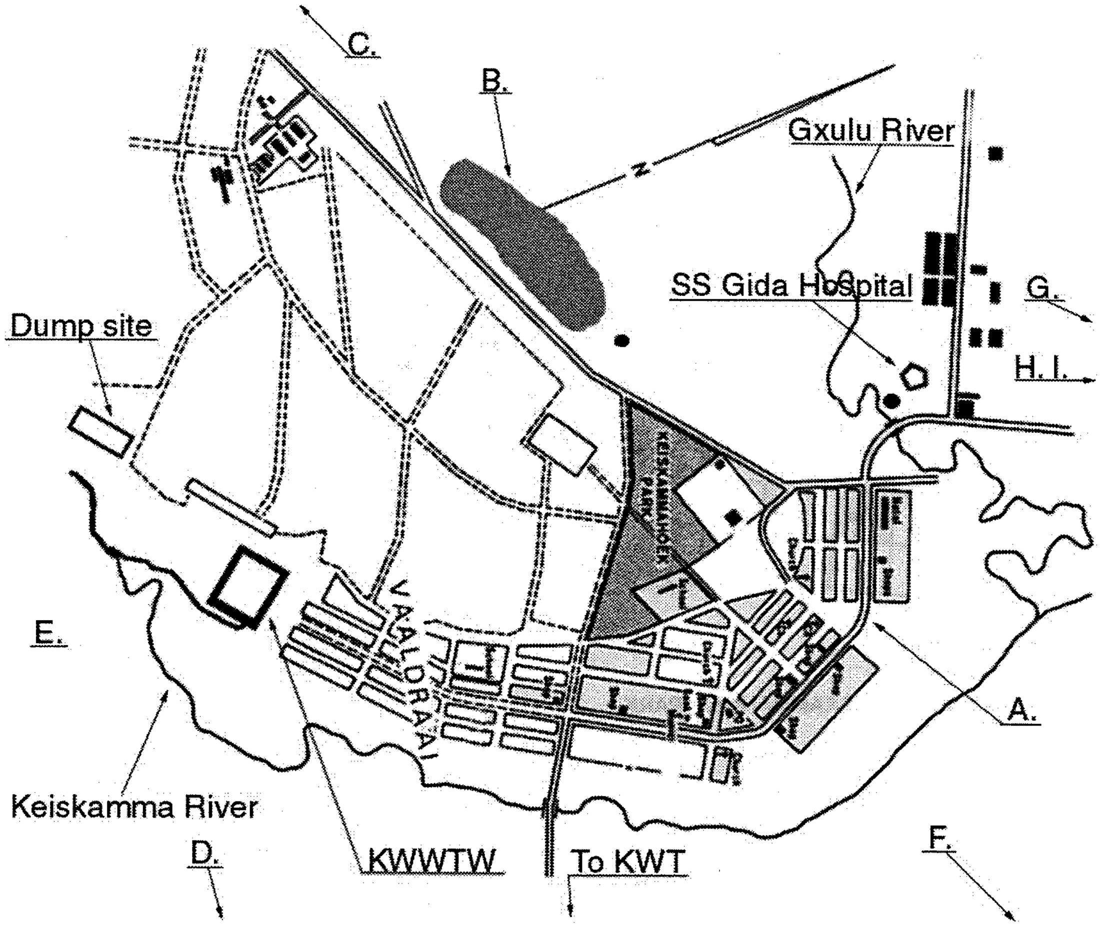

Figure 4: Keiskamma TLC with its different villages and wastewater system (described below), modified map, originally from de Wett (map 5, page xi)

The different parts of the Keiskammahoek TLC are shown in Figure 4 above and described together with the used wastewater system below. (Ms Precious 14th Oct, 1999) Note: KWWTW is the location of the present treatment works.

Keiskammahoek town:

- *Vaal Draii* uses a bucket system and septic tanks, marked with name,
- *Keiskammahoek Park* uses the waterborne wastewater system, marked with name,
- *Main Street/Old Town* uses a bucket system and septic tanks, marked A.

Surrounding villages:

- *Sophumelela Township*, is the newly built RDP housing unit area (totally 443 houses), which uses the waterborne wastewater system, marked B,
- *Masincedane* uses pit latrines, they are not connected to the treatment works but sometimes use the honey sucker[#], marked C,
- *Tshoxa* uses ventilated improved pit latrines (VIP latrines) and is marked D,
- *St. Peter's* is not connected to the Keiskammahoek treatment works, uses pit latrines, marked E,

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[#] Collection of the waste from these systems is made by the municipal "honey sucker" which is a tractor with a septic tank that transport the sewage to KWWTW where it is discharged into to the inlet works of KWWTW.

- *Ngqudela* is not connected to the Keiskammahoek treatment works, uses pit latrines, marked F,
- *Bumbane* is not connected to the Keiskammahoek treatment works and uses pit latrines. The SS Gida treatment works is situated in this village, marked G,
- *Ngxalawe/Kom* is not connected to the Keiskammahoek treatment works and uses pit latrines, marked H,
- *Nompha* is not connected to the Keiskammahoek treatment works, and uses pit latrines, marked I.

4.5 Wastewater-systems and problem identification

Both "flush and discharge" and "drop and store" sanitation systems are used in Keiskammahoek at present date.

In an ordinary waterborne "flush and discharge" system, wastewater (human excreta, washing water *etc.*) is mixed with clean water. As a result, all of the wastewater needs to be treated in the same way, which is expensive (in different ways) and can be seen as a waste of resources.

The "drop and store" system is based on storing wastewater in the ground. However, there are a number of different techniques that can be used *e.g.* pit toilet (the most common sanitation system in the world)[31] (Winblad U, 1998), septic tanks and conservancy tanks. Criteria for "drop and store systems" include access to the ground and a soil that can be dug, a low ground water table and an area that is free from flooding. Examples of disadvantages are bad odours, fly breeding and soil and water contamination.

"Drop and store"

At the moment there are 65 bucket systems, four pit latrines, five french drains, 89 conservancy tanks and ten septic tanks in Keiskammahoek. (SBA, 1999, p50) The remaining households are connected to the public wastewater system and this should add up to approximately 5 000 persons according to personal communication with Ms Precious on 14th Oct, 1999.

Problem identification

On 11th of November, 1999, when visisting KWWTW, the "honey sucker" was discharging its container into the primary aerobic pond instead of into the inlet. However, this could be due to the re-construction that is taking place close to the inlet, which is preventing access. These actions, though, lower the purification rate. It should be investigated if this discharge point is frequently used.

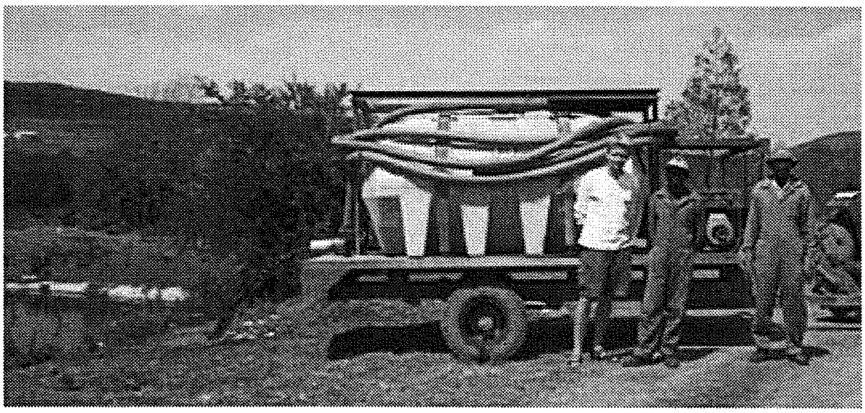


Figure 5: Mr. Persson at KWWTW, the "honeysucker" is discharging into the primary aerobic pond. (11th Nov, 1999)

Another potential source of pollution is the cleaning of the buckets that have contained human excreta. After being emptied into the inlet of the treatment works they are transported to the bucket washing facility, which is situated at the landfill area approximately 700 meters in a westerly direction. (SBA, 1999, p44, 65) Here they are cleaned and the water makes its way down to Keiskamma River untreated. No estimations have been made on possible pollution potential from this source. When visiting the site at 21st Oct, 1999 there were no signs of a ditch leading the cleaning water down to Keiskamma River. However this is potential source of pollution that needs to be investigated in further studies.

There are some additional problems connected to the use of "drop and store" systems, as Keiskammahoek has shallow groundwater and the use of these systems may result in pollution of the groundwater.[32] (Wright A, 1999). It is difficult to estimate the effects the discharge of pollutants have on the Keiskamma River. No estimations have been made regarding the impact in this report.

"Flush and discharge"

There are three wastewater systems in Keiskammahoek that are built according to the principle of "flush and discharge":

1. An old military camp is located in the area of Ngqudele, but this treatment works is not used anymore, so this point source has been disregarded, see Figure 4, p12.
2. SS Gida Hospital is situated in the vicinity of the Keiskammahoek town centre. This Hospital have its own treatment works in the village *Bumbane*, see Figure 4: Keiskamma TLC with its different villages and wastewater system (described below), modified map, originally from de Wett, p 12.
3. An estimated population of 3 000 is connected to the KWWTW via a waterborne system, which leads both black and grey water.

Problem identification

When visiting the village of Keiskammahoek and the SS Gida Hospital pump station on 21st of Oct, 1999 it was noticed that the pumps were out of order. At the treatment works, Mr. Sontshi[33], employee at SS Gida, gave us the information that the pumps had been out of order for nine months. The low water levels in the treatment ponds verified this statement,(personal visit at site 21st Oct, 1999). The consequence is that raw wastewater bypasses the pumps and discharges straight into Gxulu River. SS Gida Hospital serves a large population of approximately 30 000 and the malfunctioning of the pumps make the hospital a severe potential polluter of Keiskamma River.

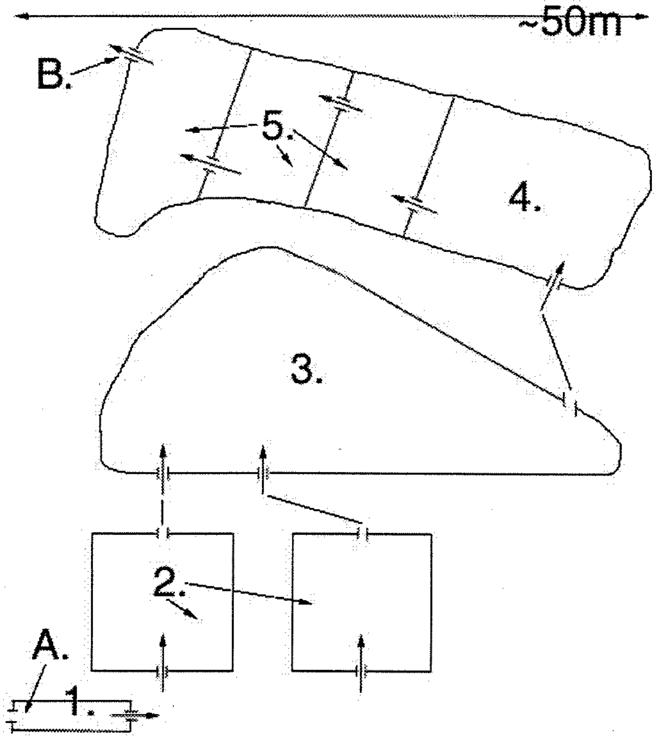
In the planning phase of the measurement campaign, a point downstream of the discharge point of SS Gida's pump station was chosen in order to evaluate the environmental impact. However, at the start of the measurement campaign (1st Nov, 1999), it were noticed that the bypass of wastewater had stopped and that the pumps were running. A site visit and discussion with Mr. Mbilase[34] (pump technician at SS Gida Hospital), gave the information that the pumps had been repaired the previous day. The measurement campaign was transformed and this point excluded, however the function of the pumps was checked on every sampling occasion. On a site visit 18th Nov, 1999 to the SS Gida treatment works, no effluent was occurring, due to the intitially low water levels in the ponds. Effluent is expected in January according to Mr. Mbilase.

A pump station connected to the RDP-housing units also provides a threat to the water quality of Keiskamma River. In the case of pump malfunction, a small pond is supposed to store the leaking wastewater, but within a few days overflow will occur and wastewater will seep down, reaching the Gxulu River.

The Keiskammahoek wastewater treatment works (KWWTW)

The WWTW in Keiskammahoek was constructed in 1983 and it is built as an anaerobic/aerobic pond system, for location see Figure 4, p12. (SBA, 1999, p46) It is built for a population of 950-1000 persons, but at the moment approximately 5 000 persons are connected. The treatment works receives both black and grey water. (Viessman Jr W, 1988).

No chemicals are added in the KWWTW, which means that treatment occurs naturally. The treatment works is designed to carry 100 m^3/d, with peak flows of 220 m^3/d in wet weather. (SBA, 1999, p46)



KWWTW

1. Screen, Coarse grit removal
2. Anaerobic settling ponds (settling of raw wastewater)
3. Primary aerobic pond
4. Secondary aerobic pond
5. Three stage tertiary pond

A. Inflow to treatment works
B. Outflow from treatment works

Figure 6: Keiskammahoek Waste Water Treatment Works (own figure)

The construction of ponds is a popular method for wastewater treatment, due to the use of natural and energy efficient processes. The wastewater is treated through a combination of physical, biological, and chemical processes. KWWTW has a combination of three different kind of ponds, anaerobic, aerobic and finally a tertiary one.

Anaerobic ponds

The word anaerobic means "without oxygen", which describes the conditions inside this type of pond. In the pond, solids in the wastewater separate and settle into layers whilst the top layer consists of grease, scum, and other floating materials. The layer of sludge that settles at the bottom of the anaerobic pond must be removed regularly. A common problem with anaerobic ponds is odour.

Aerobic ponds

Dissolved oxygen is present throughout much of the depth of an aerobic pond and wastewater treatment takes place naturally with the aid of aerobic bacteria and algae. In these ponds *e.g.* nitrification takes place.

Tertiary ponds

Tertiary or maturation ponds are mainly made for the removal of pathogens in wastewater. These ponds are usually 1-1,5 m deep and they are aerobic, which means that they are also useful for nutrient removal.

Problem identification

The inflow to the pond is so high that it occasional overflows occurs. The reason for the overflow is the combination of an under-dimensioned treatment works and rainfall. (Ms Precious 14th Oct, 1999) Another apparent impact in the vicinity of the treatment works is odour, which was substantial on all sampling dates.

Other Potential Point Sources

There are no industries of significance in the area, except for a sawmill situated close to the SS Gida Hospital. However, this industry has not been considered a polluter in this report, and measurements and evaluations between sample points 6 and 7 verify this theory. The refuse dump situated downstream of the treatment works has also been excluded as a result of a site visit. The measurement campaign took place during the beginning of the wet season, but only small amounts of rain occurred during the measurement period. Which resulted in no surface flow. No estimations considering leachate from the dumpsite have been carried out. Aside from the mentioned point sources, there has not been any other potential point sources identified in the area of Keiskammahoek.

Non-point sources

Urban and agricultural runoff are characterised by multiple discharge points and are often described as non-point sources. Polluted water often flows over the surface of land via natural drainage channels to the nearest water body. Even when this water is collected in pipes or channels, it is often transported to the nearest recipient without treatment.[35] (Davis M L et al., 1998)

Problem identification

There are some non-point sources in Keiskammahoek that may affect Keiskamma River. Previously the stormwater system has been inadequate, and as a result, stormwater has been left lying on the streets for days after rainfall, before being removed through evaporation. The stormwater system is now being reconstructed and this will result in a drainage of the streets and discharges into the Keiskamma River. (SBA, 1999) Examples of pollutants from non-point sources, such as urban runoff, are oxygen demanding substances, nutrients, salts and toxic metals. (Davis M L et al., 1998) Another problem related to urban runoff is the pouring of grey water (*e.g.* from the washing of clothes) into the street of Keiskammahoek, which is done in order to prevent a rapid filling of an individual's septic tank.[36] (SBA, 1998) Washing powder contains phosphates, which have a eutrophic effect on the river.

There are also some agricultural irrigation schemes that may have an affect the river, since these types of activities usually use fertilisers. Examples of pollutants from agricultural runoff are oxygen demanding substances, nutrients, salts and toxic organic chemicals. (Davis M L et al., 1998)

5. Measurement campaign

5.1 Measurement points

The measurement points have been chosen to evaluate the environmental impact on Keiskamma River that can be assigned to the wastewater treatment works and other sources within the Keiskammahoek TLC. The measurement campaign has been optimised with as few sampling points as possible along the watercourse. Additional points for an evaluation of the treatment works were chosen as shown in Figure 4, p12.

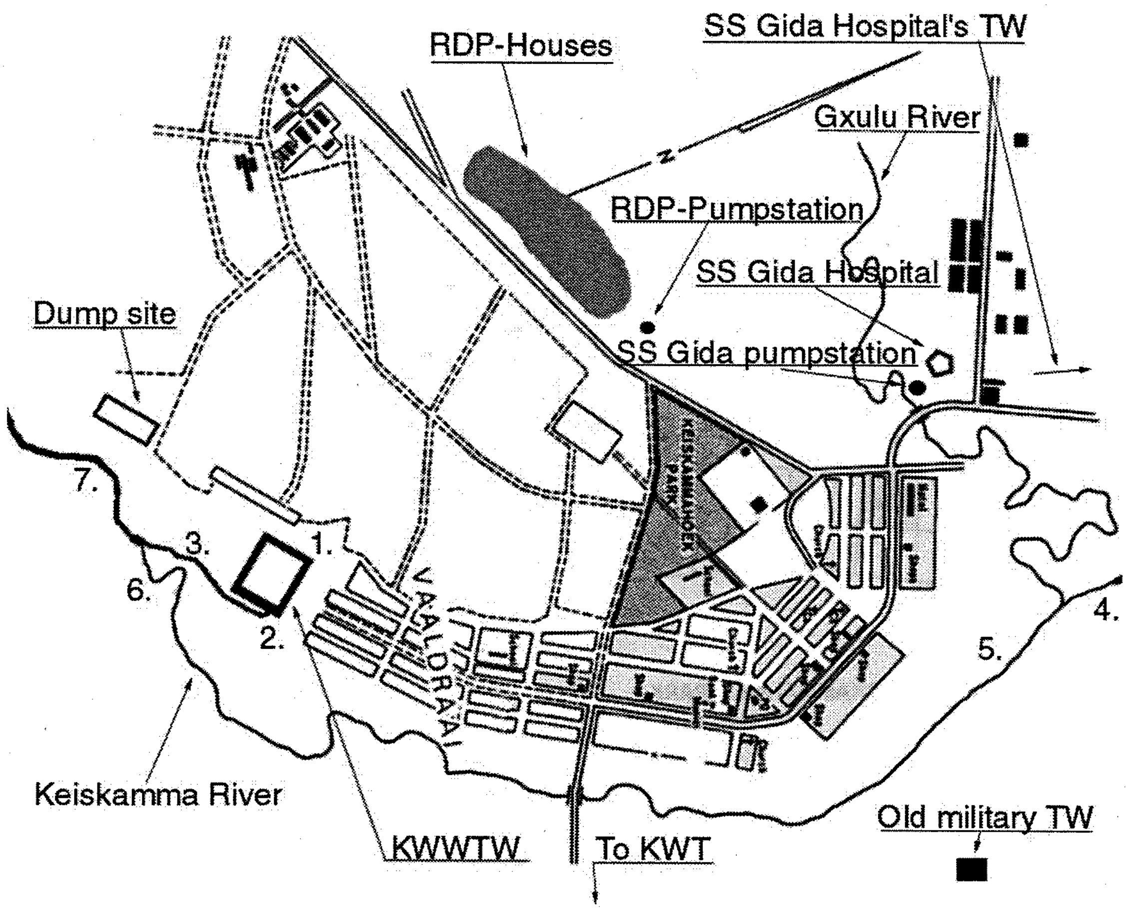


Figure 7: Keiskammahoek area with measurement points 1-7.

1. Measurement point 1 was placed after the inlet of KWWTW. Due to a low flow after the grit screen, samples were taken in one of the inlets to the primary settling ponds.
2. Measurement point 2 was in the outflow from the treatment works.
3. Measurement point 3 was placed approximately 135 meters after the second point. The outflow first merges with a water ditch, and then runs through a wetland-like area. The sampling spot is situated just after the end of the wetland area.
4. Sample point 4 is referred to as the reference point, it is situated about 110 meters upstream of the junction between the Keiskamma and the Gxulu River. The samples were taken from the shoreline of the river without a water sampler.
5. The fifth point was placed 230 m downstream of the merging point of the Keiskamma and Gxulu Rivers at an old constructed dam. Samples were taken in the middle of the river.

6. Measurement point 6 was chosen in order to investigate the impact of the town of Keiskammahoek. The point was situated downstream of Vaal Draai, but upstream of the merging point of the Keiskamma River and the effluent from KWWTW. Samples were taken from the shoreline without water samplers.
7. Sample point 7 was placed approximately 100 m after the junction between Keiskamma River and KWWTW in order to analyse the environmental impact. Sampling was done in the middle of the river.

5.2 Measurement dates

Due to time constrains and a limited numbers of samples available, the measurement campaign was limited to three weeks, 1^{st} - Nov to 18^{th} - Nov. Sampling dates were chosen to be the 1^{st}, 4^{th}, 9^{th}, 11^{th}, 15^{th} and 18^{th} of November 1999.

On November 1^{st}, samples were taken at the treatment works, *i.e.* sample points 1 to 3. Low inflow to the treatment works. Sampling was done at lunchtime. The weather was fairly good, approximately 25 degrees, sunshine with some clouds.

On November 4^{th}, samples were taken in the river, *i.e.* sample points 4 to 7. The weather was about 25 to 30 degrees C and the sun was shining. It had not rained since previous sampling. Sampling was done before lunch, approximately from 10 to 11 A.M.

9^{th} of November samples were taken in the river, sample points 4 to 7. The weather was still warm with 25 to 30 degrees and sunshine. The samples were taken at the same time as previous sampling and there had not been any rain.

11^{th} of November it was between 20 and 25 degrees and cloudy. Samples were taken just before lunch hour in sample points 1 to 3 (KWWTW).

At 15^{th} it was cloudy, it had been thunderstorms and rain in Alice during the night. The day was grey and it was a lot colder than previously sampling dates. Samples were taken at KWWTW. Sampling were done about 9 to 10 am, the inflow to the treatment works was considerably higher than previously sampling dates.

18^{th} of November was the final sampling day with warm weather, approximately 30 degrees Celsius. Samples were taken at all sampling sites (1 to 7) during the morning. The inflow to the treatment works was still high, but had halved compared to the 15^{th}.

5.3 Quality Assurance

All details in a measurement campaign need to be well prepared in order to minimise errors. There are different kinds of errors that might occur, some of them can be explained by the *accuracy* and *precision*. Precision is how well the samples correlate with each other, however this does not automatically mean good accuracy. Accuracy is how close the samples are to the "true" value.

In this measurement campaign, the analyses have been done in triplicates, and then average and standard deviation has been calculated. Standard deviation gives a good value of the precision, but tell nothing about the accuracy. In order to achieve a good accuracy, prescriptions for sampling, cleaning of bottles, analyses procedures *etc.* have been read and followed.

All bottles for sample collection were washed in 1:1 Hydrochloric acid, and then rinsed with de-ionised water before every sampling. Prior sampling, the bottles were rinsed three times with sample water and then slowly filled.

The de-ionised water used for cleaning and dilution was replaced on every sampling date. All equipment used was also cleaned with 1:1 Hydrochloric acid and rinsed with distilled water before usage. Equipment for sample handling was treated in the same way prior measuring, in order to reduce the interferences created by different handling procedures.

Samples from all measurement points were filtered for all parameters except pH, conductivity and COD before analysis. At points 1-3 (KWWTW), samples were filtered, after they been treated with activated carbon, in order to reduce the colour of the samples (0,4 mg with 100 ml sample). This was done on sampling dates 11, 15 and 18 November, on the 1st there was no activated carbon available.

Blanks were made for filters in order to measure the contribution from this source, the same procedure has been done for the activated carbon. Results have been adjusted for these contributors in the presented results.

New standards were made for each parameter every measuring week.

5.4 Potential Interference's

De-ionised water

The quality of the provided deionised water is unknown. It was supplied from a machine placed at the department of analytical chemistry and there was a few other projects running parallel with this campaign using the same water.

Dilution of samples

For some of the samples, dilution was necessary in order to get into range for analysis. Ammonia and phosphate samples from points 1 to 3 needed to be diluted 20 to 40 times, which is a potential source of error. Although precision can be evaluated by standard deviation, the accuracy due to incorrect dilution is a source of error that is impossible to estimate.

Measuring techniques

The instruments used might have an influence on the results. The pipettes used had a maximum volume of 5 ml, with a grading of 0,05 ml. This is a potential source of error, especially when dilution is needed. Unclean vials are another possible source, however standard deviation can be used to estimate these sources of error.

Standards

Standards were brought from Sweden, which means that they were exposed to temperature variations before arrival. Inaccurate standard dilutions are another probable interference for varying standard results.

Water Samples

Some of the samples in the Keiskamma River may not be representative for the whole water body, since some samples were collected from the shore. The influent of the treatment works can not be treated as a representative sample for a longer period of time since it varies throughout the day, week *etc.* These samples are treated as momentary values *i.e.* they vary constantly. Continuous measurement is necessary in order to get a trend of the variation.

6. Results

In this chapter, results are presented in graph form together with a discussion of the results. In Appendix 1, the results are presented in tables with standard deviation. Measurement dates 1st, 4th, 9th, 11th, 15th and 18th November 1999 are results from this measurement campaign, whilst 2nd February, 9th September and 15th December 1998 are results from the consultant's (SBA) measurement campaign. In some graph's legislative values are shown for comparison with the measured concentrations.

On the right side of the graphs measurement dates are presented.

The consultant's report has used a reference point upstream of the merging point of Keiskamma and Gxulu-River. The location of this point is not given, but an assumption has been made that this point can be compared with sample point 4, *i.e.* the reference point used during this measurement campaign, see paragraph 4.1 (page 10). The same assumption and comparison has been made for measurement point 2, 6 and 7. However, according to the SBA report, the measurement point downstream of the treatment works is situated close to the dump site. This means that measurements in point 7 may not be totally comparable with the SBA values.

6.1 Physical-Chemical Parameters

pH

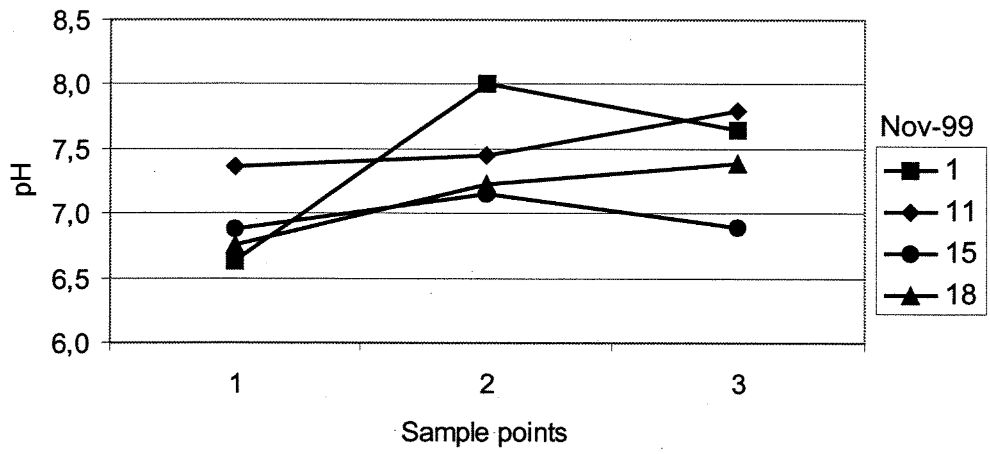


Figure 8: pH in KWWTW

The pH has shown stability throughout the measurement campaign, see Figure 8. Influent values (average 6.9) are slightly lower than effluent values (average 7.5) and this correlates well with the legislation, which gives 7,5 as a maximum. SBA values are in the same range with effluent values varying from 6,6 to 7,3, see Appendix 1.

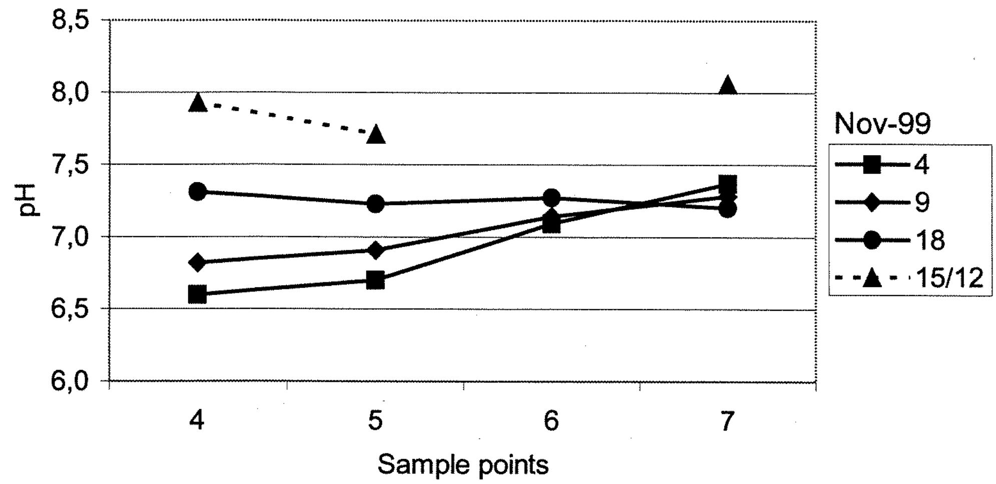


Figure 9: pH in Keiskamma River

pH is increasing downstream through the Keiskamma River, see Figure 9, from an average of 6,9 in the reference point (number 4) to a maximum downstream of the KWWTW with a pH of 7,3 (point 7). A comparison with the SBA's values shows similarities with a maximum pH (8,1) in point 7 (SBA, 1999).

The increase in pH may be explained by a comparison with results obtained at KWWTW. In measurement point 3, the average pH was 7,4 and as this point merges with Keiskamma River between point 6 and 7 the pH might increase slightly in point 7. The greatest increase in pH is however found between points 5 (average 6,9) and 6 (average 7,2).

It should be stated that the pH in Keiskamma River is at present within limits and does not provide a threat to public health or living aquatic organisms according to legislation.

Conductivity

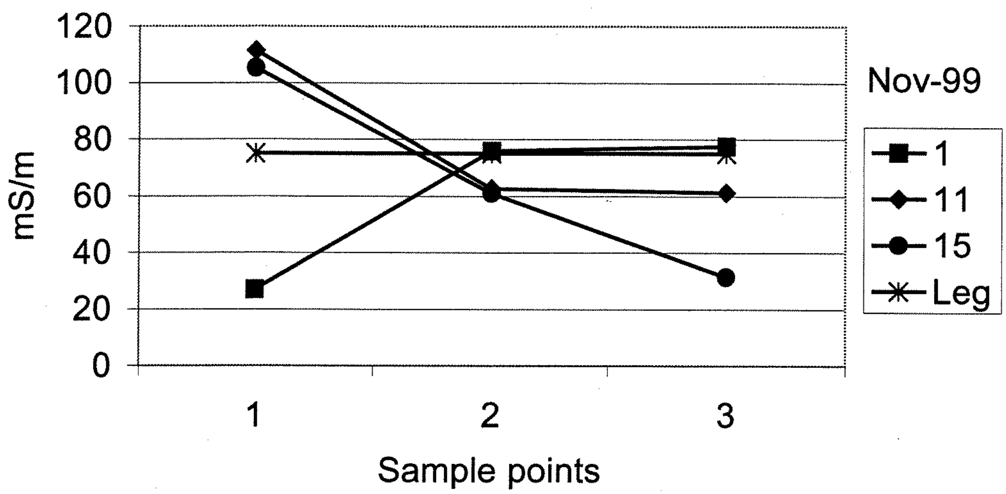


Figure 10: Conductivity in KWWTW

The purification of conductivity works satisfactorily in the treatment ponds. Levels decrease from an average in point 1 of 107 mS/m to an average of 62 mS/m in the effluent, point 2. Legislation limits are 75 mS/m. An analysis done by SBA shows an average of 77 mS/m (SBA, 1999), which is slightly higher than the legislative limits.

Note: The analysis of conductivity on 1st Nov, 1999 was disregarded as it was not reliable, since there were problems with sample point 1 (influent). The reason for these problems is not known, it may be a result of an intrusion of freshwater. The sample colour differed from later samples in point 1, see Appendix 2.

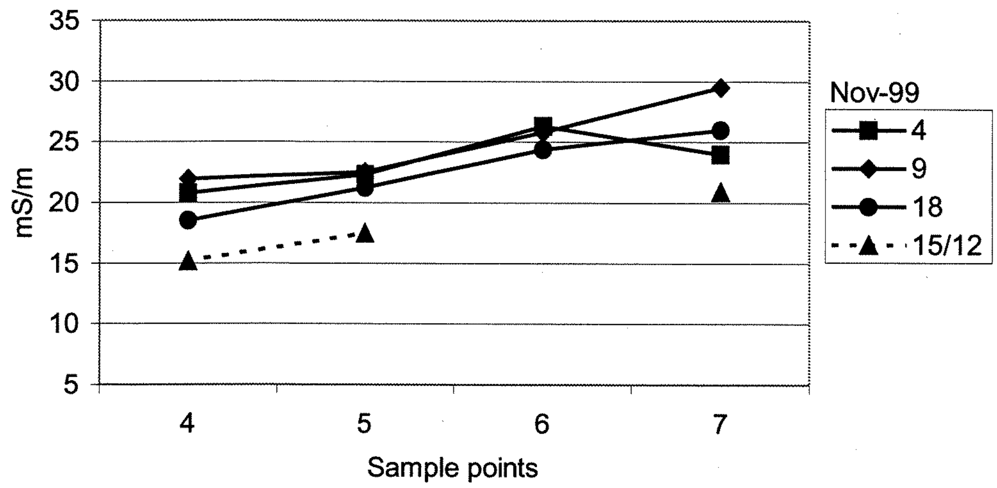


Figure 11: Conductivity in Keiskamma River

Conductivity concentrations are stable along the watercourse and no increase in concentration can be found in point 7. Concentrations vary from 20 mS/m to 30 mS/m, which correlates with SBA's values.

COD

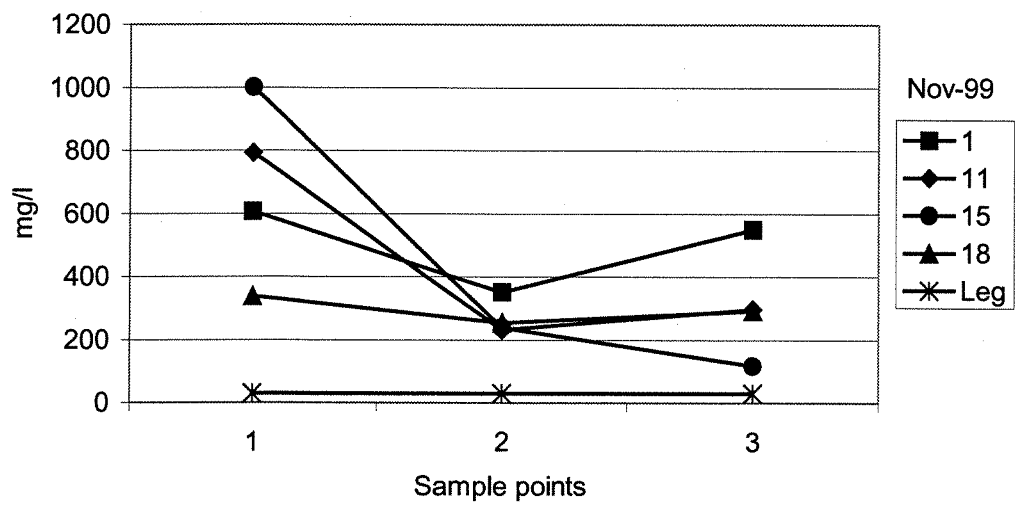


Figure 12: COD in KWWTW

The concentration of oxygen demanding substances in the effluent is extremely high, although the purification is remarkably good. Influent concentrations vary from 340 mg/l to over 1000 mg/l, the effluent concentrations are more stable with an average of about 270 mg/l. Effluent concentrations are higher than the ones obtained by SBA, which averaged 120 mg/l, see Appendix 1. However, all of this values are at least two times higher than the current legislative value of 30 mg/l (special standard limits) or 65 mg/l (general standard limits).

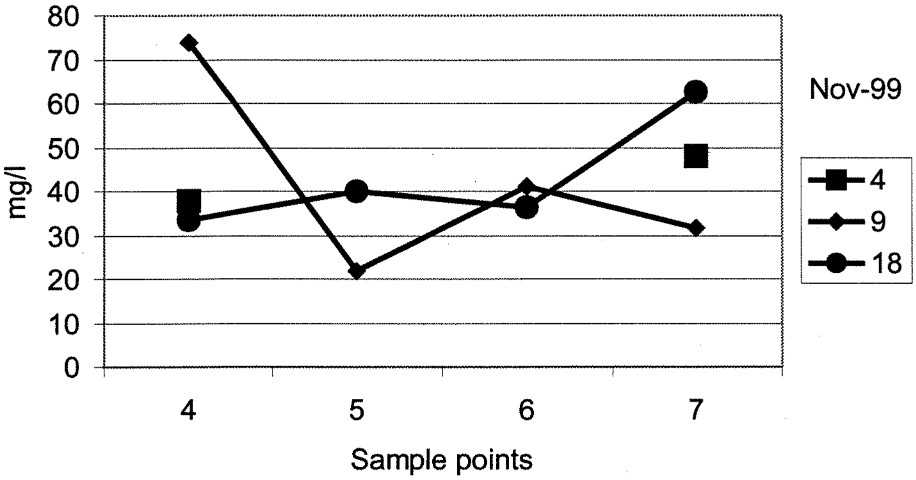


Figure 13: COD in Keiskamma River

Analysed samples in Keiskamma River are all at concentrations close to the detection limits of the used HACH equipment (30mg/l). However in point 7 where complete mixing between effluent and the water in Keiskamma River is assumed, concentrations are close to the legislative limits of effluent concentrations.

6.2 Chemical parameters (Cations and Anions)

Phosphorus (PO_4^{3-} - P)

Phosphate is an important parameter, often considered as the limiting nutrient in freshwater systems. Legislative limits are given as phosphorus in the South African Water Act.

Concentrations of phosphate vary widely throughout the measurement campaign. Concentrations obtained on November 1st have been disregarded, due to interference with colour. Samples taken in KWWTW (sample points 1 to 3) after Nov 1st were treated with activated carbon in order to reduce the coloration.

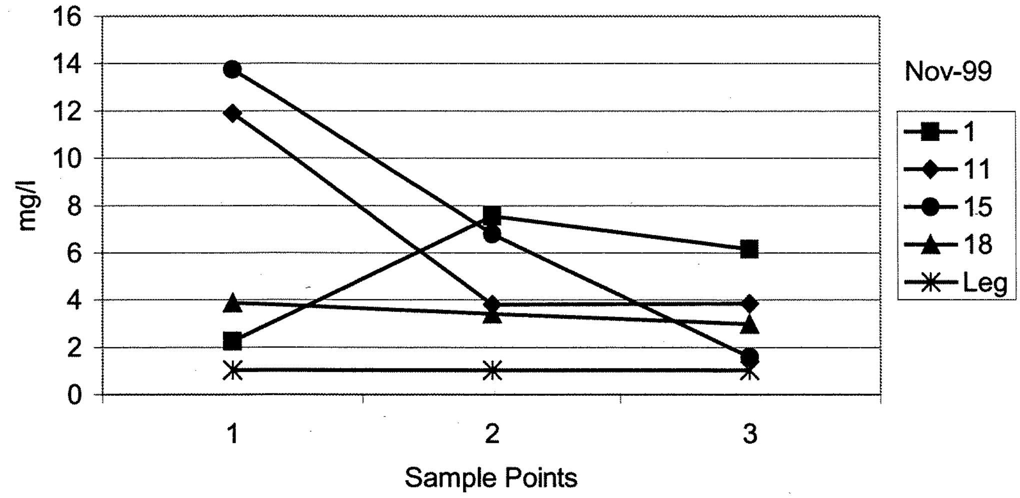


Figure 14: PO_4^{3-} - P in KWWTW

Phosphorus reactive concentrations in the effluent vary from 3,4 mg/l to 6,8 mg/l, which can be compared to the SBA average concentration of 2,8 mg/l, see Appendix 1. The legislative limit for phosphorus is 1,0 mg/l. In the effluent of KWWTW, these concentrations are exceeded several times.

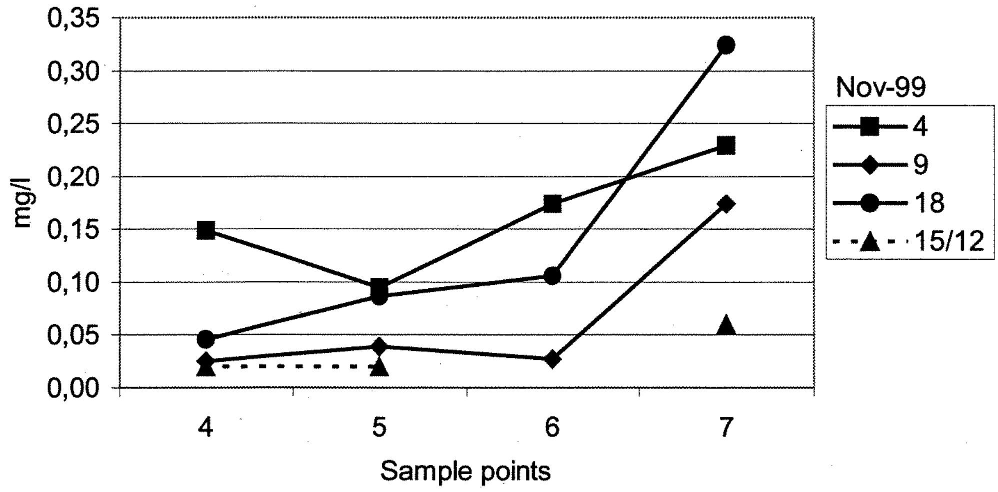


Figure 15: PO_4^{3-} - P i Keskamma River

Phosphorus reactive concentrations are more or less stable for sample points 1 to 6, however a sharp increase in concentration appears between points 6 and 7. The concentration increases 100% to 600% between these two points, see Appendix 1 for values. The source of this increase is most likely KWWTW. SBA's analyses shows a lower increase, although the same trend is there.

Ammonia (NH_3-N)

Sample date 1st Nov, 1999 and point 1 have been mentioned earlier as a problem, this goes for ammonia analyses as well. According to known interferences, a high colour in samples should not provide any problems, however concentrations in point 1 are lower than in the effluent, and compared to later analyses and theory this should not be the case.

In point 1-3 activated carbon was used to purify the samples during the rest of the measurement campaign. On sample date 18th Nov, 1999 the analyses of points 1 to 3 were lost due to dilution problems.

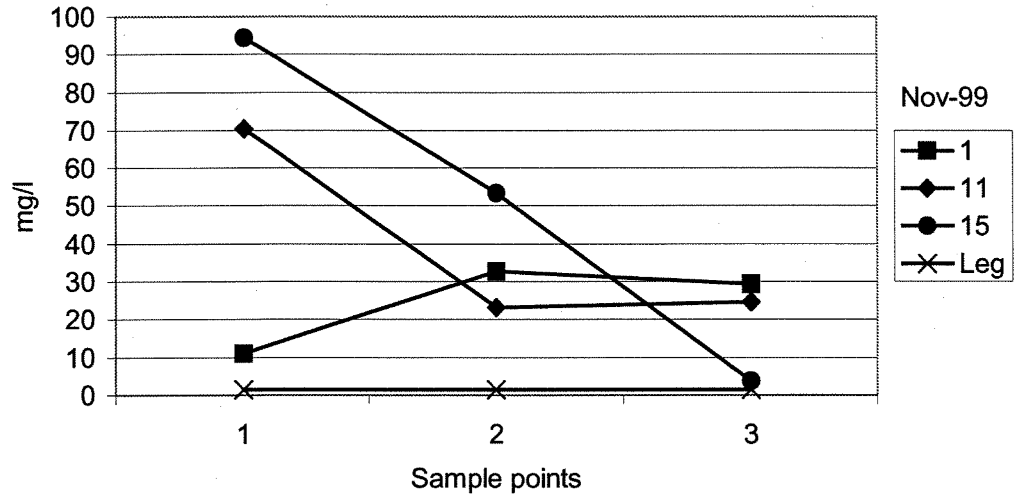


Figure 16: NH_3-N in KWWTW

Influent values to the treatment works are limited to two sampling dates, the 11th and 15th of November. Influent concentrations vary on these occasions between 70 mg/l and 95 mg/l. Effluent values from the 1st, 11th and 15th vary between 25 mg/l to 50 mg/l, which correlates with figures obtained from SBA's report, see Appendix 1. Effluent values are very high compared to legislation, which has a maximum of 1 mg/l.

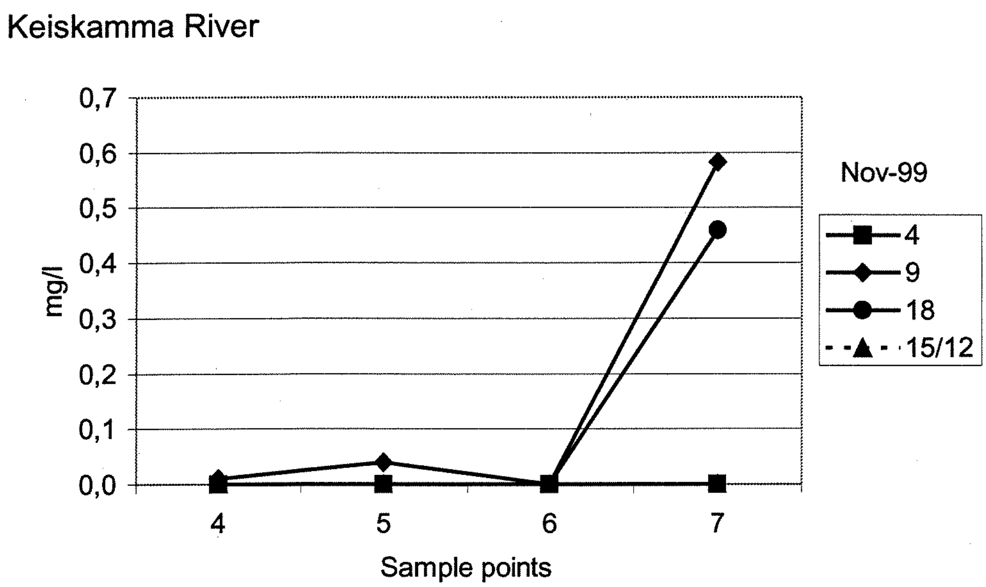


Figure 17: NH_3-N i Keiskamma River

On the 4th of November, no concentrations of ammonia were found. On the sample dates November 9 and 18, all values were below detection limit until sample point 7 where peak concentrations were found, from 0 mg/l in point 6 to about 0,5 mg/l in point 7. The high effluent concentrations from KWWTW may be the source to the increase.

Nitrate (NO_3^--N)

Nitrate values have varied throughout the measurement campaign. Influent values have been very low and one possible explanation to this might be interferences with chlorides (Cl^-). Concentrations above 100 mg/l cause low values of nitrates, and coupled with the conductivity values of 100 mS/m may result in low influent concentrations. Another interference may be strong oxidising and reducing substances that interfere at all levels.

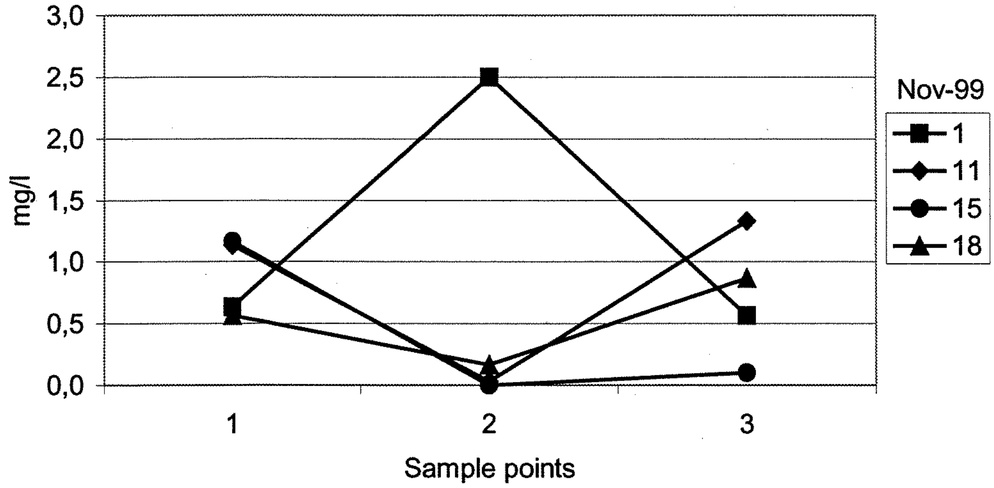


Figure 18: NO_3^- in KWWTW

Influent concentrations vary from 0,6 mg/l to 1,2 mg/l and effluent values are 0 except for on the 1st when a concentration of 2,5 mg/l was measured. These concentrations are low compared to concentrations in regular treatment works.

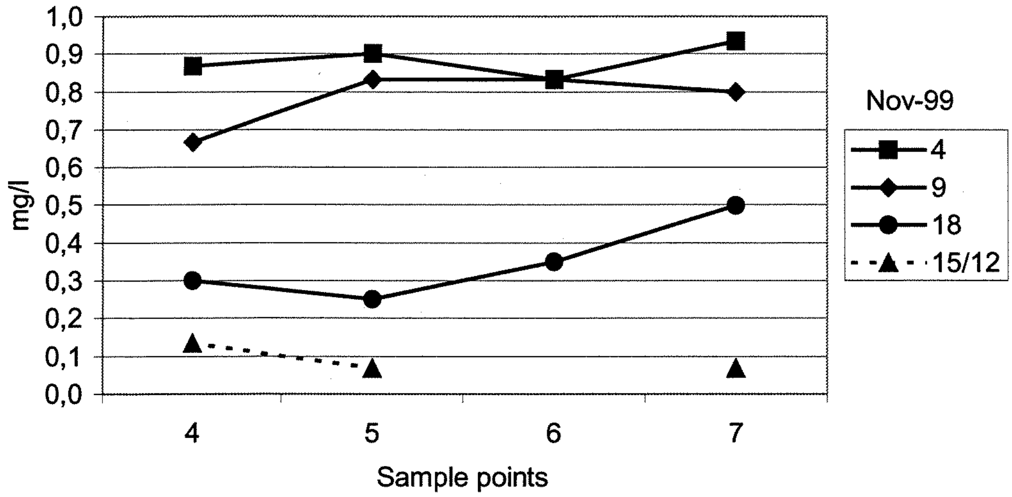


Figure 19: NO_3^- in Keiskamma River

On the 4th and 9th, concentrations of nitrate were stable along the watercourse with values varying between 0,7 mg/l to 0,9 mg/l. On the 18th, concentrations were slightly lower (0,25 mg/l to 0,5 mg/l), but rather stable with a small increase between points 6 and 7 (0,35 mg/l to 0,5 mg/l). SBA has measured values of approximately 0,1 mg/l throughout the measurement points.

6.3 Overall trends in the KWWTW

The average concentrations of the measured parameters conductivity, COD, phosphorus and ammonia have been calculated in order to estimate the KWWTW's treatment performance (see Figure 20). Nitrate concentrations have been excluded, due to problems with interferences.

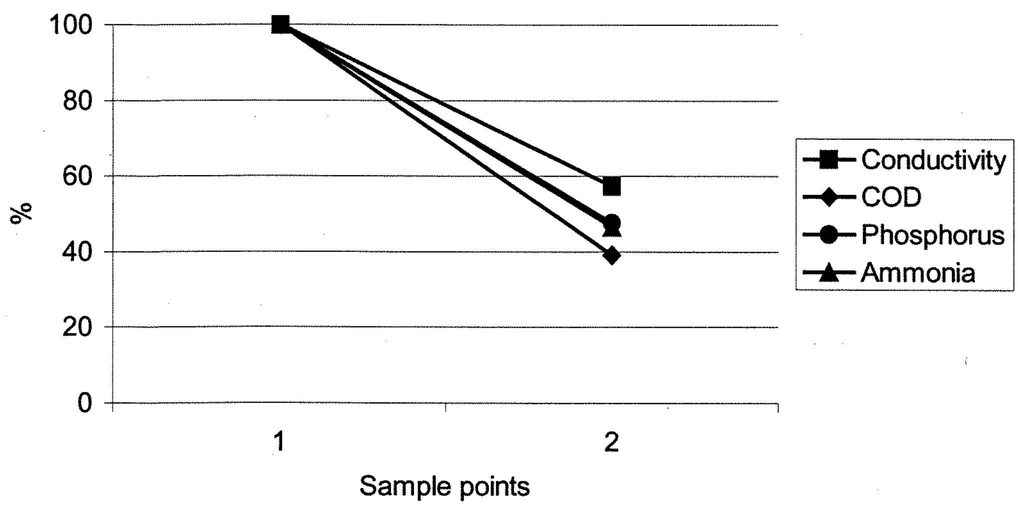


Figure 20: Overall trends in the KWWTW

The treatment performance of the KWWTW is approximately 50 percent for the parameters conductivity, COD, phosphorus and ammonia. The best results were obtained for COD-removal, with effluent concentrations at approximately 40% of the influent values. The values of conductivity decreased around 40%, which leaves a remaining 60% in the effluent. Phosphorus and Ammonia show a similar treatment performance with approximately 50% left in the effluent.

7. Evaluations and Conclusions

Measurement results from this campaign show that the environmental impact of the KWWTW on the Keiskamma River is considerable. The obtained results downstream of the treatment works are often higher than upstream. Most values found in the effluent from the wastewater treatment works exceed legislative limits several times.

The pH in the KWWTW is higher in the effluent, possibly due to fresh urine that mainly contains nitrogen in the organic form urea, $CO(NH_2)_2$. The hydrolysis of urea is catalysed by the enzyme urease, an enzyme that many micro-organisms have. During the hydrolysis, pH increases and ammonium and bicarbonate ions are produced. pH measurements in the river shows almost neutral concentrations (pH 7), with a slight increase downstream. However, the pH is well within the legislative levels for all points.

Conductivity levels in the effluent are below legislative limits, but evaluated together with SBA's values gives indications of concentrations close to legislative values.
The conductivity in the river is stable along the watercourse and no increased concentrations have been measured between sample points 6 and 7.

The influent values of COD varied considerably during the campaign, whereas the effluent showed an almost constant value. The amounts of chemical oxygen demanding substances found in the effluent from the treatment works are several times higher than the legislative limit. Measurements in the river were close to the detection limits of the used equipment (30 mg/l). The analyses showed variations between the sample points, however concentrations above 74 mg/l were not found, which make interpretations uncertain. An explanation to the high concentrations in the effluent and the low concentrations in measurement point 7 could be that the oxygen demanding substances have settled to the bottom sediments.

A freshwater resource, the Sandile Dam, is situated downstream of the treatment works. Oxygen free water entering the dam may have negative effects on the freshwater quality as well as harm aquatic organisms. However, oxygen depletion is seldom a problem in rivers, due to rapid movement and mixing with oxygen from the air, but with the present low flow rate (beginning of wet season) the situation may be different.

SBA has not measured COD in the Keiskamma River and as a result no comparison could been done.

The phosphate concentration in the three points at the KWWTW showed the same trend during the 11^{th}, 15^{th} and 18^{th}, except in point number 3 on the 15^{th} of November. Heavy rain is the probable cause, resulting in a high amount of water from the joining ditch giving a diluted sample. Results were recalculated to phosphorus in order to make a comparison with legislation, which is 1.0 mg/l. Effluent concentrations are several times higher than this value.

A clear trend is shown in the river, as the samples before the effluent are constant with a noticeable increase in point 7. The same trend is also found in SBA's measurements.

Although oxygen-demanding substances are the most important polluters of rivers, the heavy loading of nutrients can cause harm to the watercourse, due to excessive plant growth. The concentrations of phosphorus and the biological available form phosphate in the river are several times higher than legislative limits, and this may affect the biological composition as well as the oxygen status both along the watercourse and in the Sandile Dam.

The amounts of ammonia found in the samples from the treatment works in both inflow and outflow exceed the legislative limits several times, but the samples are varying and trends are hard to distinguish. The sample from point number 3 on 15th Nov, 1999 is identified as diluted with rainwater from the joining ditch.
Low amounts of ammonia are found in the river in all samples before point number 7, where a rapid increase is shown for two of the three sampling dates.

Nitrate values found in the treatment works are strange, as they do not vary much but when compared with other treatment works, the values are very low. The values are below the legislation effluent levels in all points, except for sample date 1st Nov, 1999 point number 2 (effluent). Interferences, like chloride and oxygen demanding substances, are possible reasons for the low values.

No relation between nitrate and ammonia has been established. According to theory ammonia concentrations should decrease with an increase of nitrate as a result.

Nitrate levels are quite stable along the river, which correlates with the SBA report, although lower levels were found here.

The overall trends in KWWTW show a treatment performance around 50%. Still, some effluent concentration are exceeding legislative values several times. The results show that the treatment performance needs to be improved in order to meet legislation.

8. Recommendations

Measurement results show that the KWWTW is polluting the Keiskamma River, and several actions need to be taken in order to reduce this unnecessary influence. It should be stated that the measurement campaign was too short to draw any substantial conclusions, therefore the following recommendations are given:

- The measurement campaign should continue in order to evaluate seasonal changes and, as a result, give a more accurate evaluation of the environmental status of the Keiskamma River. This is to ensure a sustainable development for both humans and nature.
- The SS Gida Hospital and its pump station should continue to be monitored since the pumps can stop working at any time, resulting in severe pollution of the river.
- When the effluent from the treatment works of SS Gida can be measured, a new measurement point should be established here.
- A measurement point needs to be established downstream of the refuse dump.

According to SBA's report, a conventional treatment works is the solution to the pollution of the Keiskama River. The author's opinion is that there should be another investigation done in order to find out if the treatment ponds, together with wetland techniques, could do the same work. A lot of research has been carried out at Rhodes University and a co-operation between the university and community of Keiskammahoek could result in a full-scale project.

Conventional treatment works are both chemically demanding and expensive to run, but by using biological treatment, both money and chemicals can be saved. This is a win-win situation and a small step towards the beautiful words: A Sustainable Development.

References

Personal communication:

Ms Precious – Town clerk of Keiskammahoek, interviews on the 14th and 21st of October and 18th of November 1999.
Mr. Sontshi, employee at SS Gida Hospital 21st Oct, 1999
Mr. Mbilase (pump technician at SS Gida Hospital) 1st Nov, 1999

Written references in index order:

[1] Houghton Hobart D. (1955) *Life in the Ciskei, A summary of the findings of the Keiskammahoek Rural Survey 1947-51*, S.A. Institute of race relations, Johannesburg
[2] Ms Precious – Town clerk of Keiskammahoek, interviews on the 14th and 21st of October and 18th of November 1999.
[3] Warren Viessman Jr., Hammer Mark J, (1998), *Water Supply and Pollution Control, sixth edition,* Addison Wesley Longman Inc, Printed in the United States of America
[4] http://www.who.int/emc-hiv/fact_sheets/pdfs/southafrica.pdf visited 2000-02-28
[5] Warner Tracy A (1999), *Let's Go South Africa,* Let's Go Publications, 67 Mount Auburn Street, Camridge, MA 02138, USA, Printed in USA
[6] *Encarta® World English Dictionary* © & (P) 1999 Microsoft Corporation. All rights reserved. Developed for Microsoft by Bloomsbury Publishing Plc.
[7] de Wett Chris, Whisson Michael (1999), *From Reserve to Region,* Institute for Social and Economic Research, Rhodes University, Grahamstown, Printed by Grocott and Sherry, South Africa
[8] Stemele Bosch & Associates, (January 1999), *Environmental scoping report for the conveyance, treatment and disposal of wastewater for the town of Keiskammahoek, in the eastern cape.* CEN Integrated Environmental Management Unit, 36 River Road, Walmer, Port Elisabeth, 6070, Printed in South Africa
[9] SETPLAN (1996) *Keiskammahoek Structure Plan. Report for the Keiskammahoek Transitional Local Council*
[10] http://www-dwaf.pwv.gov.za/idwaf/Documents/Policies/national_sanitation_policy.htm visited 14th Nov, 1999
[11] UNCSD (1997), *Comprehensive assessment of the freshwater resources of the world.* Economic and Social Council, fifth session, 5-25 April. E/CN.171997/9/. New York, USA.
[12] Allen, G.H. and R.A. Gearheart (eds.). 1988. *Proceedings of a Conference on Wetlands for Wastewater Treatment and Resource Enhancement.* Humbolt State Univiversity, Arcata, CA.
[13] http://www.iawq.org.uk/pubs/water-sc.htm, visited 25th Apr, 2000
[14] http://www.vcnet.com/koi_net/H2Oquality.html#nitra, visited 14th Nov, 1999
[15] http://www.aquatic.uoguelph.ca/general/page22.htm, visited 14th Nov, 1999
[16] http://www.aquatic.uoguelph.ca/general/page21.htm visited 14th Nov, 1999
[17] Morrison Greg, (1998) *Consequences of the imminent mercury ban on the COD test* Vatten 4, Department of Sanitary Engineering, Chalmers University of Technology
[18] http://www.aquatic.uoguelph.ca/general/page24.htm visited 14th Nov, 1999
[19] Morrison Greg, Johansson Lind Eva, (1992), *Understanding the aquatic environment,* Department of Sanitary Engineering, Chalmers University of Technology, Göteborg, Sweden
[20] http://www.geocities.com/CollegePark/Lab/6378/aquatic4.html visited 14th Nov, 1999
[21] http://www.ec.gc.ca/cceb1/eng/ammonia_summary.htm visited 20th Mar, 1999
[22] http://www.vcnet.com/koi_net/H2Oquality.html#nitra visited 14th Nov, 1999
[23] http://www.aquatic.uoguelph.ca/general/page28.htm visited 14th Nov, 1999
[24] http://www.aquatic.uoguelph.ca/general/page27.htm visited 14th Nov, 1999

[25] http://www.vcnet.com/koi_net/H2Oquality.html#nitra, visited 14th Nov, 1999
[26] http://www.aquatic.uoguelph.ca/general/page29.htm visited 14th Nov, 1999
[27] Oosthuysen Lucia (1989), *Educare Work in Ciskei, with special reference to the Keiskammahoek district.* Master Thesis Report, Rhodes University, Eastern Cape, Printed in South Africa
[28] Doni Thozama Melody (1997), *A study to identify and evaluate the impact of Keiskammahoek farmer support programme on farmer development.* Master Thesis Report, Faculty of Agriculture, University of Fort Hare, Eastern Cape, South Africa
[29] Austin M.N. (1989), *Monthly average Rainfall probability analysis for Ciskei,* Department of Agronomy, University of Fort Hare, Printed in South Africa
[30] Weather Bureau (1998), *Climate of South Africa, Climate Statistics (1961-1990),* Pretoria.
[31] Winblad Uno, (1998), *Ecological sanitation,* Sida (Swedish International Development Cooperation Agency, Stockholm, Printed by Novum Grafiska AB, Gothenburg
[32] Wright Alan, (1999), *Septic Tank Systems in The South African Coastal Zones*, Water Research Programme Commision, Report no. 597/1/99
[33] Mr. Sontshi, employee at SS Gida Hospital 21st Oct, 1999
[34] Mr. Mbilase (pump technician at SS Gida Hospital) 1st Nov, 1999
[35] Davis Mackenzie L., Cornwell David A., (1998) *Introduction to environmental engineering, Third Edition*, The McGraw-Hill Companies Inc. Printed in United States of America.
[36] Stemele Bosch & Associates, (September 1998), *Keiskammahoek Seepage Investigation*, 3 Elton Street, Southernwood 5201, P.O. Box 11116, Southernwood, East London, Printed in South Africa

Appendices:

Content:

Appendix 1 – Results

NOTES: All analyses with given standard deviation has been done in triplicates

Measurement points:
1 Influent KWWTW,
2 Effluent KWWTW,
3 After wetlandarea,
4 Reference point (upstream Keiskamma River, before Gxulu River merge point),
5 150 m downstream the junction point Gxulu- and Keiskamma River,
6 Keiskamma River (upstream effluent point of sewage treatment works),
7 Keiskamma River (downstream effluent point).

Table 1: pH

Sample	Date (Nov - 1999)						SBA (1998)		
point	1	4	9	11	15	18	2/2	9/9	15/12
1	6.6			7.4	6.9	6.8			
2	8.0			7.5	7.2	7.2	6.6	7.3	
3	7.7			7.8	6.9	7.4			
4		6.6	6.8			7.3			7.9
5		6.7	6.9			7.2			7.7
6		7.1	7.1			7.3			
7		7.4	7.3			7.2			8.1

Table 2: Conductivity (mS/m)

Sample	Date (Nov - 1999)						SBA (1998)		
point	1	4	9	11	15	18	2/2	9/9	15/12
1	27			111	105	~			
2	76			63	61	~	75	79	
3	78			61	31	~			
4		21	22			19			15.2
5		22	23			21			17.5
6		26	26			24			
7		24	30			26			20.9

Legislation 75 mS/m
New std at every sampling
~ = no concentrations available

Table 3: Chemical Oxygen Demand (COD), (mg/l)

Sample point	Date (Nov - 1999) 1	std dev	4	9	std dev	11	std dev	15	std dev	18	std dev	SBA (1998) 2/2	9/9
1	605	single				793	38	1001	66	337	23		
2	351	single				230	42	238	32	253	9	115	128
3	548	single				296	11	116	24	290	14		
4			38	74	15					~	~		
5			~	~	~					40	11		
6			~	41	25					~	~		
7			48	32	33					63	10		

Legislation 30 mg/l (effluent value)
Detection limit 30 mg/l
New std 1st, 9th and 15th
Analyses has been done on unfiltered samples
On 1th triplicates was not done for unfiltered samples
~ = concentrations below detection level

Table 4: Phosphorus (P), (mg/l)

Sample point	Date (Nov - 99) 1	4	9	11	15	18	SBA (1998) 2/2	9/9	15/12
1	2.24			11.89	13.74	3.89			
2	7.54			3.81	6.81	3.42	2.93	2.63	
3	6.15			3.85	1.59	2.97			
4		0.15	0.03			0.05			0.02
5		0.09	0.04			0.09			0.02
6		0.17	0.03			0.11			
7		0.23	0.17			0.32			0.06

Legislation 1,02 mg/l (effluent value)
This values have calculated with help of the conversation factor
Conversion factor 0.3261 (Hach instructions). Originally values
were analysed in PO43-, see table 5.

Table 5: Phosphate (PO_4), (mg/l)

Sample	Date (Nov - 99)			std		std		std		std		std	SBA (1998)		
point	1	std dev	4	dev	9	dev	11	dev	15	dev	18	dev	2/2	9/9	15/12
FB	0.6		0.2		0.1						0.12				
ACFB							0.1		0.3		0.13				
1	6.87	0.71					36.47	0.80	42.14	0.40	11.92	0.65			
2	23.13	1.15					11.67	1.56	20.87	0.12	10.48	0.78	8.98	8.06	
3	18.87	2.51					11.80	1.14	4.87	0.90	9.09	0.84			
4			0.46	0.09	0.08	0.05					0.14	0.01			0.02
5			0.29	0.12	0.12	0.02					0.27	0.02			0.02
6			0.53	0.14	0.08	0.03					0.33	0.01			
7			0.70	0.20	0.53	0.07					1.00	0.30			0.06

Detection limit 0.05 mg/l,
New std 1, 9 and 15^{th},
Analyses has been done on filtered samples,
Samples 1-3 have ran with activated carbon (400 mg with 100 ml samplewater) before filtration, except for 1th, when no activated carbon was available.
18th sample 1-3 done in tripplicates, 4-7 in duplicates,
Sample 1-3 have been diluted 20 times at Nov 11, 15 and 18th. On Nov-1th 10 times dilution was used.
FB = Filter blank
ACFB = blank has first ran with activated carbon and then been filtered and analysed

Table 6: Ammonia (NH3-N), (mg/l)

Sample	Date (Nov - 99)				std		std		std		SBA (1998)		
point	1	std dev	4	9	dev	11	dev	15	dev	18	2/2	9/9	15/12
FB	0.09		0.08			0.0		0		0.09			
ACFB										0.12			
1	10.9	0.1				70.4	19.9	94.4	3.4	o.d.			
2	32.7	single				23.3	4.4	53.3	0.6	o.d.	29	52	
3	29.5	single				24.7	0.7	3.7	0.9	o.d.			
4			0.00	0.01	0.00					b.d.			<0.1
5			0.00	0.04	0.02					b.d.			<0.1
6			0.00	0.00	0.00					b.d.			
7			0.00	0.58	0.05					0.46			<0.1

Legislation 1.5 mg/l (effluent value)
Detection limit 0.1 mg/l
New std 1, 9 and 15th
Analyses has been done on filtered samples
Samples 1-3 have ran with activated carbon (400 mg with 100 ml samplewater) before filtration, except for 1th, when no activated carbon was available.
On 1th 10 times and 20 times dilution was used. On 11th, 15th 40 times dilution was used for sample nr 1 and 20 times for sample 2 and 3.
18th measurements in points 1-3 were lost due to dilution problems.
FB = filter blank
ACFB = blank has first ran with activated carbon and then been filtered and analysed

Table 7: Nitrate (NO3-N), (mg/l)

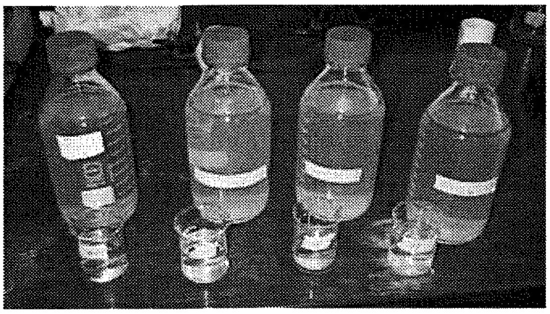
Sample	Date (Nov - 99)			std		std		std		std		std	SBA-98
point	1	std dev	4	dev	9	dev	11	dev	15	dev	18	dev	15/12
FB	0.10		0.10		0.10		0.00				0	~	
ACFB											0	~	
1	0.63	0.06					1.13	0.12	1.17	0.06	0.57	0.06	
2	2.50	0.26					0.03	0.06	0.00	0.00	0.17	0.06	
3	0.57	0.38					1.33	0.06	0.10	0.10	0.87	0.12	
4			0.87	0.06	0.67	0.06					0.30	0.00	0.14
5			0.90	0.00	0.83	0.06					0.25	0.07	0.07
6			0.83	0.06	0.83	0.06					0.35	0.07	
7			0.93	0.06	0.80	0.00					0.5	0	0.07

Detection limit 0,2 mg/l
New std 1, 9 and 15th
Analyses has been done on filtered samples
Samples 1-3 have ran with activated carbon (400 mg with 100 ml sample water) before filtration, except for 1th, when no activated carbon was available.
Consult values were calculated in NO3, recalculation was made with the conversion factor 0.225
FB = Filter blank
ACFB = blank has first ran with activated carbon and then been filtered and analysed

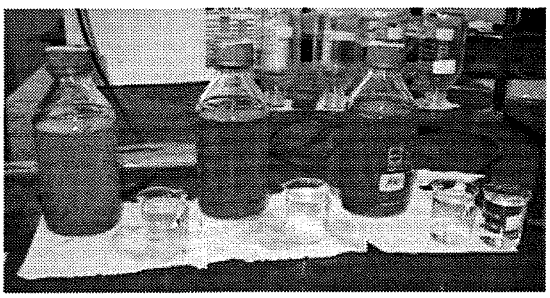
Appendix 2 – Pictures of samples

Picture 1: Samples from KWWTW 991101. From left to right sample point 1, 2 and 3. Note the coloration of the samples.

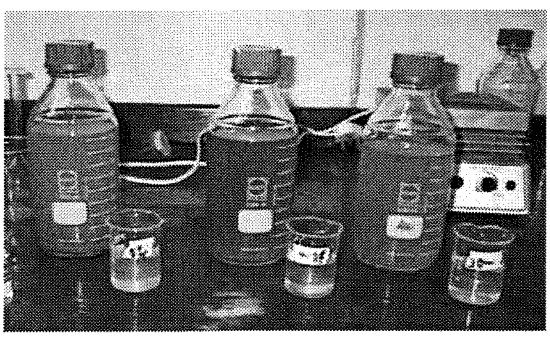
Picture 2: Samples from Keiskamma River 991104. From left to right sample point 4, 5, 6 and 7.



Picture 3: Samples from Keiskamma River 991109. From left to right sample point 4, 5, 6 and 7.



Picture 4: Samples from KWWTW 991111. From left to right sample point 1, 2 and 3. Note the coloration of the samples, in front the filtered samples (treated with activated carbon) can be seen.



Picture 5: Samples from KWWTW 991115. From left to right sample point 1, 2 and 3. Note the coloration of the samples, in front the filtered samples (treated with activated carbon) can be seen.

Picture 6: 991118, samples from all measurement points i.e. point 1 to 7 (from left to right). In front of the glass bottles, beakers with filtrated samples can be seen.
The parameters measured during the measurement campaign using the DR/890 HACH instrument were COD, Phosphate, Nitrate and Ammonia. Conductivity was measured using Hanna Instruments HI 8333 Conductivity Meter. Temperature and pH were measured with pH-meter HI 8424.

Appendix 3 – Measurement equipment

The parameters measured during the measurement campaign using the DR/890 HACH instrument were COD, Phosphate, Nitrate and Ammonia. Conductivity was measured with Hanna Instruments HI 8333 Conductivity Meter. Temperature and pH were measured with Labinett pH-meter HI 8424.

pH, temperature and conductivity

The Hanna HI 8333 Conductivity Meter measures the conductivity between 4 steel rings in a covering PVC plastic probe. The instrument needs to be temperature adjusted due to the conductivity varies with temperature. The instrument is calibrated with a 0.001 M Potassiumchloride (KCl) solution, which should theoretically give a reading of 14.7µS/m at 25°C.

The Labinett pH-meter HI 8424 measures the temperature adjusted pH with an electrode in a 3M KCl + AgCl electrolyte. The electrode have been be calibrated with 2 solutions, with pH 4 and 7 before usage.

Hach DR/890

The DR/890 HACH instrument uses a photometer suitable for colourimetric testing to measure the concentration in the sample. The instrument is precalibrated and programmed for common colourimetric measurements.

Measurement methods are breifly described below

COD (0 to 1500 mg/L COD)

COD measures the chemical oxygen demand in the sample and is defined as the mg of O_2 consumed per litre of sample under conditions of this procedure. In the HACH procedure, (for High Range 0 to 1 500 mg/L COD), is 2,00 ml of sample added to a COD digestion Reagent vial and heated for two hours. The vial contains potassium dichromate, a strong oxidising agent. Oxidisable organic compounds in the sample react, reducing the dichromate ion ($Cr_2O_7^{2-}$) to green chromic ion (Cr^{3+}).

The instrument is then measuring the amount of Cr^{3+} produced with the help of the green colour of Cr^{3+}. The detection limit for High Range 0 to 1 500 mg/L COD is estimated to 30 mg/L COD. The instrument obtained a standard deviation of ± 16 mg/L COD when the same operator made two vials with 1000 mg/L standard solution.

The COD reagent also contains silver and mercury, silver acts as a catalyst. Mercury is used to complex the chloride interference, which is the main interference up to a specified level, for High Range 0 to 1 500 mg/L COD is the level 2000 mg/L of Cl^-.

Phosphate (0 to 2.5 mg/L PO_4^{3-}-P)

Orthophosphate in the 10 ml samples reacts with the added pillow containing molybdate and an acid, to produce a Phosphomolybdate complex. Ascorbic acid from the pillow then reduces the complex giving an intense molybdenum blue colour if phosphate is present in the sample.

The instrument is then measuring the amount of PO_4^{3-} produced with the help of the blue colour of molybdenum. The detection limit for the procedure is 0.05 mg/L PO_4^{3-}. The instrument obtained a standard deviation of ± 0.05 mg/L PO_4^{3-} when the same operator made two vials with 1.00 mg/L standard solution.

Interference's in the phosphorous reaction procedure that we can determine is turbidity and colour. Large amounts of turbidity and colour can influence due to they may use some of the acid added from the pillows to dissolve suspended particles and a variable desorption of orthophosphate from the particles. (HACH)

Nitrate (0 to 5.0 mg/L NO_3^- - N)

The cadmium metal in the added pillows reduces the nitrate in the sample to nitrite. The nitrite ion reacts with sulfanilic acid to form a diazonium salt, which couples to gentisic acid to form an amber coloured product and then the instrument measures the colour.
The cadmium metal in the added pillows is at concentrations higher than the level where Federal RCRA consider as hazardous. It is not allowed to pour the samples down the drain without collecting the cadmium metal.

The instrument is then measuring the amount of NO_3^- - N produced with the help of the amber colour of the product of the genistic acid and diazonium salt. The detection limit for the procedure is 0.2 mg/L NO_3^- - N. The instrument obtained a standard deviation of ± 0.2 mg/L NO_3^- - N when the same operator made two vials with 3.0 mg/L standard solution. (HACH)

Interference's in the nitrate reaction procedure that we can determine is chloride and in concentrations over 100 mg/L. At high chloride levels can the nitrate measurements be used after a calibration with standards with the same chloride concentration.

Ammonia (0 to 2.5 mg/L NH_3 – N)

Ammonia compounds are combined with chlorine to form monochloramine, which reacts with added salicylate to form 5-aminosalicylate. The 5-aminosalicylate is oxidised in the presence of a sodium nitroprsside catalyst to form a blue coloured compound, indosalicylate. The blue colour is masked by the yellow colour resulting from an excess of reagent giving the sample a green colour.

The intensity of green is directly proportional to the concentration of ammonia in the sample. The detection limit for the procedure is estimated to 0.08 mg/L of NH_3 – N. The instrument obtained a standard deviation of ± 0.02 mg/L NH_3 – N when the same operator made two vials with 1.0 mg/L standard solution.

Interferences in the ammonia reaction are many, nitrate and phosphate are among them, but the levels needed to interference are too high for any concern in our case.