An Account of the Hydrobiology of the Umgeni Estuary and Zeekoe River with special reference to Pollution

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C O N T E N T S.

I ABSTRACT

A detailed faunal, bacteriological and physico-chemical investigation was made of the Umgeni river estuary (Durban) and of the Zeekoe (Piesang) river which enters the Umgeni river at the head of the estuary, both of which were badly polluted by sewage and industrial wastes. Sampling sites were selected to cover the major effluents as well as those sections of the rivers into which they discharged. The results showed that the Zeekoe river, although badly polluted and contaminated with bacteria of faecal origin by a village drain and effluents from a sugar mill factory at Mount Edgecombe, made a good recovery whilst flowing through a vlei before it joins the main river and did not contribute much to the pollution of the estuary. The heavy loads of faecal bacteria and thick deposits of fibrous material found in the estuary, could largely be traced back to a combined effluent from a board mill and steam laundry. In addition, numerous storm water drains and other smaller effluents from industries also contributed to the cumulative bacterial contamination and pollution of the Umgeni estuary.

The faunal associations found in the various habitats at the different sampling stations clearly depicted the state of the river water and the picture obtained thus closely agreed with the findings of the bacterial and chemical surveys.

II INTRODUCTION

When sewage and industrial effluents are discharged into streams, sudden changes in the physical and chemical environment of organisms result in ecological changes in which whole communities may be replaced by specialized associations of the fauna and flora adapted or tolerant to the new situation. In any study of the ecology of such streams it is therefore not only necessary to have a closer look at the "new inhabitants" in their changed environment, but an effort should also be made to find some of the reasons for the presence of new communities - or organisms - and the absence of others. A study of the effluent discharges and of their effects upon the physical, chemical and bacteriological nature of a receiving body of water are therefore vital in providing a background to the study of specialized communities in polluted streams.

This paper includes the results of the first two of a series of four pollution investigations undertaken in the Umgeni Basin during the years 1960 - 1961. A further paper on "the biological interpretation of river pollution in South Africa with special reference to conditions in the Umgeni Basin" will be prepared as an outcome of and conclusive to these and other relevant surveys (Harrison, 1958; Oliff, 1960; Allanson, 1961) conducted in South Africa.

Taxonomic works consulted but not referred to in the text are listed in the appendix.

The present series of pollution investigations constitute part of the hydrobiological studies of the

Umgeni Catchment in Natal, South Africa, which were conducted by the South African Council for Scientific and Industrial Research on behalf of the Town and Regional Planning Commission of the Natal Provincial Administration.

III METHODS AND TECHNIQUES

A. SURVEY PROCEDURE

As an introduction to each survey, a preliminary investigation was made of the areas traversed by the polluted streams. Special attention was paid to and information gathered on the topography, geology, soils, vegetation, rainfall, air temperatures, population densities and recreational and industrial activities. This was followed up by an investigation of the streams during which notes were made of the colour, turbidity and odour of the water. Stones in the streams were examined for the presence or absence of certain benthic fauna, algal and sewage fungal (Sphaerotilus) growths, silt and other deposits. In addition, limited physical and chemical analyses such as water temperatures, conductivities, pH and dissolved oxygen determinations provided useful data for quick assessment of stream conditions at certain places in the river systems under survey.

The compilation of maps showing industrial, residential and agricultural activities, effluent discharges, sewage disposal systems, roads, bridges etc., rounded off the preliminary investigations. Chemical and biological sampling sites were established at places to cover the effluent discharges as well as the streams

above and below the points of discharge. Some additional biological and chemical sampling stations were placed well below the entry of effluents and drains in order to provide information on the deterioration or recovery of the streams and their fauna.

Arrangements were made with the Durban Corporation and the laboratories of the State Health Department in connection with the analysis of the chemical and bacteriological samples respectively and the dates, times and duration of the sampling period agreed upon. In order to obtain comparable results, the chemical and bacteriological methods adopted were - with few exceptions - the same for all the surveys.

B. SAMPLING TECHNIQUES

1. Faunal

Various sampling devices have been developed and used by different research workers on problems of stream productivity (Needham, 1934; Ide, 1940; Sprules, 1947). However, since the introduction of the square foot stream bottom sampler (Surber, 1937; Davis, 1938), it has gained in popularity amongst research workers and has been widely used in the quantitative studies of stream bottom fauna in overseas countries as well as in Southern Africa. (Maciolek and Needham, 1957; Harrison, 1958; Oliff, 1960; Allanson, 1961; Chutter, in press).

A square foot stream bottom surber sampler and a handnet were employed in the faunal surveys of the Umgeni Estuary and the Zeekoe river system. Both the handnet, which had a brass ring of 16 inches (40.6 cm) diameter, and the surber sampler had bags of silk grit gauze of 25 meshes to the centimetre (64/inch). Quantitative

stream bottom samples comprised 2 - 3 square foot surber collections which covered the different habitats at each site. In this way a "cross section" of the fauna present at each sampling station was obtained. Marginal and submerged aquatic vegetation were sampled by sweeping the handnet vigorously upstream through the vegetation for a distance of 6 feet. Samples, together with waterproof labels bearing the necessary information such as the time of day, date and type of sample, etc. were transferred to jars, treated with 40% formalin (approximate dilution 1 in 10) and transported to the laboratory where the sorting and classifying of organisms were carried out.

2. Bacterial

All water samples for bacteriological analysis were collected in specially prepared, clean, sterilized, labelled, ground-glass stoppered, 250 millilitre bottles. Care was taken to prevent any contamination of the samples during or after collection. Bottles were submerged in the streams and effluents with their necks tilted in such a way that no water flowed over the hands into the bottles (Rubber gloves were used on most occasions for protection against schistosomiasis). The glass stoppers were removed and replaced under water.

Such factors as the time spent on collection and delivery of samples, inoculation into fermentation tubes (M.P.N. tests), duration of incubation and available space in incubators and water baths all limited the number of collections to a maximum of two per week. Surveys were concluded when a reasonably representative picture of the quality and quantity of bacterial loads in the effluents and streams was obtained.

Since most industries operate on an 8, 12 or 24-hour basis, the quality and quantity of the effluents were nearly always found to show a considerable variation over one working day period. As a result of this, time studies of effluents and streams were useful only in providing an "average" or representative picture of the quality and quantity of bacterial loads by smoothing out extreme values. A combination of collections of a series of snap samples, to show up variation, and composite samples, to give a representative picture of the prevailing bacterial conditions, were therefore carried out in the surveys under consideration.

In the case of the Umgeni Estuary where the effects of the effluents of the Board Mills and Steam Laundry were studied, hourly composite samples were obtained by mixing 4 snap samples collected at 15 minute intervals during specified hours of the day (see tables 6 and 8). A somewhat different procedure was followed in the study of the Zeekoe river system where altogether ten stations (Stations 1 - 10) were included in the special study. This necessitated the reduction of composite samples to two samples per station. Half-hourly snap samples, collected between 8 a.m. - 11.30 a.m. and 12 noon - 3.30 p.m., made up the two composite samples for each station. The afternoon collections of composite samples were, in both surveys, kept in refrigerators and inoculated into fermentation tubes the next morning.

3. Physical and Chemical

The collection of snap and composite water samples for physical and chemical determinations coincided with the bacteriological surveys.

As sampling bottles, either one gallon polythene or two pint milk bottles were used. Care was taken to collect representative samples at each site such as are obtained at narrow fast flowing channels in the streams where complete mixing - good turbulence - of the water took place.

Unlike bacteriological surveys where the magnitude of bacterial loads as a whole and therefore average conditions of streams and effluents are of prime importance, more value is attached to variation - extreme values - and the duration of such extreme conditions in the quantity and quality of streams and effluents with respect to the chemistry of dissolved and suspended matter.

In order not to loose the value of representative samples or not to smooth out extreme values and variation too much, the numbers of composite samples collected during the time studies of the Umgeni Estuary and Zeekoe river system were increased to 12 and 4 respectively compared with 4 and 2 for the corresponding bacterial samples. Composite samples for chemical analysis were distributed amongst the different laboratories of the Durban Corporation for the various chemical and physical analyses. Those samples which could not be analysed on the day of collection were kept at low temperatures in refrigerators in order to prevent changes in the composition of the samples and were analysed on the following day.

C. ANALYSIS OF SAMPLES

1. Examination of Faunal Samples

In the laboratory, the contents of each sample were transferred to a conical

The Zeiss stereo-microscope mounted upon a specially designed scanning stand, used for the examination of the faunal samples.

bag of the same mesh as that used for the surber sampler and handnet. A brass ring suspended it on a tripod placed in a sink. Water was sprayed over each sample to remove the excess formalin. The sample was then transferred to a counting dish and examined under a Zeiss stereo-microscope mounted upon a scanning stand specially designed for this type of work in the C.S.I.R. workshops. Large pieces of detritus, leaves and small stones were first removed and the animals counted, identified and classified as far as possible. This information was then entered upon cards bearing all the particulars such as the time, date and sampling station.

2. Bacterial analyses

The media used for the determination of total coliforms, faecal E.coli and faecal streptococci and the incubation periods are indicated in the following table.

Type of Organism	Inoculation media	Temperature in °C and incubation period
Total coliforms	Single strength Mac-Conkey broth	37°C for 48 hours (incubator)
Faecal E.coli	Brilliant green bile lactose broth	44.5°C for 48 hours (water bath)
Faecal streptococci	Buffered azide glucose glycerol broth	44.5°C for 48 hours (water bath)

Dilutions of samples were determined by the counts obtained from collections made during the preliminary run and adjusted, where required, after the first few determinations until the correct range of dilutions was obtained for samples from each station.

Inoculation of 1 millilitre portions of decimal dilutions of the original sample into the selective media mentioned in the table provided the most probable number (M.P.N.) of organisms capable of fermenting these media at specified temperatures. The numbers of inoculated tubes which developed gas in the MacConkey and brilliant green bile broth and those which showed a colour change in the buffered azide glucose glycerol broth were taken as positive, counted and the M.P.N. of organisms obtained from a table. The M.P.N. methods are discussed in detail by Keller, 1959 and Standard Methods, 1960.

3. Physical and Chemical Analyses

The analytical methods adopted were similar to those used by the laboratories of the National Institute for Water Research at Pretoria.

Most of the limited analyses carried out on samples collected during the weekly and bi-weekly investigations were made by the author. Composite samples obtained during the time studies of the effluents of the Board Mill and Steam Laundry in the Umgeni Estuary, on the 12th of October, 1960, were analysed by the water chemist of the Natal Regional Laboratory, Mr P.H. Kemp, who was assisted by Mr H. Vienaar. The staff of the Durban Corporation's laboratories undertook most of the analyses of composite samples collected during the 8-hour study on the Zeekoe river system on the 16th of August, 1961.

Except where otherwise indicated the techniques described in "Standard Methods for the Examination of Water, Sewage and Industrial Wastes" (American Public Health Association Inc. 1960), were employed to analyse the different samples for the following:

Temperature in ^{o}C

pH

Conductivity as mmhos/cm.

Total solids as ppm.

Suspended solids as ppm.

Dissolved solids as ppm.

Total hardness as ppm. $CaCO_3$.

Calcium hardness as ppm. $CaCO_3$

Alkalinity as ppm. $CaCO_3$.

Chloride as ppm. Cl.

Sodium as ppm. Na.

Sulphate as ppm. SO_4.

Phosphate as ppm. PO_4 ..... Method adopted from J. Murphy, J.P. Riley. J. Marine Biol. Assoc., vol. 37, p.a., 1958.

Free and saline ammonia as N.

Albuminoid ammonia as N.

Nitrite N.

Nitrate N..... R. Müller & O. Wideman. Vom Wasser, vol. 22, p.247, 1955.

Sugar as ppm. dextrose..... W.H. Wells, P.W.Rohrbaugh & G.A. Doty. Sewage & Indust. Wastes. vol. 24, p.212, 1952.

Dissolved oxygen as ppm. O.

B.O.D. (5 day) as ppm. O.

O.A.(4-hours) as ppm. O..... "Recommended Methods for the Analysis of Trade Effluents" Society for Analyt. Chem. 1958.

IV PART I: THE UMGENI ESTUARY

A. PHYSIOGRAPHY

The Umgeni river, which has a total catchment area of nearly 1700 square miles, originates in a large vlei called the Umgeni Sponge, twenty miles east of the Drakensberg Mountains. While descending from an altitude of just over

6,000 feet, over a steplike profile largely influenced by the effect of dolerite sills which lie across the river bed at places like Howick and Albert Falls, it receives the waters of tributaries such as the Lions, Karkloof, Sterk, Umkabele, Umsunduzi and Umgegu rivers. A reduction in the river gradient in the lower 8 - 15 miles result in the deposition of sand which eventually replaces stones and rocks in the stream bed. After meandering through a short flood plain of alluvial deposits, the Umgeni enters the Indian Ocean north of Durban harbour, having traversed approximately 140 miles from source to mouth.

The stretch of the river under consideration covers the lower 5 - 6 miles of the Umgeni, including the estuary. Two mildly polluted tributaries, namely the Palmiet and the Zeekoe - or Piesang Rivers, enter the main river above the estuary.

The lower part of the Umgeni river has a wide sandy bed, largely exposed during the dry season when average daily flows can be as low as 20 - 30 cusecs. The stretch of the river studied tends to meander and has no rapids. The river bed is wide and consists of a fine to coarse sand. Marginal vegetation consists mainly of Paspalum urvillei Steud., Phragmites sp., Sorghum verticilliflorum Stapf. and a few species of Polygonum. Mariscus sieberianus Nees., and M. congestus Vahl. occur in small numbers. The lower three miles are tidal. Flanking it on both sides are the Springfield Flats - alluvial deposits - which are mainly used by Indians for vegetable cultivation. On the higher-lying ground in the vicinity of the river, densely populated Indian residential areas are found, especially on that part of the Berea ridge on the northern bank of the main river which extends from below the junction of the

UMGENI ESTUARY ~ POLLUTION STUDY

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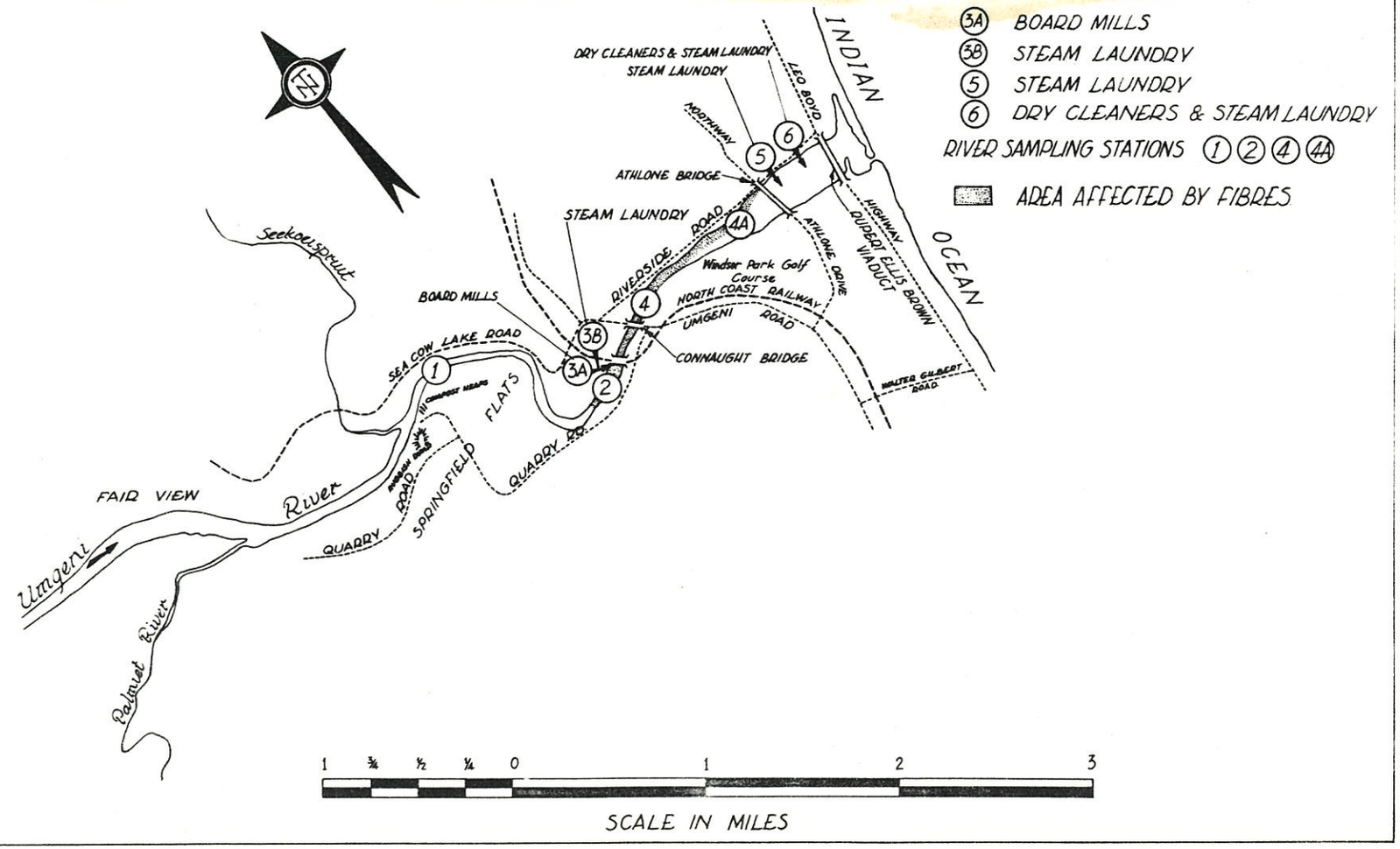


Zeekoe River to Athlone Bridge. From these residential areas numerous drains and certain industrial effluents enter the river.

On the opposite (southern) bank where the alluvial flats are more extensive, rubbish and ash dumps encroach upon the river. East of these dumps and closer to the river, compost heaps (night soil is used in the process) were found which from time to time were sprayed with water. Numerous sand companies also operate in this stretch of the river.

The lower part of the Umgeni estuary, below Athlone Bridge, is used for recreational activities such as boating, water skiing, etc. Here, many storm water drains from residential areas and some effluents from industries on the northern bank are discharged into the estuary.

During low tides, Indian fishermen can be observed digging for prawns in the exposed estuary bed, above and below the Ellis Brown viaduct, a practice which has led to a considerable denudation of the estuarine fauna.

The Blue Lagoon, extending northwards from the Umgeni River mouth from below the Ellis Brown viaduct, also receives storm water drains carrying bacteria of faecal origin.

B. SOURCES OF POLLUTION

The following are actual or possible sources of pollution:-

a. Small holdings, largely situated on the southern bank of the main river below the Palmiet tributary comprising the Springfield Flats, which may contribute to pollution as a result of agricultural

activities (the contribution of fertilizer, silt, etc. to the river during local rains).

b. The Palmiet river tributary (see map) which is badly polluted by effluents in the Pinetown - New Germany industrial area, the main source of pollution being a milk processing factory above the Escom Road Bridge on the Palmiet river. Below this factory, for a distance of a mile or more, the water was found to be depleted of oxygen during certain hours of the day. Very strong smells of H_2S polluted the air. Nevertheless, recovery from pollution is almost complete as this stream descends, from Pinetown towards the Umgeni, over numerous rapids and by the time it reaches the latter, a heavy growth of Spirogyra and diatoms were about the only remaining signs of the organic enrichment that had taken place upstream.

A detailed account of the faunal, bacterial and chemical findings of a survey conducted in the Pinetown - New Germany industrial area of the Palmiet river catchment will be given in part III of the series on pollution investigations of the Umgeni Basin.

c. The Zeekoe (Piesang) river tributary (see map) which was itself found to be heavily polluted and faecally contaminated by a village drain and effluents from a sugar mill at Mount Edgecombe. Further organic enrichment and the addition and killing off of large quantities of micro-organisms from the effluent from the maturation ponds and a stormwater drain of a sewage purification works at Kwa Mashu resulted in further deterioration of

the stream. Total oxygen depletion of the stream was recorded at places with the water turning black due to the liberation of H_2S. Although some recovery occurred, occasional high loads of faecal bacteria reached the Umgeni river.

A detailed account of the faunal, bacterial and chemical conditions of this tributary is recorded in Part II.

d. Rubbish dumps on the Springfield Flats which encroach upon the river, may in the long run contribute to the mineral and other pollution loads of the estuary.

e. The process of making compost from night soil, which is undertaken not far from the river bank, provides a possible source of bacterial and other contamination of the estuary.

f. Activities of the different sand companies operating along the stretch of the river under consideration which stir up silt and other detritus from the river bed

g. Road construction on the northern bank of the river (the Zeekoe-vlei road) which, for the time being, may result in the washing in of loose soil during and after local rains.

h. A distillery factory which returns boiler blow down to the river. (The assurance was given by the management that no other effluents are discharged into the river from this factory. However, molasses slop is emptied into ponds and drained away by seepage (nutrients may enter the river this way) and evaporation. A bad nauseating smell detectable in the vicinity of these ponds may cause a nuisance.

i. The most important source of bacterial pollution and disturbance of the estuary appears to be a Board Mill factory effluent (sampled at Station 3A) which has a flow rate of the order of 2.5 cusecs, is warm (over 30°C), carries much fibre and other suspended matter and has, on most occasions, a very high bacterial load of faecal origin. This factory operates on a 24-hour basis and has a fairly constant discharge of effluent. At its point of discharge into a drain, which takes the effluent to the river, it is joined by that of a steam laundry.

j. A Steam Laundry effluent (sampled at Station 3B) was variable in bacterial and chemical nature and composition, and joins that of the Board Mills factory which enters the Umgeni below the S.A. Railway bridge (above the newly constructed Connaught Bridge) at a distance of about two miles from the river mouth.

k. Effluents from smaller laundries between Athlone and Ellis Brown Bridges. The quantities of these effluents are small but they may have a cumulative polluting effect upon the estuary.

l. Numerous storm water drains from residential areas which enter the river from its northern bank (see Table 11).

C. SELECTION OF SAMPLING STATIONS

The selection of sampling stations was subject to the considerations set out in paragraph 2 of the survey procedure. Sites chosen for the survey were as follows (see map):-

Aerial view of the Umgeni estuary with the Board Mill factory and Steam Laundry premises flamking the S.A. Railways line(middle,below).The combined effluent can clearly be recognised in the river due to the red dyes discharged by the laundry effluent.

The Umgeni estuary between Connaught Bridge(extreme right) and Athlone Bridge(extreme left).

Station 1 : The Umgeni river below the confluence of the Palmiet and Zeekoe (Riesang) river tributaries

By placing this sampling station well above the industrial area, information could be obtained on the general, faunal, bacterial and some chemical conditions of the Umgeni which showed up the contribution to bacterial and other pollution of the estuary from that part of the Umgeni basin above the tidal limit - anarea of over 1,500 square miles, covering, at places, some of the densest populated areas in Natal. Moreover, the information obtained here served as a measure against which deterioration or improvement of stream conditions downstream of this site could be measured.

Station 2 : The Umgeni river twenty yards above and on the opposite bank of the point of discharge of a combined effluent from a Board Mill factory and Steam Laundry

During the preliminary investigation, it was noticed that this effluent was carried upstream on incoming tides and that, as a consequence, suspendable matter was deposited upstream of the point of discharge. In addition, the mixing of the effluent and river water was incomplete both in the vicinity of the outfall and along the northern bank above and for some considerable distance below the effluent outfall (see page 18 under "GENERAL CONDITIONS OF THE ESTUARY").

In order to obtain representative samples of the river before being affected by this combined effluent, Station 2 was therefore selected twenty yards above the outfall on the opposite (southern) bank of the Umgeni river.

Station 3A : At a point on the Board Mill factory effluent drain just before it joins the drain which it uses in common with the Steam Laundry effluent

Station 3B : At a point on the Steam Laundry drain just before it joins the drain which it uses in common with the Board Mill factory effluent

Station 4A: On the Umgeni river (estuary), 170 yards downstream and on the same bank from the point where the combined effluent enters the river

At this point, downstream of the combined effluent outfall, the mixing of effluent and river water was more or less complete and representative samples were therefore obtainable.

Station 4B : On the Umgeni river, 600 yards below Station 4 (faunal sampling station only)

Due to limited bacteriological and chemical services only a faunal sampling site was established in order to show up any possible sign of recovery from pollution by the above-mentioned combined effluent (3A and 3B).

Station 5 : The Army and Navy Steam Laundry effluent

Station 6 : The Lonsdale Dry Cleaners and Steam Laundry effluent

Stations 5 and 6 were included bacause the effluents of these laundries also contribute to the bacteriological contamination and other pollution of the estuary.

D. GENERAL CONDITIONS OF THE ESTUARY BELOW THE ZEEKOE RIVER DURING THE PERIOD OF INVESTIGATION

At the time of study, the river level was very low,

especially in August and September when the flow averaged only 25 cusecs. During October, after the first summer rains, the flow increased to over 60 cusecs.

No exceptional algal growth was observed below the Palmiet and Zeekoe rivers at Station 1. Some silt covered the rocks exposed in the river bed. However, there was a considerable change in the vicinity of the Board Mills effluent discharge where thick layers of silt deposits were found, near the tidal limit of the Umgeni Estuary. This may be ascribed to the following factors: (a) the coagulating effect of the saline water upon silt in suspension, and/or (b) the ponding and resulting stagnation of river water in the estuary during incoming tides. In addition, a bank of fibre and other insoluble organic matter from the effluents of the Board Mills and Steam Laundry were found on the river bed in the vicinity of the drain. Above the drain the bank of fibre was $\pm$ 6 - 12 inches deep, about four feet wide and 40 yards long. Towards the centre of the stream the fibre was mixed with silt. Immediately below the drain, the bank was more than 30 feet wide with a maximum depth of 4 feet near the effluent. It stretched seawards for 170 yards, its width decreasing towards Station 4, where it was less than 4 feet wide and about 4 - 8 inches deep. Anaerobic conditions prevailed in the layers of accumulated fibrous matter and the pulp fibre was decomposed to a black, fine sediment. During low tides, a strong smell of hydrogen sulphide was detected. Large bubbles of gas broke through the surface of deposits. This was especially noticeable in the vicinity of the effluent outfall. It was further noticed that after the first floods, large aggregates of black decomposed matter broke loose from the banks and drifted with the

flood. Most of this organic matter deposited during the low flow period, was washed away during the first heavy floods.

It was also observed, especially during low tides, that the mixing of the effluent and river was not complete, even below Connaught Bridge, 170 yards from the point of discharge.

E. DISCUSSION OF RESULTS

1. Faunal:

(Deductions made here are largely based on the author's personal experience supported in some cases by, the findings of Harrison, 1958; Oliff, 1960 and Allanson, 1961)

Station 1 A sample of the fauna at Station 1 was taken from submerged reeds and grasses which border a large pool in the main channel of the river some 150 yards below the confluence of the mildly polluted Zeekoe (Piesang) river. Although the density of filamentous algae could not be regarded as excessive, it was certainly greater than that usually found in clean, undisturbed streams in other parts of the Umgeni basin. The stream current was slow. Lymnaea columella Say, which usually has a sparse distribution in the unpolluted streams of the Umgeni river system, comprised more than 38% of the total of fauna. This, together with the occurrence of large numbers of Nematoda, the relative abundance of Nais sp. and the presence of Aulophurus furcatus (Oken), indicated very mild enrichment of the river at Station 1 (Harrison, 1958; Oliff, 1960). On the other hand the presence of such Ephemeroptera as Baetis bellus Brnrd., Centroptilum excisum Brnrd., and Caenis sp., which made up more than 20% of the number of macro-invertebrates, showed that conditions in the river were

still healthy.

Station 2 The deterioration of conditions in the river above and below Station 2, as described on page 18, resulted in a considerable change in the faunal association when compared with that of Station 1. Species known to be sensitive to pollution (heavy organic enrichment), such as members of the Ephemeroptera, showed a sharp decline in numbers. Other organisms such as Nematoda and Nais spp., which normally thrive in mild organic enriched conditions, showed a similar decline. On the other hand those species adapted to and able to utilize rich supplies of organic material viz. Oligochaeta such as Aulophorus furcatus(Oken,)together with the Copepods Paracyclops poppei Rehberg and Eucyclops euacanthus Sars., formed the bulk of the fauna, thus showing significant increases, whereas certain other species, less tolerant to the changed situation, showed a reduction in numbers or disappeared altogether. Other "pollution indicators" like Chironomus sp., and Psychoda alternata Say were also present.

Station 4A At Station 4A,the considerable reduction in the numbers of species of macro-invertebrates, a significant sign of heavy organic pollution, together with the richness of the slimy sewage fungus Beggiatoa alba (found interspersed with the vegetation), revealed conditions approaching foul pollution. Apart from the Oligochaeta, which comprised about 95% of the fauna, only Cyclops spp., and Chironomus sp., were present.

Station 4B The presence at Station 4B of the rattailed maggot Eristalis sp., of Ephydridae and Psychoda cf alternata Say., which usually dominate in foully polluted waters, clearly reflected a stretch of polysaprobic conditions in the river between Stations 4A and B. However,

the reappearance of Lymnaea columella Say together with Segmentorbis sp., the increase in numbers of Nematoda and Copepoda and the reduction in numbers of certain Oligochaeta other than Nais sp., showed some recovery of the river at Station 4B with conditions reverting to that found at Station 2.

2. Bacterial

a. The effluents and drains discharging into the estuary

i) The Board Mills effluent (Station 3A, Tables 5 and 6)

Permission was obtained from the management of the Board Mill to collect snap samples at any time during the bi-weekly collection programme. However, special arrangements were made in advance with the Board Mill factory as to the date and time of the 12-hour survey (see footnote).

(a) Bi-weekly results (Table 5)

Total coliform counts were very high, mainly over 18,000,000 organisms per 100 mls. Faecal E.coli and faecal streptococci averaged 225,000 and 192,000 per hundred mls.

(b) 12-hour survey (Table 6)

The composite samples collected, yielded insignificant counts of total coliforms, faecal E.coli and faecal streptococci.*
Snap samples taken afterwards again gave very high bacterial counts which agreed with the previous snap samples. Bacteriological data from subsequent snap samples, not included in the Tables,

* It was apparent that by chance, at the time of the 12-hour survey, the source of faecal matter responsible for the very high loads of faecal bacteria in the effluents, had been cut off.

are set out below. The counts are expressed as M.P.N. of organisms per 100 mls.

Date	Time a.m.	Total coliforms	Faecal E.coli	Faecal streptococci
25.10.60	9.45	1,800,000 +	540,000	1,600,000
27.10.60	9.45	1,800,000 +	33,000	2,000

If the flow of the river in the Estuary be taken as 25 average daily cusecs (August - September, see general conditions of the estuary, page 18), and the flow of the effluent as 2.5 cusecs, the theoretical average effect of the effluent upon the bacteriology of the estuary should be as follows (assuming good mixing) :

(a) Total coliforms below the point of discharge (Station 4A) and also during high tides above (Station 2) should be $180,000^{+}$ per 100 mls. of river water. (They were actually found to be of the same order).

(b) The average increase in faecal E.coli in the river should be 22,500 per hundred millilitre (compare with results in Table 4 Page 27).

(c) Faecal streptococci should increase to have an average of 19,200 organisms per hundred millilitre, of river water (compare with results in Table 4, Page 27).

(d) Because of the tides, high counts of faecal organisms could be expected at times above the point of discharge (Station 2, Table 3, Page 26).

ii) The Natal Steam Laundry effluent (See Tables 7 and 8)

Bi-weekly snap samples revealed that the quality of the effluent was very variable but at times contained high bacterial loads. The composite samples gave

TABLE 1

PERCENTAGE COMPOSITION OF THE FAUNA OF THE MARGINAL VEGETATION (OCTOBER, 1960.

GROUP OF ORGANISMS	Umgeni River below Zeekoe River (tributary)	Umgeni River above Railway Bridge ± 140 yds. above Connaught Bridge	Umgeni ± 20 yds. below Connaught Bridge	Umgeni ± 600 yds. below Connaught Bridge
	Station 1	Station 2	Station 4A	Station 4B
	%	%	%	%
HELMINTHES & ANNELIDA				
Nematoda	10.2	P	P	13.2
Naididae (unidentified)	-	24.1	75.76	38.5
Aulophorus sp.	2.0	22.5	18.94	1.8
Nais sp.	4.1	-	-	-
Pristina sp.	1.0	-	-	1.8
Manayunkia sp. (Polychaeta)	-	P	-	-
CRUSTACEA				
Cyclops spp.	9.2	42.3	5.0	16.5
Harpacticoidea	-	-	-	25.6
Ostracoda	5.1	-	-	-
Tanais sp.	-	P	-	-
Macrobrachium equidens Brnrd.	-	P	-	-
Caridina nilotica Roux	1.0	1.8	-	-
COLLEMBOLA	abundant	-	-	-
EPHEMEROPTERA				
Baetidae juveniles	3.1	-	-	-
Baetis bellus Brnrd.	11.2	P	-	-
Baetis latus Agnew	-	0.1	-	-
Centroptilum excisum Brnrd.	5.1	-	-	-
Caenis sp.	3.1	-	-	-
DIPTERA				
Chironomidae	-	2.4	-	-
Chironomus sp.	-	4.2	P	-
Corynoneura sp.	3.1	-	-	-
Ceratopogonidae	1.0	-	-	P
Psychoda sp.	-	P	-	P
Ephydridae	-	-	-	1.7
Eristalis sp.	-	-	-	P
ACARINA				
Hydrachnellae	1.0	-	-	-
MOLLUSCA				
Lymnaea columella Say	38.8	-	-	P
Segmentorbis sp.	-	-	-	P
AMPHIBIA				
Bufo (tadpoles)	1.0	-	-	-
Number of Organisms per 6ft. Marg. Veg.	196	994	3,168	2,184

more consistent results. Total coliforms always appeared to be over 180,000 organisms per hundred mls. Both faecal E.coli and faecal streptococci were also very high.

iii) The results for the bacteriology of the two smaller laundries are recorded in Tables 5 and 6. The counts were exceptionally high and variable.

b. The Estuary (see figure and Tables 2 - 4)

The general deterioration in the conditions of the river, as reflected by the fauna, are undoubtedly supported by the bacteriological findings.

The number of total coliforms, which was always much higher than those of the faecal E.coli and faecal streptococci, showed a progressive increase downstream from Station 1, with a significant rise at Station 4A, below the outfall of the combined effluent from the Board Mill factory and Steam Laundry, where the average number exceeded 49 million organisms (M.P.N.) per hundred millilitre (compare Tables 2, 3 and 4).

The number of faecal E.coli and faecal streptococci, although much smaller than the total coliforms in both the average and extreme values, clearly showed a similar tendency. The average values of the counts more than doubled between Station 1 and Station 2. Nevertheless average numbers of faecal E.coli and faecal streptococci at Station 2 only just hinted at mild faecal contamination (Table 3). However, heavy bacterial contamination of the river was recorded at Station 4A below the Board Mill factory and Steam Laundry effluent, where faecal E.coli and faecal streptococci averaged 28,600^{+} and 12,150 respectively (Table 4 and figure). Extremely high individual counts of the abovementioned faecal organisms were recorded at this Station.

TABLE 2.

STATION 1 : UMGENI BELOW THE ZEEKOE RIVER

Average chemical and bacteriological values of bi-weekly snap samples taken during the Survey

		Number of Samples analysed	Mean	Range
Approximate flows (cusecs)		16	41.5	20 - 99
Temperature ^{o}C		12	20.7^{o}	19.0- 23.5^{o}
pH		11	7.55	6.9- 7.8
Conductivity mmhos/cm		11	350.6	150-539
As M.P.N. per 100 mls.	Total Coliforms	16	11,606	200-54,000
	Faecal *E. coli*	16	794	Nil- 2,200
	Faecal streptococci	16	631	Nil- 4,900

TABLE 3.

STATION 2 : UMGENI 20 YARDS ABOVE THE EFFLUENT OF THE BOARD MILLS AND STEAM LAUNDRY

Average chemical and bacteriological values of bi-weekly snap samples collected during the survey

		Number of samples analysed	Mean	Range
Approximate flows (cusecs)		14	31.7	18.2 - 83.0
Temperature ^{o}C		10	20.6	19.0 - 23.0
pH		9	7.30	6.70- 7.65
Conductivity mmhos/cm		9	2,283	250 - 8,250
As M.P.N. per 100 mls	Total coliforms	14	130,378+	3,300 -180,000+
	Faecal *E. coli*	14	1,807	200 - 3,300
	Faecal streptococci	14	3,750	Nil - 22,000

TABLE 4.

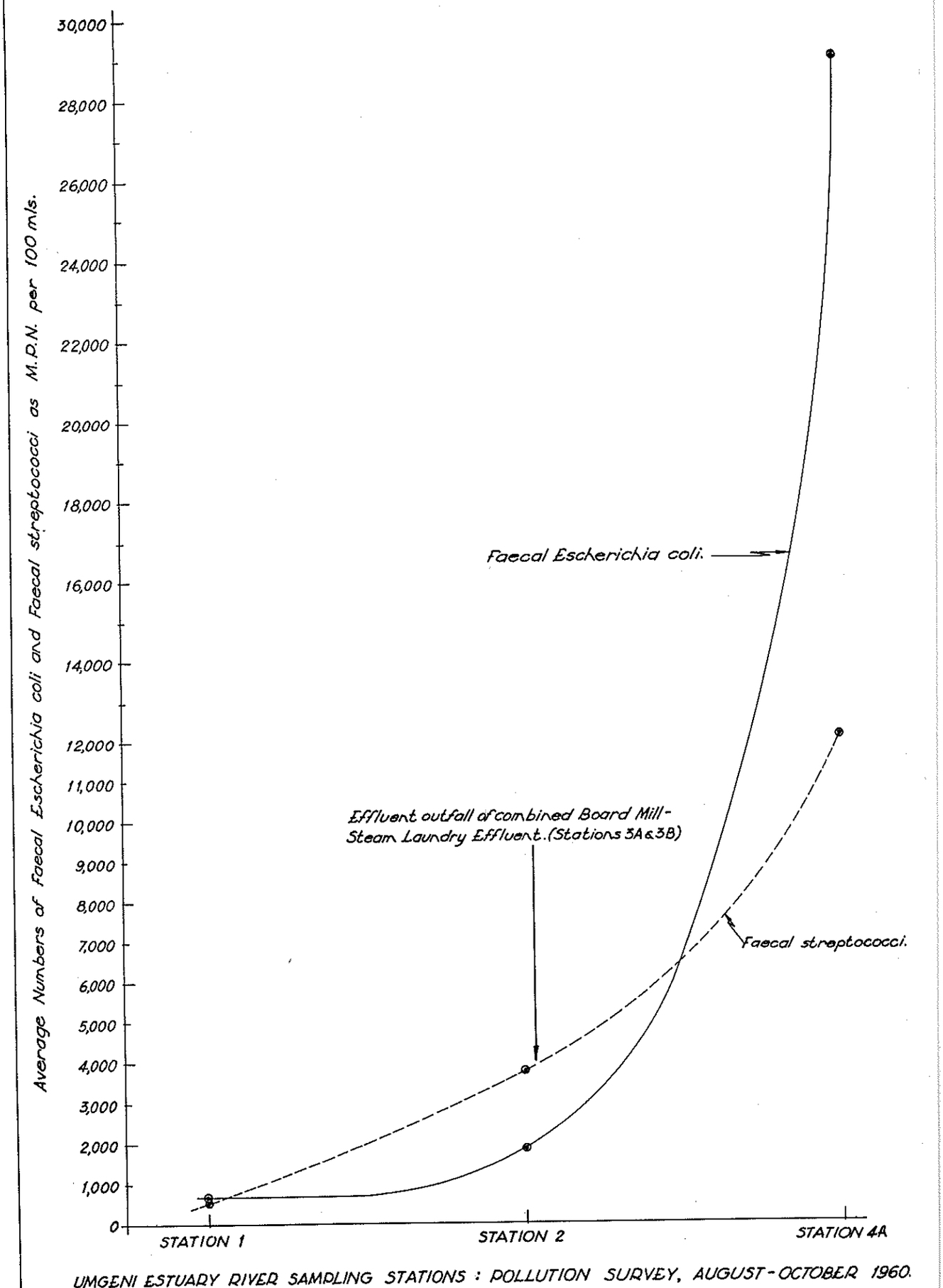
STATION 4 : UMGENI 20 YARDS BELOW CONNAUGHT BRIDGE

Average chemical and bacteriological values of bi-weekly snap samples taken during the survey

		Number of samples analysed	Mean	Range
Approximate flow (cusecs)		15	41.5	20.7 - 99.5
Temperature °C		11	22.3°	20.0 - 26.0°
pH		10	7.27	6.8 - 7.8
Conductivity mmhos/cm		10	3,155	770 - 10,450
As M.P.N. per 100 mls.	Total coliforms	15	49,982,666+	180,000+ - 18x10.7+
	Faecal E. coli	15*	68,866+	Nil - 200,000+
		8**	28,600+	2,300 - 180,000+
	Faecal streptococci	15*	6,480	Nil - 54,000
		8**	12,150	1,100 - 54,000

* Dilutions too high for first few samples. Based on all samples.

** After correct dilutions were established. Based on last eight weekly samples.



UMGENI ESTUARY RIVER SAMPLING STATIONS : POLLUTION SURVEY, AUGUST - OCTOBER 1960.

TABLE 5.

STATION 3 A : THE BOARD MILLS EFFLUENT

Average chemical and bacteriological values of bi-weekly snap samples collected during the survey (25.8.60 - 20.10.60)

DATA		Number of samples analysed	Mean	Range
Approximate flow (cusecs)		-	-	2 - 3
Temperature °C		12	31.3°	28.0° - 36.5°
pH		11	7.00	6.30 - 7.35
Conductivity as mmhos/cm		11	5,712	2,750 - 8,800
T.D.S. as ppm.		3	3,484	3,400 - 3,568
Suspended solids as ppm.		3	699	676 - 746
As M.P.N. per 100 mls.	Total coliforms	16	9,802,500+	240,000-18,000,000+
	Faecal *E. coli*	16	225,000	Nil- 1,400,000
	Faecal streptococci	16	192,000	Nil-. 1,600,000

TABLE 6.

BOARD MILL FACTORY EFFLUENT : 12TH OCTOBER 1960

Average chemical values of twelve-hourly composite samples (6 a.m. to 6 p.m.)

DATA		No. of composite samples analysed	Mean	Range
Approximate flow (cusecs)		-	-	2.0 - 2.5
Temperature °C		13	31.4°	23.0 - 36.0
pH		12	7.17	6.9 - 7.6
Conductivity as mmhos/cm		12	5450.8	5060 - 5610
Expressed as parts per million (ppm.)	Total dissolved solids	12	3383.9	2996 - 3521
	Suspended solids	12	470.6	228 - 954
	Total hardness as $CaCO_3$	12	690.0	500 - 820
	Alkalinity as $CaCO_3$	12	140.1	116 - 159
	Sodium as Na	12	824.2	720 - 960
	Chloride as Cl	12	1405.8	1300 - 1550
	Sulphate as SO_4	12	296.5	254 - 392
	Phosphate as PO_4	12	0.17	0.13- 0.30.
	D.O. as ppm O.	12	3.1	1.5 - 5.1
	O.A.(4 hours)as ppm O.	12	75.2	48.8 - 87.8
	B.O.D.(5 days)as ppm O.	12	125.5	24 - 164
Expressed as M.P.N. per 100 mls.	Total coliforms	4	474,500	2,000 - $18 \times 10^{5+}$
	Faecal E. coli	4	1,750	0 - 5,000
	Faecal streptococci	4	500	0 - 2,000

TABLE 7.

STATION 3A : STEAM LAUNDRY EFFLUENT

Average chemical and bacteriological values of bi-weekly snap samples collected during the survey

		Number of samples analysed	Mean	Range
Approximate flow (cusecs)			± 0.5	-
Temperature °C		12	27.3	22.5 -34.5
pH		11	8.17	6.9 - 9.6
Conductivity mmhos/cm		11	1,171.8	275 - 7,700
Suspended solids p.p.m.		3	228.6	154 - 330
Total Dissolved Solids p.p.m.		3	426.6	318 - 482
As M.P.N. per 100 mls.	⁂Total coliforms	16	59,129,188+	Nil -84x10^{7}+
	⁂Faecal *E. coli*	16	33,751,194+	Nil -32x10^{7}+
	⁂Faecal streptococci	16	22,000	Nil -350,000

⁂ Results very variable. Dilutions also too high for first seven weeks. More value can be attached to the 12 - hour "composite sample" results : see table 8.

TABLE 8.

TWELVE HOUR POLLUTION STUDY OF THE NATAL LAUNDRY EFFLUENT 12TH OCTOBER, 1960.

Average chemical and bacteriological values of twelve-hourly composite samples

DATA		Number of composite samples analysed	Mean	Range
Temperature °C		12	24.9°	20.0° - 27.5°
pH		12	8.83	7.8 - 9.4
Conductivity as mmhos/cm		12	55	385 - 913
Expressed as p.p.m.	Total dissolved solids	12	343.2	261 - 529
	Suspended solids	12	105.6	6 - 262
	Total Hardness as $CaCO_3$	12	81.6	45 - 158
	Alkalinity as $CaCO_3$	12	132.4	116 - 158
	Sodium as Na	12	96.4	75 - 143
	Chloride as Cl	12	65.2	30 - 149
	Sulphate as SO_4	12	29.8	21 - 51
	Phosphate as PO_4	12	0.15	0.13 - 0.17
	Dissolved Oxygen	12	7.5	6.4 - 8.7
	O.A. (4-hours)	12	17.8	2.2 - 30.2
	B.O.D. (5 days)	12	82.8	9 - 152
As M.P.N. per 100 mls	Total coliforms	12	$180,000^+$	$18x10^{4+}$ - $18x10^{4+}$
	Faecal *E. coli*	12	$94,025^+$	1,100 - $180,000^+$
	Faecal streptococci	12	$90,500^+$	Nil - $180,000^+$

TABLE 9.

STATION 5 : ARMY AND NAVY STEAM LAUNDRY EFFLUENT : SEE MAP

Average chemical and bacteriological values of bi-weekly snap samples collected during the survey (25.8.60 - 20.10.60)

		Number of samples analysed	Mean	Range
Approximate flow (cusecs)		15	0.01	-
Temperature °C		12	21.8	20.0 - 24.0
pH		11	7.46	6.62- 9.10
Conductivity as mmhos/cm		11	653.3	350 - 1,078
Expressed as M.P.N. per 100 mls.	Total coliforms	16	$18 \times 10^{9+}$ - 5,000	5,000- 18,000,000,000+
	Faecal E. coli	⁎16	3,172,750	0 - 50,000,000
		⁎⁎ 9	84,888	0 - 350,000
	Faecal streptococci	⁎16	3,142,500	0 - 50,000,000
		⁎⁎ 9	31,111	0 - 79,000

For ⁎ and ⁎⁎, see Table 4.

TABLE 10.

STATION 6 : LONSDALE DRY CLEANERS AND STEAM LAUNDRY

Average chemical and bacteriological values of bi-weekly snap samples collected during the survey (August - October, 1960)

DATA		Number of samples analysed	Mean	Range
Approximate flow in (cusecs)		12	0.01	-
Temperature ^{o}C		12	22.4	20.0 - 24.5
pH		11	7.93	7.20 - 9.90
Conductivity in mmhos/cm		11	706.4	517 - 825
As M.P.N. per 100 mls.	Total coliforms	9	836,666	70,000 - 1,800,000
	Faecal E. coli	9	43,111	2,000 - 280,000
	Faecal streptococci	9	13,777	0 - 84,000

3. Physical and Chemical Conditions

Except for the twelve-hour survey of the Board Mill factory and Steam Laundry effluents, only limited chemical analyses were carried out on water samples collected with those for bacteriological tests during all other visits to the various selected sampling stations.

a. The effluents and drains discharging into the esturary

Apart from weekly snap samples collected during August - October, 1960, a detailed 12-hour chemical and bacteriological investigation was made of the Board Mills and Natal Steam Laundry effluents.

i) The Board Mills Effluent (Station 3A ; Tables 5 and 6)

High temperatures, averaging over 30°C for both the bi-weekly and 12-hourly results, were recorded from this effluent. The pH values were of the same order as those of the estuary (between 6 and 8). Conductivities were always high and more variable in the bi-weekly samples than those of the 12-hour survey.

Dissolved solids were high, fluctuating mainly between 3,000 and 3,500 ppm. Material in suspension, such as fibre and other organic matter, averaged 470 ppm. Dissolved oxygen values were low, averaging 3.1 ppm. Oxygen absorbed by permanganate was very high (75.2 ppm) and the biochemical oxygen demand averaged 125.5 ppm.

Assuming the respective flows (of effluent and river) to have been of the same order as those mentioned under bacteriology (page 22), accordant deductions can be made for the chemical and physical effects of the factory effluent upon the river. Below its outfall, the Board Mill effluent

would, theoretically, have the following effect upon the estuary (assuming good mixing) :

(a) an increase in O.A. by 7.5 ppm;

(b) a drop in dissolved oxygen;

(c) an increase in B.O.D. by 12.6 ppm;

(d) an increase in suspended solids by 4 - 6 ppm;

(e) a slight rise in temperature.

Actually, the mixing in the vicinity of the outfall was not complete, so that these deductions can be regarded as conservative.

ii) <u>The Natal Steam Laundry effluent (Station 3B, Tables 7 and 8)</u>

In the vicinity of the Board Mills effluent outfall, the only other effluent which affected the river was that from the Natal Steam Laundry. The flow fluctuated around 0.25 cusecs. Its average temperature was found to be over 25°C. In both surveys high pH values were recorded (maximum pH = 9.0); those of the bi-weekly samples were rather variable. During the 12-hour survey, the suspended solids averaged 105.6 ppm., the average O.A. was 17.7 ppm. and the B.O.D. averaged 82.8 ppm.

iii) The limited number of chemical results on the smaller laundry effluents are recorded in Tables 9 and 10. The volumes of flow were small. This effluent also contributed to the cumulative pollution of the Estuary.

iv) Some details of the small drains flowing into the Estuary are given in Table 11 (surveyed on November 30th, 1960). The total flow of these was about 1 cusec with an average conductivity of 675 micromhos/cm. A composite sample for B.O.D. determinations gave a value of 59.2 ppm. The chemical composition of these drains were presumably

b. The Estuary

Flows: The diversion of the Umgeni river water at Nagle Dam and Natal Estates pump house, for domestic and irrigational purposes, were important factors affecting the very variable and low water levels which prevailed in the Umgeni Estuary during the period of investigation. As a result of this and also because of the usual decrease in flow during the dry season, when this survey was conducted, the approximate average daily flow in the Estuary was about 30 - 40 cusecs.

Temperature: Temperature values obtained at the different sampling stations were much the same, fluctuating between 19°C and 26°C. A slight rise in temperature occurred at Station 4, below the outfall of the combined Board Mills-Steam Laundry effluent, where an average increase of nearly 2°C was recorded.

pH: The pH values on the river sampling stations largely fluctuated between 7 and 8. No exceptionally high or low values were obtained at any of these places.

Conductivity: The consistently low conductivity values at Station 1 clearly showed this site to be beyond the tidal zone. Although no systematic tidal variation could be observed from the very variable values found at Stations 2 and 4, it was obvious that the Board Mills-Steam Laundry effluent alone could not be responsible for some of these exceptionally high conductivity readings, even if it be taken into account that complete mixing of the effluent and river water did not take place near the point of discharge into the river (compare conductivity values of Tables 3, 4 and 6). It can therefore be assumed with certainty that brackish water in the estuary at least reached the river in the vicinity of Station 2. On December 20th, during spring tides (tidal range 5 - 8 ft.),

when the river was flowing at about 200 cusecs, samples were taken at the Ellis Brown and Athlone Bridges for conductivity measurements (see Table 11 on page 38). At both stations the conductivity values of the water decreased slightly during the first two hours after low tide. The flow under Ellis Brown Bridge then reversed its direction, and 1.5 hours later the Blue Lagoon, extending North-East of the Umgeni mouth, was completely filled with sea water. The flow under Athlone Bridge reversed about one hour later than at Ellis Brown Bridge, and by that time sea water was flowing upstream at the latter point taking large numbers of jelly-fish into the estuary between the two bridges. A further two hours later, during which much of the islands in the Umgeni river estuary was submerged, the flow at Athlone Bridge had turned downstream again. This coincided with the time that undiluted sea water had arrived at this point. (It was almost as if an equilibrium between the forces of the tides, pushing upstream, and the mass of accumulated river water, pushing downstream, had been reached before peak tide and that the river was forcing its way downstream against the still incoming tide.) Half an hour later, at high tide, the normal direction of the flow was restored at Ellis Brown Bridge as well.

On this above-mentioned occasion, sea water did not penetrate the estuary much beyond the Athlone Bridge, although brackish water could be expected to move higher than this. It is therefore reasonable to expect different tidal limits in winter and summer, with low river levels and with the increase in river flows respectively.

TABLE 11.

TIDAL OBSERVATIONS (20.12.60)

Time	Conductivity in micromho/cm		Remarks
	Ellis Brown Bridge	Athlone Bridge	
10.50 a.m.	-	-	Low Tide
10.55 a.m.	1220	-	
11.10 a.m.	-	765	
11.20 a.m.	1220	-	
11.45 a.m.	-	765	
11.55 a.m.	1100	-	
12.05 p.m.	-	720	
12.15 p.m.	1000	-	
12.45 p.m.	-	660	
1.00 p.m.	1210	-	No flow under Ellis Brown Bridge
1.15 p.m.	-	530	
1.25 p.m.	990	-	At Ellis Brown Bridge the flow was upstream
1.45 p.m.	-	420	
2.00 p.m.	53900	-	
2.15 p.m.	-	485	At Athlone Bridge the flow as upstream
2.35 p.m.	64900	-	Lagoon now filled with sea water
2.45 p.m.	-	44000	
3.20 p.m.	-	51700	
3.45 p.m.	-	58300	
4.15 p.m.	-	24200	
4.30 p.m.	-	-	At Athlone Bridge the flow was now downsream
4.45 p.m.	-	60500	
5.00 p.m.	63800	-	At Ellis Brown Bridge the flow was now downstream
5.02 p.m.	-	-	High Tide

V PART II: THE ZEEKOE (PIESANG) RIVER

A. PHYSIOGRAPHY

The Zeekoe river, better known, at its headwaters, as the Piesang river, originates in the vicinity of the Itafamasi mission reserve near Lindley and for almost ⅔ rds of its entire length it flows through canefields, descending rapidly over the first 3 - 4 miles from an altitude of 1,000 ft. It flows Eastwards past Kwa Mashu (Melkhoute kraal), receiving small tributaries. Below Phoenix railway station, where it is joined by a tributary from Mt. Edgecombe, it makes a sharp bend and continues in a Southerly direction, parallel to the coast. The gradient of the stream in its lower 8 - 10 miles is very slight, especially in the Zeekoe-vlei area where the river is deep and the water almost stagnant. Because of this feature, the lower portion of the Zeekoe river is subject to periodic overflowing of its banks after heavy rains, covering large portions of what was in the past the Zeekoevlei. It flows into the Umgeni about 3½ miles upstream from the Indian Ocean.

Middle and lower Ecca series of the Karroo system form the central and Eastern portion of the Zeekoe river catchment. Towards the North-Western corner of the basin, near Lindley and Richmond there are outcrops of Table Mountain Sandstone and Dwyka. Alluvial deposits are common in the lower-lying areas of the shallow stream valleys above and in the vicinity of the Zeekoevlei. Doleritic intrusions are scattered throughout the catchment but predominate in the middle Ecca series East of Phoenix, Kwa Mashu sewage purification works and Duff's Road.

The Zeekoe river catchment is in the sugar belt (sub-tropical) and has an annual rainfall of about 40 inches of which more than 10% falls between October and March.

Intensive sugar cultivation is practised on the rolling hillslopes and in the river valleys and has almost completely wiped out the coastal evergreen bush of which remnants are found at places in the catchment.

Kwa Mashu native township, with its vast population, is rapidly encroaching on the catchment from the West. In the lower portion of the catchment, near the Umgeni river, Indians occupy the riparian lands, which are used mainly for the cultivation of vegetables.

B. SOURCES OF POLLUTION

The following are actual or possible sources of pollution near the Zeekoe river catchment:

(a) A tributary from Mount Edgecombe which receives

(i) a drain from a village just above (N.E) the sugar mill factory, and

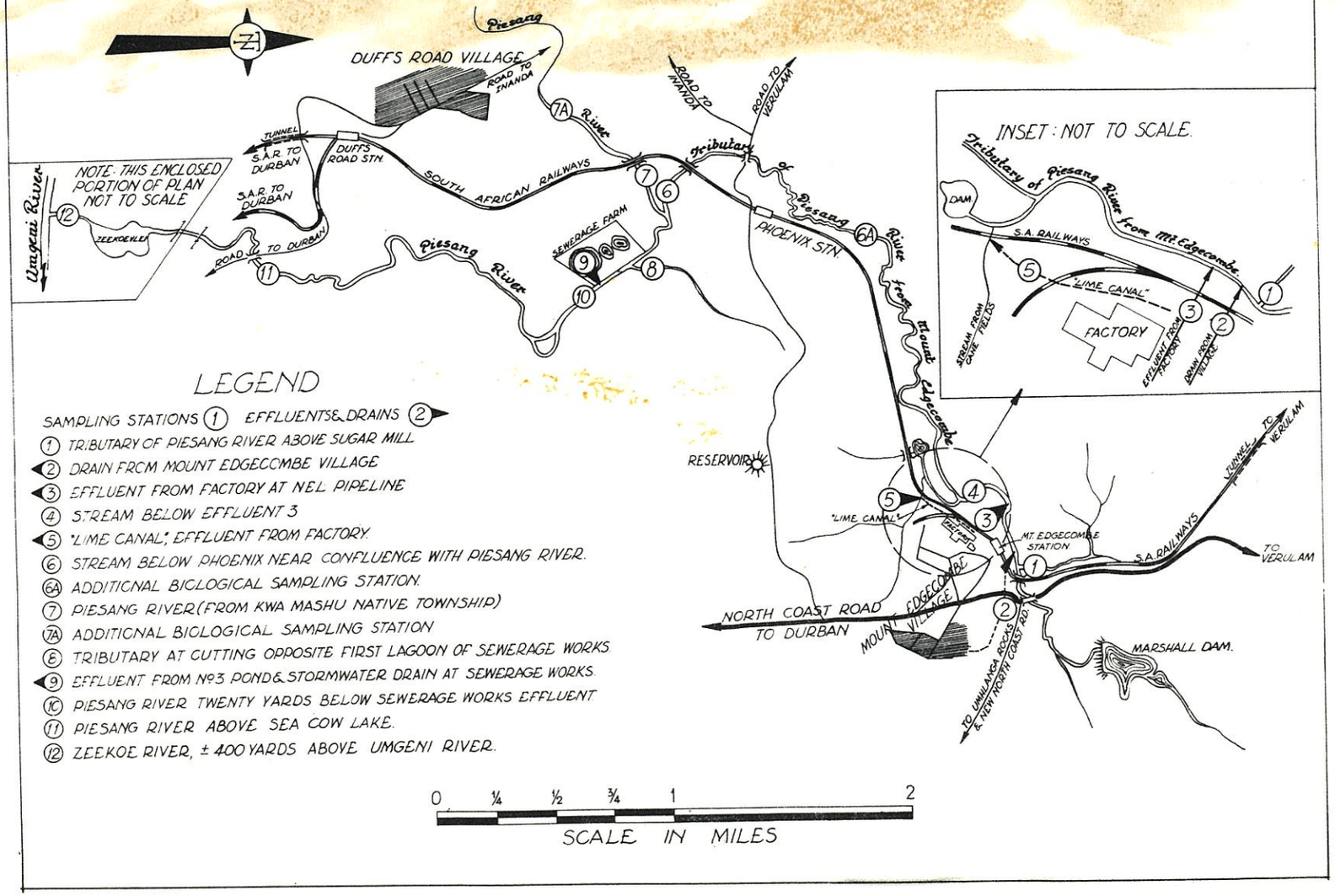
(ii) two effluents from the mill which may reach the stream either directly or indirectly as explained later. This tributary joins the main stream below Phoenix railway station.

(b) Canefields, where much fertiliser is used during the planting season. Silt is also contributed by these lands which comprise a large percentage of the catchment area.

(c) The Kwa Mashu township, through which at least one main tributary of the Piesang river flows.

(d) The Kwa Mashu sewage purification works, the effluent from which enters the Piesang river about one mile below the tributary from Mount Edgecombe.

PIESANG RIVER POLLUTION STUDY : AUGUST ~ SEPTEMBER 1961.



LEGEND

SAMPLING STATIONS (1) EFFLUENTS & DRAINS (2)

(1) TRIBUTARY OF PIESANG RIVER ABOVE SUGAR MILL
(2) DRAIN FROM MOUNT EDGECOMBE VILLAGE
(3) EFFLUENT FROM FACTORY AT N.E.L. PIPELINE
(4) STREAM BELOW EFFLUENT 3
(5) "LIME CANAL", EFFLUENT FROM FACTORY.
(6) STREAM BELOW PHOENIX NEAR CONFLUENCE WITH PIESANG RIVER.
(6A) ADDITIONAL BIOLOGICAL SAMPLING STATION.
(7) PIESANG RIVER (FROM KWA MASHU NATIVE TOWNSHIP)
(7A) ADDITIONAL BIOLOGICAL SAMPLING STATION
(8) TRIBUTARY AT CUTTING OPPOSITE FIRST LAGOON OF SEWERAGE WORKS.
(9) EFFLUENT FROM No 3 POND & STORMWATER DRAIN AT SEWERAGE WORKS.
(10) PIESANG RIVER TWENTY YARDS BELOW SEWERAGE WORKS EFFLUENT
(11) PIESANG RIVER ABOVE SEA COW LAKE.
(12) ZEEKOE RIVER, ± 400 YARDS ABOVE UMGENI RIVER.

0 ¼ ½ ¾ 1 2

SCALE IN MILES

(e) Small-holdings of riparian owners in the environment of Zeekoe-vlei.

(f) An Indian residential area North-West of the confluence of the Zeekoe river with the Umgeni river, through which flows a small tributary, originating in the vicinity of a tuberculosis settlement, which joins the Zeekoe river about 0.5 miles upstream from the Umgeni.

C. SELECTION OF SAMPLING STATIONS

Altogether twelve sampling stations were selected for the survey. The ten uppermost sites were subjected to a detailed ten hour study on the 16th of August, 1961. The stations chosen for the study were (see map) :

Station 1 : On the Mount Edgecombe tributary above the sugar mill effluents and drains.

Station 2 : At a point on a drain from the Mount Edgecombe village, East of the mill, below a culvert on the North Coast - Durban road, ± 300 yards above its confluence with the stream.

Station 3 : On the uppermost effluent from the sugar mill, ± 50 yards from its confluence with the stream, after it has received the effluent from the drain.

Station 4 : At a diversion weir on the stream, ± 300 yards below the junction of the above-mentioned effluent with the stream.

Station 5 : On the second effluent canal from the mill, about 150 yards above the dam into which it flows.

Station 6A: On the Mount Edgecombe tributary ± 800 yards above Phoenix railway station (for faunal samples only).

Station 6B : On the Mount Edgecombe tributary just above its junction with the Piesang river.

Station 7A : Below a newly constructed bridge on the Piesang river, about 1.5 miles above its confluence with the Mount Edgecombe tributary (only biological samples collected).

Station 7B : On the Piesang river at its junction with the tributary from Mount Edgecombe.

Station 8 : A tributary, at its confluence with the Piesang river, opposite the first lagoon of the Kwa Mashu sewage works.

Station 9 : The effluents from No. 3 pond of the sewage purification works and a storm water drain at their junction with the Piesang river.

Station 10 : On the Piesang river twenty yards below its confluence with the above-mentioned effluent.

Station 11 : On the Piesang river (above Zeekoe-vlei) at a road bridge near Avoca.

Station 12 : On the Zeekoe river below Zeekoe-vlei, ± 400 yards from the Umgeni river.

As was the case for the Umgeni estuary survey, (see part I), the effluents were covered by sampling sites at or near their points of entry into the streams (Stations 2,3,5 and 9; see map). River sampling points were selected in such a way as to reflect the biological and chemical conditions of stretches in the river above and below the points of entry into the streams of effluent discharges (Stations 1,4,6A,6B and 10). Moreover, at the junctions of the streams, sites were established to determine the contribution to pollution from the various parts of the Zeekoe river catchment (Stations6B,7B and 8). A series of sampling stations below the lowermost effluent

outfall (sampled at Station 9) served to assess the recovery potential of the Zeekoe (Piesang) river (Stations 10 - 12). Additional faunal sampling points (Stations 6A and 7A) were useful in providing a better picture of the stream conditions which existed in those particular stretches of the river system under consideration.

D. GENERAL CONDITIONS OF THE STUDY AREA DURING THE PERIOD OF SURVEY

In the discussion that follows, the streams and their effluents will be considered in the following order. The same procedure will be followed when the results are considered.

1. The Mount Edgecombe tributary and the effluents it receives.
2. The Piesang river above the junction with this stream.
3. The Piesang river above Zeekoe-vlei and the effluent discharged into it.
4. The Zeekoe (Piesang) river below Zeekoe-vlei.

1. The Mount Edgecombe tributary (Stations 1 - 6)

This tributary, above the effluents and drains, had a fairly constant rate of flow (0.1 cusecs) throughout the period of investigation. The water of the stream was clear, with no excessive algal growth on the small stones in the current. However, a gradual deterioration was noticed in the general condition of the stream in the course of the investigation, probably caused by the activities above the site, such as the cutting of sugar cane and ploughing, which were in process during the study.

The drain from the village (Tables 3A and 3B, p.64.) had a temperature which fluctuated around 20°C (Min. 13.8°C

and Max. 25.0°C). The flow never exceeded 0.2 cusecs during the period of survey but appeared to be very variable, as also did its composition. It always had a dirty grey colour with much suspended organic matter. A slightly nauseating smell was detectable at times during the study.

The uppermost effluent from the factory (see Tables 4A and 4B, p. 65) had a very variable rate of flow and marks in the effluent canal showed that the flows recorded during the period of study were at times exceeded. However, these periodic increases in volume appeared to be of short duration and flows were observed to fluctuate mainly between 2.0 and 3.0 cusecs. Temperatures were mainly above 25°C. Large patches of oil or grease and pieces of burnt sugar cane were floating in the effluent at times. During other visits a very fine fibre and much silt were also observed in the effluent. A slight smell like kaffir beer was detectable on occasions.

The stream below the drain and effluent had the same dirty grey colour as the drain effluent but developed a strong smell of sewage at a weir, ± 300 - 400 yards below the entry of the first factory effluent (Station 4 on map and Tables 5A and 5B p. 66). From the weir water could be partly diverted into a dam or by-passed into the stream. The temperature fluctuated between 19.5 - 31.0°C.

A second effluent discharge from the factory (see Tables 6A and 6B) was warm (28.5 - 44.0°C) and varied in colour from a syrupy brown with few solids in suspension to a pure white milky colour with a very high load of suspended solids (probably lime). It had a flow rate of the order of 2.5 cusecs and ran into the dam

mentioned above. From this dam, the effluent was pumped to different reservoirs and irrigated over sugar cane. Seepage and run-off found their way back into the Mount Edgecombe stream or into the stream sampled at Station 8 (see map and Tables 9A and 9B). Some of the mixed effluent in the dam might reach the Mount Edgecombe stream directly.

The condition of the Mount Edgecombe tributary above and below Phoenix could be described as polysaprobic (Station 6B, Tables 7A and 7B, p. 68). There was a very strong smell of hydrogen sulphide. The stones and stream bottom, which had a growth of sewage fungus, were black. Even the water was of a dark black-brown colour. Some smell could be detected at times from a distance of more than 20 yards away from the stream. Towards the end of the survey some change in the condition of the stream at Station 6B was observed when the flow increased in volume. This was accompanied by the disappearance of the black colour of the water at this station.

2. <u>The Piesang river above the junction with 1.</u>
(Tables 8A and 8B, p. 69).

Much silt was deposited in the slower flowing regions. A rich growth of <u>Spirogyra</u> was present in the pools. <u>Stigeoclonium</u> sp. occurred on stones in the current. It was difficult to determine the flow because of the sandy nature of the river bed, but 0.15 - 2.0 cusecs were recorded. Temperature measurements varied between 14.0 and 19.0°C.

3. <u>The Piesang river above Zeekoe-vlei and the effluent discharging into it</u>

The Mount Edgecombe tributary with its larger

volume of water had a significant effect upon the stream above Zeekoe-vlei and played an important role in the conditions at all these stations. The addition of phosphates and other nutrients to the river from the effluent of the Kwa Mashu sewage purification works (see Tables 9A and 9B, p. 70), which was of a much better quality than the Piesang river, is partly responsible for the conditions of the stream at Station 11, where it reverted almost to that found at Station 6B on the Mount Edgecombe tributary (compare Tables 7A and 7B with Table 12). Another effect of the sewage purification works effluents was an increase in sewage fungal growth at Station 10 and further down.

4. The Zeekoe (Piesang) river below Zeekoevlei

An improvement in the stream at Station 12 seemed to occur in the slow-flowing stretch of Zeekoevlei itself. Even so, the stream at this station was in a worse state than it was a year before, judging by a series of comparable collections of fauna.

E. DISCUSSION OF RESULTS

1. Faunal

a. The Mount Edgecombe Stream (Stations 1, 6A and 6B, see map)

Station 1 on the Mount Edgecombe tributary was located a few hundred yards above the point of discharge of the drain and effluents from a village and sugar mill factory at Mount Edgecombe. In the vicinity of this sampling site, surrounded by canefields, this small slow flowing stream forms alternating pools and rapids covered by coastal evergreen bush. Deposits of decaying leaves and detritus were found on the stream bed in the slow-flowing stretches. Collections of the fauna

of the fauna in both river bottom and marginal vegetation yielded low numbers, Ephemeroptera being absent in both habitats sampled. This fact, together with the relative abundance of Chironomidae and the relative percentage proportions of Muscidae larvae, Prostoma sp. and of Turbellaria, suggested some disturbance of the stream. This condition could perhaps be largely attributed to the deposits of decaying organic matter found in the stream. Nevertheless, no real signs of pollution could be detected at Station 1.

The deleterious effects of organic loads upon stream communities were clearly demonstrated in the conditions found at Stations 6A and 6B on the Mount Edgecombe tributary below the outfalls of the village drain and factory effluents (see map for detail).

At Station 6A, Tubifex sp. dominated the fauna of both the marginal vegetation and stream bottom (Tables 1A and 1B). Of importance was the significant reduction in numbers and variety of species of the stream bottom macro-invertebrates for, apart from Tubifex sp., Psychoda alternata Say (0.8%) was the only other species present (Table 1B). Moreover, the number of organisms per square foot of stream bottom was a mere 129. A reduction in the numbers of Tubifex sp. usually indicates stream improvement. In other instances very foul stream conditions result in the virtual or entire disappearance of macro-invertebrate communities, including Tubifex, with a corresponding increase in Protozoa. At Station 6A, liberation of toxic substances such as H_2S and of a continuous oxygen depletion on the stream bed, were important limiting factors. In the marginal vegetation, large numbers of Tubifex sp. were found with organisms such as

Nematoda, Naididae, Hydrophilidae and the larvae of Ephydridae and Culicidae (Table 1A). It is perhaps noteworthy that the faunal communities of the marginal vegetation in contrast to those of stream bottoms, are not so severely subject to factors such as the liberation of toxic substances and oxygen depletion as those of the current itself. An exception to this perhaps, is the fauna of the trailing vegetation, (see Table 1A Station 11) overhanging in the current.

At Station 6B, below Station 6A, further deterioration of the stream was indicated by the disappearance of all stream bottom macro-invertebrata including Tubifex sp. (Table 1B). In contrast to this, the marginal vegetation fauna at this site showed some improvement although still supporting the pollution indicators Tubifex sp. (22.1%) Eristalis sp. and Ephydridae. The presence of Bulinus sp., the occurrence of Prostoma sp. and the very large numbers of Nematoda, indicated some improvement of the water.

b. The Piesang River above its confluence with the Mount Edgecombe Stream at Stations 7A and 7B.

Judged by the general appearance of the stream and by the fauna and flora of the Piesang river above its confluence with the Mount Edgecombe tributary, this part of the stream system was mildly enriched and in the process of recovery.

In the slow flowing stretches at Station 7A, where the stones in the water were covered with silt, growths of Spirogyra sp. and other species of filamentous algae, Branchiura sowerbyi Bed comprised more than 80% of the fauna (Table 1B). Chaetogaster sp., which occurred in small numbers in the marginal vegetation, (Table 1A) was

the only other oligochaet found in this part of the river. In the stony rapids at Station 7B, Simulium spp. were numerous (see Table 1B). The replacement of Tubifex, which indicates bad pollution, by Branchiura sowerbyi Bed, which reflects enriched conditions, as well as the presence of Chaetogaster sp. is noteworthy.

Characteristic of this stretch of the Piesang river in particular and of very mildly enriched streams in general, were the presence and abundance in numbers and species of Gasteropoda, which included, amongst others, Biomphalaria pfeifferi (Krs), the intermediate host of Schistosoma mansoni.

c. The Tributary opposite the sewage purification works - sampled at Station 8

The water of this stream plunges over a weir and flows over a wide bed, with much turbulence, towards the Piesang river for a distance of about 20 yards. Oxygenation was found to be very good on most occasions.

Although the chemical and bacteriological evidence suggested mild to heavy organic enrichment and faecal contamination at Station 8, the stream supported a faunal community which would, under normal circumstances, only occur in clean unpolluted waters. Altogether ten Ephemeropteran species were collected, of which Baetis latus Agnew, Centroptilum sudafricanum Brnrd. and C. excisum Brnrd. are organisms sensitive and intollerant to pollution. A comparison of two sets of samples, collected in the shallow fast flowing turbulent stickles (Aeration good, Table 1B column 8a) and the deeper slower flowing runs (aeration not as well as at 8a) in the main channel of the stream (Table 1B column 8b) respectively, showed a great reduction in Ephemeropteran species and numbers of individuals in the

latter habitat (compare columns 8a and 8b of Table 1B). Simulium spp., on the other hand, showed an increase of almost 50%. From these findings it was clear that the establishment and maintainance of a clean water community at this sampling site largely depended upon the good aeration that took place at the weir and stickles. In this case, therefore, the fauna did not reflect the chemical and bacteriological disturbance of the stream, except perhaps at site 8b where the faunal picture indicated merely a slight disturbance of stream conditions.

d. The combined effluent of a storm water drain and of the No.3 pond from the Kwa Mashu sewage purification works at its junction with the Piesang river; (Marginal vegetation sampled at Station 9)

This effluent was of a good chemical and reasonable bacteriological quality and supported fish life. Although only an effluent, its fauna indicated conditions not much different from those found at Stations 7A, 7B and 12, all of which indicated mild organic enrichment. However, the nutrients and micro-organisms from this effluent, discharged into the polluted Piesang river, resulted in an increase in sewage fungal growth and deterioration of stream conditions towards Station 11, above Zeekoe-vlei.

e. The Piesang river at Stations 10 and 11 above the Zeekoe-vlei (see map)

Characteristic of this part of the stream, below the effluent from the Kwa Mashu sewage purification works, was the presence, in large numbers, of Aulophorus furcatus Oken (Table 1A Station 10), and of the bloodworm Chironomus sp. (Tables 1A and 1B, Station 10.) The phosphate and nitrate enrichment (Table 10A) and the decaying of phyto- and zooplankton in the Piesang river, due to the toxic

effects of liberated H_2S, resulted in such a deterioration of the stream at Station 11 that conditions reverted to those found at Stations 6A and 6B on the Mount Edgecombe stream. (Compare Tables 7A and 7B with Table 12). At the head of the Zeekoevlei below Station 11, the stream turned septic (during the period of investigation), killing most snails, including Bulinus (Physopsis) africanus (Krs.) and Biomphalaria pfeifferi (Krs.) the intermediate hosts of Schistosoma, which were very abundant amongst the floating Salvinia covering the water's surface in the pools of the vlei some months prior to the survey.

f. The Zeekoe river at Station 12, below Zeekoe-vlei

In both the marginal vegetation and the stream bottom two sets of samples were collected:-

(a) Marginal vegetation

(i) Eichhornia in pool below Bridge (12^{*} Table 1A)

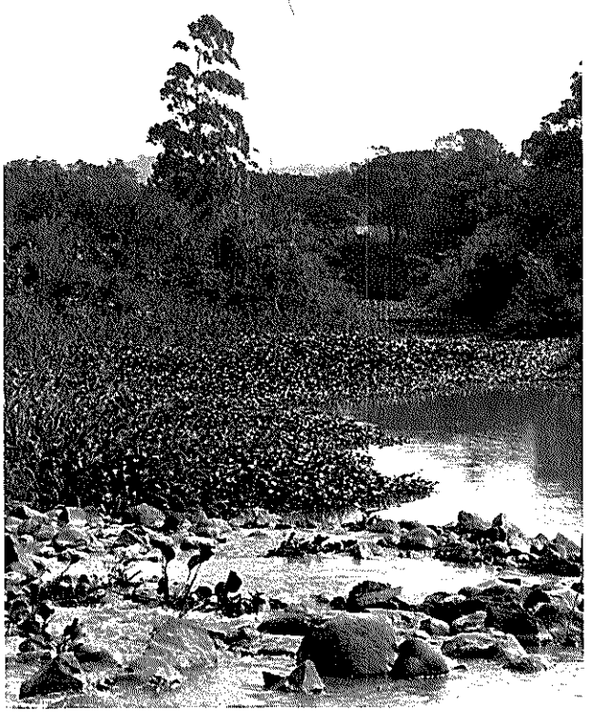
(ii) Trailing vegetation in stream (12^{**} Table 1A)

(b) Stones in the current

(i) Stony runs, deep moderate flow (12^{*} Table 1B)

(ii) Stickles and cascades, shallow rapids (12^{**} Table 1B).

The faunal picture at Station 12 as a whole indicated mild organic enrichment of the river water. Nais spp. were abundant in the trailing vegetation and stickles (Table 1B) whilst Nematoda showed a high incidence in the pool amongst the water hyacinth Eichhornia sp. It is to be noted that, compared with a previous analysis, a sharp reduction of Bulinus (Physopsis) africanus (Krs.) and Biomphalaria pfeifferi (Krs.) occurred at Station 12 during the past two



A luxuriant growth of Eichhornia sp. carpeting the river in its slow-flowing stretches above and below Station 12.

years, simultaneously with a gradual deterioration in stream conditions. Nevertheless, the stream made a good recovery whilst flowing through Zeekoe-vlei.

2. Bacterial

a. The Mount Edgecombe tributary and its effluents (Tables 2 - 7)

Results showed the Mount Edgecombe stream to be the major source of bacterial contamination in the Piesang river and further downstream.

Although the total coliform counts at Station 1 were low in both the weekly and 10-hourly study, very high loads (mainly over 1,800,000 M.P.N. or organisms per 100 mls.) were recorded at all stations on the effluents as well as at Station 6 on the Mount Edgecombe tributary where it joins the Piesang (Zeekoe) river.

The numbers of faecal E. coli were negligible at Station 1. However, the village drain, sampled at Station 2 (see map), yielded very high counts exceeding 1,800,000 M.P.N. of faecal E. coli per hundred millilitres (Tables 3A and 3B). Bacterial loads of faecal E. coli were not much different at Station 3, the first factory effluent and Station 4 on the Mount Edgecombe stream below this effluent (Tables 4 and 5). At Station 6B (Tables 7A and 7B) on the Mount Edgecombe tributary, counts of faecal E. coli were still exceptionally high.

The numbers of faecal streptococci were generally lower at all sampling stations of this tributary and of the effluents discharging into it. Nevertheless, high values were recorded from Stations 3, 4 and 5 with very large numbers from the village drain (Station 2). At Station 6, faecal streptococci counts were much lower than any of those recorded from Stations 2 - 4, showing a definite

TABLE 1A.

POLLUTION STUDY OF THE ZEEKOE RIVER SYSTEM AUGUST - SEPTEMBER 1961

Percentage Composition of the Fauna of the Marginal Vegetation

GROUP OF ORGANISMS	Station numbers (indicated on map)										
	1	6A	6B	7A	7B	8	9	10	11	12*	12**
COELENTERATA											
Hydra sp.	-	-	-	-	-	0.1	0.1	-	-	-	-
HELMINTHES & ANNELIDA											
Rhabdocoela	5.6	-	-	-	-	-	-	-	-	-	-
Prostoma sp.	-	-	0.8	-	6.5	-	-	-	-	-	P
Nematodes	5.6	0.2	64.6	-	1.1	3.9	-	-	-	0.2	75.0
Naididae (unidentified)	5.6	3.2	1.6	-	-	3.1	3.7	-	-	-	1.1
Nais sp.	-	-	-	-	-	1.7	74.6	-	-	95.6	8.6
Chaetogaster sp.	-	-	-	-	2.5	1.3	-	-	-	P	6.0
Aulophorus sp.	-	-	-	-	-	-	-	49.4	-	-	-
Tubifex sp.	-	93.0	22.1	-	-	-	-	-	-	-	-
Hirudinea	-	-	-	-	0.7	-	-	-	-	-	0.2
CRUSTACEA											
Simocephalus vetula (Sars)	-	-	-	-	-	-	1.6	-	-	-	4.5
Pleuroxis sp.	-	-	-	-	-	-	0.3	-	-	-	-
Cyclops spp.	5.6	-	-	30.8	14.3	12.6	11.9	-	-	-	2.3
Ostracoda	-	-	-	-	-	4.9	-	-	-	-	-
Caridina nilotica Roux	-	-	-	16.4	11.5	-	-	-	-	-	-

GROUP OF ORGANISMS	Station numbers (indicated on map)										
	1	6A	6B	7A	7B	8	9	10	11	12*	12**
COLLEMBOLA	P	-	-	P	-	-	-	P	-	-	-
ACARINA											
Hydrachnellae	-	-	-	-	0.4	-	-	-	-	-	0.1
EPHEMEROPTERA											
Austrocloeon virgiliae Brnrd.	-	-	-	-	-	0.2	-	-	-	-	-
Caenis sp.	-	-	-	-	-	0.1	-	-	-	-	-
ODONATA											
Pseudagrion spp.	22.2	-	-	-	-	1.3	-	-	-	-	-
Paragomphus sp.	5.6	-	-	-	-	-	-	-	-	-	-
HEMIPTERA											
Micronecta dimidiata Poisson	-	-	-	-	-	0.1	-	-	-	-	-
COLEOPTERA											
Guignotes spp.	-	-	1.6	-	-	-	-	-	-	-	-
Laccophilus sp.	-	P	-	-	-	-	-	-	-	-	-
Scymus sp.	-	-	-	-	0.7	-	-	-	-	-	-
Hydrophilidae larvae	-	P	0.8	-	-	-	-	-	-	-	-
Berosus sp.	-	-	0.8	-	-	0.2	-	-	-	-	-
Hydraenidae (adults)	-	-	-	1.0	-	-	-	-	-	-	0.2
Helodidae	-	-	-	-	-	0.1	-	-	-	-	-

GROUP OF ORGANISMS	Station numoers (indicated on map)										
	1	6A	6B	7A	7B	8	9	10	11	12*	12*
DIPTERA											
Dipteran larvae + pupae (unidentified	-	-	-	4.8	-	-	-	-	-	-	-
Psychoda sp.	-	-	-	-	-	1.0	-	6.6	-	-	-
Eristalis sp.	-	-	2.4	-	-	-	-	0.8	-	-	-
Ephydridae	-	1.7	1.6	-	-	-	-	4.0	-	-	-
Muscidae	5.6	-	-	-	-	-	-	-	-	-	-
Culex larvae	-	1.1	3.2	-	-	0.4	-	-	-	-	-
Simulium larvae	-	-	-	-	-	-	2.2	0.1	-	3.6	-
S. adersi Pom.	-	-	-	-	-	-	P	-	-	-	-
S. medusaeforme Pom.	-	-	-	-	-	-	0.1	-	-	-	-
S. ruficorne Macq.	-	-	-	-	-	-	-	-	-	-	-
Chironomidae	44.4	-	-	1.0	6.8	37.9	3.0	8.2	-	0.5	-
Orthocladinae	-	-	-	-	3.9	7.7	0.4	-	-	0.1	-
Chironominae	-	-	-	-	2.2	1.6	-	-	-	-	-
Pentaneura sp.	-	-	-	-	-	0.3	-	-	-	-	-
Chironomus sp.	-	-	-	-	-	-	1.3	30.9	-	P	-
Corynoneura sp.	-	-	-	-	-	0.9	-	-	-	-	-
Ceratopogonidae	-	-	-	-	-	0.1	-	-	-	-	P
MOLLUSCA											
Septaria tessellaria (Lam.)	-	-	-	-	0.7	-	-	-	-	-	-
Lymnaea spp.	-	-	-	30.8	20.4	-	0.4	-	-	P	0.5
Biomphalaria pfeifferi (Krs)	-	-	-	1.4	0.4	-	-	-	-	-	0.1
Gyraulus corniculum (Conn.)	-	-	-	-	-	-	-	-	-	-	0.1

GROUP OF ORGANISMS	Station numbers (indicated on map)										
	1	6A	6B	7A	7B	8	9	10	11	12*	12**
Gyraulus costulatus (Krs)	-	-	-	-	-	-	-	-	-	-	0.1
Anisus natalensis (Krs)	-	-	-	-	-	-	-	-	-	-	-
Segmentina planodiscus (M & P)	-	-	-	P	-	-	-	-	-	-	0.1
Bulinus spp.	-	-	0.8	11.5	19.4	-	0.2	-	-	P	1.2
Ferrissia sp.	-	-	-	-	1.1	-	-	-	-	-	-
Burnupia sp.	-	-	-	1.0	-	-	-	-	-	P	-
Pisidium sp.	-	-	-	-	-	0.1	-	-	-	-	-
AMPHIBIA											
Xenopus laevis (Daudin)(plus tadpoles)	-	-	-	-	4.3	-	-	-	-	-	-
Bufo tadpoles	-	-	-	-	-	20.4	-	-	-	-	-
PISCES											
Barbus sp.	-	-	-	1.0	-	-	P	-	-	-	-
Number of organisms per 6ft. Marginal Vegetation	18	1876	254	208	279	1,425	4,824	1,458	0	251,095	7,999

TABLE 1B.

POLLUTION STUDY OF THE ZEEKOE RIVER SYSTEM AUGUST - SEPTEMBER 1961

Percentage Composition of the Fauna : Stones in the Current

GROUP OF ORGANISMS	Station numbers (indicated on map)										
	1	6A	6B	7A	7B	8*	8**	10	11	12*	12**
COELENTERATA											
Hydra sp.	-	-	-	-	-	P	-	-	-	-	-
BRYOZOA											
Plumatella	-	-	-	-	-	-	-	-	-	P	P
HELMINTHES & ANNELIDA											
Planarians	9.0	-	-	0.2	P	0.4	0.1	-	-	-	-
Prostoma sp.	3.0	-	-	0.9	1.2	-	-	-	-	-	0.3
Nematodes	-	-	-	2.3	-	0.9	P	-	-	0.8	0.6
Naididae (unidentified)	-	-	-	-	-	-	-	13.1	6.1	-	-
Chaetogaster sp.	-	-	-	-	-	-	-	-	-	P	0.2
Dero sp.	-	-	-	-	-	-	-	-	-	-	-
Aulophorus sp.	-	-	-	-	-	-	-	-	-	0.7	-
Tubificidae (Tubifex sp.)	-	99.2	-	-	-	-	-	3.0	93.9	1.3	-
Branchiura sowerbyi Bed.	-	-	-	80.7	-	-	-	-	-	-	-
CRUSTACEA											
Cyclops spp.	-	-	-	-	-	1.1	0.2	1.2	-	2.9	0.2
Ostracoda	-	-	-	-	-	0.7	0.1	0.3	-	-	-
ACARINA											
Oribatoides sp.	-	-	-	-	-	-	-	-	-	-	-

GROUP OF ORGANISMS	Station numbers (indicated on map)										
	1	6A	6B	7A	7B	8*	8**	10	11	12*	12**
COLLEMBOLA	P	-	-	-	P	-	-	-	-	-	-
EPHEMEROPTERA											
Adenophlebia sylvatica Crass	-	-	-	-	-	0.2	-	-	-	-	-
Baetis harrisoni Brnrd	-	-	-	-	-	0.6	-	-	-	-	-
Baetis glaucus Agnew	-	-	-	-	-	0.4	P	-	-	-	-
Baetis latus Agnew	-	-	-	-	-	0.3	-	-	-	-	
Centroptilum sudafricanum Lest	-	-	-	-	-	1.4	0.1	-	-	-	-
Centroptilum excisum Brnrd.	-	-	-	-	-	0.1	-	-	-	-	-
Caenis sp. 3	-	-	-	-	-	0.3	-	-	-	-	-
Caenis sp. 5	-	-	-	-	-	0.5	-	-	-	-	-
ODONATA											
Pseudagrion natalense Ris	3.0	-	-	-	-	-	-	-	-	-	-
COLEOPTERA											
Gyrinidae larvae	-	-	-	-	-	0.2	P	-	-	-	-
DIPTERA											
Tipulidae	-	-	-	-	-	P	-	-	-	-	0.1
Ephydridae	-	-	-	-	-	P	-	-	-	-	-
Psychoda sp.	-	0.8	-	-	..	-	-	1.1	-	-	-
Simulium larvae	-	-	-	-	63.7	28.8	78.2	15.0	-	2.7	9.1
S. adersi Pom.	-	-	-	-	1.1	-	-	-	-	-	0.1
S. alcocki Pom.	-	-	-	-	-	-	0.1	-	-	-	-

GROUP OF ORGANISMS	Station numbers (indicated on map)										
	1	6A	6B	7A	7B	8*	8**	10	11	12*	12**
S. medusaeforme Pom.	-	-	-	-	30.1	1.6	1.4	1.4	-	0.5	0.2
S. nigritarsus Coq.	-	-	-	-	-	1.7	0.1	-	-	-	0.1
S. ruficorne Macq.	-	-	-	-	0.4	-	-	-	-	-	-
Chironomidae	48.5	-	-	0.5	0.7	6.9	4.0	-	-	2.1	2.1
Orthocladinae	-	-	-	-	0.9	1.4	2.3	15.7	-	-	1.1
Chironominae	-	-	-	-	0.2	-	-	-	-	-	-
Tanytarsini	15.2	-	-	-	-	-	-	-	-	-	-
Rheotanytarsus sp.	9.0	-	-	-	1.2	0.2	0.3	-	-	-	-
Corynoneura sp.	-	-	-	-	-	0.2	-	P	-	-	-
Chironomus sp.	-	-	-	-	-	-	-	37.8	-	-	-
Ceratopogonidae	-	-	-	-	-	P	-	-	-	-	-
MOLLUSCA											
Lymnaea spp.	-	-	-	3.0	0.1	-	-	-	-	-	-
Biomphalaria pfeifferi (Krs)	-	-	-	0.9	-	-	-	-	-	-	-
Bulinus spp.	-	-	-	11.0	-	-	-	-	-	-	0.3
Burnupia sp.	6.1	-	-	0.5	0.1	-	-	-	-	-	0.7
Ferrissia sp.	-	-	-	-	-	-	-	-	-	-	P
Number of Organisms per sample	33 qual.	129 sq.ft.	0 sq.ft.	218 sq.ft.	848 sq.ft.	3456 sq.ft.	13049 sq.ft.	1530 sq.ft.	25 sq.ft.	1559 sq.ft.	5648 qual.

qual. * qualitative

sq.ft. * square foot

reduction in numbers downstream in contrast to the values of faecal E. coli and total coliforms, (Tables 3 - 7) which still remained high.

b. The Piesang river at Station 7B above its confluence with the Mount Edgecombe tributary

Low values for total coliforms, faecal E. coli and faecal streptococci, were obtained from this station (Tables 8A and 8B). It was evident that none, or very little, of the bacterial loads encountered in the Piesang (Zeekoe) river below its confluence with the stream from Mount Edgecombe came from this part of the catchment.

c. The tributary (sampled at Station 8) opposite the Kwa Mashu Sewage Purifications works.

This stream, which receives the surface run-off from irrigated canefields, carried high and variable bacterial loads (Tables 9A and 9B). The numbers of total coliforms were extremely high. Faecal E. coli values, which were very much higher than those of the corresponding faecal streptococci, indicated mild to heavy faecal bacterial contamination (Tables 9A and 9B).

d. The combined effluent from the No. 3 pond and storm water drain of the Kwa Mashu sewage purification works (Station 9)

At the beginning of the survey, the bacterial quality of this combined effluent was not good, individual faecal E. coli values exceeding 18,000 M.P.N. of organisms per 100 mls. (Table 10A). Even the counts of faecal streptococci, which were usually much lower than faecal E. coli, had high values of 13,000 organisms per 100 mls. in the 8 a.m. - 11.30 a.m. composite sample (16th August, 1962). However, the gradual decrease in all bacterial counts towards the end of the survey coincided with a reduction and cease of flow in the storm water drain.

e. The Piesang river below the Kwa Mashu Sewage Purification works effluent (above Zeekoe-vlei at Stations 10 and 11).

No reduction in the numbers of faecal E. coli and faecal streptococci could be observed between Station 10 (Tables 11A and 11B) and Station 11 (Table 12) whilst total coliform counts were still very much higher than those of the faecal organisms (compare Tables 11 and 12). From these tables, the proportionally small numbers of faecal streptococci, when compared with those of faecal E. coli, were noticeable. From the data, however, it was clear that heavy faecal contamination of the water still prevailed at the head of Zeekoe-vlei.

f. The Zeekoe (Piesang) river tributary below Zeekoe-vlei about 400 yards from the Umgeni river.

The purification potential of the Zeekoe-vlei, between Station 11 and 12, was clearly demonstrated in the great reduction in numbers, at Station 12, of both total coliforms, faecal E. coli and faecal streptococci (compare Tables 12 and 13). Faecal bacterial loads here could merely be described as being mild. Nevertheless, occasional heavy loads (Table 13) still reached Station 12 and consequently the Umgeni river into which this tributary discharges.

3. Physical and chemical

a. The Mount Edgecombe Tributary and its effluents (See Tables 2A, 2B - 7A, 7B)

In addition to the detailed 10-hour study of the chemistry of the streams and effluents, limited analyses were also made on weekly samples. These results are compared where possible.

Except for Stations 5 (Tables 6A and 6B) and 6B (Tables 7A and 7B), the pH values were mainly between 7 and 8. The second effluent from the factory (Station 5) had very variable and exceptionally high values (pH = 10.2) at times. At Station 6B values of less than seven were obtained but even here an increase in pH was observed towards the end of this survey. The increase in pH at Station 6B (Table 7B, 5.9.61 and 14.9.61) coincided with the general improvement of the stream and an increase in volume of flow.

The dionic conductivity values of the snap samples (compare all A and B tables) differ somewhat from those of the composite samples, being mainly lower. The values obtained from Station 1 were high for an unpolluted stream. Station 3 (Tables 4A and 4B) had very variable levels. The drain (Station 2) had some effect upon the conductivity of the stream at Station 4 (compare Tables 3A, 3B and 5A, 5B). An increase in the volume of flow at Station 6B towards the end of the survey resulted in a drop in conductivity.

The drain (Table 3A) and effluents from the factory contained solids in suspension. Station 5 (Table 6A) had the highest and most variable values.

The drain from the village had exceptionally high phosphate values (Table 3A). The effect of this on the stream at Station 4 (Table 5A) was noticeable.

Fairly high ammonia values at Station 1 (Table 2A), where the stream appeared to be clean (combined with high conductivities and solids), indicated some pollution upstream from this station. All the other remaining stations in the section under discussion had much free and saline and albuminoid ammonia. At Station 2 for instance, the values recorded were all over 7 ppm. of Ammonia N. (Table 3A).

TABLE 2

STATION 1 : TRIBUTARY OF PIESANG RIVER ABOVE FACTORY AND DRAINS (SEE MAP)

A Average chemical and bacteriological values of composite samples of an 8-hour study (16.8.61 : 8am - 4 pm.)

	DATA	Number of samples analysed	Mean	Range
	Approximate flow (cusecs)	-	0.1	
	Temperature ^{o}C	3		14.0^{o} - 19.0^{o}
	pH	3	7.6	7.3 - 7.8
	Conductivity as mmhos/cm	3	1366	1200 - 1600
Expressed as p.p.m.	Total solids	3	474.3	410 - 538
	Suspended solids	3	11	0 - 29
	Total Hardness as $CaCO_3$	3	170.7	164 - 176
	Calcium Hardness as $CaCO_3$	3	77.3	72 - 80
	Phosphate as PO_4	3	Nil	Nil
	Free and Saline Ammonia as N	3	0.83	0 - 2.4
	Albuminoid Ammonia as N	2	0.45	0.3 - 0.6
	Nitrite N	3	Nil	Nil
	Nitrate N	3	0.5	0 - 1.5
	Sugar as Dextrose	3	Nil	Nil
	Dissolved oxygen	3	7.2	6.9 - 7.8
	O.A. (4 hours)	3	2.7	1.4 - 3.6
	B.O.D. (5 day)	2	1.8	1.8
As M.P.N per 100 mls.	Total coliforms	2	945	490 - 1400
	Faecal E. coli	2	110	50 - 170
	Faecal streptococci	2	35	20 - 50

B Average chemical and bacteriological values of weekly snap samples (8.8.61 - 14.9.61)

	DATA	Number of Samples Analysed	Mean	Range
	Approximate flow (cusecs)	5	0.1	-
	Temperature ^{o}C	5	16.9^{o}	14.0 - 20.5^{o}
	pH	3	8.0	7.8 - 8.2
	Conductivity as mmhos/cm	3	810.3	715 - 990
	D.O. ppm	3	7.2	6.7 - 7.3
	B.O.D. ppm	1	1.8	-
As M.P.N per 100 mls.	Total coliforms	5	796	490 - 1100
	Faecal E. coli	5	156	20 - 490
	Faecal streptococci	5	72	20 - 130

TABLE 3

STATION 2 : DRAIN FROM VILLAGE ABOVE SUGAR MILL FACTORY (SEE MAP)

A Average chemical and bacteriological values of composite samples of an 8-hour study (16.8.61 -8a.m. to 4p.m.)

DATA		Total No. of composite samples analysed	Mean	Range
Temperature °C		4	-	13.0 - 25.0
pH		4	7.1	7.0 - 7.2
Conductivity as mmhos/cm		4	1825	1500 - 2200
Expressed as parts per million.	Total solids	4	1300	740 - 1680
	Suspended solids	4	741.8	97 - 1100
	Total hardness as $CaCO_3$	4	191.0	172 - 212
	Calcium hardness as $CaCO_3$	4	107.0	96 - 120
	Phosphate as PO_4	4	3.5	1.2 - 6.0
	Free & saline Ammonia as N	3	9.7	7.2 - 12.8
	Albuminoid Ammonia as N	2	7.6	7.2 - 8.0
	Nitrite N	4	0	0
	Nitrate N	3	0	0
	Sugar as Dextrose	4	0.05	0.0 - 0.1
	Dissolved oxygen	4	2.75	0 - 4.5
	O.A. (4 hours)	3	64.5	19.4 - 98.4
	B.O.D. (5 day)	2	410.0	310 - 510
As M.P.N. per 100 mls.	Total coliforms	2	1,800,000+	-
	Faecal E. coli	2	1,800,000+	-
	Faecal streptococci	2	1,800,000+	-

B Average chemical and bacteriological values of weekly snap samples 8.8.61 - 14.9.61

DATA		Total No. of Snap samples analysed	Mean	Range
Approximate flow (cusecs)		5	0.19	0.15 - 0.2
Temperature °C		5	20.0	18.0 - 21.0
pH		5	7.4	7.2 - 7.8
Conductivity as mmhos/cm		4	1273.3	990 - 2090
D.O. as ppm		3	1.27	0.9 - 1.8
B.O.D. as ppm		1	80	
Expressed as M.P.N. per 100 mls.	Total coliforms	5	14,448,000	240,000 - 18,000,000+
	Faecal E. coli	5	12,020,000	1,800,000 - 18,000,000+
	Faecal streptococci	5	1,186,000	450,000 - 2,400,000

TABLE 4.

STATION 3 : EFFLUENT FROM FACTORY (SAMPLED AT N.E.L. PIPELINE) SEE MAP

A Average chemical and bacteriological values of composite samples of an 8-hour study (16.8.61: 8.00 a.m. to 4.00 p.m.

	DATA	Total No. of composite samples analysed	Mean	Range
	Approximate flow (cusecs)	4		2.0 - 2.5
	Temperature °C	4		23.0°- 32.0°
	pH	4	7.1	6.9 - 7.2
	Conductivity as mmhos/cm	4	787.5	650 - 900
Expressed as parts p.m.	Total Solids	4	470	420 - 520
	Suspended solids	4	111.5	51 - 200
	Total hardness as $CaCO_3$	4	154.5	148 - 160
	Calcium hardness as $CaCO_3$	4	113.0	104 - 120
	Phosphate as PO_4	4	Nil	Nil
	Free & saline ammonia as N	4	1.1	0.8 - 1.6
	Albuminoid ammonia as N	2	2.25	2.2 - 2.3
	Nitrite N	4	Nil	Nil
	Nitrate N	4	0.2	0.3 - 0.5
	Sugar as Dextrose	4	5.8	0.2 -23.0
	Dissolved oxygen	5	0.2	0.0 - 1.0
	O.A. (4 hours)	4	28.9	14.4 -56.4
	B.O.D. (5 day)	2	85	80 - 90
As M.P.N. per 100 mls	Total coliforms	2	1,800,000+	-
	Faecal *E. coli*	2	281,500	23,000 - 540,000
	Faecal streptococci	2	36,000	2,000 - 70,000

B Average chemical and bacteriological values of weekly snap samples (8.8.61 - 14.9.61)

	DATA	No. of samples analysed	Mean	Range
	Approximate flow (cusecs)	5	2.5	2.0 - 3.0
	Temperature °C	5	24.6°	21.0°- 28.0°
	pH	5	7.6	7.2 - 8.7
	Conductivity as mmhos/cm.	4	444.4	330 - 715
	D.O. as ppm	3	0	0
	B.O.D. as ppm	1	93.6	-
As M.P.N.per 100 mls.	Total coliforms	5	1,276,600+	18,000+- 1,800,000+
	Faecal *E. coli*	5	1,093,400+	18,000+- 1,800,000+
	Faecal streptococci	5	31,200+	0 - 70,000

TABLE 5.

STATION 4 : TRIBUTARY AT WEIR BELOW EFFLUENT NO. 3

(SEE MAP)

A Average chemical and bacteriological values of composite samples of an 8-hour study (16.8.61 : 8 a.m. - 4 p.m.)

	DATA	No. of composite samples analysed	Mean	Range
	Approximate flow (cusecs)	4		2.5 - 3.5
	Temperature °C	4		23.0 - 31.0°
	pH	4	7.1	6.9 - 7.2
	Conductivity as mmhos/cm	4	1125	1000 - 1300
Expressed as parts p.m.	Total solids	4	705	540 - 1075
	Suspended solids	4	152	110 - 264
	Total hardness as $CaCO_3$	4	179	172 - 188
	Calcium hardness as $CaCO_3$	4	117	112 - 124
	Phosphate as PO_4	4	0	0
	Free & saline ammonia as N	4	3.4	2.2 - 5.6
	Albuminoid ammonia as N	2	2.8	2.6 - 2.9
	Nitrite as N	4	Nil	Nil
	Nitrate as N	4	0.05	0 - 0.2
	Sugar as Dextrose	4	5.9	0.2 - 23.0
	Dissolved oxygen	3	0	0
	O.A. (4 hours)	4	28.9	16.0 - 38.8
	B.O.D. (5 days)	2	160.0	120 - 200
As M.P.N. per 100 mls.	Total coliforms	2	1,800,000+	-
	Faecal E. coli	2	1,020,000+	240,000 - 1,800,000+
	Faecal streptococci	2	28,000	23,000 - 33,000

B Average chemical and bacteriological values of weekly snap samples (8.8.61 - 14.9.61)

	DATA	No. of snap samples analysed	Mean	Range
	Approximate flow (cusecs)	5	3.4	3.0 - 3.5
	Temperature °C	5	22.8	19.5 - 26.0
	pH	5	7.4	7.2 - 7.8
	Conductivity as mmhos/cm.	5	763.4	682 - 869
	Dissolved Oxygen as ppm	3	0	0
	B.O.D. as ppm	1	146	146
As M.P.N. per 100 mls	Total coliforms	5	1,258,000+	350,000 - 1,800,000+
	Faecal E. coli	5	952,000+	110,000 - 1,800,000+
	Faecal streptococci	5	732,000	0 - 1,600,000

TABLE 6.

STATION 5 : EFFLUENT FROM FACTORY (CONTAINS LIME ON OCCASIONS) SEE MAP

A Average chemical and bacteriological values of composite samples of an 8-hour study (16.8.61 - 8.00 a.m. to 4.00 p.m.)

DATA		No. of composite samples analysed	Mean	Range
Approximate flow (cusecs)		4		2.0 - 2.5
Temperature °C		4		31.0 - 44.0
pH		4	7.5	7.4 - 7.6
Conductivity as mmhos/cm		4	1187.5	1000 - 1400
Expressed as parts per million	Total solids	3	2433.3	1800 - 2800
	Suspended solids	3	1190	770 - 1800
	Total hardness as $CaCO_3$	4	286.5	174 - 440
	Calcium hardness as $CaCO_3$	4	234	160 - 356
	Phosphate as PO_4	4	Nil	Nil
	Free & Saline ammonia as N	4	2.0	1.0 - 2.8
	Albuminoid ammonia as N	2	1.0	0.8 - 1.2
	Nitrite N	4	0.05	0.02
	Nitrate N	4	Nil	Nil
	Sugar as Dextrose	4	2.3	1.8 - 3.2
	Dissolved oxygen	5	0	0
	O.A. (4 hours)	4	181.2	130.4 -310.0
	B.O.D. (5 days)	1	170.0	-
As M.P.N. per 100 mls.	Total coliforms	2	18,000+	-
	Faecal E. coli	2	18,000+	-
	Faecal streptococci	2	9,475+	950 -18,000+

B Average chemical and bacteriological values of weekly snap samples (8.8.61 to 14.9.61)

DATA		No. of snap samples analysed	Mean	Range
Approximate flow (cusecs)		5	2.5	-
Temperature °C		5	36.0°	28.5° - 43.0°
pH		5	8.5	7.4 - 10.2
Conductivity as mmhos/cm		5	345.4	286 - 429
D.O. as ppm		3	0.6	0 - 1.8
B.O.D. (5 days) as ppm		1	230	-
As M.P.N. per 100 mls.	Total coliforms	5	105,770+	950 - 180,000+
	Faecal E. coli	5	71,970+	950 - 180,000+
	Faecal streptococci	5	11,920+	1,700 - 22,000

TABLE 7.

STATION 6B : TRIBUTARY FROM SUGAR MILL FACTORY (BELOW PHOENIX) NEAR CONFLUENCE WITH PIESANG RIVER (SEE MAP)

A Average chemical and bacteriological values of composite samples of an 8-hour study (16.8.61 - 8 a.m. to 4 p.m.)

DATA		No. of composite samples analysed	Mean	Range
Approximate flow (cusecs)		1		0.80 - 1.50
Temperature		4	16.C°	-
pH		4	6.5	6.3 - 6.8
Conductivity as mmhos/cm		4	2025	1850 - 2200
Expressed in parts per mil.	Total solids	4	2777	1080 - 7800
	Suspended solids	2	28.5	28.0 - 29.0
	Total hardness as $CaCO_3$	4	416.5	410 - 424
	Calcium hardness as $CaCO_3$	4	276	232 - 296
	Phosphate as PO_4	4	trace	Nil
	Free & Saline Ammonia as N	4	1.3	0.3 - 3.7
	Albuminoid Ammonia as N	2	0.9	0.5 - 1.3
	Nitrite N	4	0	0
	Nitrate N	4	0.05	0 - 0.2
	Sugar as Dextrose	4	0.35	0.3 - 0.5
	Dissolved Oxygen	5	0	0
	O.A. (4 hours)	4	63.6	44.8 - 77.6
	B.O.D. (5 days)	-	-	-
As M.P.N. per 100 mls.	Total coliforms	2	1,800,000+	-
	Faecal E. coli	2	100,000+	20,000 - 180,000+
	Faecal streptococci	2	27,000	5,000 - 49,000

B Average chemical and bacteriological values of weekly snap samples (8.8.61 - 14.9.61)

DATA		No. of Snap samples analysed	Mean	Range
Approximate flow (cusecs)		5	1.4	0.5 - 2.5
Temperature °C		5	18.0°	15.0° - 20.0°
pH		5	7.3	6.7 - 7.7
Conductivity as mmhos/cm		5	915.2	550 - 1254
D.O. as ppm		3	1.1	0.0 - 1.9
B.O.D. (5days) as ppm		1	87.6	-
Expressed as M.P.N. per 100 mls.	Total coliforms	5	538,000+	180,000+ - 1,800,000+
	Faecal E. coli	5	7,680	0 - 33,000
	Faecal streptococci	5	7,680	0 - 33,000

TABLE 8.

STATION 7B : PIESANG RIVER ABOVE CONFLUENCE WITH TRIBUTARY FROM SUGAR MILL FACTORY (SEE MAP)

A Average chemical and bacteriological values of composite samples of an 8-hour study (16.8.61 - 8 a.m. to 4 p.m.)

	DATA	No. of composite samples analysed	Mean	Range
	Approximate flow (cusecs)	-	-	0.15 - 0.20
	Temperature °C	-	-	-
	pH	4	7.9°	7.8° - 8.0°
	Conductivity as mmhos/cm	4	1887.5	1700 - 2000
Expressed as parts per mil.	Total solids	4	632.5	620 - 650
	Suspended solids	4	6.0	0 - 14
	Total hardness as $CaCO_3$	4	213	208 - 216
	Calcium hardness as $CaCO_3$	4	73	72 - 76
	Phosphate as PO_4	4	Nil	Nil
	Free & Saline Ammonia as N	4	0.075	0.1 - 0.2
	Albuminoid Ammonia as N	2	0.25	0.2 - 0.3
	Nitrite N	4	Nil	Nil
	Nitrate N	4	Nil	Nil
	Sugar as Dextrose	4	0.075	0.0 - 0.1
	Dissolved Oxygen	5	7.0	5.8 - 7.6
	O.A. (4 hours)	4	3.6	1.8 - 6.0
	B.O.D. (5 day)	-	-	-
As M.P.N. per 100 mls.	Total coliforms	2	400	0 - 800
	Faecal *E. coli*	2	100	0 - 200
	Faecal streptococci	2	Nil	Nil

B Average chemical and bacteriological values of weekly snap samples (8.8.61 - 14.9.61)

	DATA	No. of snap samples analysed	Mean	Range
	Approximate flow (cusecs)	5	0.2	-
	Temperature °C	5	17.2°	14.0° - 19.0°
	pH	5	7.4	6.0 - 8.0
	Conductivity as mmhos/cm	5	864.6	660 - 1045
	Dissolved Oxygen as ppm	3	6.4	5.6 - 6.9
	B.O.D. as ppm	1	3.2	3.2
Expressed as M.P.N. per 100 mls	Total coliforms	5	428	130 - 800
	Faecal *E. coli*	5	408	130 - 700
	Faecal streptococci	5	22	0 - 50

TABLE 9.

STATION 8 : TRIBUTARY OPPOSITE FIRST LAGOON OF SEWAGE WORKS (ABOVE CONFLUENCE WITH PIESANG RIVER) SEE MAP.

A Average chemical and bacteriological values of composite samples of an 8-hour study (16.8.61 - 8 a.m. to 4 p.m.)

DATA		No. of composite samples analysed	Mean	Range
Approximate flow (cusecs)		3		1.0 - 1.5
Temperature °C		4	8.1	15.0 - 16.8
pH		4	1987.5	7.7 - 8.3
Conductivity as mmhos/cm				1850 - 2100
Expressed as parts per million	Total solids	4	740	670 - 820
	Suspended solids	4	11.8	0 - 27
	Total hardness as $CaCO_3$	4	327	280 - 364
	Calcium hardness as $CaCO_3$	4	143	72 - 184
	Phosphate as PO_4	4	Nil	Nil
	Free & Saline Ammonia as N	4	0.1	0 - 0.2
	Albuminoid Ammonia as N	2	0.3	0.3
	Nitrite N	4	0	0
	Nitrate N	4	0.1	0.0 - 0.5
	Sugar as Dextrose	4	0.05	0.0 - 0.1
	Dissolved Oxygen	4	5.4	0.3 - 9.5
	O.A. (4 hours)	4	9.8	4.8 - 17.2
	B.O.D. (5 days)	-	-	-
As M.P.N. per 100 mls.	Total coliforms	2	927,000+	54,000+ - 1,800,000+
	Faecal *E. coli*	2	144,000	8,000 - 280,000
	Faecal streptococci	※2	※Nil	※Nil

※ Dilutions too high.

B Average chemical and bacteriological values of weekly snap samples (8.8.61 - 14.9.61)

DATA		No. of snap samples analysed	Mean	Range
Approximate flow (cusecs)		4	1.8	1.0 - 2.5
Temperature °C		4	19.1°	18.8° - 19.5°
pH		3	7.6	6.5 - 8.2
Conductivity as mmhos/cm		4	1235.3	1001 - 1850
Dissolved Oxygen as ppm		3	6.0	3.6 - 7.5
B.O.D. (5days) as ppm		1	35	-
As M.P.N. per 100 mls.	Total coliforms	4	58,500+	18,000+ - 180,000+
	Faecal *E. coli*	4	54,370+	3,500+ - 180,000+
	Faecal streptococci	4	4,802.5+	220+ - 18,000+

TABLE 10.

STATION 9 : EFFLUENT FROM NO. 3 POND AND STORM/WATER DRAIN (KWA MASHU SEWAGE PURIFICATION WORKS) SEE MAP

A Average chemical and bacteriological values of composite samples of an 8-hour study (16.8.61 - 8 a.m. to 4 p.m.)

DATA		No. of composite samples analysed	Mean	Range
Approximate flow (cusecs)		3		0.8 - 1.2
Temperature °C		4		19.0° - 20.0°
pH		4	8.9	8.6 - 9.1
Conductivity as mmhos/cm		4	1312.5	1200 - 1500
Expressed as parts per million	Total solids	4	446.3	390 - 500
	Suspended solids	4	28.8	11 - 45
	Total hardness as $CaCO_3$	4	111.0	108 - 116
	Calcium hardness as $CaCO_3$	4	40	36 - 44
	Phosphate as PO_4	4	15.3	13.0 - 16.4
	Free & Saline Ammonia as N	4	1.1	0.6 - 1.4
	Albuminoid Ammonia as N	2	1.4	1.2 - 1.6
	Nitrite N	4	0.9	0.4 - 1.6
	Nitrate N	4	16.4	14.0 - 20.0
	Sugar as Dextrose	4	0.025	0.0 - 0.1
	Dissolved Oxygen	5	11.1	10.3 - 12.5
	O.A. (4 hours)	4	10.5	9.0 - 12.8
	B.O.D. (5 day)	-	-	-
As M.P.N. per 100 mls.	Total coliforms	2	18,000+	-
	Faecal E. coli	2	18,000+	-
	Faecal streptococci	2	8,250	3,500 - 13,000

B Average chemical and bacteriological values of weekly snap samples (8.8.61 to 14.9.61)

DATA		No. of snap samples analysed	Mean	Range
Approximate flow (cusecs)		5	0.8	0.6 - 0.9
Temperature °C		5	16.3°	14.5° - 21.0°
pH		4	8.3	7.5 - 9.2
Conductivity as mmhos/cm		5	756.8	616 - 880
D.O. as ppm		3	5.7	2.4 - 7.8
B.O.D. as ppm		1	7.1	7.1
Expressed as M.P.N. per 100 mls.	Total coliforms	5	14,060+	0 - 50,000
	Faecal E. coli	5	11,120	0 - 50,000
	Faecal streptococci	5	260	0 - 1,300

TABLE 11.

STATION 10 : PIESANG RIVER 20 YARDS BELOW KWA MASHU SEWAGE DISPOSAL WORKS EFFLUENT (SEE MAP)

A Average chemical and bacteriological values of composite samples of an 8-hour study (16.8.61: 8 a.m. to 4 p.m.)

DATA		No. of composite samples analysed	Mean	Range
Approximate flow (cusecs)		3		3.0 - 3.5
Temperature °C		4		19.0° - 21.0°
pH		4	7.7	7.5 - 8.2
Conductivity as mmhos/cm		4	1825	1650 - 2000
Expressed in parts per million	Total Solids	4	663.8	575 - 740
	Suspended Solids	4	34.8	10 - 65
	Total hardness as $CaCO_3$	4	281	256 - 296
	Calcium hardness as $CaCO_3$	4	146	132 - 152
	Phosphate as PO_4	4	3.1	1.5 - 5.4
	Free & Saline Ammonia as N	4	0.23	0 - 0.6
	Albuminoid Ammonia as N	2	1.4	0.8 - 2.0
	Nitrite N	4	0.3	0.0 - 1.2
	Nitrate N	4	3.5	0.2 - 8.0
	Sugar as Dextrose	4	0.025	0.0 - 0.1
	Dissolved Oxygen	5	4.2	2.4 - 5.6
	O.A. (4 hours)	4	13.3	11.2 - 15.6
	B.O.D. (5 days)	-	-	-
As M.P.N. per 100 mls.	Total coliforms	2	1,800,000+	1,800,000+
	Faecal E. coli	2	900,000+	0 - 1,800,000+
	Faecal streptococci	2	0	0

B Average chemical and bacteriological values of weekly snap samples (8.8.61 - 14.9.61)

DATA		No. of snap samples analysed	Mean	Range
Approximate flow (cusecs)		5	3.0	3.0
Temperature °C		5	19.5	15.0 - 21.5
pH		4	7.9	7.5 - 8.3
Conductivity as mmhos/cm		4	547.5	111 - 880
D.O. as ppm		3	2.7	2.3 - 3.25
B.O.D. as ppm		1	36	36
Expressed as M.P.N. per 100 mls.	Total coliforms	5	85,200+	18,000 - 350,000
	Faecal E. coli	5	17,800+	13,000 - 22,000
	Faecal streptococci	5	3,860+	0 - 18,000+

TABLE 12.

STATION 11 : FIESANG RIVER NEAR AVOCA ABOVE ZEEKOEVLEI (SEE MAP)

Average chemical and bacteriological values of weekly snap samples (8.8.61 - 14.9.61)

DATA		No. of snap samples analysed	Mean	Range
Approximate flow (cusecs)		5	3.0	2.0 - 3.5
Temperature °C		5	17.7°	14.0° - 20.5°
pH		4	7.1	6.4 - 7.8
Conductivity as mmhos/cm		5	974.6	869 - 1045
D.O. as p.p.m.		3	0	0
B.O.D. (5 days) as p.p.m.		1	⟨ 189	⟩ 189
Expressed as M.P.N. per 100 mls.	Total coliforms	5	358,800+	18,000+ - 1,600,000
	Faecal E. coli	5	82,800+	18,000+ - 220,000
	Faecal streptococci	5	5,276	230 - 14,000

TABLE 13.

STATION 12 : LOWER ZEEKOE RIVER (± 400 YARDS ABOVE UMGENI) SEE MAP

Average chemical and bacteriological values of weekly snap samples (8.8.61 - 14.9.61)

DATA		No. of snap samples analysed	Mean	Range
Approximate flow (cusecs)		5	3.4	2.5 - 4.0
Temperature °C		4	19.0	16.0 - 21.0
pH		4	7.3	6.1 - 7.8
Conductivity as mmhos/cm		5	1013	940 - 1100
D.O. as p.p.m.		3	0.9	0 - 2.8
B.O.D. (5 days) as p.p.m.		1	3.9	-
Expressed as M.P.N. per 100 mls.	Total coliforms	5	41,540+	800 - 180,000+
	Faecal E. coli	5	9,266	280 - 35,000
	Faecal streptococci	5	750	0 - 2,700

None of the stations had high values of nitrates or nitrites, except for Station 1, where a value of 1.5 ppm. Nitrate N was recorded in the 2 - 4 p.m. composite sample (Table 2A) of the 10-hour study.

The two main sources of sugar in the water are the effluents from the factory (Tables 4A and 6A). The one at Station 3, which was located on the more variable effluent, had a value of 23 ppm. dextrose sugar (Table 4A). In fact, at Station 6B, on the Mount Edgecombe stream near its junction with the Piesang river, sugar was still present in excess of 0.3 ppm. in all composite samples (Table 7A).

At Station 1, the oxygen dissolved in the stream was relatively high. The D.O. of the drain at Station 2, however, was practically nil on all occasions. The effluents from the factory were, moreover, depleted of oxygen on most occasions. In the stretch of the Mount Edgecombe stream above the Piesang river, where the conditions are septic, no dissolved oxygen was recorded except during the last two weeks of the survey when oxygen was just present at Station 6 B (Tables 7A and 7B).

The high O.A. values obtained at Station 2 (19.4 - 98.4 ppm.), Station 3 (14.4 - 56.4 ppm.), Station 4 (16.0 - 38.8 ppm.), Station 5 (130.4 - 310.0) and on the Mount Edgecombe stream at its junction with the Piesang river (44.8 - 77.6 ppm.), coupled with the very high B.O.D. and low dissolved oxygen values (see Tables 2A, 2B - 7A, 7B) reflect the bad condition of this stream. It was therefore not surprising to find the Piesang river below the junction with this tributary in a badly polluted state.

b. <u>The Piesang river above its junction with the Mount Edgecombe tributary (Stations 7A and 7B)</u>

The pH values were slightly higher than usual

for an undisturbed stream. In addition, high concentrations of solids in solution and O.A. (4 hour) of 1.8 - 6.0 ppm., ammonia of 0.2 - 0.3 ppm. (Table 8A), all indicated mild organic disturbance of this stream above its junction with the badly contaminated Mount Edgecombe stream.

c. The tributary opposite the Kwa Mashu sewage purification works (Tables 9A and 9B)

Although the pH, conductivity and O.A. values were higher than normal for an unpolluted stream, the chemistry of this tributary at Station 8, did not show any signs of pollution. At the most conditions can be described as mildly enriched. However, a variable diurnal dissolved oxygen contents (Table 9A) and an odd high B.O.D. value of 35 showed this stream to carry high organic loads at certain times of the day.

d. The combined effluent from the sewage purification works (Station 9)

The combined effluent of a storm water drain and of the No. 3 pond of the Kwa Mashu sewage purification works was sampled at its confluence with the Piesang river. It was very rich in phosphates and nitrates.

Dissolved oxygen values were high. Oxygen absorbed by permanganate (4 hours) did not exceed 12.8 ppm. Only one B.O.D. analysis was made (7.1 ppm.) on a snap sample.

e. The Piesang river below Station 10.

Results obtained at Station 10 and 11 clearly illustrate the deterioration of the stream (partly caused by the enrichment from the sewage purification works effluent) towards Station 11, where polysaprobic conditions existed (See Tables 11A, 11B and 12).

f. The Zeekoe (Piesang) river below Zeekoevlei (Table 13, page 74).

Only limited chemical analyses were made at Station 12. pH values obtained during the survey were mainly between 7 and 8. Conductivities were high, fluctuating around 1,000 mmhos/cm. The dissolved oxygen contents of the stream, when measured, were either low or nil.

VI SUMMARY

Preliminary surveys indicated that the Umgeni estuary and some of the streams flowing into it were polluted. A detailed hydrobiological survey was undertaken to establish the nature and actual sources of pollution. The survey was conducted along three lines viz. faunal, bacterial and physical-chemical analyses of the streams at carefully selected sampling stations along the Mount Edgecombe tributary, the Zeekoe (Piesang) river and the Umgeni estuary. The survey once more proved the importance of the examination of the stream fauna in the assessment of river pollution. Of special interest in this respect was the presence, quantitatively, of Eristalis sp., Tubifex sp., Aulophorus furcatus Oken and some Naididae in the badly polluted zones of the streams surveyed. Mild organic pollution was characterized by the large numbers of Nais sp., Nematoda and a rich variety of snails such as Bulinus spp., Lymnaea spp., and Biomphalaria pfeifferi (Krs). In the clean unpolluted stretches species of Ephemeroptera were dominant.

The conditions of the water at the stations along the Zeekoe river above Zeekoevlei not only reflected faecal contamination but also heavy pollution with a total depletion of oxygen at some places.

The Mount Edgecombe tributary proved to be the major contributor to the pollution of the Zeekoe (Piesang) river. As revealed by the fauna, bacteria and chemistry, foul pollution occurred in this tributary below the outfalls of a village drain and sugar mill effluents.

While the faunal associations in the Zeekoe (Piesang) river above its confluence with the Mount Edgecombe tributary showed no more than mild disturbance of the stream, that part of the river below the junction and down to the head of Zeekoevlei revealed further deterioration in the stream conditions due to the addition of nutrients from the Kwa Mashu Sewage Purification Works effluent.

A significant improvement was, however, revealed below Zeekoevlei where both the faunal associations and chemistry suggested only mildly enriched conditions. Variable but generally low bacterial values were recorded here.

At Station 1 in the Umgeni estuary below the confluence of the Zeekoe river, very mildly enriched conditions occurred. Proceeding downstream, however, the estuary was found to be badly polluted and contaminated with faecal bacteria by the combined effluent of a Board Mill factory and Steam Laundry. Large quantities of fibrous matter, which accumulated in the estuary, could be traced to the Board Mill factory effluent, while numerous storm water drains, and some small effluents discharging into the estuary, also contributed to its cumulative pollution. Some recovery in stream conditions was reflected by the fauna at station 4B, although the presence of some organisms like Eristalis sp. indicated foul conditions in the Estuary upstream from this site.

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X LIST OF ABBREVIATIONS USED IN TEXT

B.O.D.	=	Biochemical oxygen demand.
cusec	=	cubic feet per second.
D.O.	=	Dissolved oxygen.
M.P.N.	=	Most probable number.
N as in Nitrate N	=	Nitrogen
P as in faunal tables	-	Present but less than 0.05%.
p.p.m.	=	parts per million.