THE ECOLOGY OF PERCOLATING FILTERS CONTAINING A PLASTIC FILTER MEDIUM IN RELATION TO THEIR EFFICIENCY IN THE TREATMENT OF DOMESTIC SEWAGE

by

ANDREW DAVID WHEATLEY

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SUMMARY

The suitability of a new plastic supporting medium for biofiltration was tested over a three year period. Tests were carried out on the stability, surface properties, mechanical strength, and dimensions of the medium. There was no evidence to suggest that the medium was deficient in any of these respects.

The specific surface ($320m^2m^{-3}$) and the voidage (94%) of the new medium are unlike any other usedin biofiltration and a pilot plant containing two filters was built to observe its affects on ecology and performance. Performance was estimated by chemical analysis and ecology studied by film examination and fauna counts. A system of removable sampling baskets was designed to enable samples to be obtained from two intermediate depths of filter.

One of the major operating problems of percolating filters is excessive accumulation of film. The amount of film is influenced by hydraulic and organic load and each filter was run at a different loading. One was operated at $1.2m^3m^{-3}day^{-1}$ (BOD load $0.24kgm^{-3}day^{-1}$) judged at the time to be the lowest filtration rate to offer advantages over conventional media. The other filter was operated at more than twice this loading ($2.4m^3m^{-3}day^{-1}$BOD load $0.55kgm^{-3}day^{-1}$) giving a roughly 2.5x and 6x the conventional loadings recommended for a Royal Commission effluent.

The amount of film in each filter was normally low (0.05-3kgm^{-3} as volatile solids) and did not affect efficiency. The evidence collected during the study indicated that the ecology of the filters was normal when compared with the data obtained from the literature relating to filters with mineral media. There were indications that full ecological stability was yet to be reached and this was affecting the efficiency of the filters.

The lower rate filter produced an average 87% BOD removal giving a consistent Royal Commission effluent during the summer months. The higher rate filter produced a mean 83% BOD removal but at no stage a consistent Royal Commission effluent.

From the data on ecology and performance the filters resembled conventional filters rather than high rate filters.

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SECTION ONE

INTRODUCTION

SECTION 1

INTRODUCTION

1.1 THE HISTORICAL DEVELOPMENT OF THE PERCOLATING FILTER

Problems of waste disposal are largely a consequence of urbanisation. The large quantities of human waste produced as a result of high population densities cannot easily be rendered innocuous by micro-organisms of the natural environment. The earliest Persian and Greek civilisations are known to have overcome the problem by diverting natural water courses, through the urban areas, to act as sewage disposal systems. There were several advantages to the system: once built, it cost nothing; the process was continuous; and the obnoxious wastecarried downstream. In Britain the Romans produced similar schemes and traces of their complex sewers are still in use. With the downfall of Roman Britain a more rural existence was once again resumed and these systems fell into disuse. The urbanisation of the Middle Ages presented a similar waste disposal problem, but in this case it was solved with the minimum of effort, the waste being deposited in the streets. This practice, despite the appalling conditions of odour and disease which resulted from it, persisted until 1842 when, amidst sweeping social reform, Sir Edwin Chadwick revived the use of the water carriage system. This reduced the filth in the streets but converted the water courses into open sewers. The health hazard and intolerable pollution of the urban rivers resulted in the setting up of a Royal Commission to investigate methods of treating sewage (the first Royal Commission on River Pollution, 1868). The first processes were based on the ancient practice of using soil as a purifying agent; the waste water carrying the sewage was channelled onto the land, and the liquid purified as it percolated through the soil. It rapidly became apparent however that the volume of sewage which could percolate through the land in a suitable time was low, and to treat the sewage from large towns would require massive areas of land. This led to experiments to find the best type of soil for treatment. Sand was found to be the most efficient and clay the worst, thus establishing a relationship between the void space of the soil and the efficiency of treatment. At the St.Lawrence Experimental Station Massachusetts in 1890 (Stanbridge 1954), research showed that, by using gravel and stone instead of soil, it was possible to treat sewage at even higher rates. The potential of this discovery was rapidly recognised and in 1893, the first large scale stone beds were introduced at Salford Sewage Works by Josephe Corbett. Corbett not only devised an effective distribution system, by spraying the sewage onto the bed, but also realised the importance of a drainage system which allowed proper ventilation of the media (Stanbridge 1972).

Since this evolution the percolating filter has become the most common method of treatment and despite the reports of investigation, modification and variation of operation that 75 years of use has brought, the process remains essentially unchanged. It consists of a container filled with an inert medium supported on a drainage system. The sewage is sprayed over the surface of the medium producing the required contact between the micro-organisms responsible for treatment (which colonise the surface of the medium), the sewage as it percolates through the medium and the air in the void spaces between the pieces of medium.

The volume of water used in this country is currently rising at the rate of three percent per annum. At present the volume used is around 23 million cubic metres (5000 million gallons), equivalent to 400 litres per person per day. Two thirds of this supply is obtained either from water impounded in the upper reaches of rivers or from underground sources. The remaining one third is obtained from lowland rivers. Sewage effluent is already a significant proportion of some lowland rivers used in public supply, but the difficulty in meeting future demand from upland or undergound sources makes inevitable the increased use of this source of water. Therefore high quality effluents must be produced from sewage treatment both to provide the raw water for public supply and to meet the increased amenity demands of modern society. Present methods of sewage treatment depend on the aerobic activity of micro-organisms. The waste materials in the sewage are extracted and used in metabolism by micro-organisms growing in contact with the sewage, leaving the treated effluent suitable for discharge to a natural water course. The process involves a constant wastage of the micro-organisms involved, the surplus being removed by physical settlement prior to discharge. The necessary contact between organisms, sewage and air is achieved by two techniques:

1. The activated sludge process. In this process the micro-organisms and sewage are mixed in a tank and the mixture aerated by compressed air or by vigorous agitation.
2. Biofiltration. In this process sewage is passed over an inert medium on which the micro-organisms become established. The aeration is achieved by natural ventilation through the spaces between the medium.

Although historically the first process used, biofiltration still has certain advantages over activated sludge. Biological filters require virtually no skilled maintenance or close control, use less energy and are more versatile in responding to changes in flow and characteristics of the sewage than is the activated sludge process. Their major disadvantage is capital cost, and normally they are uneconomic in serving populations in excess of 50,000 because of the land they occupy (Jeger 1970).

1.2 OBJECTIVES OF THE INVESTIGATION

This thesis is a report on a three year experimental investigation (October 1972 - August 1975) to test the efficiency of a new random pack synthetic filter medium for treating domestic sewage. Synthetic biofiltration media have now been in general use for over a decade and the advantages they have over mineral media are now well established. The low density of synthetic materials, and the higher rates of filtration possible with synthetic media enable substantial savings to be made in the construction of biological filters. The use of these media has, however, been largely confined to preliminary high rate treatment removing large amounts of BOD but producing low quality effluents. To date therefore, economic synthetic media capable of removing smaller amounts of BOD at higher efficiency (that is, in excess of 90% removal, as in the case of conventional biological filtration) have not been available. The two media design variables which exert most influence on the efficiency of biological treatment are the specific surface area of the medium available to biological growth, and the void space between the pieces of medium allowing ventilation, discharge of solids, and drainage. Providing a large specific surface while retaining adequate voidage has in the past been the problem in selecting mineral media. Although plastic materials can be fabricated into shapes optimising the surface area to void space ratio, they also have to be capable of promoting uniform utilisation of the considerably greater surface areas at relatively low hydraulic loadings. This process is easier to promote in natural media where only 50% of the volume is voidage, and redistribution within the medium is possible. The modular synthetic media currently in use have channels through the depth of the medium and do not allow redistribution of the liquor within the medium. Such packings rely on a high irrigation rate to ensure adequate wetting of the available surface (Section 2, plate 2.1). One method of overcoming this problem of wetting at lower flows is to use random pack medium to promote a random flow pattern through the filter depth. A prototype random pack plastic medium was therefore devised for experimental trials to determine its suitability for producing high quality effluents at higher than conventional loadings. The new medium, is a corrugated, cylindrical design, and is thought to offer the maximum surface area to void space ratio while retaining an essentially simple form to minimise production costs. It was expected that the corrugations of the medium would assist in the distribution of liquor, each corrugation only being able to accept a certain volume of fluid with the surplus passing over into the next corrugation (Plate 2.1).

It is now well established that for a biological filtration system the quantity of bio-degradable material removed is affected by two environmental parameters; the ambient temperature, and the organic load applied (Hawkes

1963; Eden 1964; Bruce 1969). Both vary independently with the meteorological conditions and the flow of the sewage to the works. This means that studies on biological filtration are necessarily long term because of the need to observe the effect of seasonal variables. Two pilot scale biological filters were built for the project (design details Section 3) and operated at two different loadings. Routine tests were carried out on the effluent quality and regular observations made on the ecology of the two filters over the two and a half year experimental period (methods Section 4, results and discussion Sections 5 and 6). In addition an investigation into the physico-chemical nature of the medium was also carried out to determine its physical suitability as a filtration medium (Section 2).

1.2.1 Ecological Investigations

It is now well established that in conventional filters only a very thin film is necessary to achieve high efficiency BOD removals (reviewed in Section 5.1). Greater accumulations of biomass occlude the voidage of the medium and reduce efficiency by restricing the ventilation of the filter. One of the principal questions was whether the much great voidage associated with the new medium was sufficient to overcome this effect. In addition to the ambient temperature, one of the most important factors promoting film growth is the organic loading of the filter. To determine what affect this variable had on film accumulation in the new medium, one of the two available filters was irrigated at twice the rate of the other.

With the exception of two brief surveys on operating high rate filter plants using plastic media (Bruce, Merkens and Macmillan 1970; Water Research Centre 1974), there have been no systematic investigations into the ecology of synthetic media. Past research has shown that the physical characteristics of the media are an important influence on the diversity of the grazing fauna of the filter (reviewed in Section 5.1). The grazing fauna are important in controlling the film accumulation of the filter and this improves the efficiency by assisting the ventilation. Since the pilot plant was purpose designed for the project, the initial stages were to be spent maturing the filters thus enabling the sequence of colonization to be observed.

The results and discussion of the maturation and general ecology of the filters are presented in Section 5.

1.2.2 Investigations into the Performance

The new medium has five times the surface area and twice the voidage of conventional medium and was expected to be more efficient in biofiltration. The important criterion in this respect was a BOD removal greater than 90%, to produce an effluent conforming to the 5th Royal Commission Standard (1908). When a consistently high quality effluent is required, it is often necessary to forego the maximum possible efficiency, in terms of the quantity of biodegradable material removed per unit volume of medium, to ensure reserve capacity to effectively treat the seasonal variation in sewage strength.

Important in this respect was the mechanism by which the BOD removal was taking place. There is evidence that at conventional hydraulic loadings most of the BOD removal occurs in the first one third of the filter (reviewed in Section 5.1). At higher rates of filtration, there is evidence of a more even removal of BOD down the total depth of the filter, (reviewed in Section 6.1). By sampling effluent at successive levels in each filter the progress of BOD removal was to be followed through the depth of the filters at two different hydraulic loadings.

Sewage is a complex mixture and a whole range of removal processes occur in biofiltration (reviewed in Section 6.1). In high rate filtration however, there is evidence that some of these processes are reduced in range and extent and that high rate filtration is most affective removing the soluble component of sewage (reviewed in Section 6.1). Both the soluble and the total BOD removals therefore, were tested todetermine which was the major removal process

Crucial to the mechanism of removal is the residence time of sewage in the filter. High efficiency removals are dependent on the sewage being able to flow over the bios as a thin film to give maximum contact between the biological film and the liquid. Three factors affect the residence time, the hydraulic loading, type of distribution, and the shape of the media. Comparisons of the residence time at the two different hydraulic loadings and with two different types of distribution were therefore planned.

Ideally, since every treatment plant and the characteristics of every sewage varies, pilot scale investigations into treatability in situ should be carried out. Practically, because of the long term nature of such trials, this procedure is not always possible. One possibility is to incorporate empirical data into a mathematical model which may then be used to design plant in different locations. One of the aims of the project was to use the empirical data of the experimental trials in a mathematical model, to describe the affects of operating variables: hydraulic loading, organic loading and temperature on the performance of the filter.

With increasing emphasis placed on the degree of nitrification and reports in the literature concerning the effect of organic and hydraulic loading on nitrification (Section 6.1.4), ammonia and oxidised nitrogen were measured at different depths through the filter to determine what affect the increased loads had on nitrification.

The results and discussion on the performance of the medium are presented in Section 6.

1.2.3 Physico-Chemical Investigations

The media used in the experiments was a prototype which had not been previously used in any long term trials. No accurate data on its physical or mechanical characteristics therefore existed.

In 1968 the ideal physical properties of supporting medium were reviewed by the Department of the Environment:

1. It must offer a large surface area per unit volume for biological growth, the nature of the material being such that it will promote the uniform spread of the liquid to all parts of the available surface.

2. The liquids being purified must be able to flow over the bios as a thin film to produce maximum contact between film and liquid.

3. There must be adequate void space to allow steady ventilation and free flow of the effluent under all conditions.

4. It must be chemically inert, not degrading with age or in the presence of small quantities of organic solvents.
5. It must be mechanically stable, being able to tolerate long term subjection to compressive stress.

Therefore, as a third facet to the project, experiments to test the stability and wettability of the media were devised. A random sample was also statistically analysed to determine the weight, dimensions, surface area and voidage of the media. The results of this investigation are presented in Section 2.

1.2.4 Limitations of the Investigation

Finance and facilities were made available for a three year project beginning in October 1972. The pilot plant was designed late in 1972 and construction commenced early the following year. Construction problems and subsequently certain modifications delayed the start-up of the plant until April 1973. As with any intricate new mechanical equipment, the first two months of operation were not without problems. This meant a rather protracted maturation period lasting until August 1973.

The most serious limitation to the extent to which research data obtained from pilot scale investigations can be used in practical situations is caused by the difference in size. The hydraulic characteristics of the lower flows produce different irrigation problems from those associated with higher flows (Bruce, Merkens & Haynes 1975; Hambleton & Kirby 1974).

Ideally, because of these limitations, a pilot filter containing mineral media should have been operated under the same conditions to quantify these differences. Financially a third pilot plant was not possible, and it was felt that if any useful data was to be obtained from operations at the different hydraulic loadings, a test period of two years was the minimum (Bruce, Merkens & Haynes 1975; Solbe, Williams & Roberts 1967). This required the use of a separate filter at each loading.

Despite these limitations, pilot scale studies remain the only method of determining the affect of the environmental variables (the characteristics of the sewage and the meteorological conditions) on performance, in a given situation.

A further limitation was that the medium investigated was a prototype. The equivalent medium now being marketed by ICI (Flocor RC) is slightly different in dimensions (Rogers 1974).

It was decided for simplicity in comparing the affects of the two different loadings, that one filter should be operated at twice the hydraulic load of the other.

Three factors influenced the setting of the lower rate:

(a) Experience with the apparatus showed that $1.2m^3\ m^{-3}\ day^{-1}$ was the minimum pipe velocity required to maintain self cleansing;

(b) At the time $1.2m^3\ m^{-3}\ day^{-1}$ represented the minimum flow which would produce significant economic advantage over mineral media (Appendix 1);

(c) Twice the lower rate $2.4m^3\ m^{-3}\ day^{-1}$ was approaching the definition of high rate filtration proposed by the Department of the Environment (1968) ($3.0m^3\ m^{-3}\ day^{-1}$).

SECTION TWO

THE MEDIUM

SECTION 2

THE MEDIUM

2.1 THE DEVELOPMENT OF PLASTIC MEDIA

After the evolution of the percolating filter the medium remained at the focus of the investigations for greater efficiency. Thompson (1925) observed that certain media degraded with age. This reduced efficiency by blocking the filter with fining. This established one of the important characteristics of media, that it should be mechanically stable and be able to withstand long term subjection to compressive stress.

Two years prior to Thompson's research, Leo Baekeland patented the first synthetic material, Bakelite.

Later work by Levine, Leubbers, Galligan and Vaughan (1936) on the efficiency of treatment using different types of media included two types of artificial media, 'potrashig rings' and clay blocks. Levine and his colleagues found that performance was proportional to the surface area of the medium. Both the artifical media, having significantly larger surface areas than the natural media, gave improved performance. This established a second important characteristic, that the medium should offer a large surface area per unit volume for biological growth.

There were however two problems associated with the artificial media; one was their brittle nature, the other was their cost in relation to natural media. This in turn established a third characteristic; that media should be economic in relation to other available materials.

During the next twenty years interest centred on the new methods of operation, alternating double filtration, recirculation, and low frequency dosing (they are reviwed historically by Jenks 1937). In this intervening period Karl Zeigler succeeded in polymerising ethylene, the first totally synthetic material.

Schroepfer (1951), in investigations into a number of media to determine the effect of shape on performance, concluded that the media units should be almost spherical. Excessively long or flat particles reduced the interstitial voidage and reduced ventilation.

A number of investigations into the ideal characteristics of media followed (Hawkes and Jenkins 1955; Wilkinson 1958; Truesdale, Wilkinson and Jones 1962). In all these studies the smaller media consistently produced better results, offering the larger surface area, but suffered from a susceptibility to occlusion of the voids by excessive biological growth. Truesdale _et al_. (1962) in their investigation established a fourth important feature. They concluded that to generate the maximum retention time the shape of the media should promote the formation of as thin a film of sewage as possible over the bios. By this time, plastic materials were relatively common and had already found a wide range of uses, including as filling media in mass transfer and heat transfer towers (Noble 1966). In 1958 the Dow Chemical Corporation introduced a polystyrene packing for use as a biological filter media (Bryan and Moeller 1960). Almost parallel development in this country (Chipperfield 1964) produced an ICI polyvinyl chloride packing in 1963 (Robjohns 1963). Although the technical superiority of the synthetic over the conventional media was demonstrated (Pearson 1965; Eden, Truesdale and Mann 1966; Bruce 1969), deliberate design of media produced serious economic obstacles. The cost of the new media was three times that of conventional media (Anon. 1969).

This restricted the use of plastic packings to high rate 'roughing' functions, with the removal of large weights of BOD per unit volume of media at relatively low efficiencies of removal in terms of the BOD concentration (50% to 80%). High rate filtration, therefore, requires a packing shaped to promote uniform flow of large volumes of liquor over the surface of the media while preventing short cutting, or free fall. The media are characterised by being constructed of alternate corrugated sheets in modular packings, and by requiring the application of a minimum irrigation rate to maintain efficiency (plate 2.1). A number of such media are marketed by different companies and have gained wide acceptance in high rate filtration of

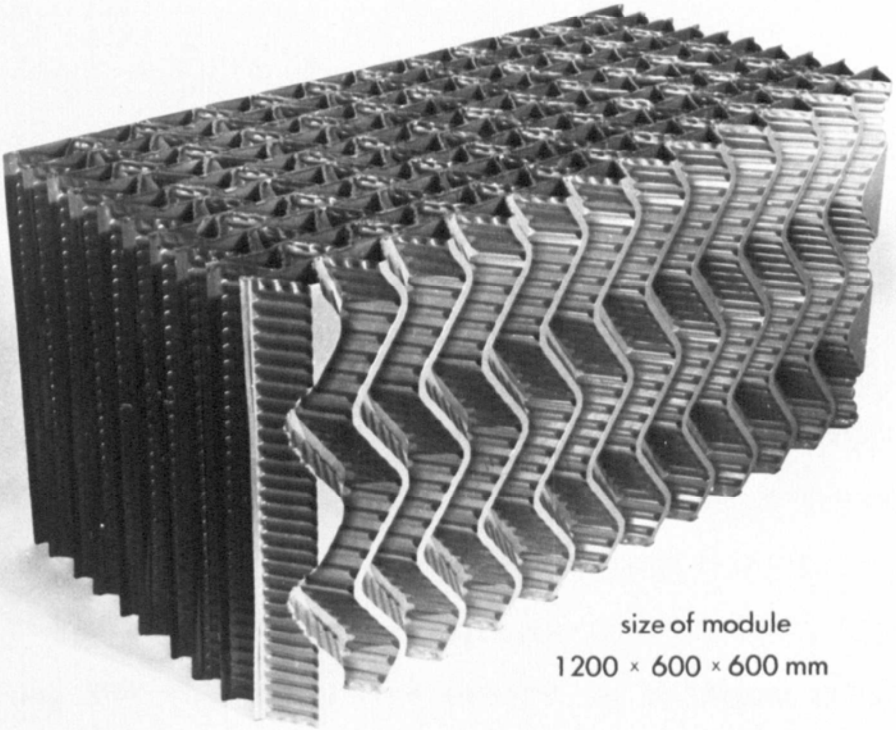
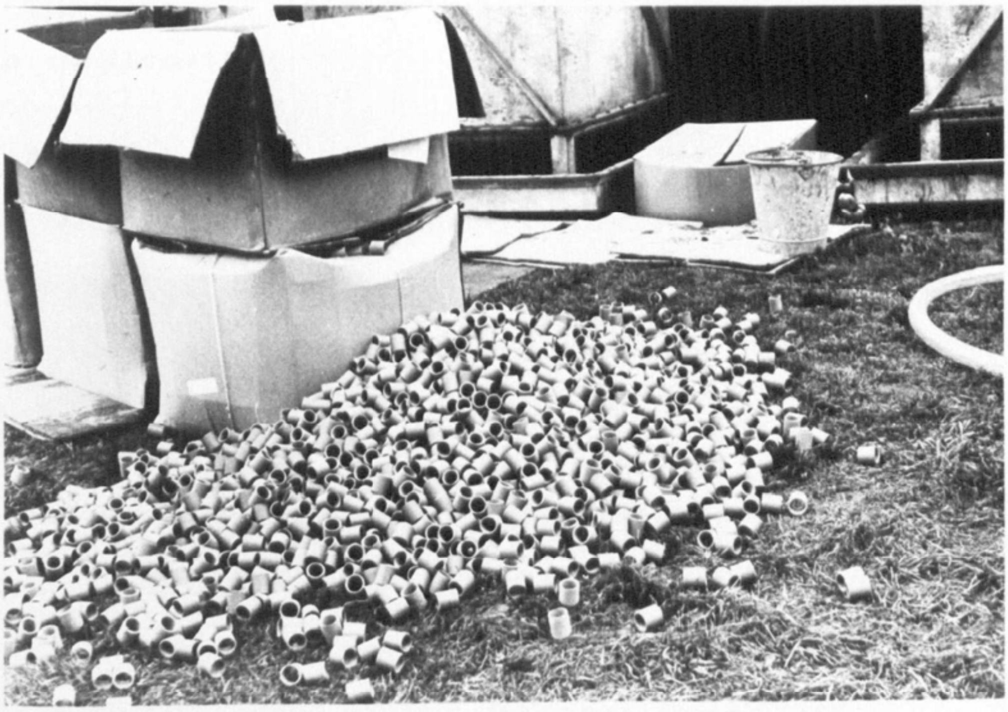


Plate 2.1 ICI SYNTHETIC MEDIA

(a) High rate modular filter medium 'Flocor E'



(b) The new random medium 'Flocor RC' prior to loading into the experimental filters both industrial and domestic wastes (Anon 1973). More recently random plastic filter media have been introduced to increase the surface area and improve redistribution of the flow within the filter (Ramsden I. 1972).

2.2 CHEMICAL NATURE OF THE MEDIUM

A number of synthetic polymeric materials exist which are less expensive than PVC the material from which the new medium is made. The majority of these alternative polymers lack the stability necessary for filtration media. Certain resins, for example, have proved to be chemically and biochemically degradable. Polystyrene, polyvinylidiene chloride, polypropylene and polyethylene, on the other hand, although more resistant to biochemical breakdown, possess a low degree of rigidity and strength and require support in construction.

Polyvinychoride is thought to offer the best compromise between cost and stability and has been adopted by ICI for media in water cooling, gas absorption and flume scrubbing as well as in biological filtration systems (Chipperfield 1967).

The media used in the experiments was a prototype and no accurate data existed concerning its stability under operating conditions. A programme of tests was therefore devised to determine some of its physical properties.

2.3 PHYSICAL PARAMETERS

The dimensions of 200 units were analysed Tables 2.1 and 2.2.

	Length	Diameter	Weight
	cm	cm	grms
MEAN	3.82	3.4	4.55
S.D.	0.11	no	1.00
C.V.	2.93	variation	8.70
S.E.	0.01		0.03
RANGE MIN	3.50		4.00
MAX	4.10		5.70

TABLE 2.1 : Physical parameters single module mean of two hundred measurements

Media	Weight	Number	Specific surface	Voidage
			m^2m^{-3}	
+Flocor RC	91.1 kg	20×10^3	max min 320 132	90%
6.3 mm Blast *Furnace Slag.	1350 kg	-	100	50%

TABLE 2.2 : Physical parameters m^3 of the experimental media.
+calculated from the data in table 2.1
*taken from Bruce 1968

The largest variation in the physical parameters occurred in the weights of the media. Statistical analysis of the data revealed two populations of media. The difference did not correlate with a variation in dimensions and was attributed to differences in the thickness of PVC.

2.4 STABILITY

2.4.1 pH Stability

Initial tests on stability were carried out by subjecting the media to extremes of pH. Samples (200 units) were immersed in sodium hydroxide pH 10 and sulphuric acid pH 2 solutions for five days and the weights re-examined; there was no significant change Table 2.3.

	Control		pH 2.0		pH 10	
	1st	2nd	1st	2nd	1st	2nd
Mean	4.4304	5.5056	4.4569	5.5416	4.4061	5.4853
Variance	1.0016	1.0005	0.0352	0.0254	0.0402	0.0177
S.D.	1.0008	1.0002	0.1877	0.1595	0.2005	0.1329
Range	0.8468	0.3838	0.9327	0.5763	1.2963	0.5718
Min Value	4.0193	5.3472	4.0093	5.2753	3.5567	5.1854
Max Value	4.8661	5.7310	4.9420	5.8516	4.8530	5.7572

TABLE 2.3 : Statistical analysis weight check with change in pH mean of 200 observations in grams

Changes in synthetic polymers under similar conditions are known to occur. Some polymers, for example polypropylene, are known to absorb water and increase in weight while others are known to lose weight through the loss of the inorganic filler incorporated into the polymer.

2.4.2 The leaching of metallic stabilisers

Organo-metallic compounds are used in both the preparation and stabilisation (against oxidation) of synthetic polymers. It was considered possible that some of, or any excess of, these compounds might be leached out by the water flowing over the polymer (Packham 1971).

Two test procedures were devised. One to determine the potential concentration of metals within the plastic, and secondly the extent of leaching from the plastic under normal operating conditions. A number of other compounds, normally complex organic molecules, are included in the plastics as dyes, anti-oxidants, agents to assist in moulding, or compounds as simple 'builders' to increase the volume of the plastic without increasing the volume of the actual polymer. No information exists concerning the potential toxicity of these compounds. There is however some literature on the toxicity of the organo-metallic compounds and the leaching effect from uPVC material (Packham 1971; Boelens 1960; Nicklas and Mayer 1961). In every case however the levels of leached metals fell sharply following one or two days use of the plastic material.

The possible stabilising, moulding, and other agents used in this particular polymer are not readily available since the polymer is already formulated on arrival for production.

Methods

(a) X-Ray Analyser

This device coupled to a scanning electron microscope is capable of qualitative and quantitative inorganic analysis. The technique depends on the differing energy characteristics of the elements under the electron microscope. There are two problems with the technique. It is only able to sample a very small area, and probe only the molecular structure at the surface. The quantitative analytical results are also crude, that is it can only differentiate between very small quantities and significant quantities. A sample of approximately $5mm^2$ was subjected to X-ray analysis.

(b) Atomic Absorption

Since it was already known that it was possible to leach metals from plastic, previously unused media were sealed into a vessel volume $13.3 \times 10^3 cm^3$ and distilled deionised water continually recirculated over the media. This was done using a peristaltic pump, to eliminate metallic contamination from the pump. A sample was withdrawn from the vessel every day for seven days for analysis by atomic absorption. This data was compared with control data produced from the same apparatus without the media, prior to the test run.

Results

(a) X-Ray Analysis

The X-Ray analysis revealed significant levels of chlorine, calcium, phosphorus and carbon but the concentrations of the metals were not significant above the background levels.

(b) Atomic Absorption

CONTROL RUN							
METAL	DAY 1	2	3	4	5	6	7
CADMIUM	0.001	0.003	0.023	0.001	0.002	0.001	0.04
CHROMIUM	0.002	0.002	0.002	0.002	0.004	0.004	0.002
COPPER	0.012	0.012	0.036	0.014	0.017	0.018	0.012
NICKEL	0.002	0.002	0.002	0.002	0.002	0.002	0.002
ZINC	0.005	0.012	0.020	0.010	0.020	0.030	0.070
LEAD	0.010	0.020	0.017	0.010	0.010	0.010	0.012

TEST RUN							
METAL	DAY 1	2	3	4	5	6	7
CADMIUM	0.09	0.03	0.07	0.05	0.04	0.03	0.05
CHROMIUM	0.002	0.002	0.002	0.002	0.002	0.002	0.002
COPPER	0.012	0.001	0.003	0.004	0.009	0.007	0.002
NICKEL	0.002	0.002	0.002	0.002	0.002	0.002	0.002
ZINC	0.37	0.23	0.30	0.39	0.36	0.36	0.33
LEAD	0.12	0.16	0.20	0.20	0.19	0.20	0.20

TABLE 2.4 : Atomic Absorption Analysis Results in mgl^{-1}

Conclusions

1. X-Ray profile: the high levels of carbon and chlorine can be attributed to the structure of the polymer itself the calcium and phosphorus to the presence of a 'builder' probably calcium phosphate.

2. Leaching tests: the results show significant changes in the concentration of zinc lead and cadmium. In all cases the increase was about ten-fold. The other metals show negligible changes. Whether this increase is liable to cause any significant toxicity or inhibition is doubtful. All the levels are below thos normally encountered in settled sewage.

SEWAGE	METALS		
	Zinc	Lead	Cadmium
Langley Mill settled sewage	0.350	0.150	0.00
Minworth settled sewage	0.976	0.224	0.10
Langley Mill filter effluent	0.150	0.130	0.00
Minworth filter effluent	0.347	0.190	0.01

TABLE 2.5 : Mean Total Metals mgl^{-1} settled sewage and effluents Langley Mill a domestic sewage and Minworth an industrial sewage

3. The concentration of the leached lead from 4.0 m^2 of PVC surface was less than that recorded elsewhere from PVC. Packham (1971) noted an accumulated total of 30 mgl^{-1} from 1.0 m^2 surface with one type of PVC.

4. It is significant that in all cases of increased metals, they reached a maximum in a short time. The zinc and cadmium after one day and the lead after three days. This seems to confirm Packham's observations that there is an initial leaching of metals not bound to the polymers after which no significant leaching takes place.

2.5 SURFACE PROPERTIES

Although plastic materials can be formulated into designs of large surface areas, they also have to be capable of promoting effective use of this area. PVC and plastics in general have very flat surfaces plate 2.4 (plate 2.4 shows the surface of the new medium compared with slag and granite.) This produces high contact angles at the interphase with water. It was thought possible that this hydrophobic characteristic might prove restrictive in making effective use of this surface. Electron micrographs (plates 2.2, 2.3) following use of the media indicated that microbial growth does occur in the indentations of the media. With the surface of the media becoming covered by active film the wetting characteristics and surface properties change. Medium deeper in the filter

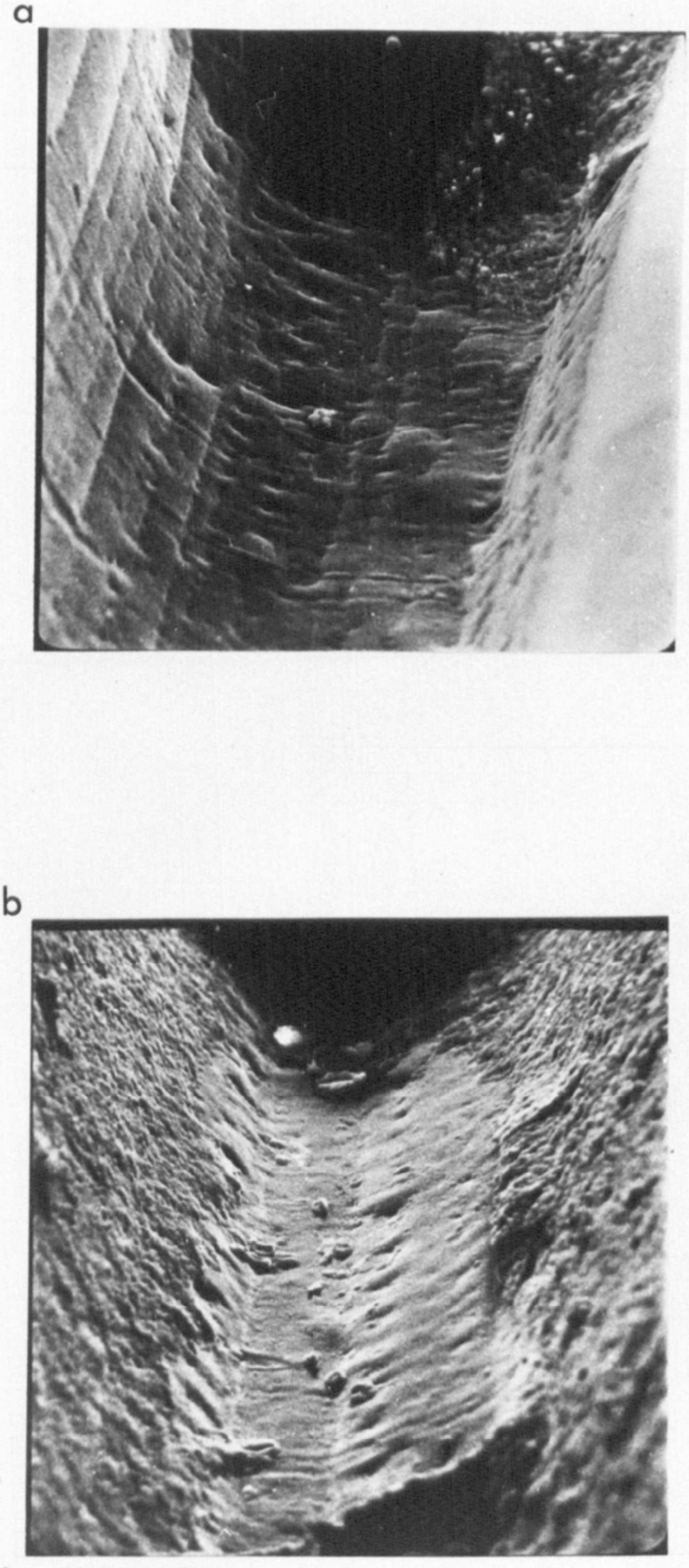


Plate 2.2 ELECTRON MICROGRAPH OF A TROUGH ON THE OUTSIDE SURFACE OF THE MEDIA (x100)

(a) Media prior to use

(b) Media with film

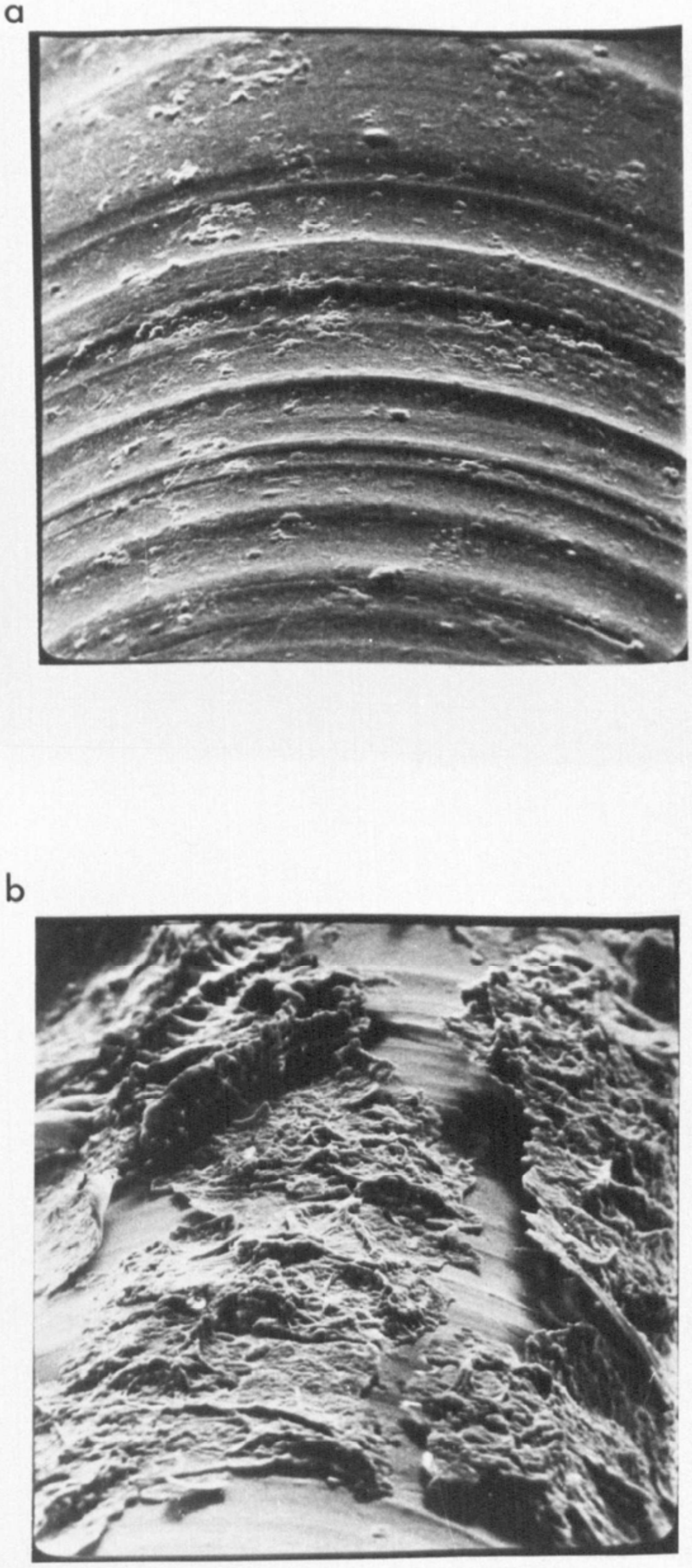


Plate 2.3 ELECTRON MICROGRAPH OF A RIDGE ON THE INSIDE SURFACE OF THE MEDIA (x 100)

(a) Media prior to use

(b) Media with film

a

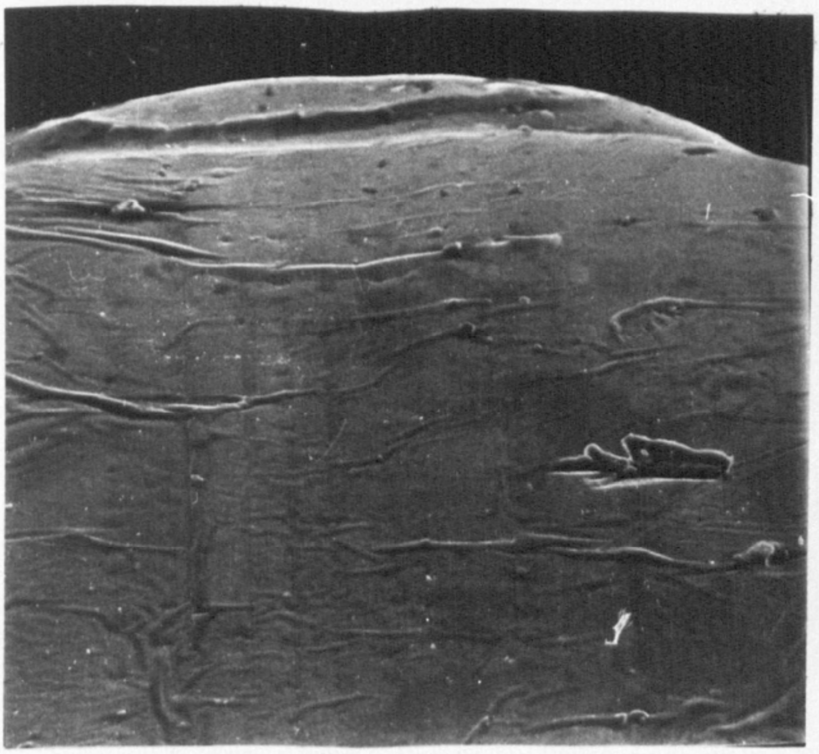


Plate 2.4 ELECTRON MICROGRAPH OF THE SURFACE OF MEDIA

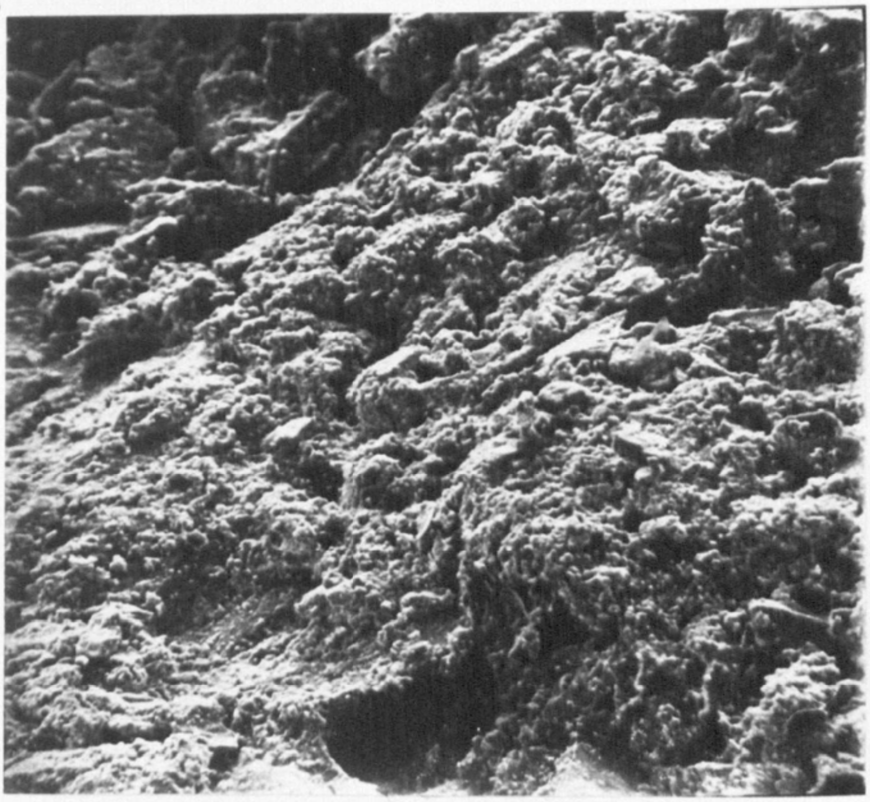
(×100)

(a) Experimental media

(b) Furnace slag

(c) Granite

b



c

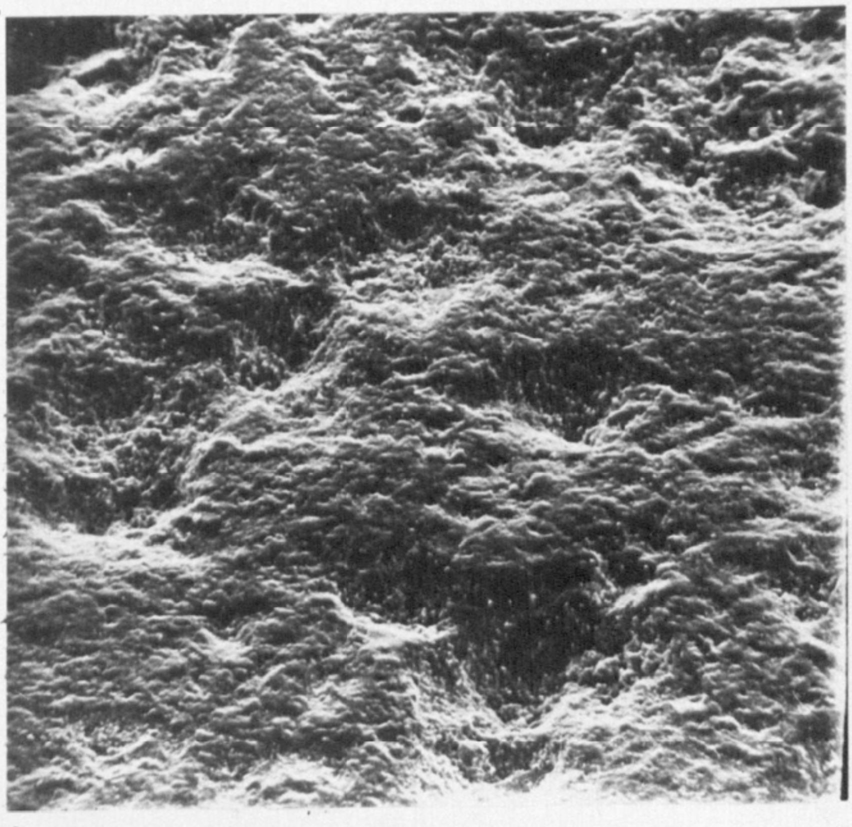


Plate 2.4

where less film growth occurs would retain their hydrophobic nature. Surface etching of the medium in this region might be expected to improve the physico-chemical removal of the material in suspension by increasing the surface activity.

Film distribution on the medium indicated that 90% of the available surface area was potentially usable with effective distribution. It was considered possible at one stage that, because of its rectangular shape the medium might pack in a predominant pattern. Test packing showed the first units did pack in a pattern but the uneven surface produced ensured the remainder was random. The horizontal position is the least efficient in terms of surface utilisation, but after this first layer most of the units lay out of the horizontal.

Tests were also carried out with different packed depths of medium to determine the extent of the lateral flow through the medium. It was found to increase with depth, a half metre increase in depth produced a 100 mm increase in lateral distribution. A drum containing different depths of the medium, mounted above a series of concentric collecting troughs was used for this purpose. The proportion of the applied liquor recovered in each ring was then measured. The tests revealed that the flow pattern was conical producing greater wetting around the periphery of the cone shaped pattern.

DEPTH	LATERAL SPREAD	
	0-50	50-150
150	56.5	39.5
300	17.0	75.0
500	3.0	86.0

TABLE 2.6 : The percentage recovery of water in a circular area between 50 mm and 150 mm. Each value is the mean of ten measurements.

Observations of the medium in use

Changes in the media used in biofiltration were observed. Anaerobic conditions at the surface of the medium, such as results from excessive film growth, produced black staining of the normally grey medium. The staining is produced by metallic sulphides which have been adsorbed onto the surface of the medium. The staining can only be removed by vigorous scraping of the media.

2.6 COMPRESSION TESTS

A series of compression tests to determine the strength of the medium were carried out with loads up to 1.5×10^3 kgm^{-2}. The results show continual compression following Hooks law without a collapse point up to this load, fig.2.1. A 1% compression occurs every 500 kgm^{-2}

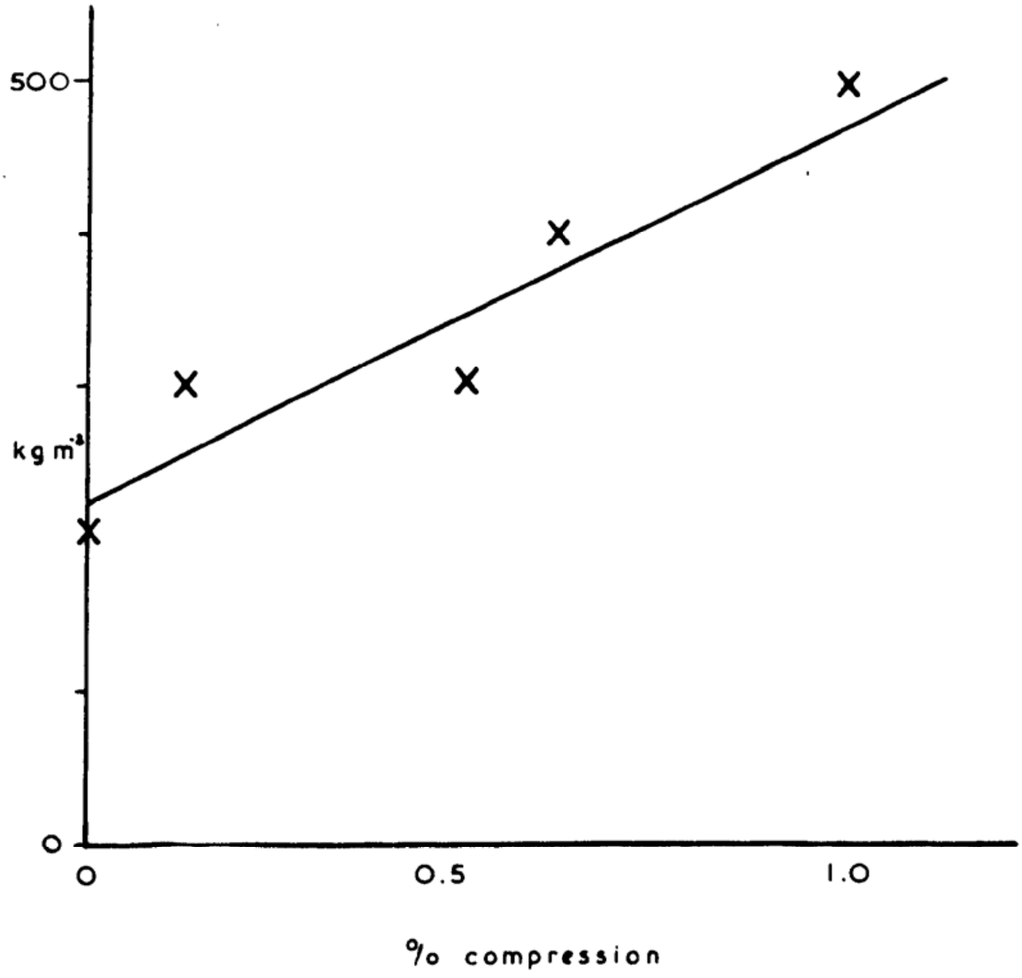


Fig 2.1

Media Compression Test

(the data presented was collected with assistance of the Technical Section ICI Pollution Control Systems).

SECTION THREE

THE PILOT PLANT

SECTION THREE

THE PILOT PLANT

3.1 THE SITUATION OF THE PILOT PLANT

The pilot plant was located at the Langley Mill Sewage Treatment Works, Birmingham. The sewage arises from a housing estate (the Falcon Lodge estate) in the north-east corner of Birmingham, formerly part of the Borough of Sutton Coldfield.

The estate was built in two phases, a pre-war development of approximately 250 dwellings incorporating a Royal Air Force barrage balloon site, and a post-war phase of council house dwellings. Neither component of this sewage could be economically drained to another works. Initially treatment was by septic tank, the present storm tanks, followed by land irrigation. With the second phase of development, work was begun on a new plant in 1953 designed to treat a dry weather flow of 1630 m^3 day^{-1} (360,000 gallons) from a population of 7,200. The original development was built with a partially separate system of storm sewage, but the later development was on a totally separate system.

The catchment area covers 90 hectares and currently contains 2,500 dwellings giving an estimated population of 8,600, plate 3.1. The only commercial premises on the site are seventeen shops (including a launderette) a garage, a public house, three schools and an Army barracks (formerly the Royal Air Force Establishment). There are no industrial premises on the site.

The trunk sewer is 1.38 km long and 760 mm in diameter. It runs beneath agricultural land beyond the eastern boundary of the catchment area and is served by three main sewers, two 610 mm in diameter and a third 300 mm in diameter. The site has been used in a number of University investigations in the past. (Hawkes 1965; Shepherd 1967).

The substratum of the area is Keuper Marl. The northern and western regions of the area are overlaid by boulder clay while the remaining area is covered with sand and gravel (Eastwood 1925).

3.2 CHARACTERISTICS OF THE SEWAGE

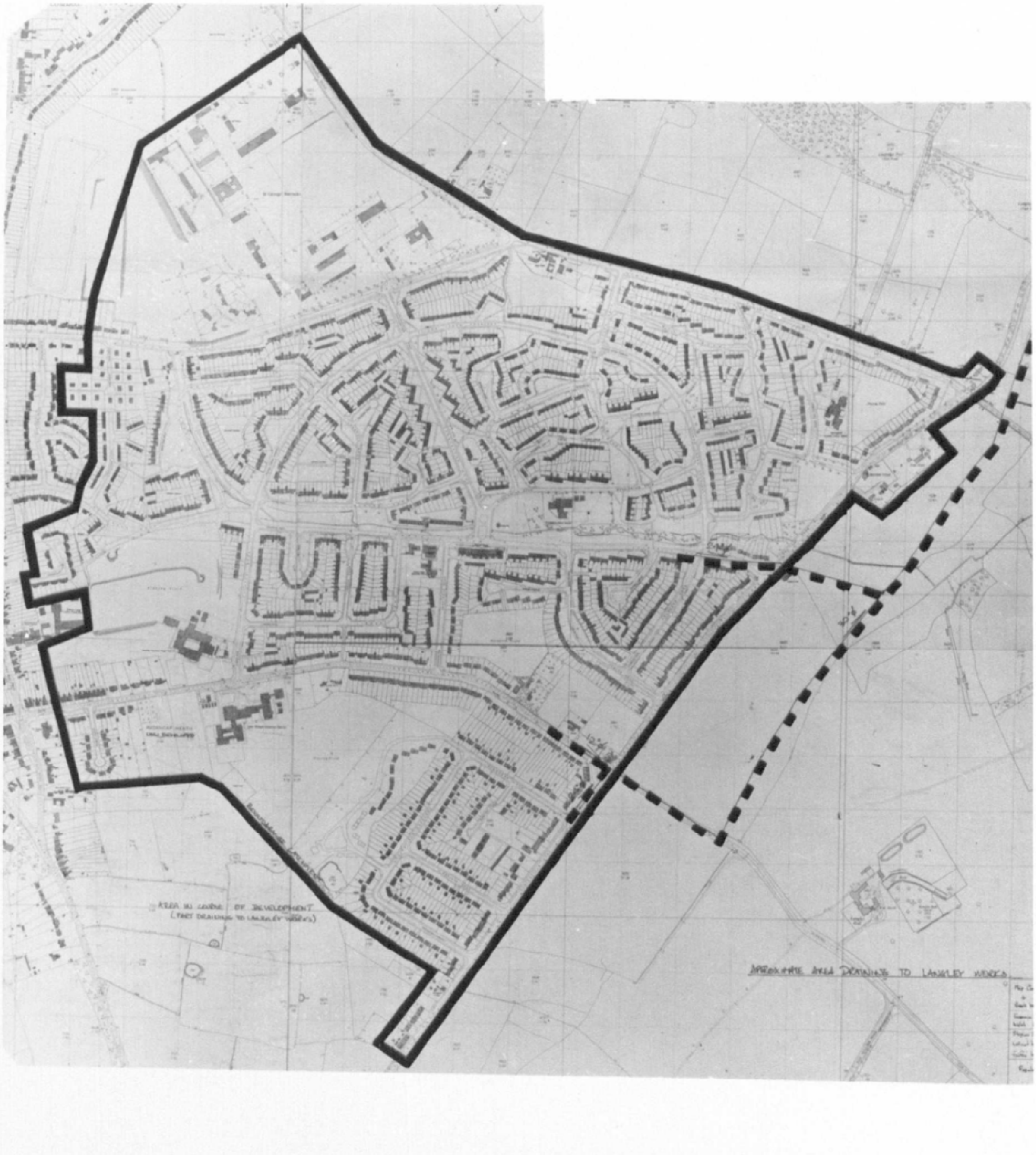
The flow of treatment varies between 45 m^3 (10,000 gallons) to 4,900 m^3 day^{-1} (1,080,000 gallons); that in excess of this figure passing to the storm water tanks. The greatest influences on flow are the works operations (cleaning screens, returning liquors etc.) and storms. The minimum flows occur in the early hours of the morning (fig. 3.3 shows a survey carried out on the 28th February 1974 the night of a General Election). The

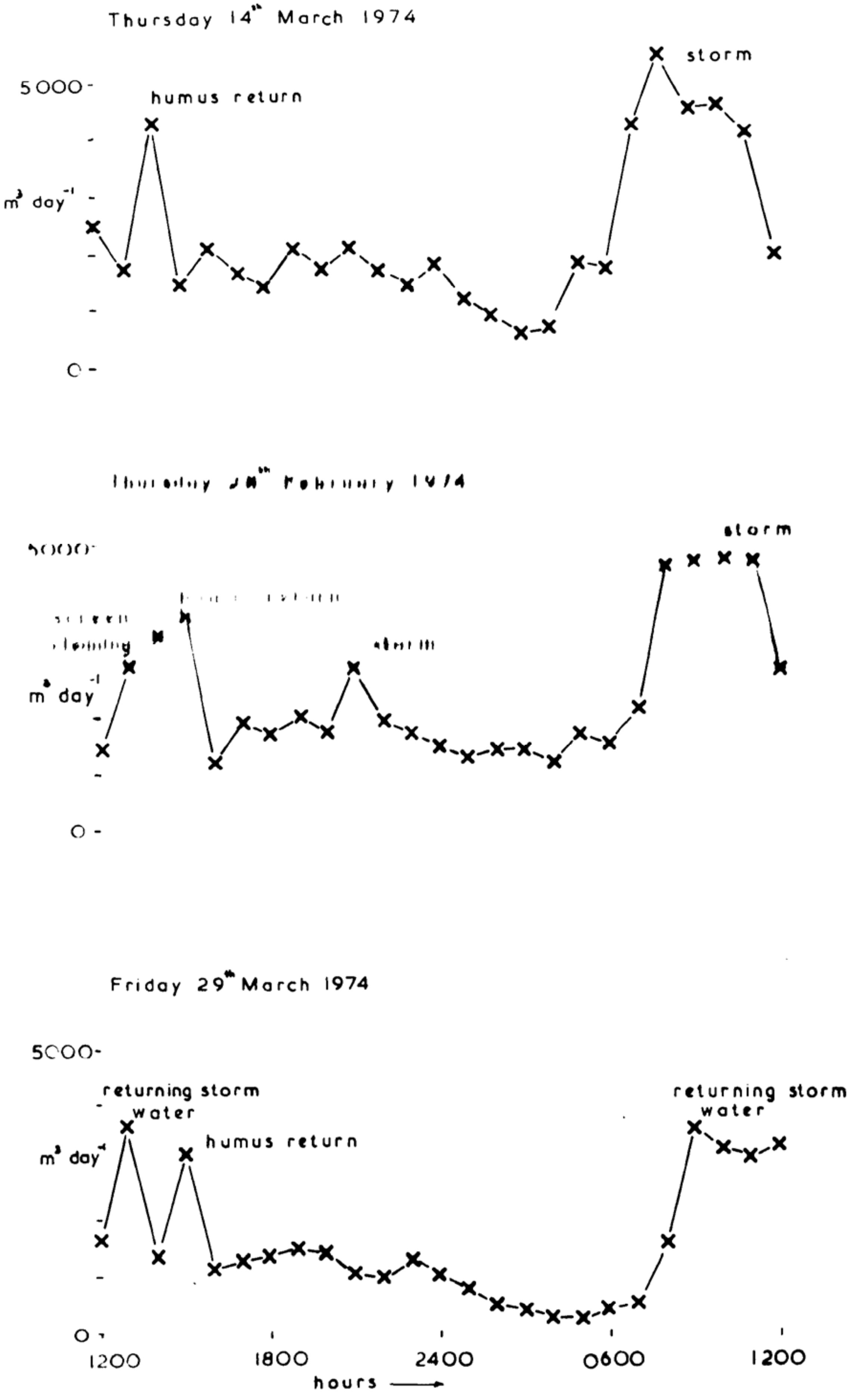
Plate 3.1: THE CATCHMENT AREA OF LANGLEY WORKS

KEY:

Boundary of area ▬

Trunk sewers ■ ■ ■


AREA IN COURSE OF DEVELOPMENT
(PART DRAINING TO LANGLEY WORKS)
APPROXIMATE AREA DRAINING TO LANGLEY WORKS



Thursday 14th March 1974

Thursday 28th February 1974

Friday 29th March 1974

Fig 3.3 Diurnal flow to treatment

peak flows with the exception of storms occur with the return of humus sludge early in the afternoon and with the cleaning of the screens. The highest sewer flows usually occur at about midday. Flow is normally greater at the weekends reaching a maximum on Sundays. This is a similar pattern to that noted by Painter (1958) investigating Stevenage sewage. The two sewages are similar in origin.

Fig. 3.4 shows the change in the BOD of the sewage in relation to the sewage flow over 24 hours. Protracted periods of rainfull reduce the BOD to below 100 mgl^{-1}. A similar variation occurs in the ammonia although in this case the survey was during dry conditions and the variation is small, (fig. 3.5).

Table 3.1 shows the mean and variation in the parameters of the settled sewage. Table 3.2 shows the metal analysis of the crude sewage. Table 3.3 shows the annual means of BOD, ammonia and detergent from 1958-1969. The BOD:COD ratio is therefore 2:1 which is normal for domestic sewage (Hawkes 1963; Hambleton and Kirby 1974).

Fig. 3.6 shows the variation in BOD in relation to rainfall and flow over two years of the project. Although the BOD, rainfall, and flow are directly related, heavy rainfall appears to have a protracted effect.

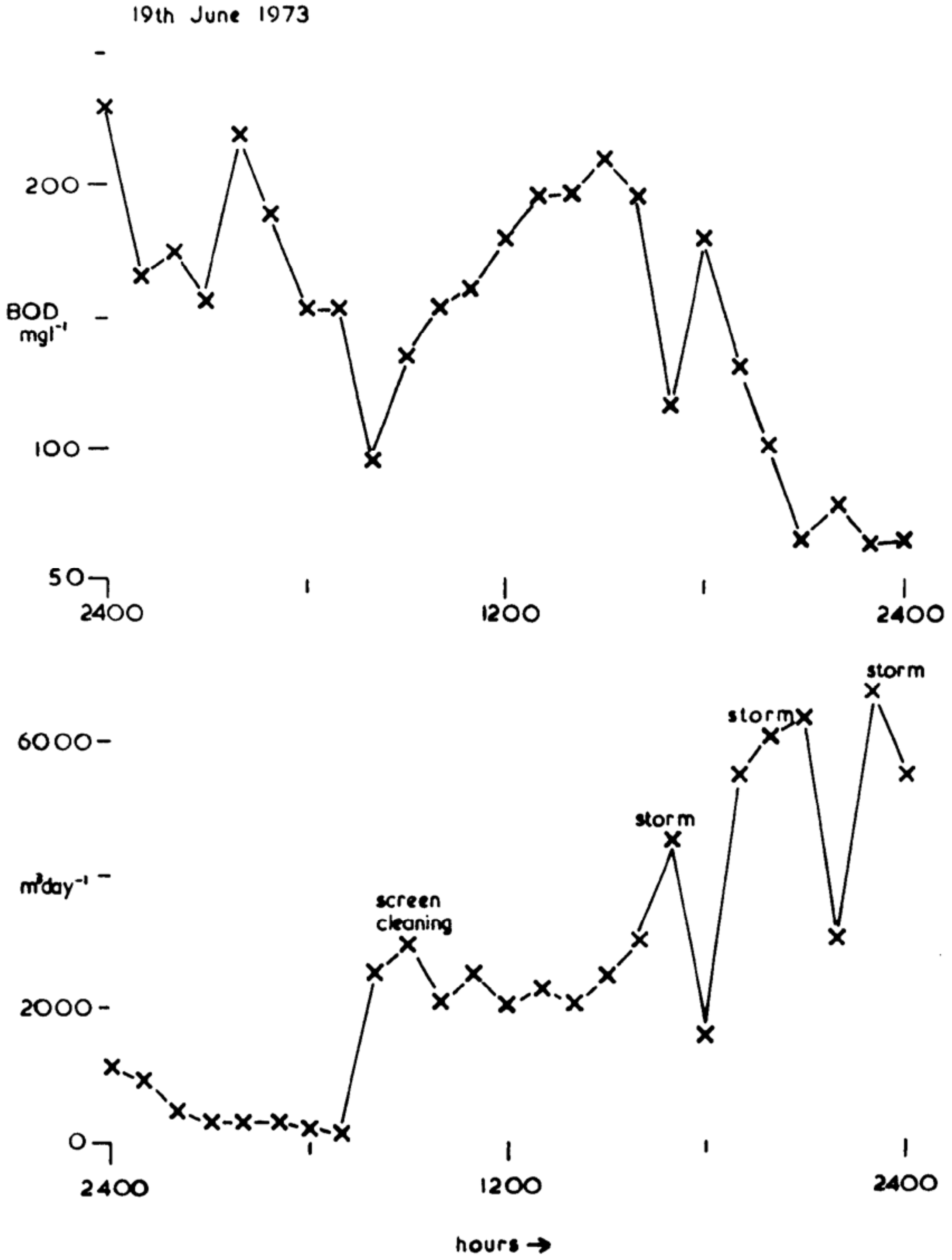


Fig 3.4 Diurnal flow and BOD

	pH	BOD	Sol BOD (% of total)	COD	SS	NH_3	NO_3	Detergent
MEAN	7.2	230.8	49.6	440.9	185.5	39.1	4.8	35.0
S.D.	0.4	43.5	9.8	78.6	31.6	13.0	7.8	15.9
C.V.	6.0	18.0	19.0	17.0	17.0	33.0	163.0	45.0
S.E.	0.0	8.7	1.3	19.0	6.4	1.6	0.95	2.32
RANGE								
Min	6.3	56.5	30	202	40	7.5	0.0	9.4
Max	8.4	379.0	72	544	418	71.0	55.8	84.0

TABLE 3.1 : Mean and Variation paramters measured during the project (results mgl^{-1})

	IRON	CHROMIUM	COPPER	NICKEL	ZINC	CADMIUM	LEAD
MEAN	0.82	0.11	0.24	0.06	0.31	0.00	0.12
S.D.	0.4	0.00	0.02	0.00	0.22	0.00	0.00
C.V.	48.0	0.00	58.0	0.00	70.0	0.00	0.00
S.E.	0.1	0.00	0.00	0.00	0.00	0.00	0.00
RANGE							
Min	0.56	0.03	0.16	0.02	0.17	0.00	0.00
Max	1.73	0.3	0.58	0.15	1.02	0.01	0.16

TABLE 3.2 : Annual Means and variation in metals in Langley Crude sewage (results in mgl^{-1})

Friday 6th June 1975

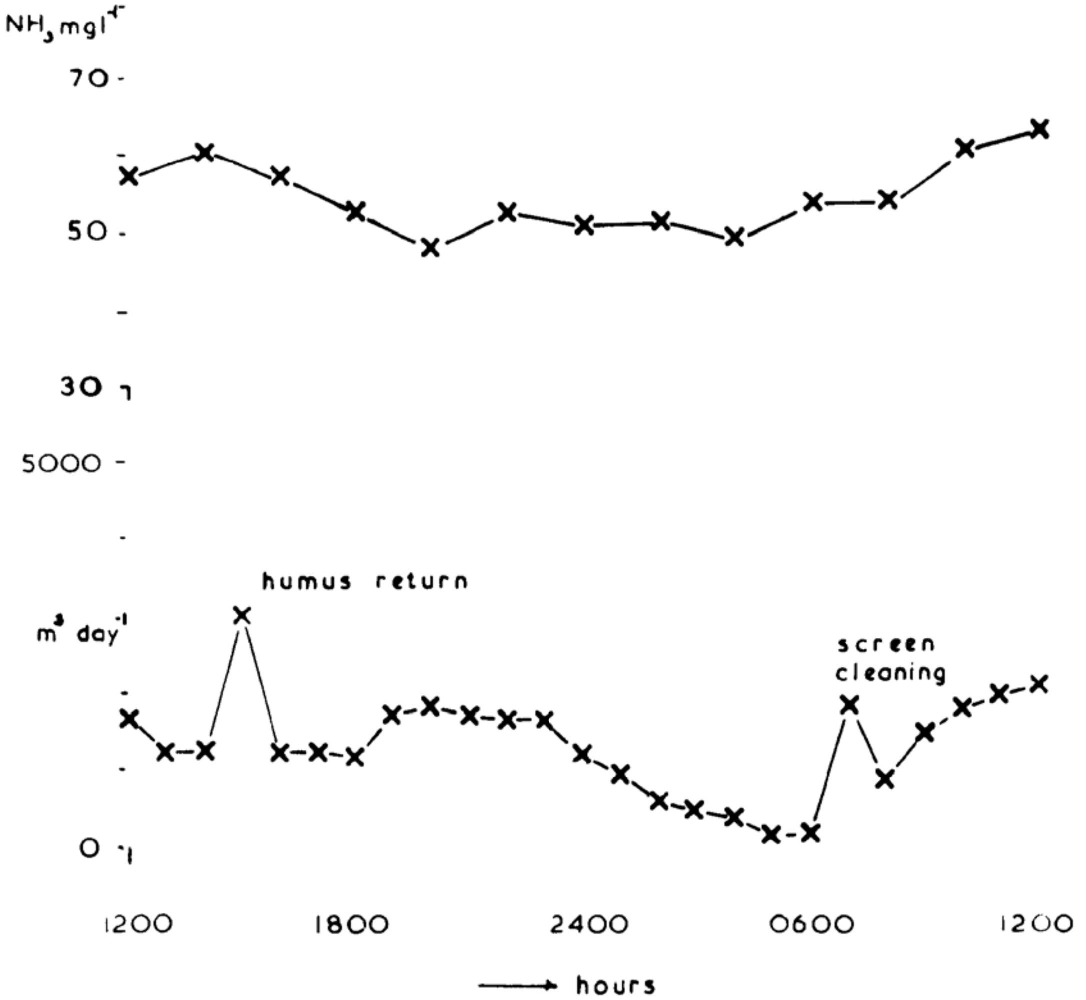


Fig 3.5 Diurnal change in ammonia & flow

LANGLEY (values in mgl^{-1})

Year	B.O.D. Annual Average	Range of Monthly Averages	P.V.	Ammon. N	Organic N	Total N
1958	206	-	32.6	39.3	10.9	51.1
1959	246	-	43.1	48.6	15.1	65.3
1960	224	132-322	41.6	37.3	12.3	50.8
1961	258	204-404	44.1	47.3	12.3	61.9
1962	261	198-344	44.3	46.5	14.5	61.5
1963	227	127-357	40.0	42.6	13.1	56.1
1964	273	160-546	53.1	50.1	15.2	60.5
1965	219	144-273	40.4	44.9	14.1	60.5
1966	218	153-363	40.2	37.5	13.0	51.4
1967	257	158-414	35.2	42.6	13.0	57.2
1968	221	176-282	42.1	39.2	12.0	52.4
1969	199	124-336	31.6	38.4	13.0	53.0

TABLE 3.3 : Annual means of BOD, ammonia, and nitrogen 1958 - 1969

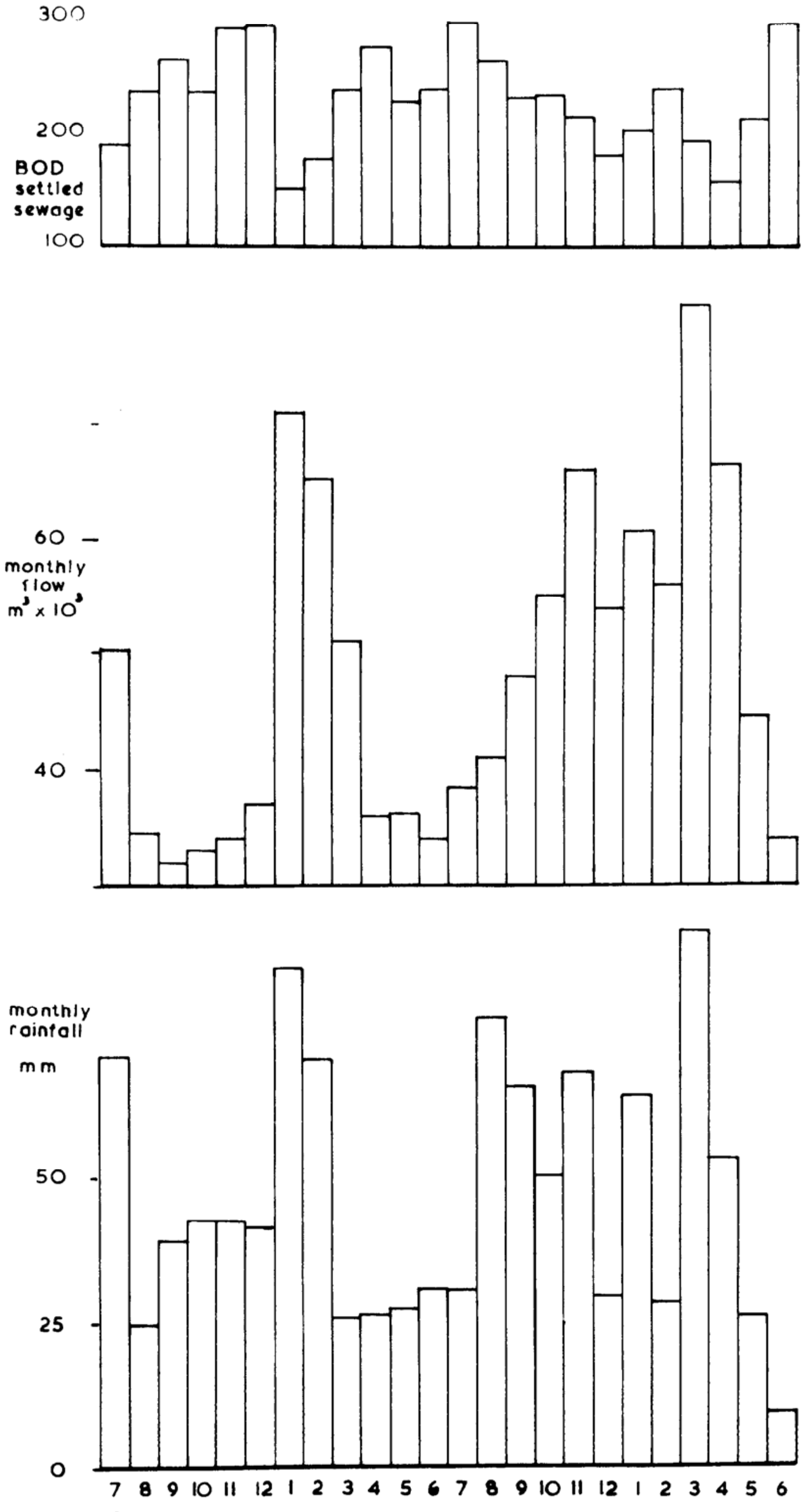


Fig 3.6
Sewage Strength in Relation to Flow & Rainfall

The trunk sewer follows the contours of a natural water course and is for the most part thought to be below the water table. Under these conditions there is likely to be a continuous seepage of ground water into the sewer (Rogers 1974). Observations on the empty storm and sedimentation tanks confirmed there was a steady stream of water entering these vessels, through the buoyancy valves. The ground water is therefore thought to act as a reservoir of rainwater, producing a delayed response in the flow and BOD to rainfall, the actual amount of infiltration water entering the sewer being a function of the height of the water table. If it is assumed that most of the flow in the early hours of the morning is infiltration water (Ragurman, Paramasiam, Deshpande and Dave 1965) then under dry conditions it would constitute 40 m^3 day^{-1} or three percent of the flow.

The elevated water table is also thought to be responsible for the variation in nitrate in the sewage. Following large quantities of rain there is consistently higher than normal nitrate in the sewage between 5-10 mgl^{-1}. On one occasion (February 1974) a value of 56 mgl^{-1} was recorded, possibly arising from the leaching of inorganic fertiliser from the agricultural land above the trunk sewer.

Another interesting feature about the sewage is the level of synthetic detergent.

The mains water, unlike most of Birmingham water is hard (200-250 mgl^{-1} as $CaCO_3$) which seems to promote liberal use of detergent. The average detergent (as Manoxol) in the sewage is the highest in the area and above the national average (Winsor 1960).

Since the sewage is totally domestic it contains a high proportion of colloidal material. The soluble portion is 49% (table 2.1). In view of the evidence that soluble BOD is easier to remove (Bruce, Merkens and Macmillan 1970) it was thought that the sewage would be difficult to treat at high rates of filtration.

3.3 DESCRIPTION OF THE PILOT PLANT

For the investigation two pilot filters were constructed between the primary sedimentation tanks at Langley Mill (fig. 3.1). Each tower was built of reinforced 6 mm galvanised mild steel; was 3.5 high, 1.5 m^2 in cross section and contained 4 cubic metres of medium (details of the medium are in section 2). The medium was supported by a 30 mm mesh wire grid at the base of the tower positioned half a metre above the basal sump to provide ventilation for the media.

A submersible pump in the right hand sedimentation tank (plate 3.2, figs 3.1, 3.2) provided the sewage feed to the pilot plant. The pump was fitted with a 20 mm screen and suspended at a depth of 1.2 m in the tank to eliminate the possibility of any scum or floating debris being taken in. The flow was bifurcated by a 'T' piece

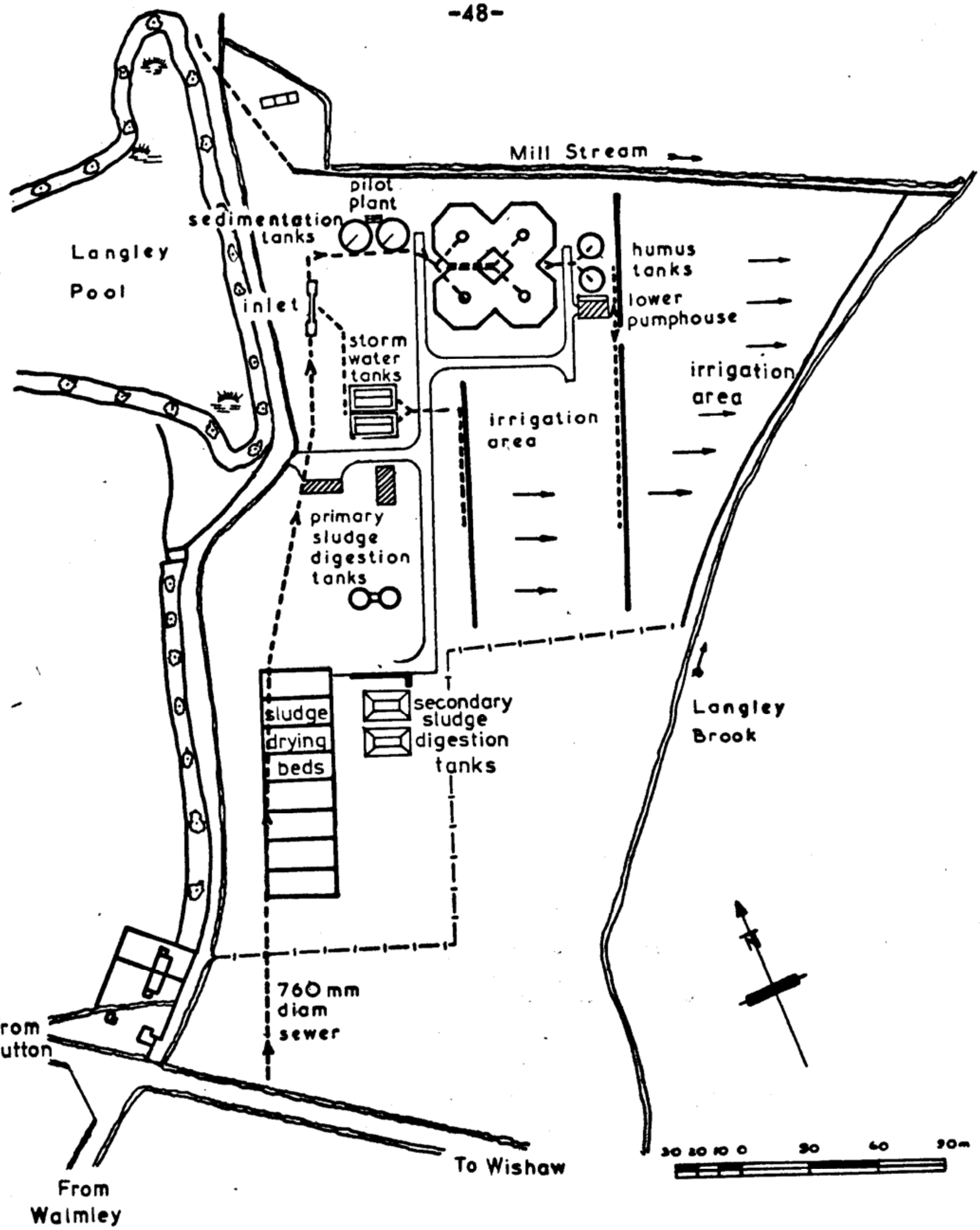


Fig 3.1 GENERAL PLAN

LANGLEY MILL WORKS

a

b

Plate 3.2 LANGLEY MILL PILOT PLANT

(a) Submersible feed pump in position in sedimentation tank

(b) General view of the pilot plant, humus tanks to the front to provide the feed for each tower, and directed into two distribution header tanks. The flow of incoming sewage to the distribution header tanks was controlled by valve and flow meter.

Each header tank was divided longitudinally into three compartments; a central mixing chamber where the incoming sewage could be diluted with recycled effluent, a feed chamber separated from the central mixing chamber by a baffle, and linked to the distribution system, and a waste compartment separated from the central mixing chamber by a broad weir (fig 3.2). Surplus sewage from the mixing chamber flowed over the broad weir into the waste chamber for return to the works primary sedimentation tanks.

The sewage was pumped from the feed chamber of the header tanks to the distribution system via two more valves and flow meters. Adjustment of the distribution feed valves and the sewage feed valves enabled the proportion of recirculated effluent to be varied. If no recirculation was desired then the effluent from filtration was diverted straight into the waste chamber of the header tanks. There were certain practical limitations to the amount of recirculation possible. To maintain self-cleansing, the minimum flow of settled sewage was five litres a minute and the minimum flow to the distribution system three litres a minute which meant that the recirculation ratio at the lower flow was limited. The header key

1 Submersible pump
2 Distribution header tanks
3 Distribution feed pumps
4 Distribution troughs
5 Balancing tanks
6 Humus pumps
7 Humus header tanks
8 Neutron probe tubes
9 Sampling racks

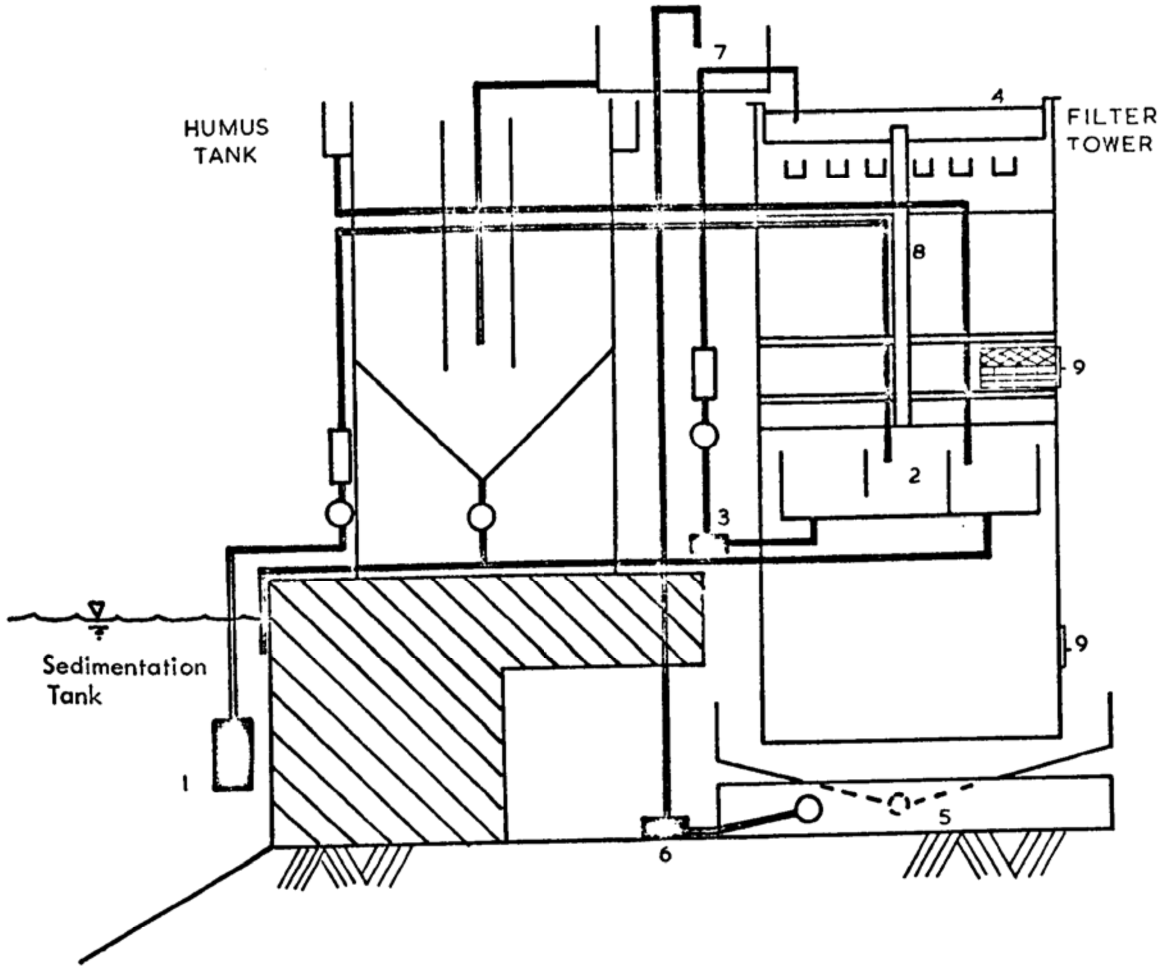


Fig 3.2

Schematic Section Through Pilot Plant

tanks were fitted with level electrodes, so that if the level of liquor dropped below the critical required to maintain the head to the pumps (as resulted on more than one occasion due to flow meter blockage) the electrode automatically shut off the electrical supply to the pilot plant.

Originally the distribution system consisted of a central trough feeding a series of 'V' notch troughs set in parallel covering the surface of the filter. Problems arose through uneven distribution resulting from the continual blockage of the 'V' notches. The system was replaced after a year by a reciprocating arm distribution system (plate 3.3). Each arm contained eight 9 mm orifices 150 mm apart, the flow then impinging on a splash plate to achieve final dispersion.

Later the splash plate on the high rate filter was replaced by four 'Floodjets' (Devalan-Watson) which incorporated integral splash plates to give better dispersion (plate 3.3).

Effluent from filtration was collected in a basal sump and balancing tank at the foot of the tower.

Flow from the lower balancing tanks was then pumped to two upper header tanks above the humus settling tanks. These were divided into two chambers. The first was connected through a valve to the mixing chamber of the

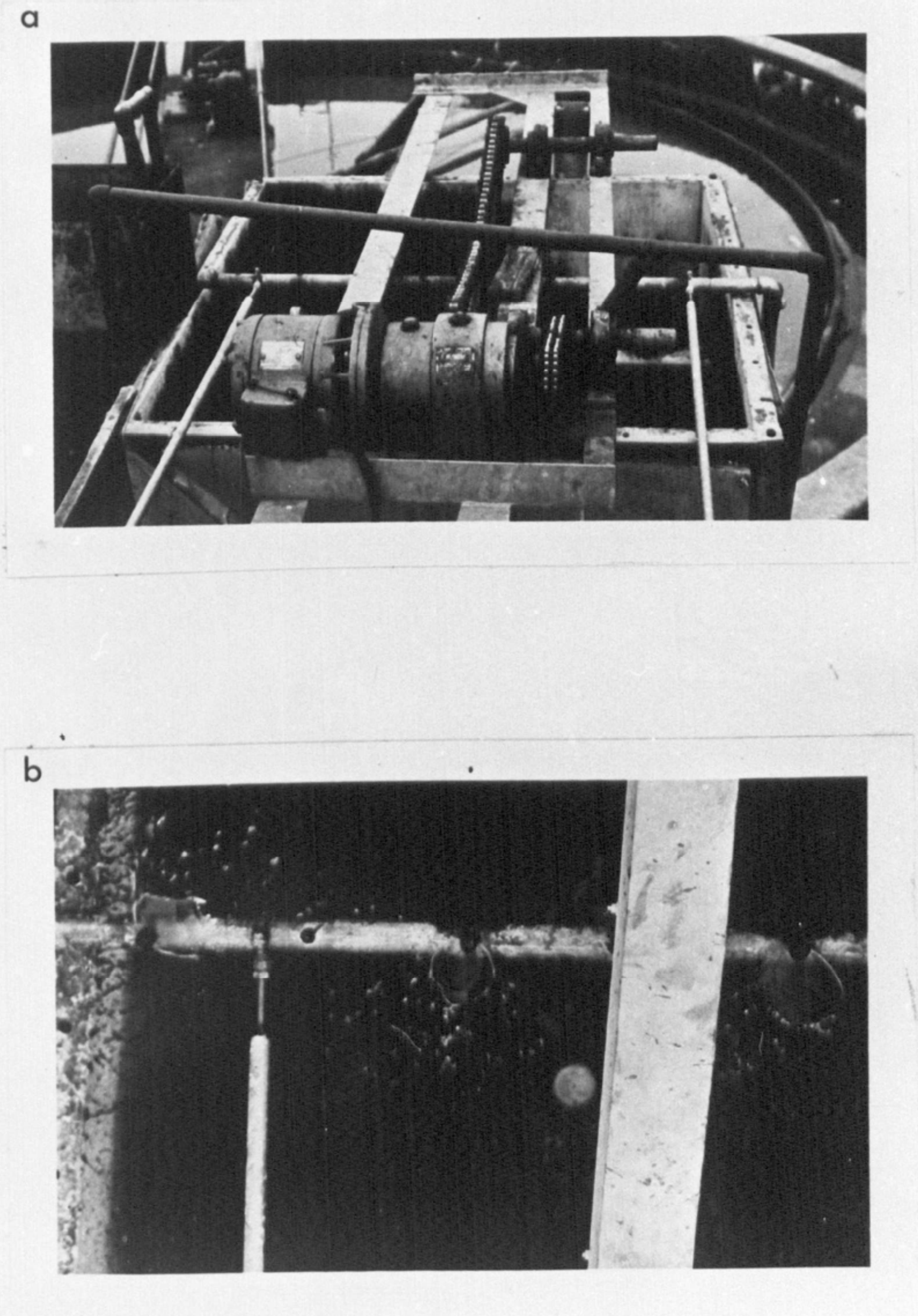


Plate 3.3 DISTRIBUTION SYSTEM

(a) Distribution system mechanism showing splash plate on filter G

(b) 'Floodjets' on the high rate filter F distribution header tanks. This allowed the recirculation of unsettled effluent to the incoming feed. The flow from this first chamber passed into the second chamber and then to the baffle box of the humus tank. The surface loadings of the humus tanks were $8.8 m^3 m^{-2} day^{-1}$ at the higher flow and $4.4 m^3 m^{-2} day^{-1}$ at the lower.

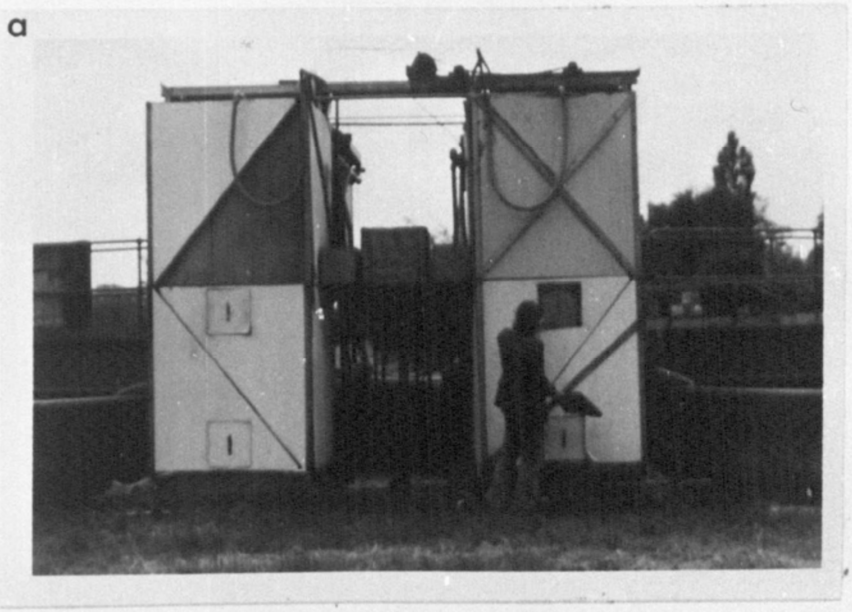
Each humus tank was constructed of 6mm painted mild steel with a hopper bottom. The tanks had a cross section of $1.2\ m^2$ and at the lower flow a retention time of 8 hours (four hours at the higher flow). The effluent from settlement was gravity fed either to the waste chamber or the mixing chamber of the distribution header tank according to whether recirculation was being employed or not.

Insulation

During the experiments problems were encountered with temperature losses from the filters (discussed in section 6). To overcome this, ventilation was restricted on the three exposed sides of the filters by fitting strips of thick black polythene around the base of the tower. (plate 3.4)

Later further insulation was thought necessary and a timber frame enclosing 25 mm waterproof 'Purlboard' (ICI polyurethane insulation material) lagging was packed around the towers. A 25 mm air space was left between the surface of the tower and the Purlboard to augment the insulation.

a



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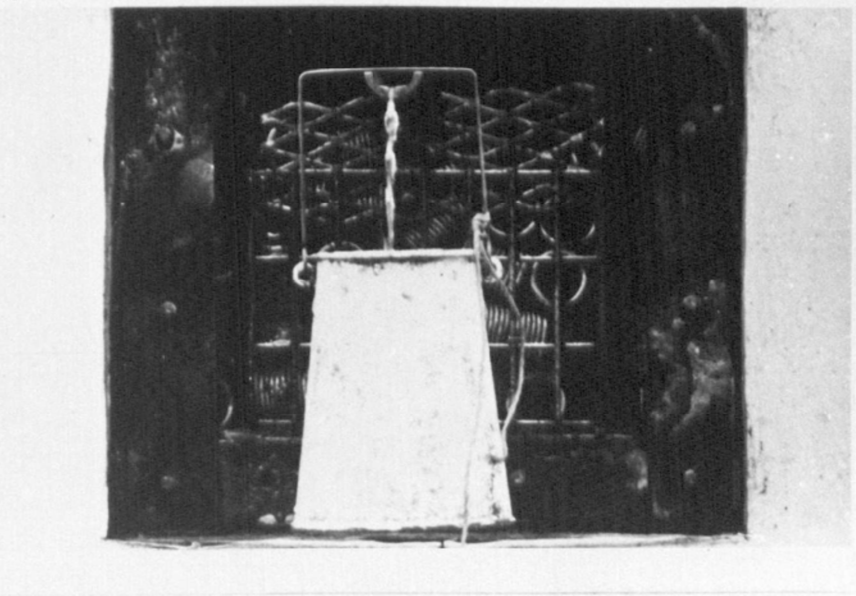


Plate 3.4 PILOT PLANT SAMPLING SYSTEM

(a) The sampling hatches, lower ventilation screens and Purlboard insulation sheets

(b) Chemical sampling trough in use

Sampling Facilities

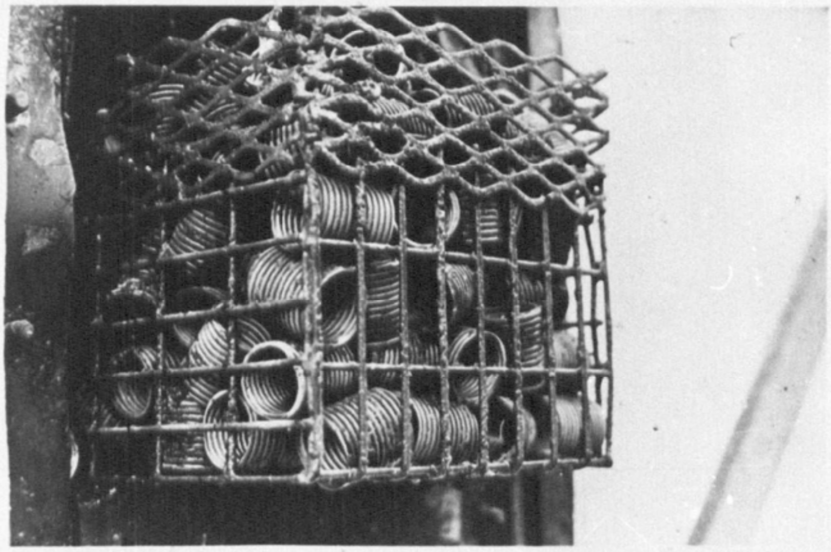
Certain sampling facilities were designed into the pilot plant (details of sampling procedure are in section 4).

1. To provide access for the neutron probe for studies on film a vertical aluminium tube was inserted in the centre of each filter. The tubes were 50 mm in diameter and extended through the depth of the filter.

2. Biological sampling was facilitated by the provision of two galvanised sampling racks positioned horizontally through each filter (fig 3.2, plates 3.5, 5.1). Each rack consisted of a 30 mm mesh wire cage strengthened by a 5 mm thick angle iron frame. The first rack was positioned at 0.5 m depth, the second at 1.5 m depth of the filter. Each rack contained four baskets measuring 320 mm x 220 mm x 200 mm and constructed of the same 30 mm square wire mesh. They fitted closely into the rack and were withdrawn at the required intervals through hatches in the side of the filters (plate 3.5).

3. Chemical sampling taps were provided at various points on the plant. These were not used in routine analysis however. The procedure was slow because of the need to flush the taps for some time prior to taking the sample to remove the accumulated sludge within the taps, and the small bore tap 15 mm may have produced

a



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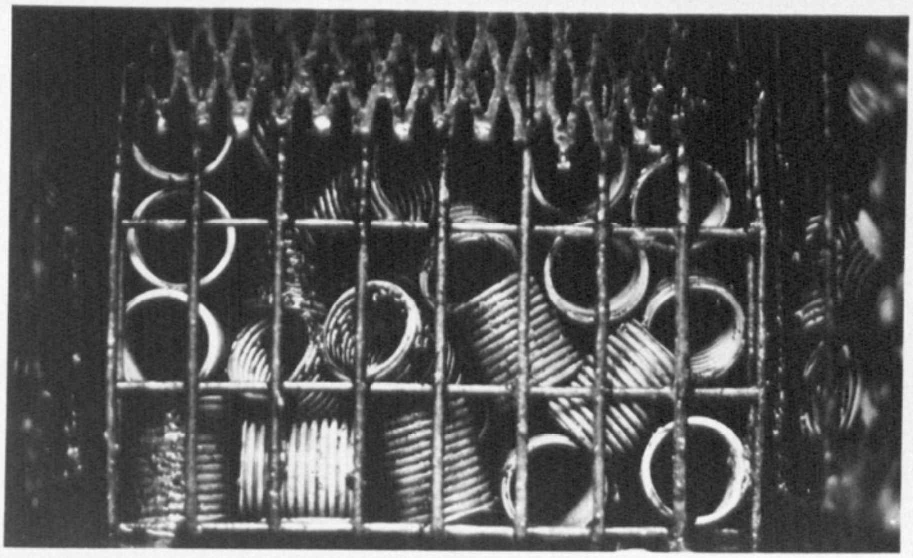


Plate 3.5 SAMPLING BASKETS

(a) Sampling baskets being removed from the filter

(b) Sampling rack inside the filter

anomalous results.

Samples were therefore taken from the surface of the various tanks using wide necked bottles.

SECTION FOUR

METHODS

SECTION 4

SAMPLING AND METHODS

Ideally continuous automatic recording of data would have provided the most detailed survey possible, but equipment was not available for this and information was collected by laboratory analysis of samples. The precision of the information gathered (discounting the sensitivity of the tests) depended on the frequency of sampling that was possible.

4.1 BIOLOGICAL PROGRAMME

The major function of the biological sampling was to provide information concerning the ecology in relation to performance and season. This would enable a comparison with the literature on the ecology of mineral media filters. The frequency of sampling was a compromise since the continual disturbance of the media by the sampling procedure might have produced anomalous results. Sampling was therefore carried out once a fortnight. The samples were taken from the first two baskets of the middle and bottom sampling racks of the filter, (section three). The remaining two baskets in the rack were examined at six monthly intervals as controls to show up any differences due to distribution, or the disturbance due to the sampling, (appendix two).

The modules of media were taken in a set pattern across the surface of the filter, and in the case of the middle and lower baskets in a pattern covering the first two baskets. The modules of media obtained in this manner, approximately 0.0005 m^3, were then washed to remove their film by a mechanical shaker. 150ml of distilled water was added to the sample containers and agitated for twenty minutes. Each module was then rinsed with distilled water and discarded. Finally the sample was made up to 250mls, and the discarded modules scored to ensure they were not resampled.

Organic Matter

A 50ml aliquot of the shaken sample was rinsed into a previously ignited and weighed 'vitreosil' evaporating basin and dried at 105°C to give the total solids. After cooling and weighing the sample was ignited at 550°C for an hour to dispel the organic matter. A correction factor was applied for the macrofauna in the sample. This was 0.2grms per 1,000 individuals of Psychodidae, Chironomidae, and Enchytraeidae and 0.2grms per 2,000 individuals of mites, (Shephard 1967).

Macrofauna

A second 50ml aliquot was diluted to 100ml and filtered through a 185mm filter paper (Green's 904) using a Buchner funnel. The paper had previously been cut into quarters a convenient size for the field of view of the binocular microscope. The number of macrofauna on the filter paper was then counted. Identifications were made with the aid of a paper by Tomlinson 1946a.

Microfauna

The remaining part of the original sample was then settled in a 250ml cylinder and the precipitate transferred to a universal bottle. Three drops, one from the surface, one from the middle and one from the bottom of the universal were pipetted on to a slide. The contents of twenty fields of view of the microscope (x100) were then counted. It was calculated that the volume represented by 20fv. was 8.6×10^{-3}mls. An estimation of the film in terms of the dominant components was made at the same time.

4.2. CHEMICAL PROGRAMME

Domestic sewages vary in composition according to the meteorological conditions, the behaviour of the populus, and works practice. Only the average analytical data was required and a number of sub-samples subsequently combined to form an average sample would have sufficed. Two automatic sampling machines were not available (one for each tower) so a programme using one 24 sample machine sampling each tower alternatively every two hours was devised. The programme was arranged such that a sample of effluent would have been taken an hour after the sampling of the influent. Test experiments comparing the automatic sampler with samples taken by hand showed significant variation took place in the collection and storage of the sample taken by the machine (appendix three). Had more sophisticated equipment been available this problem could have been overcome (Wood and Stanbridge 1968; Lewin and Hatten 1973). The sampling scheme was redesigned on single snap samples. The samples were subsequently analysed or prepared for analysis within an hour of being taken. Due to the duration of the BOD test, sampling three times a week involved visits to the pilot plant five days a week. Week-end sampling was normally carried out on a once a month basis to incorporate variation into the average.

In addition to the information concerning the overall performance, sampling facilities were available to extract effluent from one third and two thirds of the depth of the filter, (section three). This was to provide information concerning the progress of BOD removal down the depth of the filter. Two sampling schemes were therefore drawn up one with full analysis on a once a week basis, and a second with sampling of a restricted nature on three occasions a week (table 4.1).

Frequency per Week								
Parameter	pH	SS	PV	NH_3	NO_3	S.D.	BOD_t	BOD_s
Sample								
Influent	1	3	1	1	1	1	3	1
1st Depth		1		1	1		1	
2nd Depth		1		1	1		1	
Effluent	1	3	1	1	1	1	3	1
Settled effluent		3					3	

TABLE 4.1 : Analysis programme (all samples received 20 minutes settling prior to analysis except the solids, which were carried out on shaken samples, and the filtered BOD samples).

Tests

pH

This was carried out using a laboratory pH meter. (Model 78, Pye Instruments).

Suspended Solids

The filtration method as described in the Analysis of Raw, Potable, and Waste Waters (1972) was used. Experience showed that diffusing the vacuum over a wider area of the filter paper, with gauze above the perforated plate of the Hartley funnel, improved the speed of filtration. Melbourne (1964) found better reproducibility, if prior to use the filter papers were washed to remove the debris, and if the smooth side of the paper was used uppermost. This procedure was followed and the papers dried for two hours at 105°C. Normally 50ml of the settled sewage samples and 100ml of the effluents were used.

Permanganate Value

The test was carried out according to the procedure given in the Analysis of Raw, Potable, and Waste Waters (1972). It was found unnecessary to filter the permanganate solution after preparation the supernatant could easily be pipetted without disturbing the small precipitate due to the organic matter. Ten minutes were allowed after the addition of the potassium iodide following the incubation period to allow the iodine to fully develop, (Vogel 1961). The problems associated with the reproducibility of the PV test (Analysis of Raw, Potable, and Waste Waters 1972) are well known but the simplicity of the test made it suitable as a rough check on the BOD test.

Ammonia and Oxidised Nitrogen

The Milner and Zahner (1960) modification of the distillation method as described in the Analysis of Raw, Potable, and Waste Waters (1972) was used. Devardas alloy (45% Al 50% Cu 5% Zn) was used for the reduction reaction of the oxidised nitrogen compounds, as some difficulties had been noted with other proportions, (Water Research Laboratory 1972). The distillations were continued for two hours, and sulphamic acid used as the titrant. Ammonia free distilled water was not prepared for the dilutions, but a blank was incorporated into each series and subtracted from the samples.

Synthetic Detergent

Detergent was determined by the Longwell and Maniece method (1955) as described by the Analysis of Raw, Potable, and Waste Waters (1972). The buffer as suggested in the Abbot modification (1962), (i.e. alkaline borate instead of alkaline phosphate) was used in the test, as it was reported that this buffer is less liable to form emulsions. Phase separating paper instead of cotton wool was used in the final separation of the choloroform before taking the reading. The calibration line (Manoxol O.T.) was replotted every time fresh reagents were prepared.

The BOD test

Although not an ideal test (Montgomery 1967) it incorporated two important features, one is its simplicity and the second is its widespread use as an indicator of pollution. It was carried out according to the standard method (Analysis of Raw, Potable, and Waste

Waters 1972). A 100ml of the effluent samples and 20 ml^{-1} of the settled sewage samples per litre of dilution water was found to normally leave between 30% and 50% of the original dissolved oxygen after the five days. Nitrification was suppressed with allyl thiourea, and the dissolved oxygen determined by the Alsterberg modification of the Winkler method, (Analysis of Raw, Potable, and Waste Waters 1972). Some initial problems were encountered with the dilution water giving rise to excessive blank values, but these were eliminated when the source of the distilled water was changed. The dissolved oxygen of the dilution water was controlled, as experience showed that supersaturation tended to lead to problems with the blank determinations. The thiosulphate used in the titration was standardised against iodate on a weekly basis, and a one per cent starch solution (preserved with 5mg 100ml^{-1} mercuric iodide, Vogel 1961) used as indicator.

Capillary Suction Time

A series of capillary suction time tests to provide some measure of the filterability of the sludges were carried out using the apparatus of Baskerville and Gale (1968).

Retention Time Tests

A tracer of saturated sodium chloride was used for this purpose (300mg litre^{-1}). Before the tracer was added to the filter, three control samples were taken and subsequently subtracted from the test samples. To avoid displacement the sewage feed was first switched off and the distribution system drained before being refilled with the tracer. After restarting the sewage feed samples were taken at five minute intervals for the first hour and at twenty minute intervals for the second hour. The chloride was analysed using the Mohr method as described in the Analysis of Raw, Potable, and Waste Waters, (1972). An indicator of potassium chromate and potassium dichromate was used as suggested by Vogel (1961).

The Neutron Probe

In conjunction with the volatile solid determinations of the organic matter contained in the filter, it was hoped to monitor film accumulation by using the neutron probe technique, (Harvey Eden and Mitchell 1963). It was at one time thought that it might be possible to differentiate between the active biological film and the humus material in the lower levels of the filter, by their different water retention characteristics. However all the readings taken with the Wallingford probe (Bell 1969) produced counts below the level which was significant above the control counts so the use of the instrument on a regular basis was abandoned. This is not a general problem with plastic medium; Bruce and Merkens (1970) obtained useful data using this technique.

SECTION FIVE

ECOLOGICAL STUDIES

SECTION 5

ECOLOGICAL STUDIES

5.1 REVIEW

Sewage treatment by land irrigation, predating both Leuwenhoek and Pasteur, was originally thought to rely on mechanical filtration. Discoveries by Schwann and Shultz (1839) and Pasteur (1862) (reported by Lockett 1932) established both the existence and role of micro-organisms in the decomposition of organic matter. Sir Edward Frankland however reported to the second Royal Commission on River Pollution 1868, which was investigating methods of sewage treatment, that land treatment brought about the physical filtration and chemical oxidation of sewage. Frankland in his report said that if treatment was to be maintained then the land required periodic resting and aeration to promote the chemical oxidation. The St Lawrence experimental station Massachusetts in 1890 confirmed the relationship between aeration and efficiency. Noting that the finer soils rapidly clogged with organic matter they recommended gravel or stone be used instead of soil for treatment. Emphasis was again placed on the physico-chemical nature of the process (Stanbridge 1954).

In 1900 Dunbar, (Dunbar and Calvert 1908) having observed the biological growth that inevitably occurred on the filtration medium, proposed that materials in suspension and solution in the sewage, were absorbed and then oxidised by this biological film. This view was later supported by Harrison who in reporting to the fifth Royal Commission on Sewage Disposal (which established the St Lawrence percolating filter as the major method of treatment) stated that an active biological slime on the surface of the stones of the filter was responsible for treatment. Harrison in his report also emphasised the role of higher organisms in the filter whose grazing activity helped to ventilate the filter. The earliest implications were that performance should show a direct relationship to the biomass contained in the filter (Stanbridge 1954). Lloyd (1945) considered that as thick a film growth as possible without causing actual clogging of the filter would produce maximum efficiency. This view persisted until 1957 when the Water Pollution Research Laboratory (Water Pollution Research 1957) established that films of 0.1 to 0.2 mm thick were as efficient as thicker films. Wuhrmann (1963) in experiments on the affect of oxygen tension on reaction rate, calculated that 0.1 - 0.2 mm was the maximum thickness of film which would be adequately oxygenated by passive diffusion. This was supported by Tomlinson and Snaddon (1966) who demonstrated that film at depths greater than 0.1 - 0.2 mm would tend to be anaerobic. Maier (1968) in specific investigations on the uptake of glucose by biologically active films, demonstrated that no significant improvement of glucose removal was achieved by increasing the film thickness beyond 0.04 mm. In addition accumulating film by gradually restricting the voidage of the medium restricts the possible ventilation of the filter. Controlling film accumulation therefore, is fundamental to the operation of percolating filters and various practical solutions have evolved to reduce the biological growth within percolating filters (Hawkes 1963; Eden 1964; Bruce 1969). An alternative approach has been the use of media with sufficient voidage to accommodate greater accumulations of film without restricting the ventilation of the filter, (Hawkes and Jenkins 1958).

The introduction of synthetic media has enabled this concept to be put into practice without the reduction in surface area associated with the larger natural media. It still remains to be determined experimentally whether large accumulations of film can be contained in the synthetic medium without being detrimental to performance.

The solid organic matter within a filter (that portion contributed by the sewage solids trapped by the film, and that portion contributed by the active film) is in dynamic equilibrium. The amount present at any one time is a balance between those factors tending to increase the organic matter present (increasing cell mass and accumulating sewage solids) and those factors which tend to reduce the organic matter present (the activity of grazing organisms and the autolysis of the film). The nature of the waste being treated and the environment of the percolating filter exert major influences on this balance.

Fundamental to the growth rate and potential biomass of the micro-organisms contained in the filter is the concentration of organic matter in the waste feed to the biological filter. O'Shaghnessy (1931) when investigating methods of alleviating ponding, observed that diluting the sewage applied to the filter bed reduced the amount of biological growth. Several practical methods of controlling film growth in percolating filters evolved from this original observation. The first of these techniques was alternating double filtration. In this process extensively investigated by Wishart and Wilkinson (1941), it was discovered that up to four times the conventional sewage loading could be effectively treated using a system of alternating double filtration. The sewage normally applied to two filters in parallel was instead applied to two filters in series. Periodic alternation in the order of the two filters prevented excessive film accumulation. Wishart and Wilkinson also found that the shorter the period of alternation the less the accumulation of film. Tomlinson (1941) during concurrent biological investigations into the process, observed that 90% of the purification took place in the primary filter. The remaining organic matter was insufficient to maintain the film in the secondary filter, and it was reduced in amount. If for any reason the quality of the primary filter effluent was reduced then the biomass in the secondary filter was maintained or increased. In a second series of experiments Mills (1945a) noted that the greatest accumulation occurred in the uppermost layers of the filter which were receiving the highest concentration of waste. Mills found that 80% of the removal of organic matter took place in the first 700mm depth of the filter. Tomlinson (1946b) in biological investigations of the same experiments, found differences between the film accumulation patterns in conventional single filters, and those of the ADF operated filters. Tomlinson showed that in a conventionally operated plant 62% of the total film occurred in the top 700 mm of the filter, whereas in the ADF plant only 44% of the total film occurred in the surface of the primary filter. Tomlinson concluded that, since the strength of the waste was the same in each case, the increased hydraulic loading was reducing the assimilation by the film in the surface layers. Thus any mode of operation that appreciably reduces the strength of the original sewage or increases the hydraulic loading to the filters reduces the film growth in the surface layers of the filter. Dilution of the sewage by recirculation of effluent is doubly satisfactory in this respect, the strength of the original sewage is diluted by the returned effluent and the residence time reduced by the increased hydraulic load, (Mills 1945b); Lumb (1956) also found significant improvement in the annual performance of filters using this technique. Later investigations Lumb and Eastwood (1958) confirmed that the reduction in the concentration of the waste achieved in the top 700 mm of the recirculating filter was less than with single filtration over an equivalent depth. The results also showed that there was a reduction in the amount of surface film with a more diffuse vertical distribution of film. Two other techniques evolved to increase the hydraulic flow through the filter. Lumb and Barnes (1948) reported that increasing the downward rate of velocity through the filter by slowing down the speed of the distributor improved the performance of an experimental filter by reducing the surface accumulation of film. Lumb and Barnes reported that they thought that the increased flushing action of the higher rate of application of the sewage was responsible for the reduction in the accumulated film at the surface of the filter.

At this time there was some difference of opinion concerning the importance of the mechanical action of sewage in the breakdown and removal of the film. A number of workers (Levine 1940; Holtje 1943; Lumb and Barnes 1948; Cooke and Hirsch 1958; Ingram 1959) considered that this was of major importance in controlling the film. Although the situation has never been clearly resolved, more recent work suggests that any physical scouring of the film from the filter is relatively minor, (Tomlinson 1946b; Hawkes 1957; Hawkes 1961; Eden 1964; Bruce 1969). In the latest reference to the problem Wheatland and Bruce (1970) reported that with the possible exception of very high rates of filtration, physical scouring played virtually no role in the control of film accumulation. The flow through the filter serving only to flush out already loose solids within the filter. These loosely bound solids are partly derived from the viable film but also contain a contribution made by sewage solids entrained in the film (this aspect is more fully review in section 6).

Later work by Tomlinson and Hall (1955) indicated that a 10% improvement in BOD removal was possible using low frequency dosing. This was associated with a 50% reduction in the accumulated film in the low frequency dosed filter when compared with a control filter. Evidence from this and some later investigations (Hawkes 1955a; Hawkes 1961; Hawkes 1965a; Hawkes and Shephard 1972) provided a more complex theory concerning the mechanism of the improvement. It was proposed that low frequency dosing was in fact increasing the residence time by altering the hydraulic characteristics of the filter rather than simply restricting the assimilation by the surface film. This work is more fully considered in section 6.

Another technique of increasing the velocity of flow to the surface of the bed, which has also been shown to reduce the film accumulation, is to reduce the dispersion of flow produced by the distribution nozzles or jets. This method has so far attracted little attention. The data in the literature however (Hawkes 1959; Hawkes 1963) indicates that the technique does improve the utilisation of the depth of the bed by increasing the velocity of flow. Hawkes tested six types of distribution applying equal volumes of sewage. He found that the greatest accumulation was associated with fish plate and splash plate nozzles. The split jets tested although producing less even dispersion of flow generated less film.

In addition to the concentration the mode of application of the waste, the temperature of the filter also exerts an important influence on the accumulation of organic matter. This directly governs the rate of metabolism of the film. It is well known that there is a tendency for filters to accumulate organic matter in the colder months of the year. (Tomlinson 1941; Tomlinson and Hall 1955; Hawkes 1961; Hawkes 1965; Hawkes and Shephard 1970). This occurs despite the reduced anabolism associated with the low temperature and has been attributed to a number of interacting indirect temperature effects.

One possible effect is a change in the microbial composition of the film. Tomlinson (1946b demonstrated that the filter fungi had a wider temperature range than the filter bacteria such that in the colder months of the year the competitive balance of the film was shifted in favour of the fungi. Tomlinson also showed that the fungi required a critical concentration of organic matter in the sewage. Sewage diluted with 20% effluent produced one fifth of the growth rate of undiluted sewage in laboratory experiments. This confirmed a general observation (Stanbridge 1956; Hawkes 1957) that the fungi were favoured by strong sewages, normally with an industrial component. Hawkes (1955b) and Williams (1971) found a similar inhibition of the fungi by low frequency dosing. In this case it was demonstrated that the long periods between doses of the sewage affected the growth rate of the fungi. A predominantly fungal film increases the accumulation of organic matter in the filter in two ways. The fungi are more efficient converters of organic matter into biomass. Research has shown (Water Pollution Research 1955) that in oxidising the same quantity of organic matter the filter fungi increase their weight more than zoogloeal bacteria when both are oxidising an identical waste. This therefore increases the density of the film. Secondly the tenacious mycelial growth of the fungi increases the quantity of the trapped sewage solids contained in the film (Heukelekian 1945; Hawkes 1965a). In situations where conditions do not promote fungal growth there is still an accumulation of organic matter in the colder months

(Hawkes 1955b; Shephard and Hawkes 1976). This has been variously attributed to reduced autolysis of the film, increased accumulation of sewage solids trapped in the film and reduced grazing activity by the macrofauna of the filter.

Film autolysis has been demonstrated in controlling the fungal growth within filters (Tomlinson 1941). In common with the rate of conversion of organic matter into biomass the direct temperature affect on film autolysis is less important than the indirect effects. Tomlinson (1942) in an investigation into the factors which governed interspecific competition between the micro-organisms of the film showed that the fungi were most susceptible to autolysis and bacterial attack at temperatures over 10°C and with a feed low in organic matter. The rapidity of this autolysis is fundamental to the effective operation of the ADF process. Seasonally there is a spring unloading of the accumulated winter organic matter, and this is thought to be due to a combination of increased autolysis and increased grazing activity in the warmer conditions (Hawkes 1955b, Hawkes 1961). Hawkes (1955b) in experiments in which the grazing fauna were suppressed, demonstrated that the unloading still took place but was delayed, stressing the importance of both factors in the unloading process.

In conditions of thick film growth, autolysis of the film is ultimately brought about by the onset of anaerobic conditions within the film. Tomlinson and Snaddon (1966), in laboratory experiments on oxygen diffusion through biological films, noted the importance of this affect in controlling film accumulation. They demonstrated that film thicknesses in excess of 0.3 - 0.4 mm produced anaerobic conditions at the base of the film. This resulted in lysis of the lower portion of the film, which then lost its adherence to the medium, producing sloughing of the total film.

A second indirect effect of temperature on the organic matter of a percolating filter, is its affect on the life cycles of the grazing organisms contained in the filter. The importance of the metazoal grazing population in reducing the organic matter within the filter has been known since the earliest biological filters. Harrison (1908) in reporting to the fifth Royal Commission on Sewage Disposal, suggested that the discharge of solids from operating percolating filters was probably due to the activity of macrofauna within the filter. Parkinson and Bell (1919) and Bell (1921, 1926) demonstrated the beneficial effects of the most common filter Collembolan Hypogastrura viactica (Achorutes) in ponding situations. But what was probably the first systematic research into the ecology of the higher trophic levels of percolating filters was initiated by Thompson at Leeds. Thompson (1925, in a review on the operation of percolating filters) questioned, in discussing fly nuisance what contribution this 'flying BOD removal' made to the efficiency of operation of the percolating filters. Thus with the co-operation of Lloyd at Leeds University initiated a succession of studies on the insect and protozoan populations of percolating filters (Lloyd 1945). Attention focussed on the two practical problems in operating percolating filters; the fly nuisance, and the choking of the filters due to accumulated organic matter within the filter. Lloyd (1935, 1937, 1943, 1945) characterised, demonstrated the grazing activity, and observed the seasonal cycles of the filter flies. Reynoldson made a similar study of the annelied worms in filters (1939, 1941, 1943, 1947, 1948). More general ecological investigations into the efficiency of treatment in relation to film accumulation, grazing activity, and operation were made by Tomlinson (1939, 1941, 1942, 1946a) and Hawkes (1955a, 1955b, 1957, 1959, 1961, 1965b). Experimentally the beneficial affect of the grazers was demonstrated by Williams and Taylor (1968). They found that compared with a control filter containing no grazing organisms the BOD of the effluents of a series of filters, containing different grazing and different combinations of grazing organisms, was noticeably lower. The amount of film contained in these filters was also noticeably reduced, with the least film in the filter containing the worms only. This led to further studies into the efficiency of the various grazing organisms within percolating filters in relation to their contribution to the overall filter metabolism (Solbe and Tozer 1971; Solbe 1971; Williams, Solbe, and Edwards 1969).

A complex picture emerged concerning the factors which controlled the range and numbers of grazing organisms within filters. Primarily the available food supply, or the amount of film, governed the total number of grazing organisms. The available voidage in the medium of the filter (itself controlled by the amount of film in conventional medium) and the hydraulic loading of the filter are major factors influencing interspecific competition. Crisp and Lloyd (1954) noted that in the natural environment psychoda species fed on organic detritus as found in mud and rotting vegetation and that they could be expected to prefer filters containing large amounts of film. Several investigations have associated psychoda flies with thick growths of film (Lloyd 1945; Hawkes 1957; Hawkes and Shephard 1972). Chironomid larvae on the other had have been shown to predominate in filters in which there is little film (Terry 1956; Hawkes 1957; Hawkes and Shephard 1972). No particular preference has been assigned to the enchytraeidae worms but it is assumed that, for much the same reasons as the psychoda flies, they prefer thicker films (Terry 1951). As previously noted the concentration and mode of application of the sewage to the filter affect the distribution and quantity of film within the filter. This therefore in turn affects the range of grazing organisms.

Several workers have also noted affects due to the physical size of the medium. Hawkes and Jenkins (1955, 1958) in a comparison of four sizes of medium, found that the smallest media (27 mm) contained a balanced population of species of anisopus, psychoda, enchytraeidae, and lumbricids. The largest media however (51mm) contained a smaller population with the lumbricid worms the dominant grazer. A similar pattern was found when the same filters were used in ADF experiments, but in this case anisopus and psychoda larvae were virtually absent from the largest filter medium. In this situation the velocity of flow was thought to be augmented by the large size of the media and the lumbricid worms, whose setae enable them to withstand higher flows through the filter, were therefore better able to survive the environment of the large medium. Terry (1951), in a study on the distribution of larger worms in filters, however found the largest number of lumbricid worms in filters containing the smaller media.

Lloyd (1945) noted an affect due to the texture of the medium. Having observed that of the two common filter Enchytraeidae, _Lumbricillus lineatus_ was more abundant in smooth surfaced media than _Enchytraeus albidus_, proposed that the smooth surfaces were not suitable for the straight setae of _Enchytraeus albidus_. _Lumbricillus lineatus_ on the other hand, having bifid curved setae, was able to grip the smooth surface.

Ranges of hydraulic loadings to the filter are also known to affect the macrofauna of the filter. Tomlinson and Hall (1950) in experimental studies on the affect of hydraulic loading, observed that *Hypogastrura viatica*, *Anisopus fenestralis*, and *Psychoda sp.* were the most sensitive of the grazing organisms to high hydraulic loadings. They noted that *Hypogratrura viatica* and *Anisopus fenestralis* were common only up to a loading of 2.2 m^3m^{-3} day^{-1}(400 gyd), *Psychoda sp.* was abundant between 2.2 and 3.4 m^3m^{-3} day^{-1} (400 - 600 gyd), and only loadings in excess of 3.4 m^3m^{-3} day^{-1} seemed to affect *Enchytraeidae sp.* Hawkes (1959) found that there was a difference between the sub-jet and the inter-jet ecology in filters with modified nozzles to reduce the dispersion of the flow of sewage. This followed a similar pattern, the lumbricid and enchytraeidae worms were common in the sub-jet zone where the flow was greatest, while *Psychoda sp.* and *Hypogastrura viatica* were common in the inter-jet zone. A number of workers using elevated rates of filtration have noted similar affects on the fly larvae and the collembolans (Lumb and Eastwood 1958; in recirculation, Hawkes 1955b; and Hawkes and Shephard 1972; in low frequency dosing, and den Otter 1966 in the control of psychoda flies). In addition to the actual concentration of the waste its character also affects the accumulation of organic matter within the filter. Certain industrial effluents are directly toxic to film components, and indirectly affect film accumulation by their toxic effect on the grazing organisms. Both Lloyd (1945) and Reynoldson (1948) in investigations at Huddersfield found restricted grazing activity due to the nature of the sewage. Based on Reynoldsons findings (1947), Green, Willetts, Bennett, Crowther, and Bourton (1975) suggested using typical filter fauna to assess the potential toxicity of industrial effluents to sewage treatment processes. The physical status of the waste, the ratio of soluble organic matter to suspended organic matter may also exert an influence on the grazing fauna. Large quantities of suspended materials in the sewage have been recorded as causing excessive accumulations of organic matter within filters, (Stanbridge 1954; Wood and Smith 1972).

With regard to the response of the grazing organisms to temperature a number of workers have noted a complex pattern of behaviour. Lloyd (1937) observed the temperature, as well as being critical in the rate of development of individuals (therefore governing the seasonal rhythms), was also a major factor in influencing intra-specific competition. Similar intraspecific differences have been discovered in the enchytraeids (Reynoldson 1943), the chironomids (Lloyd 1945), and in the lumbricid worms (Solbe 1971). Solbe and Tozer (1971) in studies on psychoda flies in laboratory filters confirmed Lloyds original findings, adding that they thought it was unlikely that the numbers and species of macro-invertebrates present in a filter ever reached stability.

Reynoldson (1939) when investigating the enchytraeid worms discovered a migratory response to low temperature conditions. He observed that the worms left the cold surface areas of the filter in favour of the warmer lower regions of the filter in winter. Williams, Solbe and Edwards (1969) however, also working on the enchytraeids, failed to confirm Reynoldson's original findings. Terry (1951) and Solbe (1971), both found seasonal migrations in the lumbricids. Solbe noted that the worms were normally absent from the first 600 mm depth of the filter, except in summer and autumn.

The remaining macrofauna of percolating filters have received less attention. The information available in the literature indicates that they become established incidentally and not in sufficiently large numbers to play a significant role in the total filter metabolism (Hawkes 1963). Pillai and Subrahmanyan (1946) however, in a study of the conversion of organic matter in biological media, noted that they found copepod Crustaceans in large numbers and emphasised their beneficial role in the purification process. Tomlinson (1946a) in a key to the common filter fauna, included members of the Arachnida which he had identified in investigations into filter ecology. Hawkes (1963) noted that certain of the less common filter macrofauna may become more prominent due to local operating conditions. Calaway (1968) in a survey of sewage treatment metazoa produced a comprehensive list of the 'additional' fauna which he had observed in percolating filters in the United States. Calaway also noted crustaceans in significant numbers.

During the early ecological investigations at Leeds attention was also drawn to the possible beneficial role of the protozoa in percolating filters. Barker (1942), began a series of investigations to determine the distribution, seasonal occurrence, and possible role of protoza in sewage treatment processes. Barker discovered that the peritrichous protozoa, specifically Opercularia, were the most common. A number of workers have since noted a similar pattern, (Tomlinson 1941; Baines, Hawkes, Hewitt and Jenkins 1953; Brown 1965; Curds and Vandyke 1966). Curds and Cockburn (1970) carried out a national survey of the protozoa of sewage treatment plants and observed that the peritrichous protozoa were present in large numbers at almost every plant. The holotrichous and spirotrichous protozoa on the other hand, although present at most sites, were present in lower numbers. Again the most common group of protozoa were the Operculates. A similar situation has been shown to exist in the United States (Varma, Finley and Bennett 1975).

Interest had already been focussed on the ciliate protozoa by several reports of their role in the activated sludge process, (Ardern and Lockett 1936; Barritt 1940; Pillai and Subrahmanyan 1942), when it had been proposed that the protozoa were important in flocculating and digesting the bacteria which had broken away from the sludge flocs. More recently laboratory experiments by Curds, Cockburn, Vandyke (1968) have confirmed that the ciliated protozoa play a major role in the removal of suspended material in the activated sludge process. Pilot activated sludge plants kept free of protozoa produced turbid effluents with a high BOD, whereas plants containing ciliated protozoa produced clear effluents with a low BOD. In later papers Barker (1946, 1949) demonstrated the flocculating activity of Paramoecium caudatum (one of the common filter protozoa), and observed seasonal rhythms of population in certain of the ciliate protozoa. Barker attributed these variations to the competititve interaction of the insect grazing fauna, and the seasonal variations in temperature. Barker forwarded the view that the insect larvae devoured most of the available film in the warmer months of the year which restricted the food supply of the protozoa. In winter the reduction in the strength of the sewage and the drop in temperature were sufficient to reduce the numbers of the protozoa.

Barritt (1940) in his study of the ecology of activated sludge noted that certain ciliate protozoa could be used as indicators of efficiency of treatment. He observed that in an inefficient plant the protozoa were varied but peritrichous protozoa were absent while they were the most abundant in an efficient plant. Tomlinson

(1941) in the ADF experiments noted a similar stratification of the ciliate protozoa in percolating filters. He discovered that the holotrichous protozoa were associated with the highest levels of organic matter in the surface of the filter, and the peritrichous and spirotrichous protozoa with the lowest levels in the bottom of the filter. A similar pattern emerged in later laboratory scale work (Tomlinson and Snaddon 1966) with the peritrichous forms most common at the foot of the simulated filter. Work by Curds (1969) on the other hand indicated that this concept was probably an over generalisation. In investigating the protozoa as biotic indicators of activated sludge efficiency, Curds (1969) noted that the protozoa, if they were to be used as saprobic indicators had to be identified to species. The peritrichous _Vorticella microstoma_ was for example commonly associated with high levels of organic matter.

Although their presence is unlikely to be any less important, the remaining micro-organisms contained in percolating filters have received less attention. Holtje (1943) noted the presence of a large number of nematodes in his survey of percolating filter ecology and assumed they made a significant contribution to the total metabolism of the filter. Shephard and Hawkes (1976) attributed the continuing discharge of humus material from filters in which the other grazers had been suppressed, to the presence of large numbers of nematode worms. Tomlinson and Snaddon (1966) in laboratory scale experimental rotating tube filters noted that the nematodes, in the absence of macrofauna, may have been responsible for the loosening and disturbing of film which they observed. Little work has been done on the identification and distribution of the nematodes. Peters (1939) listed the species he found in a survey of nematodes in sewage treatment. Some interest has been expressed more recently in the United States due to concern over the possible contamination of river water and reservoirs with nematodes from sewage treatment processes (Calaway 1968). Murad and Bazer (1970) in a fifteen week study on nematode populations in treatment plants found that the numbers of nematoda increased with reductions of temperature. The variation in the sewage feed to the filters during this period was between 5°C to 20°C and the variation in the numbers of nematodes about five per cent.

Little work has ever been done on the rotifers which inhabit percolating filters although their presence has been noted for some time (Holtje 1943; Tomlinson 1946b). Calaway (1968) listed the species of rotifers he found in a sewage treatment plant and indicated that he thought they played a very similar role to that of the ciliated protozoa.

To summarise, natural percolating filter medium having a void space of less than fifty per cent is susceptible to restrictions in ventilation by excessive accumulation of organic matter within the medium. The primary factors influencing this accumulation are the characteristics and mode of application of the waste being treated, and the temperature of the filter. One of the major temperature dependent factors is the activity and presence of grazing fauna whose populations are also influenced by the physical environment and the hydraulic loading of the biological filter.

5.2 RESULTS WITH DISCUSSION

5.2.1 Presentation of Results

The results are presented and discussed in two sections related to the two phases of plant operation; firstly the colonization phase, lasting four months, when the two filters were run under identical conditions, and secondly an experimental phase, lasting two years, when the filters were operated at two different loadings.

In view of the close proximity of the conventional filters to the pilot plant (twenty metres) observations on the progress of colonization were begun with the start of irrigation. For the first three months biological samples were taken at monthly intervals, and then with the achievement of 75% BOD removal at fortnightly intervals; these results were then averaged to give one graphical point per month. During the colonization, performance and temperature results were based on the means of four samples but routinely they were based on the means of twelve samples (the analytical methods are given in section four).

The temperature of the air, sewage feed and effluent at each level were taken at the time of sampling. Observations showed that the sewage feed temperature was directly related to the air temperature and the effluent temperature almost identical to air temperature (± 1°C discussed in section six). To emphasise the environmental component associated with performance and film accumulation, the results are presented in relation to air temperature. The results also show that over 80% of the BOD removal took place in the surface layers of the filters (discussed in section six) so for simplicity of presentation performance is graphically related to surface accumulation of organic matter only.

Problems arose with identification of the microorganisms of the film, the macrofauna and the microfauna. Less than ten per cent of the film under examination was identifiable at any time. In the lower depths of the filter, where there were considerable amounts of humus and debris, virtually nothing was identifiable on a routine basis. The results of film composition therefore are tabulated in terms of the easily recognisable components. Similarly it was not always possible to identify individual species of the grazing fauna. The ciliate protozoa are in some cases difficult to identify to species without specialised technique. Some of the ciliate protoza therefore are expressed as genera, and species which occurred only spasmodically in small numbers, were omitted from the graphical results. The macrofauna, Psychodidae, Chronomidae, Enchytraeidae, and the Acarina were also represented by more than one species, but again with the exception of the two enchytraeid worms which were easily separated (Lumbricillus lineatus being distinguished from Enchytraeus albidus by the possession of haemoglobin and curved setae, Reynoldson 1943) they are also depicted as groups. The graphical representation of the insects include the larvae and pupae but not the flies. A list of all the species positively identified during the project are included in tables 5.1, 5.2 and 5.3.

5.2.2 Colonization

The micro-organisms constituting the film of a percolating filter treating domestic waste are thought to be derived from the fresh water environment (Wattie 1943; James 1964; Curtis 1969; Curtis and Curds 1971). Normally therefore colonization is quite rapid, storm and infiltration water providing an inoculm of bacteria. In warm weather one or two months is usually sufficient to establish 80% to 90% BOD removal. (Symposium on maturation, 1960). The establishment of grazing organisms, in the absence of mature filters in close proximity, can take considerably longer. If the establishment of a grazing population is delayed then the resulting excessive accumulation of film can reduce efficiency again (Taylor 1960). Therefore a filter can only be considered as mature when an effective balance between biological film and grazing organisms has been established (Hawkes 1963). Even the establishment of this dynamic equilibrium cannot be considered as representing full ecological maturity as the ultimate trophic structure normally takes a number of years to establish. Solbe, Williams and Roberts (1967), found frequent changes occurred in the development of filter fauna, some species only surviving the early stages of colonization.

The daily recirculation of humus sludge to the primary sedimentation tanks on the main works (from which the sewage feed to the pilot plant was derived) was expected to provide quite rapid colonization of the pilot plant. To avoid overloading the filters during maturation, both filters were initially irrigated with settled sewage diluted by a 1 : 1 recirculation of returned effluent. If the colonization of grazing fauna had then been delayed, the build up of film would probably have been controlled by the reduced sewage strength. After four months at an irrigation rate of 1.2 $m^3m^{-1}day^{-1}$ both filters were achieving 75% BOD removal (fig. 5.1). At this point the recirculation to both filters was halted and the hydraulic loading to the designated high rate filter (Filter F) increased to 2.4 $m^3m^{-1}day^{-1}$.

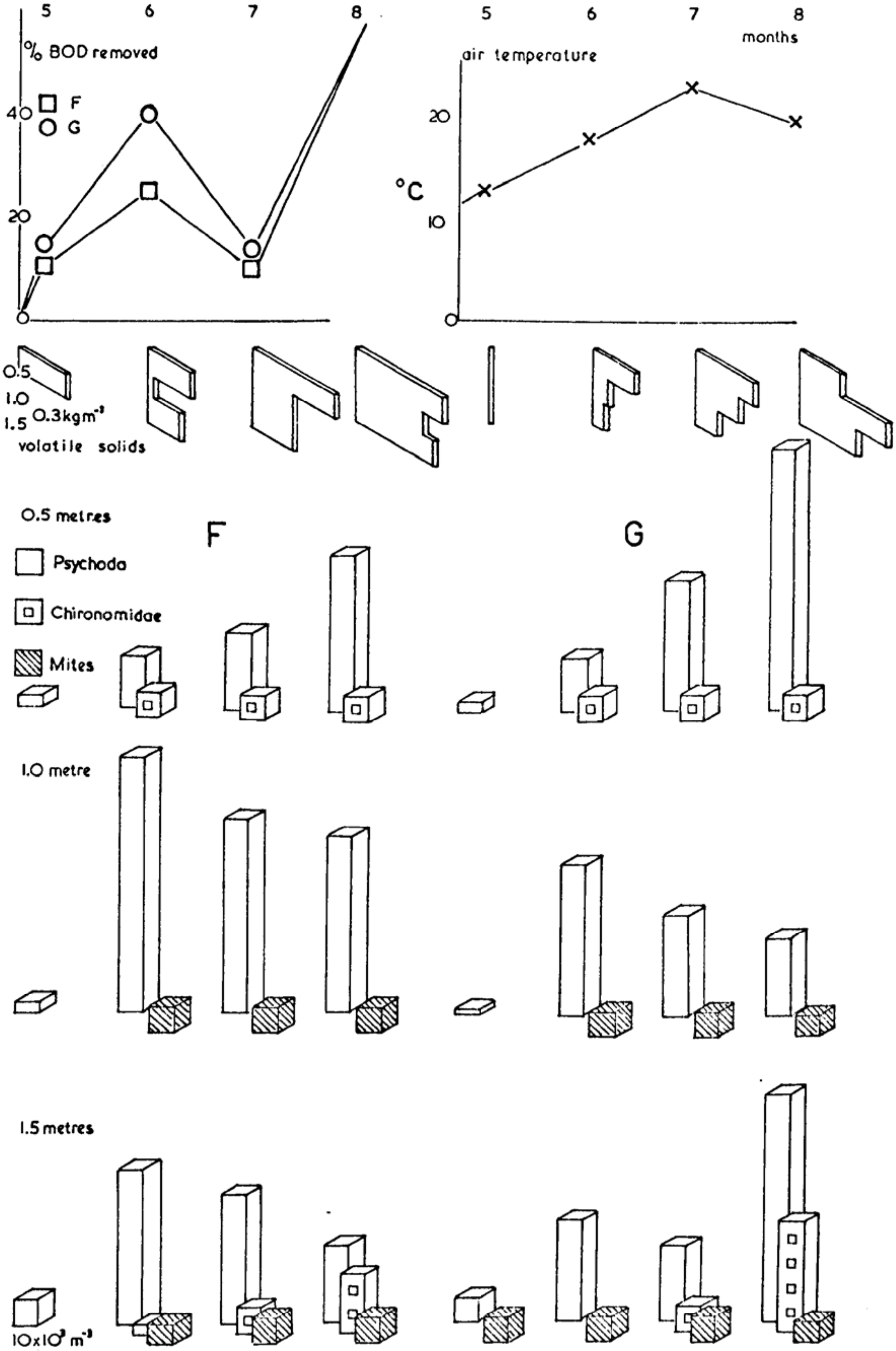


Fig 5.1 Period of colonisation

Film was visible in both filters on the medium directly beneath the distribution jets two weeks after the beginning of irrigation. Further examination revealed that although the majority of this material was unidentifiable, it contained bacteria in the zoogloeal condition (table 5.1). Zoogloeal bacteria are normally the major components of both the sludge flocs in activated sludge, and the film in percolating filters, treating domestic sewage (Wattie 1943; Hawkes 1963; Cooke 1959). Two weeks later (four weeks after the beginning of irrigation) a green alga colonized the inter-jet splash zone of the surface of each filter. The alga appeared to be identical with the unicellular alga Chlorella found by Tomlinson (1941), to be a common filter alga in the warmer months of the year. Despite the identifiable film and ten per cent BOD removal, the first quantitive samples taken at this time did not reveal any significant accumulation of organic matter in either filter (fig.5.1). The next quantitative surface sample two months after the beginning of irrigation contained two filamentous bacteria identified as species of <u>Sphaerotilus</u> and <u>Beggiatoa</u> neither were in large quantities. Both these bacteria are recorded as being common but not abundant components of filter film (Tomlinson 1941; Holtje 1943; Cooke 1959; Hawkes 1963). By the third quantitative sample (ten weeks June), both microfauna and macrofauna had become established in the filters (tables 5.2, 5.3). The same three groups of microfauna were recorded at the three

	WHERE RECORDED		
	DEPTH in metres	FILTER	TIME OF COLONIZATION in weeks
<u>BACTERIA</u>			
Zoogloeal forms	all depths	both	2
Sphaerotilus	0.0/0.5	both	6
Beggiatoa	0.0/0.5	both	8
Thiothrix	0.0/0.5	both	20
<u>FUNGI</u>			
Subbaromyces	all depths	both	18
<u>ALGAE</u>			
Chlorophyta			
Chlorella	0.0	both	4
Stigeoclonium	0.0	both	54
Cyanophyta			
Phormidium	0.0	both	76

TABLE 5.1 : Micro-organisms of the film

	WHERE RECORDED		
	DEPTH in metres	FILTER	TIME OF COLONIZATION in weeks
INSECTA			
COLLEMBOLA			
Hypogastrura viatica	0.5/1.5	G	76
DIPTERA			
Psychodidae	all depths	both	10
Psychoda alternata			
Psychoda severini			
Chironomidae	0.0/1.5	both	12
Metriocnemus sp.			
Hydrobaenus sp.			
ACARINA			
Mesostigmata	0.5/1.5	both	10
Platyseius italicus			
Iphidozercon gibbus			
Trachygamasus ambulacralis			
CRUSTACEA			
Copepoda			
Canthocamptidae	all depths	both	70
ANNELIDA			
OLIGOCHAETA			
*Enchytraeidae			
Lumbricillus lineatus	all depths	both	72
Enchytraeus albidus	all depths	both	64

(*Solbe 1975 considers these to be wrongly identified)

TABLE 5.2 : Macrofauna of the film

	WHERE RECORDED		
	DEPTH in metres	FILTER	TIME OF COLONIZATION in weeks
CILIATEA			
HOLOTRICHIA			
Trachelophyllum pusillum	0.5/1.5	both	60
Litonotus sp.	0.5	G	24
Chilodonella unicata	0.5/1.5	both	52
Colpoda sp.	0.5/1.5	both	20
Glaucoma scintillans	all depths	both	10
Colpidium sp.	0.5/1.5	both	10
Paramoecium caudatum	0.5/1.5	both	8
PERITRICHIA			
Vorticella sp.	all depths	both	36
Vorticella microstoma	all depths	both	40
Opercularia coarctata	all depths	both	16
Epistylis rotans	1.5	F	52
Epistylis plicatilis	1.5	both	43
SPIROTRICHIA			
Aspidisca costata	0.5/1.5	both	52
Aspidisca lynceus	0.5/1.5	both	60
Oxytricha sp.	0.5/1.5	both	20
Stylonychia sp.	0.5/1.5	both	20
Euplotes sp.	1.5	both	102
NEMATODA	all depths	both	8
ROTIFERA	all depths	both	10

TABLE 5.3 : Microfauna of the film

measured depths in both filters. These, the nematode worms, and two ciliates Opercularia coarctata and Glaucoma scintillans, were to comprise much of the microfauna in the subsequent two years. Opercularia has been noted as the most common ciliate in sewage treatment processes. Glaucoma scintillans is also a common ciliate in percolating filters; Curds and Cockburn (1970) in their national survey found that it was the fourth most common protozoan. The relatively early establishment of these organisms, and the fact that they were also able to colonize the surface layers of the filters, indicates a fairly high tolerance to organic matter. Opercularia, a peritrichous protozoan, has by some workers been associated with low levels of organic matter (Barritt 1940; Tomlinson and Snaddon 1966). Curds (1969) in a key to the fresh water protozoan, lists Opercularia coarctata as being mesosaprobic. Glaucoma scintillans on the other hand, a holotrichous protozoan, has been associated with higher levels of organic matter. Curds (1969) lists it as a meso- to polysaprobic.

The first macroinvertebrates, which become established at the same time as the microfauna, were larvae of the dipteran fly Psychoda and a terrestial mite of the order Mesostigmata (table 5.2). The close proximity of established filters (20 metres) should have made conditions ideal for colonization by Psychoda sp once sufficient film had become established in the pilot filters. As with the microfauna colonization took place synchronously at the three measured depths, where there were similar amounts of accumulated organic matter (fig.5.1). Neither of the first two quantitative samples contained any measurable organic matter. Solbe, Williams and Roberts (1967) in a study on the sequence of colonization also found that species of Psychoda were the first macrofauna to colonize new filters, (table 5.2) and found establishment at similar levels of organic matter (0.5 kgm^{-3}). Although using a similar type of sewage, Solbe et al. did not observe colonization by mites in their experimental filters. The mites were, and continued to be restricted to the middle and lower levels of the filters indicating a link with the humus material found in these regions. Hawkes (1963) noted that accumulations of humus as a result of low velocities of flow seemed to favour the detritus feeding organisms such as the coleopterans and arachnida. Therefore as anticipated and despite the higher than conventional hydraulic loading, it seemed likely that the corrugations and the large surface area were reducing the velocity of flow within the medium. The presence of the terrestrial mites, which were later to temporarily become the dominant grazing organism, may also have been indicative that large areas of the surface of the medium in the lower reaches of the filter were not being wetted. Chironomid larvae were found in both filters 14 weeks after the start of irrigation. The chironomids (mostly Metriocnemus sp) remained in small numbers and did not become established in the middle regions of either filter. This is not a general characteristic exhibited by the chironomid larvae, both Shephard (1967) and Hussey (1975), in investigations into the affect of different operating conditions on the metazoal populations of percolating filters, found chironomids at all depths. The lack of colonization of the middle regions in the filters was thought to be a symptom of the generally low numbers within the filters. Rotifers were also observed in the filters at this point. They had become established in the middle regions of one filter and in the surface and bottom regions of the other indicating little preference to a particular depth. By this time the filters were achieving over 70% BOD removal and the mode of operation was altered (week 20 August). The recirculation of effluent to both filters was stopped, and the irrigation rate to one filter increased (designated filter F). The samples taken in week 18, from the high rate filter, and week 20 (August) in the low rate filter (G) contained growths of the filter fungi Subbaromyces splendens. With the exception of Subbaromyces, filter films treating domestic sewage are normally predominantly bacterial, (Hawkes 1963). Subbaromyces on the other hand has been associated with domestic sewage, Cooke (1963) in a guide to the fungi of polluted water, noted that Subbaromyces was common in filters treating domestic sewage. Previous investigations at Langley have also noted growths of fungus in the conventional filters. (Hawkes 1965a; Hawkes and Shephard 1972) and was identified as Subbaromyces splendens by Williams (1971). Tomlinson and Snaddon (1966) in considering the sequence of colonization of their experimental tube filters, also treating domestic sewage, noted that Subbaromyces became established sometime after the initial colonization by bacteria.

During the autumn there was, with the fall in temperature, a progressive accumulation of organic matter in the filters. No additional macrofauna became established during the period (table 5.2) but the ciliate protozoa, despite the adverse temperature, continued to diversify (table 5.3). The sequence of colonization, and the estabilished populations at the end of the first year, were, despite the difference in hydraulic loading to the filters, very similar.

The following summer (1974) the accmulated organic matter in the filters fell to its lowest level since the start of the experiment. This produced marked reductions in the populations of the previously dominant grazers, the psychoda larvae and the mites. This seemed to stimulate a second phase of colonization and enchytraeid worms were first observed in the filters. Initially colonization was by Enchytraeus albidus in the lower levels of each filter (week 64 July). The distribution system was altered from a fixed to a reciprocating system in week 66. A second species Lumbricillus lineatus colonized the filters three months later (week 74 September). Solbe, Williams, and

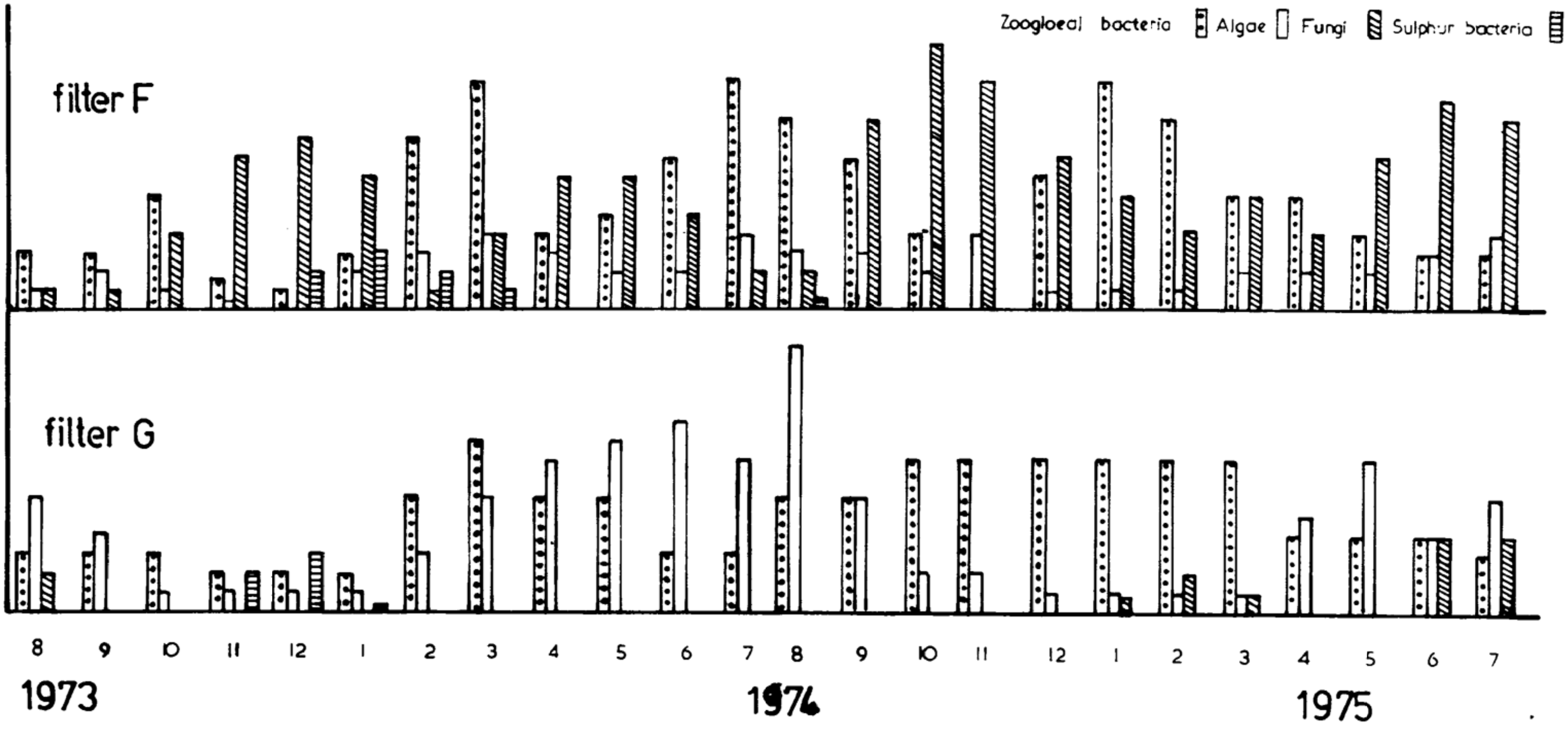
Roberts (1967) in their study on the sequence of colonization, also noted that species of Psychoda were the first macrofauna to appear in new filters and only when the Psychdoa population had been reduced did colonization by the Enchytraeidae take place. A crustacean Canthocamptus, also colonized the filters in this second phase, again initally in the lower levels of the filters (week 74) they later became established throughout the depth of the filters. Crustaceans have been identified in filters on previous occasions (Liebmann 1949; Hawkes 1963; Calaway 1968) but have received little attention. Like the mites the population was transitory lasting only the later months of 1974. Towards the end of 1974 (week 78) as the organic matter in both filters was increasing, Hypogastrura viatica was observed in the middle and bottom of the low rate filter. Hypogastrura viatica did not colonize the high rate filter and this was the only recorded difference between the colonization patterns of the two filters. Both Tomlinson and Hall (1950) and Hawkes and Jenkins (1955) in their investigations into different rates of filtration noted that Hypogastrura was the most sensitive of the macrofauna to elevated rates of filtration. No new ciliate protozoa became established during 1974 or 1975.

5.2.3 Seasonal Changes in Film and Fauna

Fig.5.2 shows the seasonal changes in surface film microorganisms, figs 5.3 to 5.10 the seasonal changes in fauna and quantity of film. Three major peaks in film accumulation occurred during the experimental study. Peaks in film weight were recorded in the autumn of each year under observation with a third in the spring of 1974. Winter accumulations of film in percolating filters are well known and are thought to be the result of a number of interacting factors, notably ambient temperature, sewage strength and composition, and mode of application of the sewage of the filters. Film accumulation leading to the Autumn peaks began in the late Summer on both occasions and thus appeared linked to changes in ambient tempeature. The unloading of these peaks however were not related to increases in temperature but occurred during the coldest months of the year. Further, the 1974 Spring accumulation of film took place in a period of increase in temperature. Therefore the film fluctuations in the experimental filters did not appear to be simply linked to ambient temperature.

Another possible influence of film accumulation was the seasonal changes in sewage strength. Figs.5.11 and 5.12 show the film weight in relation to filter load. With the exception of the Spring 1974 increase in film weight, fluctuations did not appear to be simply linked to sewage strength. Sewage strength was at a maximum in July 1974 when film weight was at a minimum and maximum film weight occurred when there was a steady decrease in

FIG 5.2 Relative abundance of identifiable surface micro-organisms



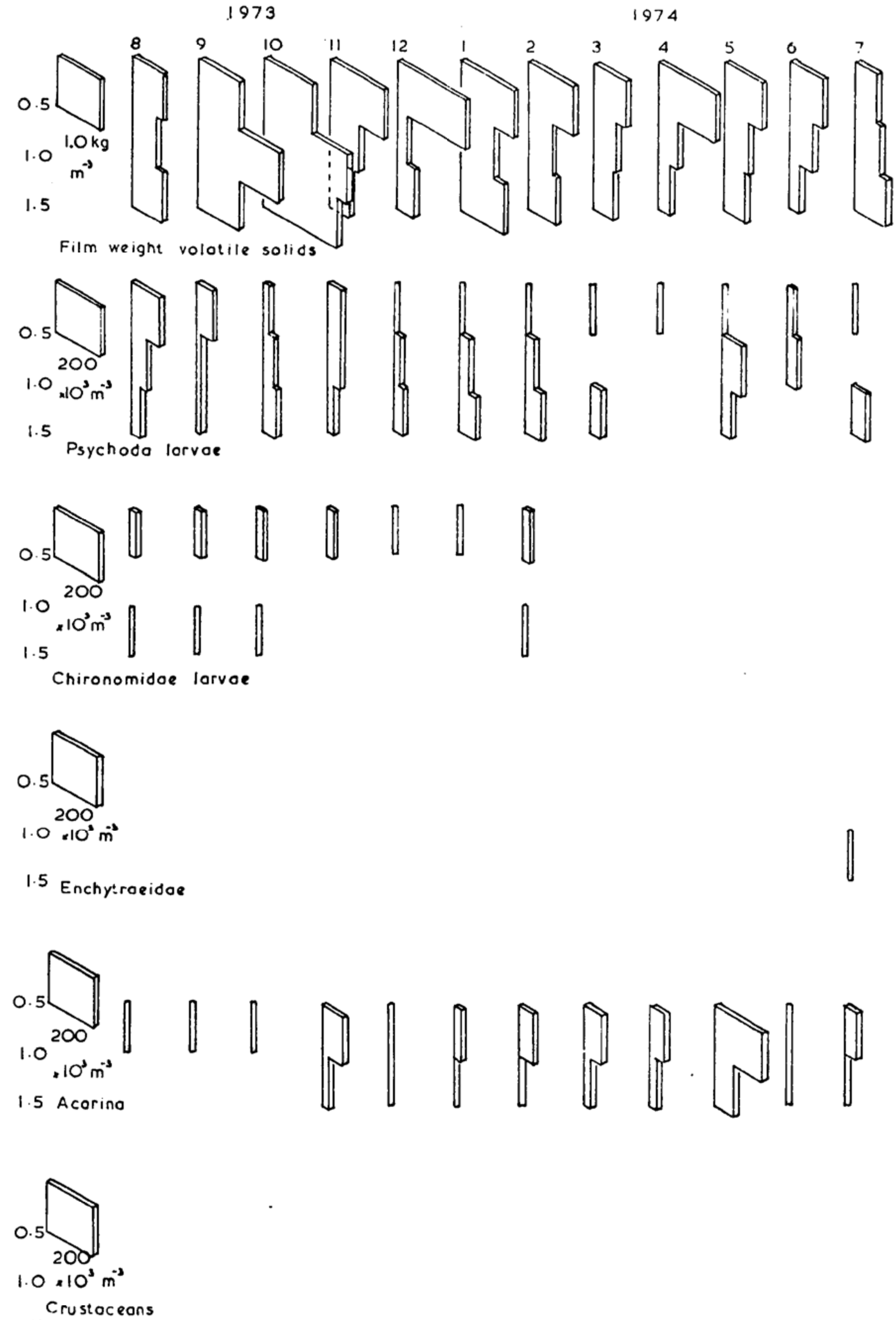


Fig 5.3 Vertical Distribution of Film & Macrofauna High Rate Filter F

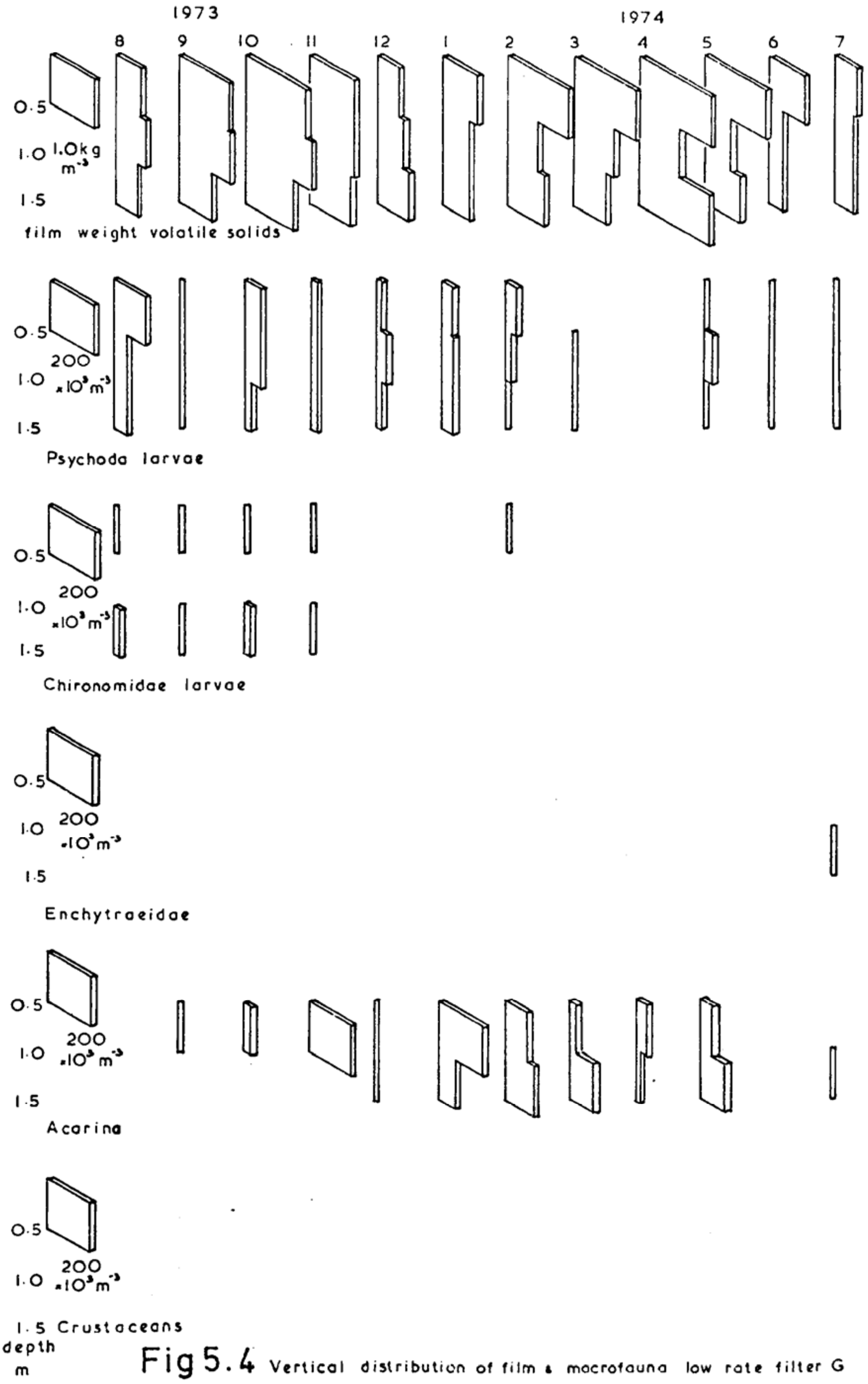


Fig 5.4 Vertical distribution of film & macrofauna low rate filter G

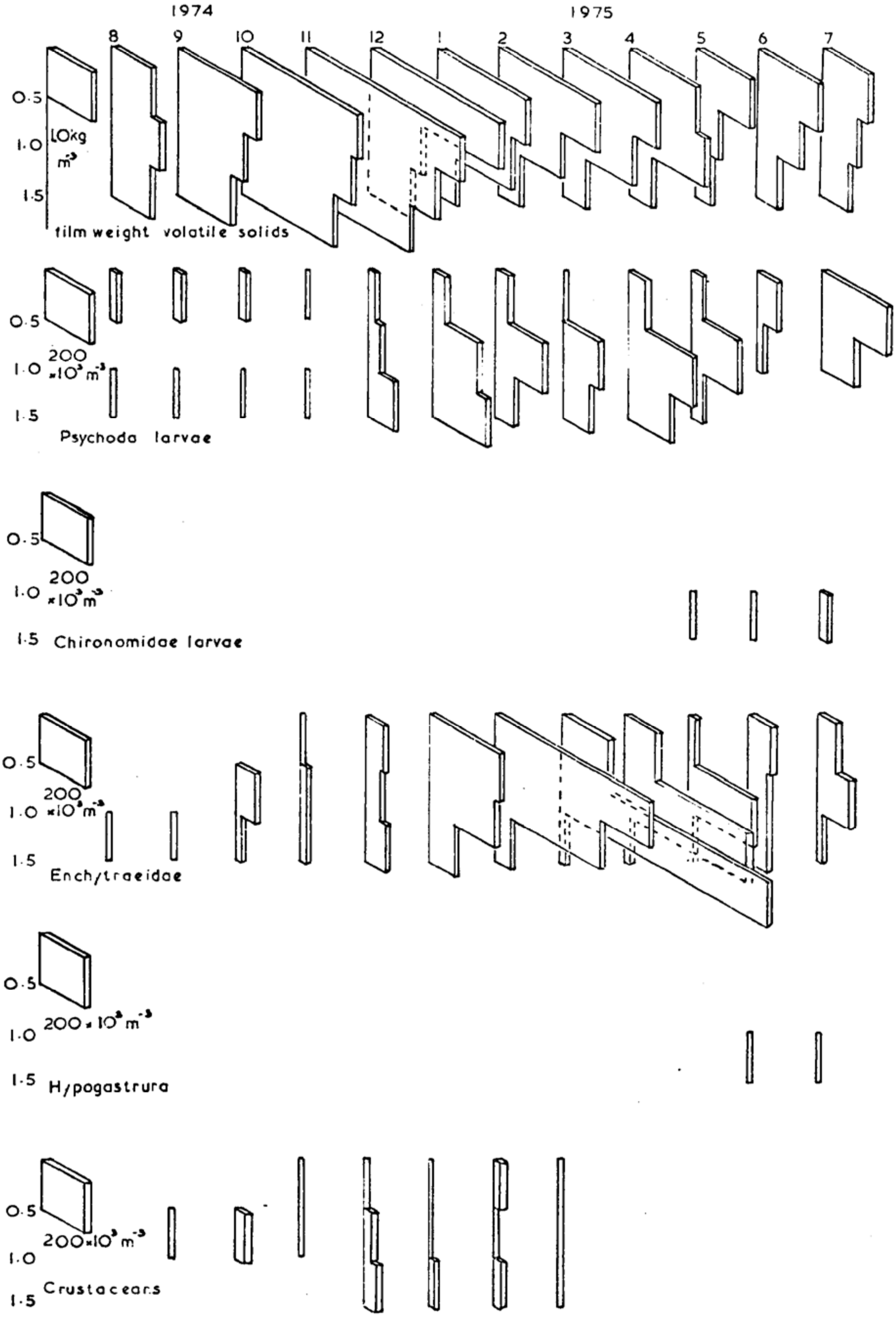


Fig 5·5 Vertical Distribution of Film & Macrofauna High Rate Filter F

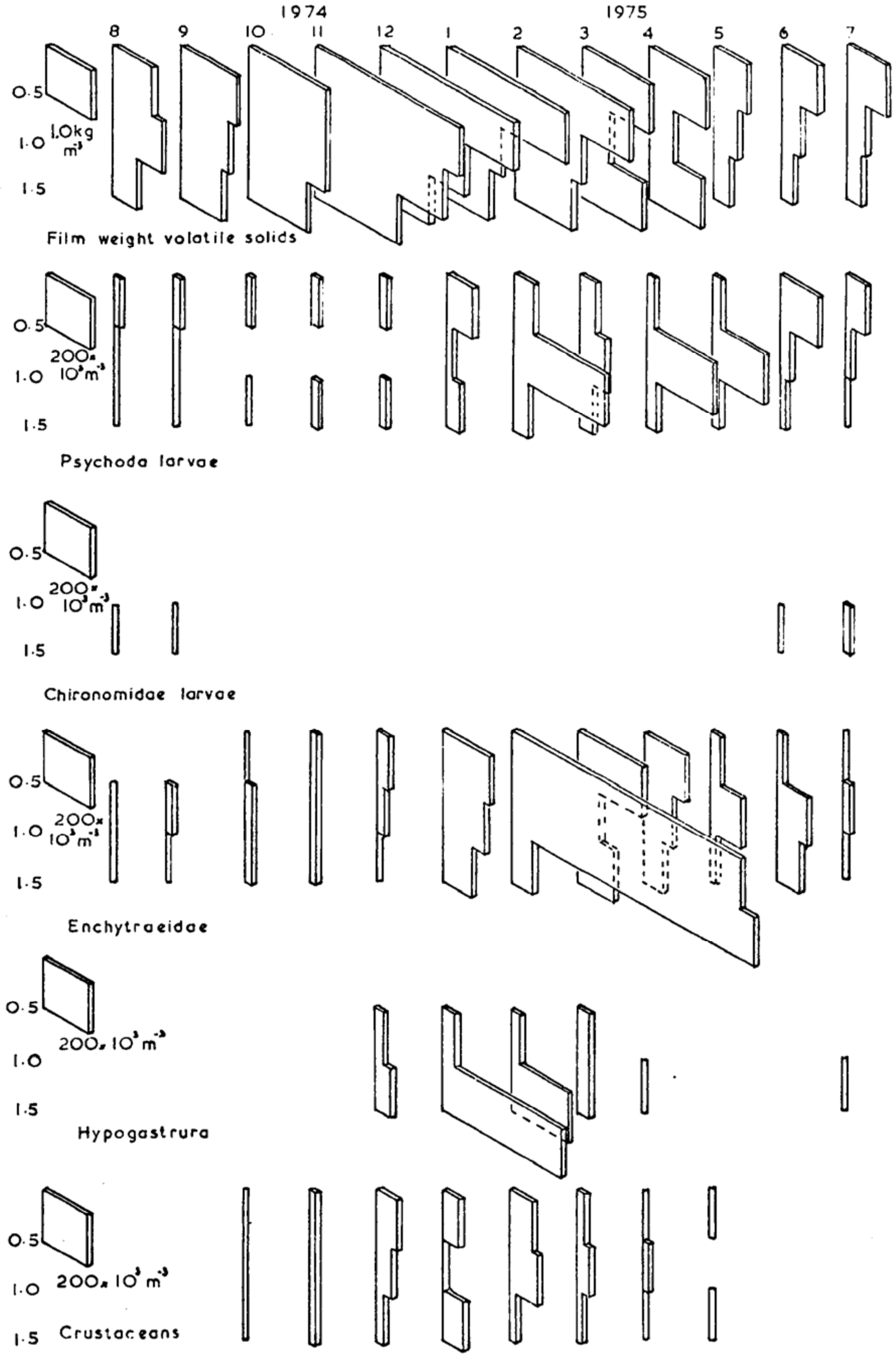


Fig 5.6 Vertical Distribution of Film & Macrofauna Low Rate Filter G

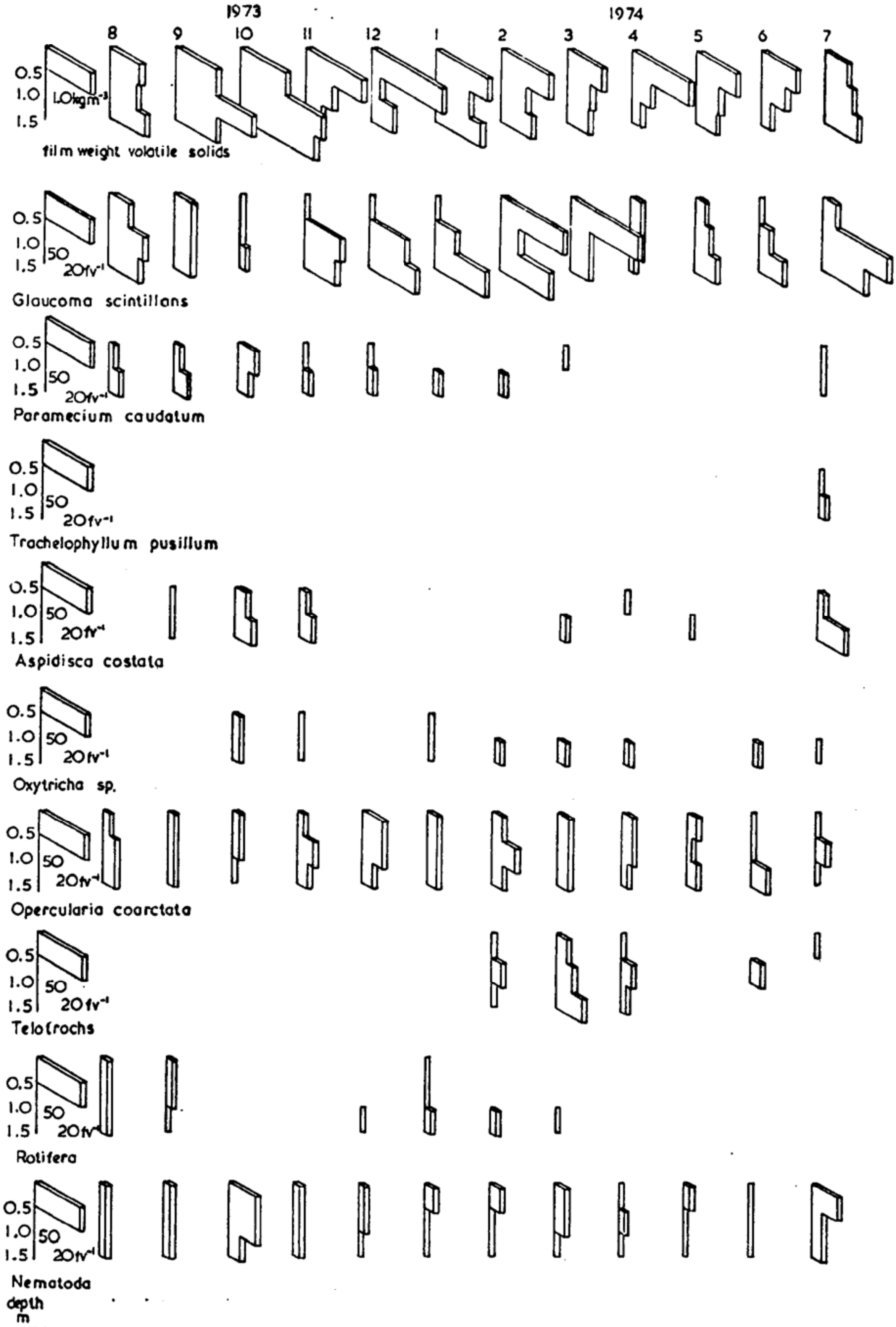


Fig 5.7 Vertical distribution of film and microfauna high rate filter F

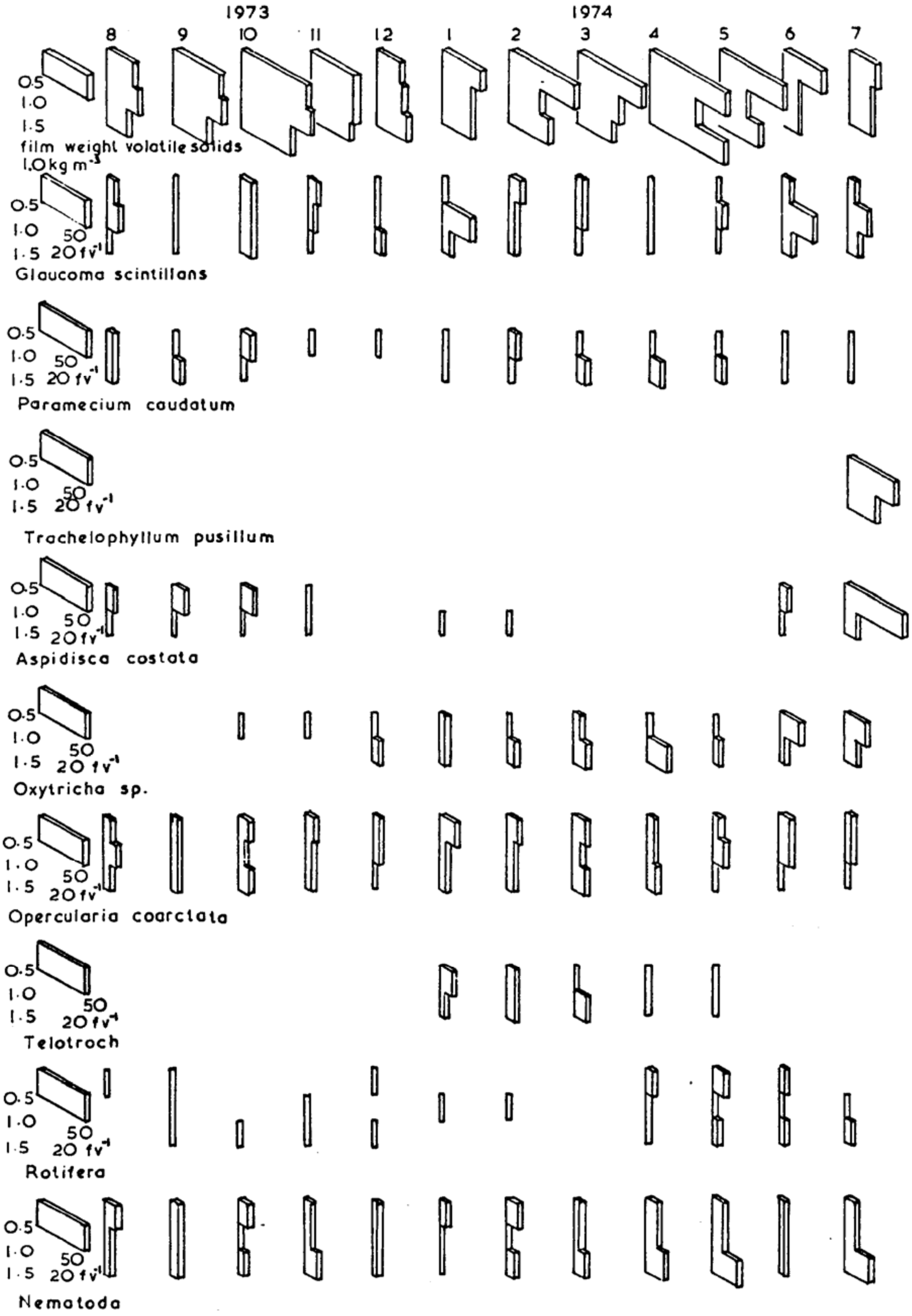


Fig 5.8 Vertical distribution of film & microfauna low rate filter G

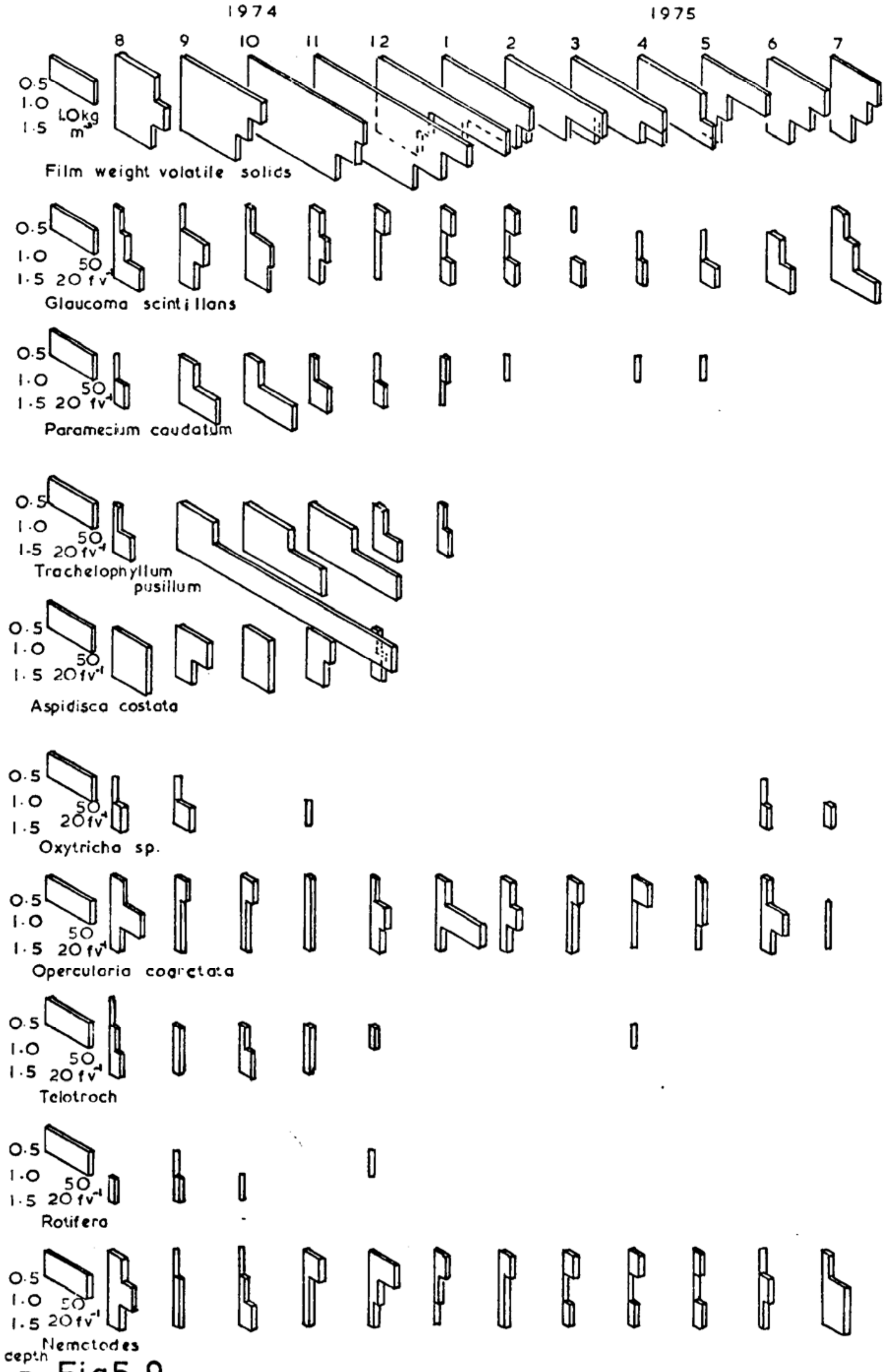


Fig5.9 Vertical Distribution of Film & Microfauna High Rate Filter F

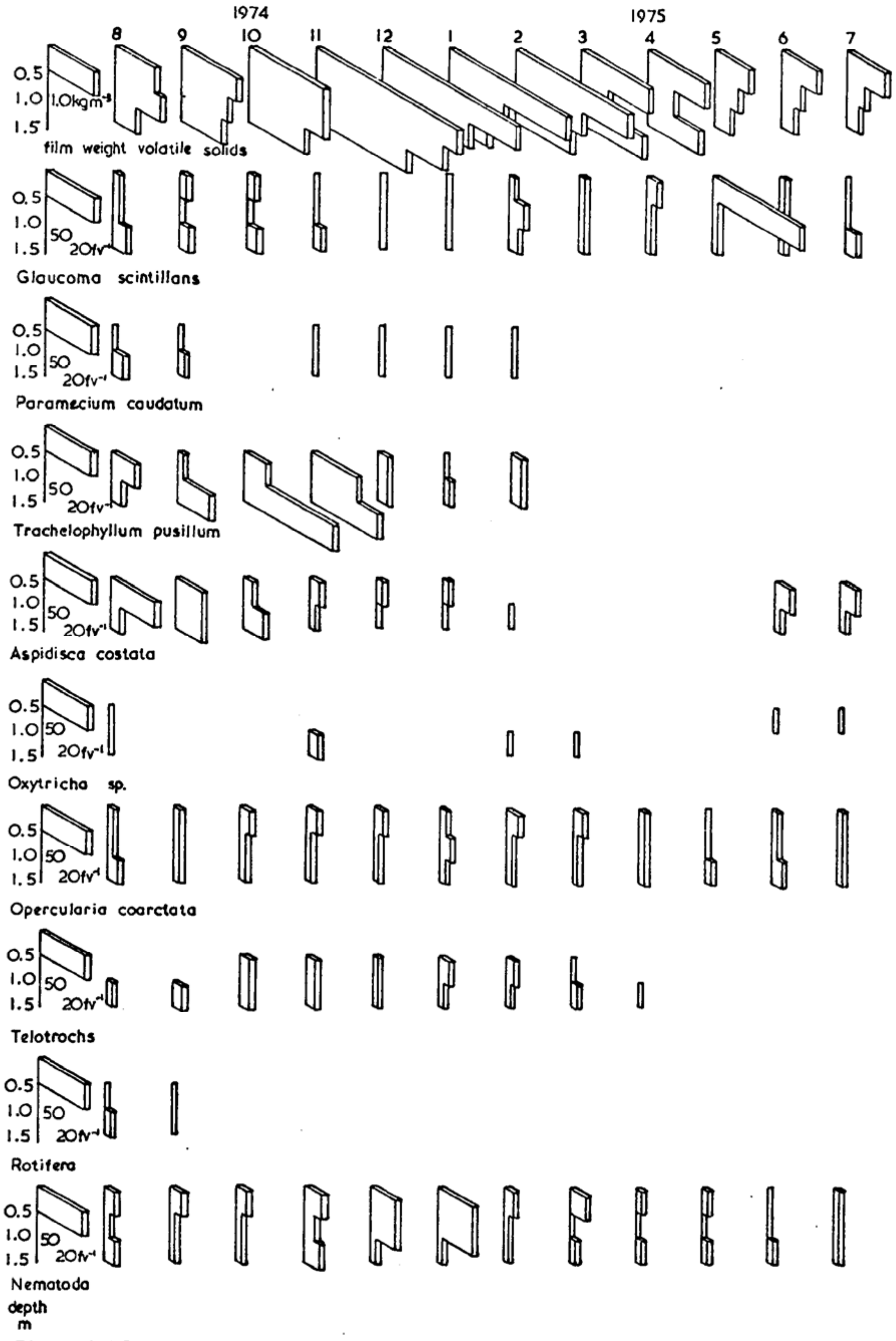
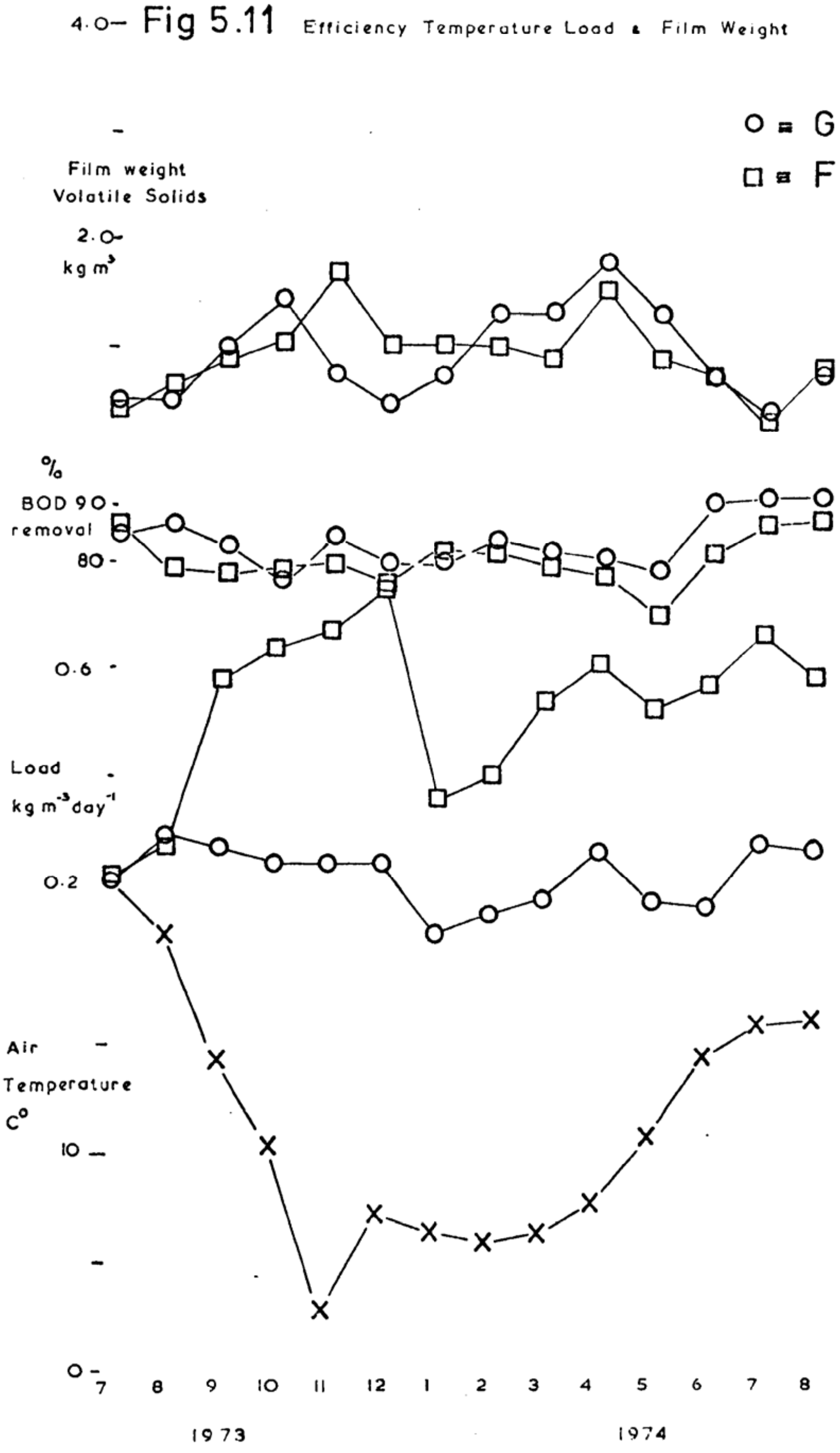


Fig 5.10 Vertical distribution of film and microfauna low rate filter G

Fig 5.11 Efficiency Temperature Load & Film Weight



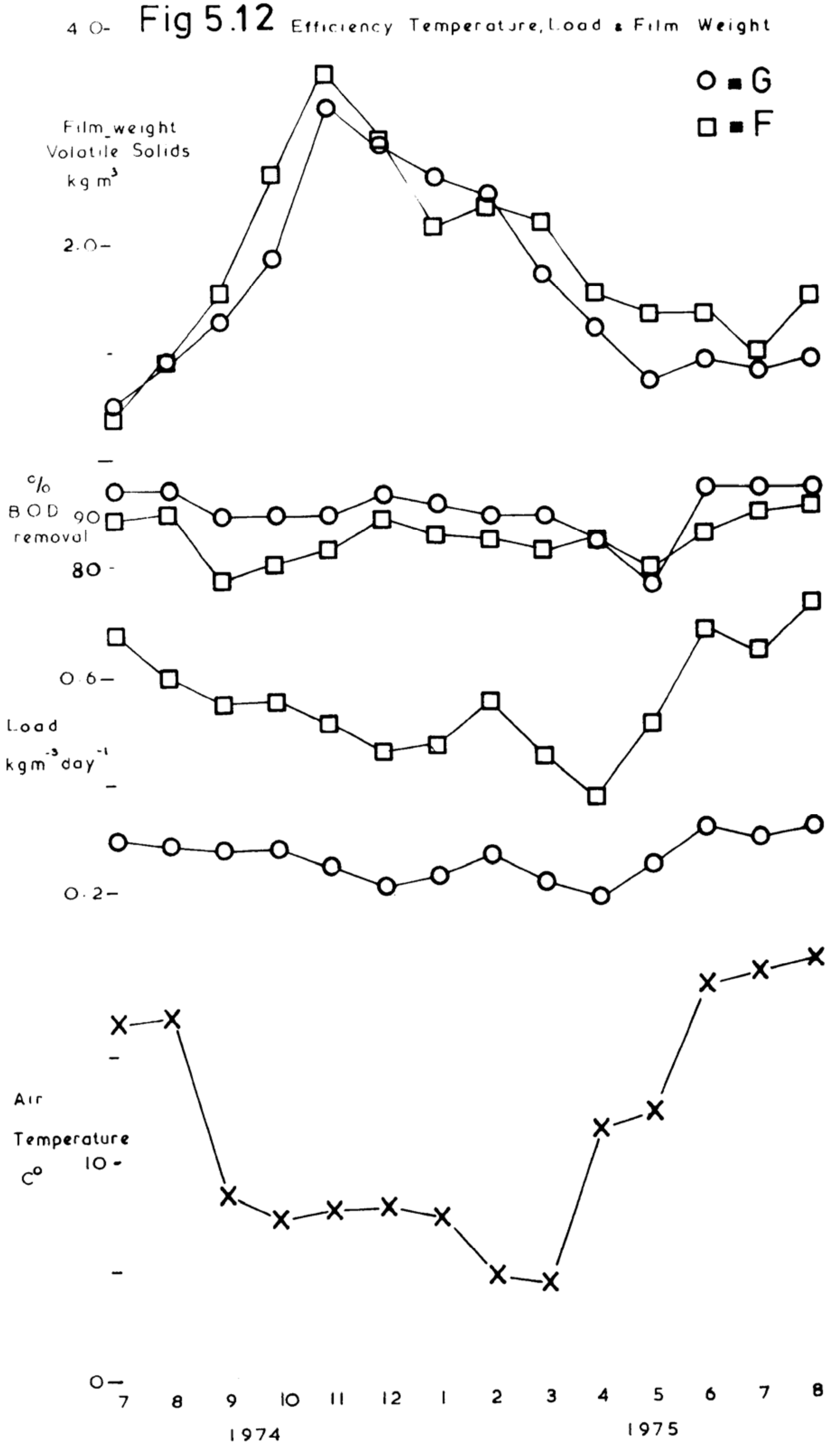


Fig 5.12 Efficiency Temperature, Load & Film Weight

sewage strength due to the Winter rainfall September to November 1974.

One of the indirect effects of temperature is often a change in the composition of the film. Many sewage filter fungi have a wider optimal temperature range than bacteria flourising in the same habitat, and in particular some are capable of appreciable growth at low temperatures (Tomlinson 1946b; Williams 1971). This tends to promote fungal growths in situations where nutrient conditions also suit them, as is usually the case in filters receiving strong industrial sewage. Large winter accumulations of film are therefore often linked to a change from a bacterial to predominantly fungal film. In filters fed with domestic sewage although the film is typically bacterial there is a fungus Subbaromyces, (plates 5.1,5.2) which is often found in these situations (Tomlinson and Snaddon 1966; Williams 1971; Hawkes and Shephard 1972). Examination of the filter films revealed the Subbaromyces was a significant component of the film only in the high rate filter (F) (fig. 5.2). The major components of the film in the low rate filter (G) were the algae and the bacteria. The algae dominated the film in the lighter warmer months of the year and the bacteria in the colder months of the year (fig. 5.2).

In the high rate filter (F) the growth pattern of the fungus Subbaromyces followed the film accumulation closely, appearing as the dominant film growth at the end of the Summer and reaching a peak in the Autumn and Spring of each year (fig. 5.2). These correspond to the peak film accumulations in the high rate filter (F). Some Subbaromyces was found in the low rate filter (G) but the amounts were, unlike the situation in the high rate filter (F) never sufficient to dominate the film. The type and rate of irrigation affects the composition of the film; continuous dosing favours fungal growths, as shown by workers experimenting with low frequency dosing (Tomlinson and Hall 1955; Hawkes and Shephard 1972). The differences in the film of the two filters are similar to those found by Shephard (1967) who investigated the ecological differences between a low frequency dosed filter and a continuously dosed filter. Shephard however found a reduction in the accumulated organic matter with the elimination of the fungi in the low frequency dosed filter. High organic loads also promote fungal growths (Hawkes 1965a). Observations on the surface of the filter showed that the fungi grew more prolifically in the areas of greatest wetting, that is directly under the distribution points. Changing the distribution system to one of a more continuous irrigation with jets increased the area covered by fungal growths. In the experimental filters, despite the differences in the film between the two filters, the film accumulation patterns were very similar (fig. 5.11 and 5.12). It therefore seems unlikely that the differences in the film composition affected film accumulation in this investigation.

Another influence on fluctuations in film amounts is the seasonal activity of grazing organisms. Larvae of Psychoda were the dominant grazing organisms during the first year of operation and remained in significant numbers throughout the investigation (figs. 5.3, 5.4, 5.7, and 5.8). Enchytraeid worms, common in the full-scale filters, did not appear until the second year of operation. They increased with the autumnal film accumulation in 1974 and reached peak populations early in 1975 at the same time as Psychoda. A few chironomid larvae were observed in the Summer and Autumn periods but were never an important component of the grazing macrofauna. Throughout most of the year the numbers of grazing organisms were relatively low and it was only after a major rise in film weight that the numbers of grazing organisms began to increase. Figs. 5.10 and 5.11 show that there is a two month delay following the peak in film accumulation before the numbers of enchytraeid worms and Psychoda began to develop. This suggests that the macrofauna are not responsible for the seasonal fluctuations in film weight. The numbers of macrofauna reached a peak in the period December - February 1975 and the reduction in film weight increased over this time, the macrofauna were therefore partly involved in the reduction in organic matter which occurred.

There were some unusual features in the macrofaunal population; in the Autumn and Winter of 1973 - 74 a large population of mites built up in both filters but were confined to the lower levels and have not appeared since in such large numbers. In the following Winter large numbers of a Canthocamptid crustacean occurred in the low rate filter and to a smaller extent in the high rate filter (figs. 5.5 and 5.6). The presence of Canthocamptids was also temporary and by the Spring of the following year had disappeared.

Towards the end of 1974 large numbers of the springtail Hypogastrura viatica were also found in the low rate filter, and like the mites were confined to the lower regions (fig. 5.6). All these populations built up at the same time that increases were taking place in the numbers of Psychoda larvae and enchytraeid worms, and there appears to be little evidence of competition between the various species of the macrofauna.

The microfauna of the film was studied by regular microscopical observations, and the populations were found to consist mainly of ciliated protozoa and nematodes, with small numbers of rotifers also present. The species of protozoa most consistently present were Glaucoma scintillans, Paramoecium caudatum, Opercularia coarctata and members of the Oxytrichidae (figs. 5.7, 5.8, 5.9 and 5.10). At times large increases in the microfaunal populations occurred when the numbers of macrofauna were low. In November

1973 *Psychoda* larvae and mites were largely restricted to the lower layers of the filters but an unloading of organic matter took place from all depths. This coincided with a general increase in the microfaunal populations suggesting that they might be responsible for the unloading near the surface. A similar affect was observed in the Spring 1974 when both macrofauna and microfauna increased but the macrofauna were restricted to the lower levels of the filters (figs.5.5, 5.6, 5.9, 5.10). A number of workers have noted that nematode worms are responsible for a significant portion of the grazing activity in percolating filters (Hawkes 1955b; Tomlinson and Snaddon 1966; Shephard and Hawkes 1976).

In the period June - September 1974 the filters contained only small numbers of macrofauna but a large microfaunal population. Most members of the microfauna increased in numbers but the largest increases occurred in two ciliates *Aspidisca costata* and *Trachelophyllum pusillum*. Curds, Cockburn and Vandyke (1968) have suggested that *Trachelophyllum* is one of the few carnivorous protozoa found in sewage treatment processes and their presence in large numbers with large numbers of *Aspidisca costata* may indicate a predator-prey relationship. Eventually *Trachelophyllum pusillum* became the dominant protozoan in both filters and the numbers of other protozoa were markedly reduced, suggesting that *Trachelophyllum* was responsible (figs.5.9, 5.10). Once the population of microfauna had fallen the numbers of macrofauna in the filters increased (figs. 5.5 and 5.6). In general the populations of microfauna and macrofauna were inversely related, the lowest numbers of macrofauna were recorded when the film weight was at a minimum. Competitive antagonisms between macrofauna and microfauna have been noted by two workers (Barker 1946; Hussey 1975).

5.2.4 Film accumulation in relation to efficiency

Since the efficiency of a percolating filter is dependent on the aerobic activity of micro-organisms contained in the filter except at the lowest film levels, performance is normally inversely related to film accumulation. Excessive amounts of film may prevent the flow of both sewage and air through the medium. Observations were therefore carried out over the two and a half year test period to determine whether the new medium contained sufficient voidage to overcome this problem at higher organic leadings. Figs. 5.11 and 5.12 show the performance of the two filters in relation to the accumulation of organic matter, sewage strength, and ambient temperature. Although the poorest performance was obtained from the filters when film accumulation was at a maximum (October to December) this also corresponded to the lowest ambient temperatures of the year. Performance would therefore be expected to be at a minimum because of the direct effect of the low temperature on the metabolism of the film. Similarly minimum film accumulation corresponded with both the highest temperatures and best performance. During the 1974 spring peak in film accumulation (January - April) the mean air temperature varied little and while the organic matter in both filters increased (1.5 kgm^{-3} in the high rate filter (F) and 0.5 kgm^{-3} in the low rate filter (G) the performance of the two filters remained unchanged. Later in the same year (September - November) the mean air temperature again showed little variation and despite a doubling of the organic matter in the filters, the performance in the low rate filter (G) remained constant while that of the high rate filter improved slightly (figs. 5.11, 5.12). The poorest performance was recorded not in the winter months, but in May of each year. The reason for this behaviour was not entirely clear, but in both cases this was the final phase of an unloading period. Suspended solids in the settled effluent were high at this time (figs. 5.13, 5.14) but the origin of the material could not be determined. The products of film lysis or the release of accumulated solids could have contributed substantially to the BOD. No increase in the numbers of grazing organisms were recorded in these periods.

During the winter accumulation of 1974 the depth of the film did in some areas of the filter exceed the 3mm necessary to fill the corrugations of the medium. It was anticipated that there might be some loss in performance

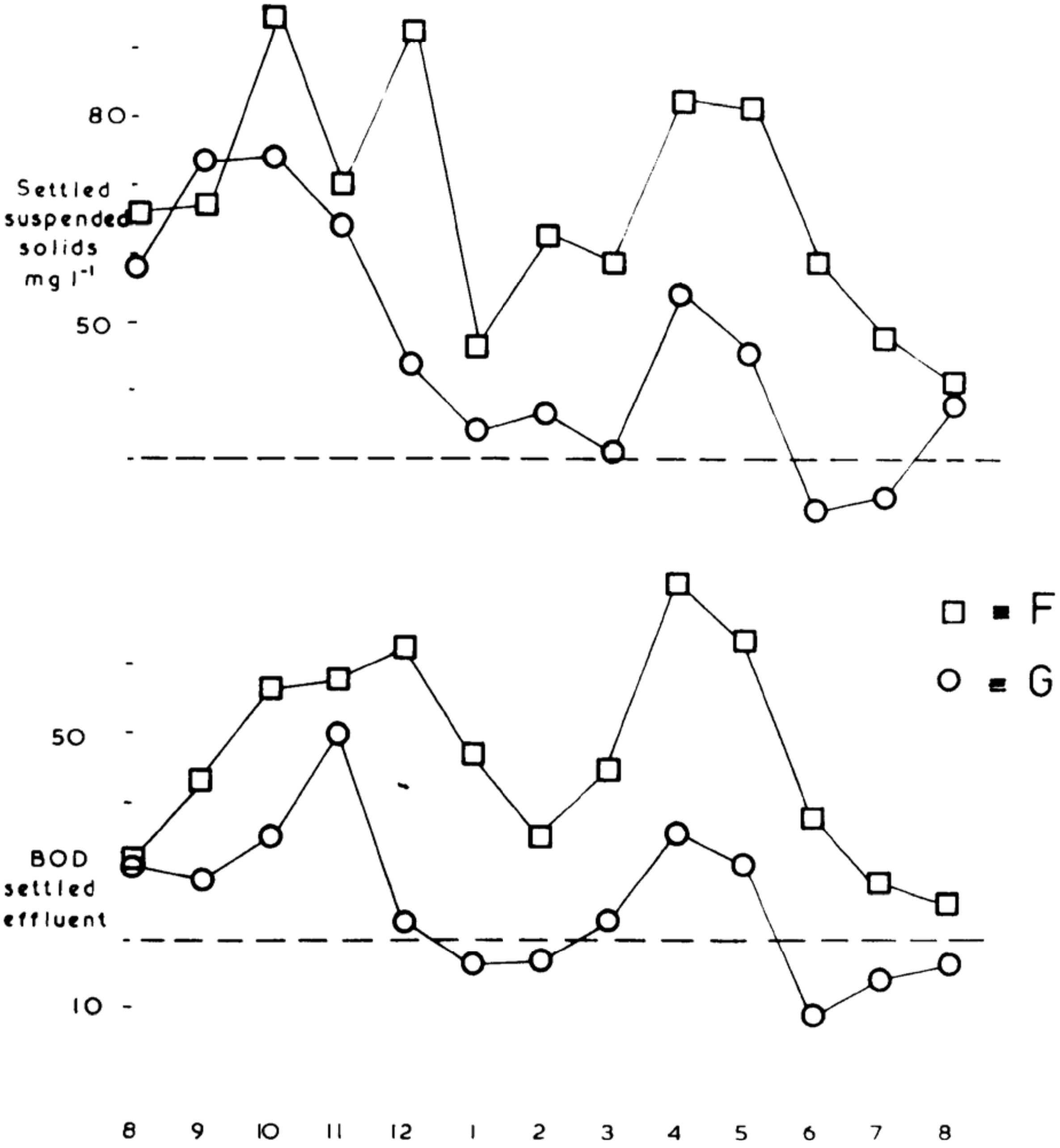


Fig 5.13 Mean effluent quality 1973 - 1974

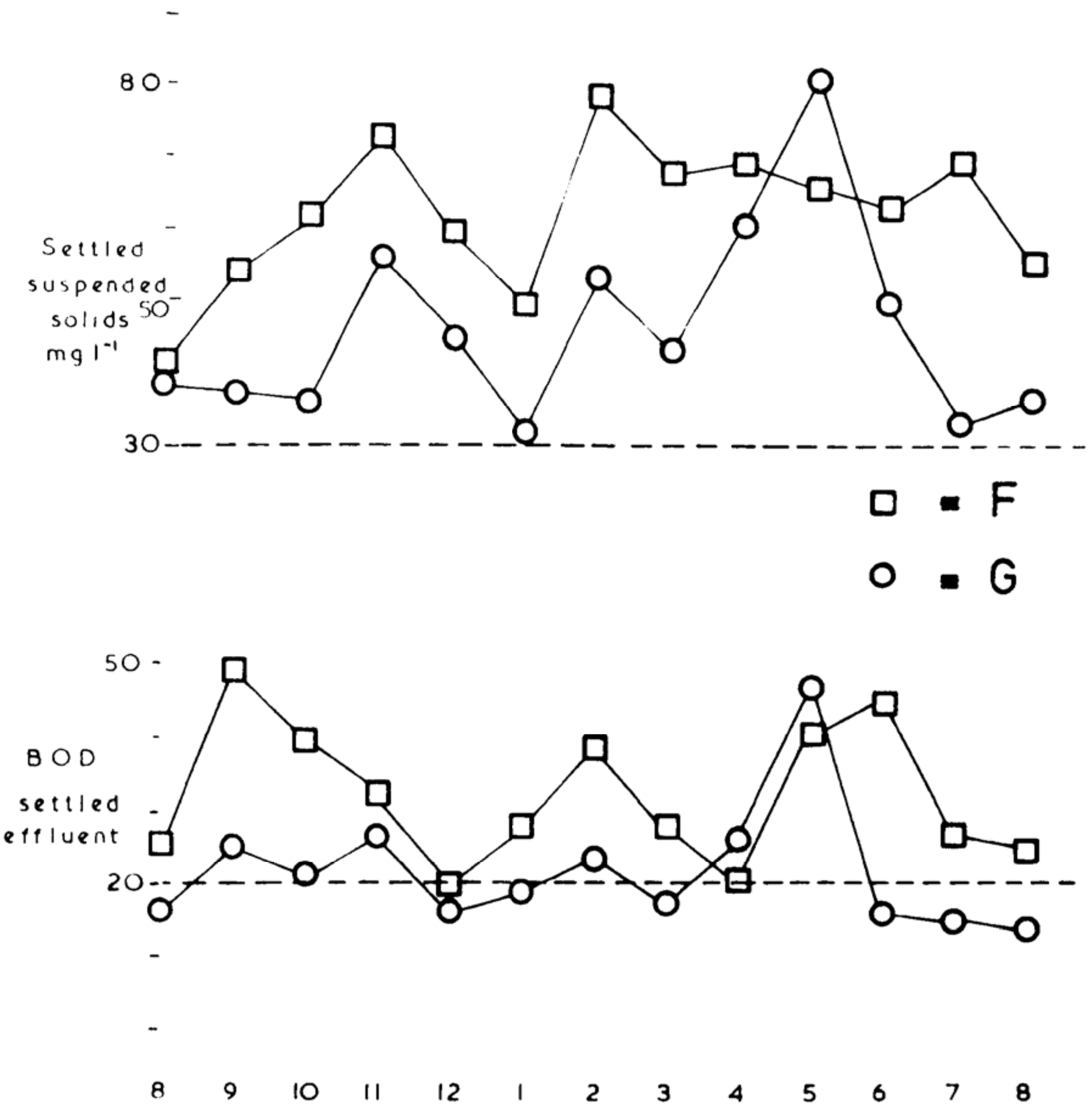


Fig 5.14 Mean effluent quality 1974 – 1975

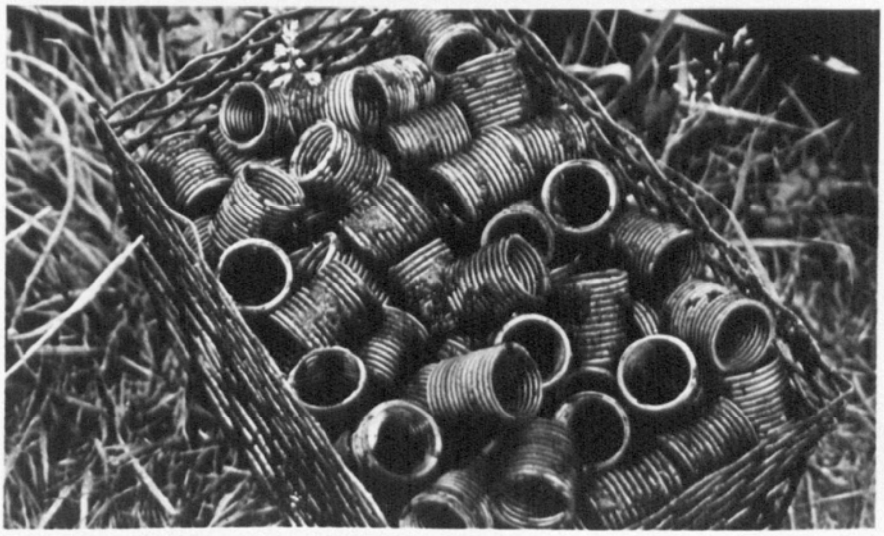
associated with the reduction in surface area, but this was not reflected in the results (fig. 5.12). The critical film accumulation, where the corrugations began to be occluded was observed to be in excess of 2.5 kgm^{-3} (as volatile matter). Hawkes (1963) noted that ponding occurred in 60 mm mineral media at 10 kgm^{-3} accumulated organic matter (as volatile solids).

A series of measurements with the neutron probe were carried out at peak film accumulation in November 1974. As on previous occasions when the probe had been used the counts were not significant above the control counts, indicating a less than 4% occlusion of the voidage.

5.2.5 The Vertical Distribution of Film and Fauna

At conventional rates of filtration (recommendations of the 5th Royal Commission on Sewage Disposal, 0.3-0.4$m^3m^{-3}day^{-1}$) a number of workers have noted that most of the BOD removal occurs in the surface layers of the filter (reviewed Section 5.1). Mills (1945a) in the early experiments on ADF found that in excess of 80% of the total BOD removal took place in the first half metre of the filter bed. Tomlinson (1946b), in the same series of experiments, noted a similar distribution of film with 62% of the film growth in the surface layers of the filter. This, he assumed, was because the surface of the filter was receiving the highest concentration of organic matter. Increasing the hydraulic loading to the filter is known to increase the utilisation of the bed depth (Tomlinson 1946b; Tomlinson and Hall 1955; Hawkes 1955a; and Hawkes 1963). The low rate filter (G) was being irrigated at almost four times the conventional loadings ($1.2m^3m^{-3}day^{-1}$) and the high rate filter (F) at almost eight times conventional loadings ($2.4m^3m^{-3}day^{-1}$). Observations on the composition of the film at different depths in the filters indicated that there was little viable film in the lower levels of either filter, the material present being largely humus (plate 5.1). There were some differences between the filters, growths of both zoogloeal bacteria and fungi were observed in the middle regions of the high rate filter but only traces of identifiable material were ever observed in the middle regions of the low rate filter (G). Some traces of fungi were also observed in the bottom of the high rate filter, but this may have been fragments of mycelium washed down from the upper layers. The chemical data on the effluent taken from the different depths (Tables 6.4 and 6.5) confirms this pattern. Over 85% of the total BOD removal occurred in the top half metre of both filters. So while there was some difference between the filters in terms of film and BOD removal, (table 6.4) there was, despite the high hydraulic loadings, little BOD removal in the lower regions of either filter.

a



b

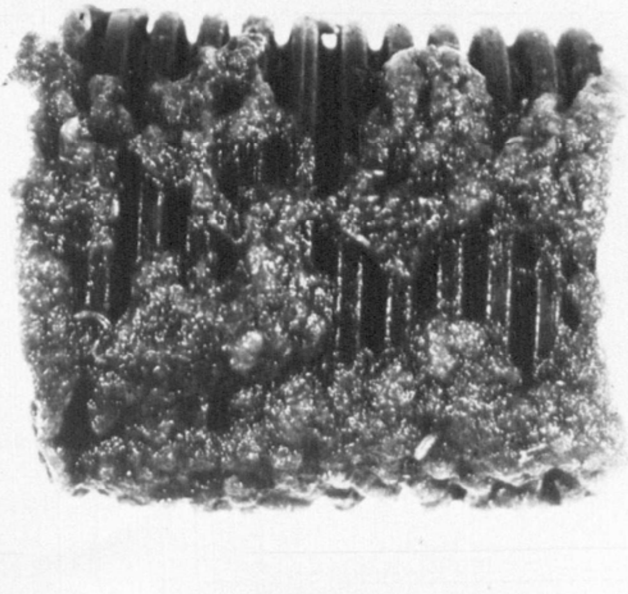


Plate 5.1 EXPERIMENTAL MEDIA IN USE

(a) Sampling basket removed from the filter

(b) Experimental media with fungal growth and Psychoda larvae taken from the surface of filter F

The vertical distribution of the film in percolating filters, and consequent levels of effluent quality, produce a similar vertical distribution of the grazing fauna (Tomlinson 1946b; Tomlinson and Hall 1955; and Hawkes 1961).

In the experimental filters Psychoda larvae and enchytraeid worms were the dominant grazers, and both have been shown to prefer thick growths of film (Lloyd 1945; Terry 1951; Hawkes 1957). Generally the largest numbers of <u>Psychoda</u> and <u>Enchytraeidae</u> were recorded in the middle regions of the filters. Normally this level contained less organic matter than the surface. One possible reason was that the higher than conventional hydraulic loading was inhibiting the macrofauna in the surface of the filter. Psychoda larvae are known to be sensitive to hydraulic loading. (Tomlinson and Hall 1950; Hawkes 1955a; Lumb and Eastwood 1958). Tomlinson and Hall (1950) however reported that inhibition began at loadings in excess of $3.0m^3m^{-3}day^{-1}$, and Bruce Merkens and Macmillan (1970) found a large number of psychoda larvae present in filters being dosed at $6.0m^3m^{-3}day^{-1}$. The voidage of the medium may have been important in this respect. Hawkes and Jenkins (1955;1958) noted that the affect of hydraulic loading was enhanced by media with a greater voidage which promoted a greater velocity of flow within the medium. This affect would not have been as important lower down the filter because of the ability of the medium to redistribute the flow. The cylindrical nature of the medium was observed to offer some protection against the impact of the sewage; numbers of psychoda flies were found hanging within those media units in a horizontal position. The small amount of film in this part of these media units made the situation inhospitable for the larvae.

The Enchytraeids have been reported to thrive in the conditions of reduced competition created by the increased hydraulic loadings, (Tomlinson and Hall 1950; Hawkes 1955a; Hawkes 1961). A further physical effect of the medium may explain the low numbers of these organisms in the surface layers. Terry (1951) observed a burrowing type behaviour in lumbricid worms with a tendency to maintain maximum contact between body surface and organic matter. In the surface layers the film was spread relatively thinly over the surface of the medium, while the humus in the lower regions of the filters tended to form heaps of material in the voidage of the medium (plate 5.1).

Of the species of Enchytraeidae, Enchytraeus albidus was more common in the low rate filter (G) (appendix 4). Lloyd (1945) noted that Enchytraeus albidus was sensitive to high hydraulic loadings.

Chironomid larvae were recorded only during the early stages of the experiments when film accumulation was at a minimum. The chironomid larvae are known to prefer thin films (Terry 1956; Hawkes and Shephard 1972). The chironomids were found in the surface and bottom of the filters (figs. 5.3 and 5.4). Lloyd (1945) and Tomlinson (1946a) noted that the chironomids unlike Psychoda sp. might not be able to undergo their full life cycles within the filter, but that some species retained the need for a mating flight so the adult female flies may have preferentially laid their eggs within easy access of one of the surfaces of the filters. Other investigations (Shephard 1967; Hussey 1975) found the largest numbers of chironomid larvae in the surface of the filters.

In the early stages of experiments the filters contained large numbers of terrestrial mites. Three species were identified by the British Museum (table 5.2)(plate 5.3). The mites were limited to the lower levels of each filter (figs. 5.3 and 5.4). Hawkes (1963) noted certain macrofauna such as the beetles and mites were found in the lower regions of filters where the lower rates of flow and consequent accumulation of detritus suit them. Hypogastrura viatica was also found only in the lower regions of the filters (figs. 5.4 and 5.6). Hypogastrura was never recorded in large numbers in the high rate filter (F) and its sensitivity to high rates of flow is well known (Tomlinson and Hall 1950; Hawkes and Jenkins 1955; Hawkes and Jenkins 1958).

The Canthocamptids observed in the second year of operation were found throughout the depth of the filter.

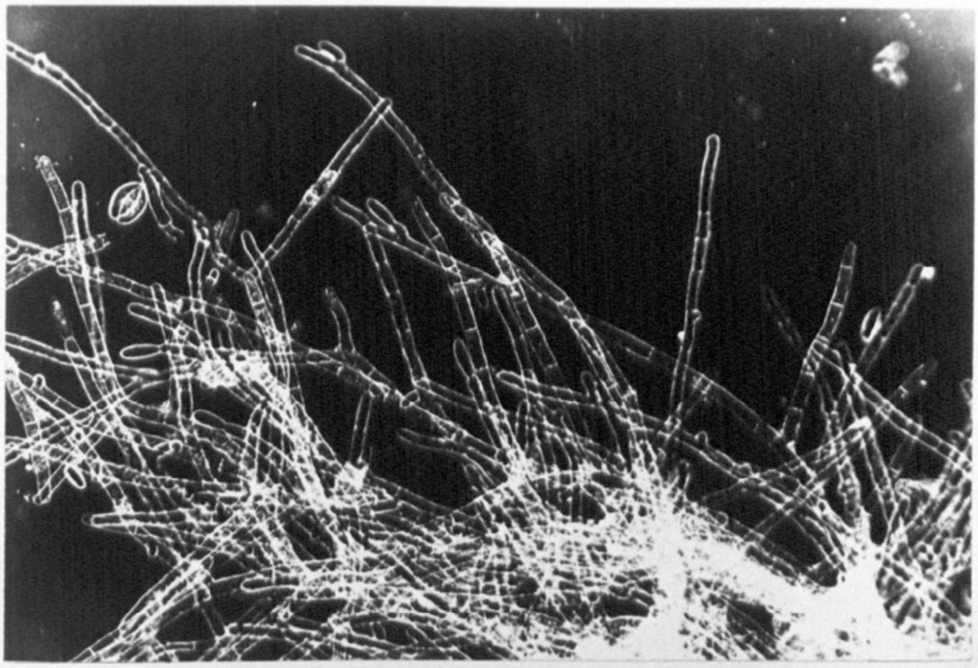


Plate 5.2 *Subbaromyces.*

Mycelium from film with conidia borne singly at the tips of some of the hyphae

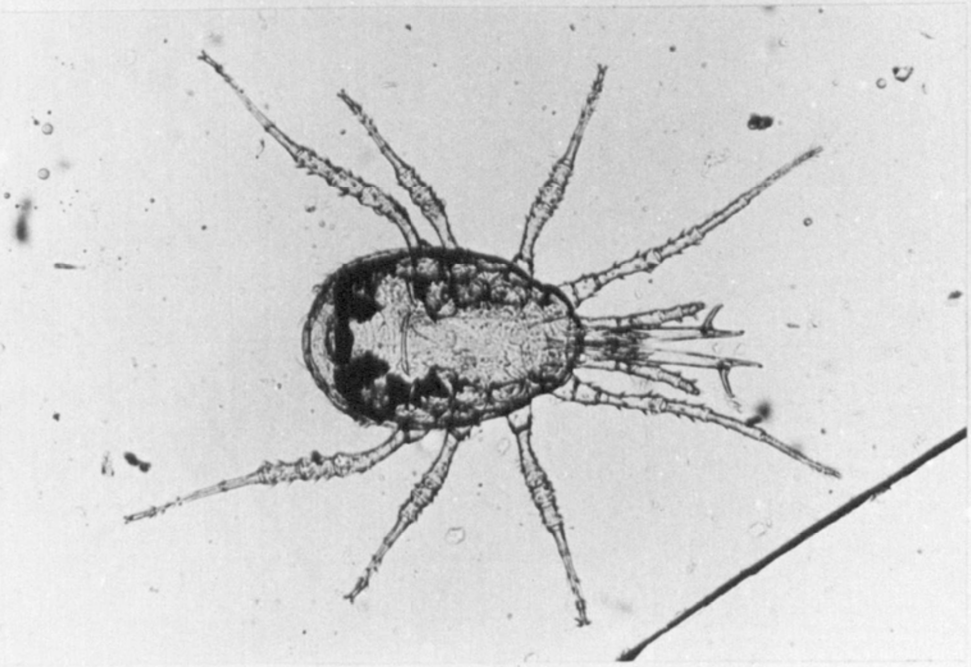


Plate 5.3 *Platyseius italica* (×40)

the most common mite in the filters

Pillai and Subrahmanyan (1946) noted that the crustaceans in filters, like many protozoa and rotifera, fed on suspended matter in the effluent stream.

As with the mites, the population of crustaceans was transitory lasting only the early months of 1975 (figs. 5.5, 5.6). Solbe Williams and Roberts (1967) found a number of temporary populations and suggested that the ultimate trophic structure may take several years to develop. Notable in this respect was the absence of *Lumbricid* worms. The *Lumbricid* worms were also the last of the macrofauna to colonise the filters in the study made by Solbe, Williams and Roberts (1967) into the sequence of colonization so it is possible that the experimental filters had not been operating long enough for the colonization by the Lumbricids.

Following a number of surveys on the protozoa found in percolating filters and activated sludge plants, it is now established that the distribution of protozoa occurs in accordance with the organic matter remaining at different stages of the process (reviewed 5.1).

Vertical distribution of the ciliate protozoa did occur in the experimental filters but not in the pattern suggested by earlier work.

The most common protozoan throughouts the depth of both filters was *Opercularia coarctata* (figs. 5.9, 5.10.).

The largest numbers occurred in the high rate filters (F) at periods of greatest film accumulation, suggesting a link with the organic matter contained in the filter. *Opercularia sp.* have previously been associated with environments containing small amounts of organic matter, (Barritt 1940; Barker 1946; Tomlinson and Snaddon 1966). Other investigations have indicated a more general distribution of *Opercularia sp.* (Curds 1969; Curds and Cockburn 1970; Hussey 1975).

The other common peritrichous ciliate *Vorticella microstoma*, recorded by Curds and Cockburn (1970) as the second most common ciliate, was observed only as the telotroch stage in the experimental filters. *Vorticella microstoma* has been recorded in the conventional filters at Langley in large numbers (Shephard 1967) and has been associated with poor activated sludge effluents and the surface layers of filters (Curds and Cockburn 1970). A direct effect of the plastic medium or void space is unlikely in view of the typical environment created on the medium by the film and the other grazing fauna. High hydraulic loadings in the experimental filters may have been responsible. Hussey (1975) also recorded low numbers of *Vorticella sp.* in filters with recirculation.

Although never in large numbers *Paramoecium caudatum* was observed in the lower levels of both filters. *Paramoecium caudatum* has been found to be one of the most common holotrichous ciliates in sewage treatment processes and normally linked to high levels of organic matter (Barker 1946; Curds 1969; Curds and Cockburn 1970). Paramoecium caudatum was hardly ever found in the surface regions of the experimental filters, but through the depth the numbers were substantially lower in the high rate filter (F). Another holotrichous protozoan Glaucoma scintillans was found at all levels in both filters in much greater numbers than paramoecium. Both Glaucoma scintillans and Paramoecium caudatum have substantially the same modes of nutrition. Barker (1946) demonstrated the ability of Paramoecium caudatum to remove bacteria. McKinney and Gram (1956) demonstrated that Glaucoma scintillans was able to remove bacteria in suspension thus clarifying the effluent. Glaucoma scintillans may have been more successful in this situation because of its greater tolerance to higher hydraulic loadings.

The other important holotrichous protozoan was Trachelophyllum pusillum. The peak populations correspond to the largest numbers of another protozoan Aspidisca costata both were found only in the lower regions of the filters.

In addition to the aspidiscidae several species of another family of spirotrichous protoza, the oxtrichidae were also observed in the experimental filters. All the spirotrichous protoza appeared restricted to the lower levels of the filters

The greatest diversity and the largest numbers of protozoa occurred in the lower levels of the filters in association with the lowest concentrations of organic matter in the sewage. Baines, Hawkes, Hewitt and Jenkins 1953; and Curds, Cockburn and Vandyke 1970 observed a similar distribution. They suggested that the protozoa fed on suspended organic detritus derived from the film but the majority were unable to effectively compete with the organisms of the film in the low dissolved oxygen concentrations at the surface of the filter.

The nematodes were found throughout the depth of the filters with the largest numbers in the surface regions. There was evidence (discussed in 5.2.1) that in the absence of the macrofauna they were responsible for the major grazing activity in the filters.

Rotifera were found at all levels in both filters but normally only in low numbers. Calaway (1968) in an investigation into the Rotifera also noted their presence throughout an activated sludge plant. Calaway observed that they colonised the process quite early on and assumed that they had a high tolerance to organic matter with a role similar to the ciliate protozoa but doubted whether they were as hardy as the ciliates.

SECTION SIX

PERFORMANCE

SECTION 6

PERFORMANCE

6.1 REVIEW

Biological filters provide an environment in which the waste, the organisms responsible for purification, and air are brought into contact. If as a simple approximation biological filters are considered as continuous biochemical reactors then primarily the physical environment generated by the filter, in part governed by the medium (its size, shape and available surface area) establishes the hydraulic characteristics and the amount of film within the reactor. These characteristics, the amount of film and the time of contact between sewage and film therefore determine the potential performance of the filter. If then the concentration (in terms of nutrients), volume, or temperature of the influent to the reactor change then there is a disturbance of the equilibrium within the reactor with a consequent change in the characteristics of the effluent. Application of this simple analogy to predict the performance of the biological filter under different operating conditions is limited by the biological nature of the process. The complex heterogeneity of the system and the surroundings permit few direct relationships between variables.

Once the population of the micro-organisms has been established by the available surface area two interdependent factors limit the extent of treatment, one is the metabolic rate of the film, the other is the capacity of the film to adsorb and absorb material from the waste. Dunbar (1900) (reported in Dunbar and Calvert 1908) in his original hypothesis proposing the biological nature of treatment by the percolating filter, noted that adsorption or organic material prior to the oxidation was the first stage in the removal process.

The major factor controlling adsorption and absorption by the film is the residence time of the filter. A crucial influence on the residence time is the hydraulic loading to the filter. The 5th Royal Commission (1908) recommended that to achieve their proposed effluent requirements (of $20mgl^{-1}$BOD; $30mgl^{-1}$SS for discharge to natural waters affording at least eight times dilution), biological filters should be irrigated at $0.3-0.4\ m^3m^{-3}day^{-1}$ (75 to 100 gal $yd^{-3}day^{-1}$) and loaded at $0.10-0.15\ kgm^{-3}day^{-1}$ ($0.15-0.21b\ yd^{-3}day^{-1}$). With a feed of around 200 mgl^{-1} BOD this could be achieved in a single pass through a standard filter giving 90% BOD removal. It was noted that if the irrigation rate was increased the quality of the effluent was reduced. Carter-Bell (1908) reported to the commission, on work which he had carried out at Salford, that if the hydraulic load was increased beyond the 0.3 to 0.4 $m^3m^{-3}day^{-1}$ range then the quality of the effluent, in terms of the percentage BOD removal, decreased in proportion to the increase in load. Carter-Bell in his report also mentioned work carried out by Stoddart (1903), who had carried out laboratory scale experiments on treating sewage at loads up to $4.0m^3m^{-3}day^{-1}$, and noted that Stoddarts conclusions supported his own view that, as the rate of filtration was increased the mechanism of purification changed from one based on the biological removal of the waste to a rather more physical process. Carter-Bell reported that such filters were now being successfully employed at Salford as roughing filters to remove suspended material which escaped settlement in the sedimentation tank. The suspended material was physically trapped by the medium which was then washed every three or four months. The idea did not gain a wide acceptance.

Stanbridge (1956), in his paper on the historical development of percolating filters, noted that a few straining or roughing filters, incorporating facilities for washing, were in use in certain circumstances where special problems with suspended material existed. In the United States however, where the discharge conditions were less stringent and the sewage was normally weaker, rates of filtration in excess of those in this country were normal practice. The early St Lawrence experiments had indicated that above a certain critical rate of irrigation, accumulations of organic matter within the filter increased the frequency of cleaning the media that was required. This was confirmed by a succession of investigations in America (Levine, Luebbers, Galligan, and Vaughan 1936; Halvorson, Savage and Piret 1936; Edwards and Adams 1938; Keefer and Kratz 1940) all observed that choking of the filters with excessive accumulations of organic matter was a serious problem with higher rates of filtration. It was also noted that the total weight of BOD removed per volume of media per day could be increased by elevated hydraulic loadings but only at the expense of the quality of the effluent. Levine *et al.* (1936) overcame the problem of the accumulating organic matter by designing two synthetic media, one was made of ceramic rashig rings, the other was made of building blocks. Both had significantly greater voidages and surface areas than the conventional media. Using synthetic milk effluent, Levine *et al.* found that at 0.8 m^3m^{-3}day with sewage strengths of 100, 500 and 1,000 mgl^{-1}BOD there was 92, 85 and 82% BOD removal respectively. The removals from the control (mineral medium) filter was approximately ten per cent lower in each case. Halvorson *et al.* (1936) sought to overcome the problem of film accumulation by applying the sewage at such a rate as to restrict the growth of the film by increasing the physical scouring action of the sewage. Using rates of irrigation between 0.4-8.0m^3m^{-3} day^{-1} they noted that as the rate was increased the BOD removal fell from 70 to 23% and that nitrification ceased at just over 2.0$m^3m^{-3}day^{-1}$. Levine (1940) in a later paper published particulars on the mechansim of high rate filtration. Following filtration at eight times the hydraulic loading recommended by the 5th Royal Commission, which removed only 50% of the applied BOD he found that a further 50% of the remaining BOD could be removed by efficient settlement of the effluent. Levine noted that the effluent from the high rate filter was always turbid, and concluded that the reduction in residence time associated with high rate filtration was restricting the adsorption of suspended material by the film. The suspended material was however changed by its passage through the filter making it more amenable to settlement. Levine therefore considered that the suspended and colloidal material underwent flocculation and coagulation in the filter.

By this time film accumulation and the aggregation of organic matter within filters had been recognised as the most serious practical problem in operating percolating filters (reviewed in 5.1) and a number of changes in operating methods emerged to control accumulation. All actually increased the rate of irrigation: recirculation by dilution of the sewage with effluent, ADF by applying over twice the normal load to a single filter, to two filters in succession, and low frequency dosing, by increasing the instantaneous rate of application. These techniques were primarily designed to increase the use of the depth of the filter to prevent blockage of the

the surface of the filters by excessive accumulations of film. High rate single filtration still met with little success, Barraclough (1954) in 1949 carried out a series of experiments in which he attempted to treat Reading sewage at higher than normal rates using a larger than normal medium, (7.0 and 10.0 mm instead of 5.0 mm). He noted that nitrification was eliminated at $2.4m^3m^{-3}day^{-1}$, a very similar figure to that noted by Halvorson in earlier experiments. The media however rapidly clogged at $2.4m^3m^{-3}day^{-1}$ and the experiments were abondoned. Tomlinson and Hall (1950) carried out a four year investigation into the effects of a range of hydraulic loadings on filtration ($0.4 - 8.0m^3m^{-3}day^{-1}$). Although hampered by problem with excessive accumulations of organic matter clogging the filters, they discovered a linear relationship between the PV of the settled effluent and the hydraulic load, and a logarithmic relationship between the BOD of the settled effluent and the hydraulic load. Their results showed that at a hydraulic load of $8.0m^3m^{-3}day^{-1}$ the filter was removing 32% of the applied BOD at the rate of 0.73 $kgm^{-3}day^{-1}$, while at $0.8m^3m^{-3}day^{-1}$ although removing 86% of the applied BOD the removal rate was only 0.2 $kgm^{-3}day^{-1}$. Tomlinson and Hall used retention time data from the filters at different hydraulic loadings to determine the rate constant of BOD removal, and discovered that there were in fact two rate constants. They concluded that because the initial removal was so rapid, that it was likely to be a purely physical process. Investigations into the settling characteristics of the sludges produced at the different loadings indicated that although there was little difference in the sludge production figures, the solids from the low rate filters were more readily settled.

In later investigations, Tomlinson and Hall (1955) together with Hawkes (1955a), noted another important influence on the residence time of filters. This was the way the sewage was distributed over the surface of the filter. It was observed that while maintaining the same overall rate of irrigation the sewage could be applied either as a continuous spray or as a succession of doses. The first inferences were that the spray type distribution would give the greater residence time by dispersing the flow over the largest surface area of the bed. However tracer studies showed (Hawkes 1961) that when the sewage was applied intermittently it passed into the bed as a surge mixing with and displacing some of the interstitial fluid, but most was retained in the bed until the next dose. This meant that the flow characteristics of the system had changed from an essentially continuous flow system to a surge flow system. This had important implications as far as the film accumulation was concerned; the film was exposed to a much longer interval between doses and once the nutrients in the interstitial fluid had been consumed the film was subjected to longer periods of endogenous respiration. This produced a marked reduction in the film accumulation in the filter (Tomlinson and Hall 1955; Hawkes 1955a; Hawkes 1961).

Hawkes and Jenkins (1958) demonstrated a further influence on residence time. After observing a difference in performance of two filters containing identically sized mediums one with a smooth surface and one with a rough surface, concluded that the latter gave better results because it improved the effective surface area and film flow characteristics of the medium. Eden, Brendish and Harvey (1964) carried out a comprehensive investigation into the factors affecting residence time. They observed that it was controlled by three factors, the hydraulic flow through the filter, the accumulation of organic matter within the filter and the size and shape of the media. The authors proposed that complete wetting of the film was in a practical situation virtually impossible and flow channels were produced by the accumulation of film such that the greater part of the surface remained unused. As the film accumulated the channels gradually blocked and the liquor was forced down an alternative channel until this too became blocked and the whole cycle began again. It was also noted that the number of these channels decreased with depth due to a progressive convergence of the streams of effluent.

It was at this time that the first totally synthetic media emerged and renewed interest in the high rate filtration (Bryan and Moeller 1960). The new plastic media were designed to optimise surface area and voidage, overcoming the problem of the accumulation of organic matter by doubling the voidage, and increasing the efficiency by doubling the surface area (Hawkes 1963; Eden 1964; Chipperfield 1964; Pearson 1965). Pearson (1965) in a study on the newly available media noted the fundamental differences between the uses and mechanism of high rate and low rate filtration. Pearson observed that in high efficiency removals, because sewage was heterogenous, two fundamental biophysical processes had to occur, the absorption and the adsorption of organic material, by the biological film. These were only the primary stages of a whole sequence of metabolic stages including the breakdown of solids by extra-cellular enzymes, the absorption of dissolved molecules into the cells of the micro-organisms, growth of the primary population, endogenous respiration by the film, release of excretory products and ingestion of the primary population by secondary grazers. It was noted that in low rate filtration 80% of the organic matter was eventually converted into mineral salts or released as carbon dioxide, the remaining 20% was discharged from the filter as humus. The humus was semi-stable organic matter representing the residue of this chain of events occurring within the filter. Pearson reiterated that as the loading was increased so was the rate of removal but at the expense of the total efficiency. Parallel with this change in performance was a change in the biological activity. As the load was increased certain of the stages in the filtration process were restricted more rapidly than the others. One of the first to be interfered with was the biophysical adsoption of suspended material in the sewage. The effluents became turbid and the humus sludge changed to a lighter coloured, unstable, solid representing a much greater proportion of the original organic matter than the conventional low rate sludge. Pearson's theoretical approach supported the earlier American workers observations which had indicated that a change in mechanism of filtration occurred when the rate of irrigation was increased.

Eden, Truesdale and Mann (1966) in a comparative assessment of the new media with conventional media, noted that their primary advantage lay in their ability to accommodate large volumes of film without interfering with the passage of the effluent. They emphasised the role of the geometric shape of the new media which because of their configuration and large voidage made inherent redistribution of the applied sewage within the filter impossible. The design therefore had to promote a thin film flow, as channelling or plug flows would seriously reduce the residence time and effective surface area, with no possibility of redistribution from reservoirs or interstitial fluid in the voidage. They therefore noted that because of the problems associated with wetting the available surface at lower rates of irrigation, high qualty effluents from synthetic media were unlikely. The advantages of the synthetic media in high rate treatment were demonstrated in a number of investigations (Chipperfield 1967; Department of the Environment 1968; Askew 1970; Bruce and Merkens 1970; Bruce, Merkens and Macmillan 1970; Joslin, Sidwick, Greene and Shearer 1971; Bruce and Boon 1971; Bruce and Merkens 1973; Water Research Centre 1974). The exhaustive investigations by Bruce _et al._ at the Water Research Centre provided further experimental evidence concerning the changes which occurred in the filtration mechanism at higher rates of flow. Bruce and Merkens (1970) found that performance was related to both surface area and geometric shape. They demonstrated, confirming the observations of Eden, Truesdale and Mann (1966) that one of the synthetic media under test, Cloisonyle, (vertical PVC tubes) lacked the shape necessary to promote a thin film flow of sewage over the surface of the media. The results showed that the medium had a significantly lower residence time and performance than media, which although inferior in surface area promoted a better flow.

Bruce, Merkens and Macmillan (1970) also found that high rate filtration with plastic media actually produced both less and a more even distribution of film through the depth of the filter. Most workers on high rate filtration had observed an increase in the amount of film with a tendency toward ponding. The actual rates of filtration used by Bruce et al. were broadly similar to those used by other workers ($6m^3m^{-3}day^{-1}$ and $12m^3m^{-3}day^{-1}$) which seems to indicate that the configuration of the plastic medium was the critical factor in reducing film accumulation at higher rates of filtration. Another possibility however was the characteristics of the sewage, Heukelekian (1945) also recorded a reduction in the organic matter contained in a high rate filter when compared with a low rate filter, a factor which he attributed to the reduction in adsorption of sewage solids by the film (factors which affect the accumulation of film reviewed in section 5.1). Bruce, Merkens and Macmillan (1970) also noted that the removal from the sewage of the dissolved BOD was appreciably greater than the total BOD removal. The results also indicated that effluent BOD was directly proportional to the suspended solids it contained. The authors therefore concluded that the higher rates of application were restricting the adsorption of solids by the film and that removal of the fine suspended material in the sewage presented the major obstacle to improving the efficiency of high rate filtration.

Bruce and Boon (1971) reported other significant changes in the mode of filtration. Noting the work of Hawkes (1961), they proposed that the range and numbers of secondary organisms, and therefore their contribution to the conversion of organic matter, would be significantly reduced in high rate filtration. They observed that the solids from a high rate filter were not the characteristic dark brown associated with a large secondary grazing population (due to the faeces and debris produced by the grazers) but a much lighter coloured putrescible sludge. At the same time the proportion of influent organic matter emerging as sludge increased to in excess of 50%. In low rate filtration Bruce and Boon noted that approximately 0.2 kg of sludge were produced for every kilogram of BOD removed, in high rate filtration this increased to 0.8 kg for every kilogram of BOD removed. Similarly they recorded that over 80% of the sludge from high rate filtration was organic matter, whereas only 60% of the sludge from low rate filters was organic matter.

Prior to the oxidation of the organic matter entering the percolating filter is its physical adsorption by the film. In high efficiency filtration therefore the period of contact between the film and waste, the residence time, must be sufficient to ensure that this process is complete. There is evidence that in respect of the organic matter in suspension this adsorption process is restricted by high rates of filtration. There is little data in the literature concerning the possible affect of higher rates of filtration on the adsorption of the soluble component in the sewage. The soluble component is theoretically available for immediate uptake by cells of the film. Painter Viney and Bywaters (1961) found that 33% of the soluble component of sewage was due to the sugar residue of carbohydrate breakdown (the soluble residues of the fat and protein added together were equivalent to only about 10%) which would be expected to be specifically absorbed by the film for metabolism. Both Tomlinson and Hall (1950) and Hawkes (1963) have noted that at least some of the removal of BOD is extremely rapid. Other soluble components in the sewage, such as detergent and ammonia would normally be used by much smaller populations in the film and assimilation would be less rapid. Bruce, Merkens and Macmillan (1970) noted that the rate of removal of detergent was appreciably less than both the total BOD removal and the soluble BOD removal.

The removal of ammonia is well known to be inhibited by higher rates of filtration. Research has, almost without exception, showed virtual elimination of the removal of ammonia at filtration rates of over 2.5 $m^3m^{-3}day^{-1}$ with undiluted sewage. Although the factors affecting the rate of removal of ammonia in filters are not fully understood, it is thought that the fact that nitrification is promoted by autotrophic bacteria, known to normally have a lower rate of growth in competitive situations, is the major reason why the nitrification process is sensitive to change in operation (Hawkes 1963; Painter 1970). Most authors consider this to be inevitably associated with autotrophic nutrition. Research has indicated that this is probably due to limiting oxygen concentrations (Barrit 1933; Heukelekian 1947; Hawkes 1963; Tomlinson and Snaddon 1966). Studies using controlled oxygen concentrations in the atmosphere of small scale filters confirmed that reductions in the oxygen concentration inhibited nitrification, (Water Pollution Research 1956). Most workers agree that, in pure culture at least, although the nitrifying organisms appear susceptible to a wide range of inhibitory compounds, organic matter does not directly inhibit nitrification (Painter 1970). No inhibition was observed by Painter and Jones (1963) in culture experiments using fresh sewage, glucose and peptone. The literature reviewed by Painter (1970) also indicates that the nitrifying organisms need to adhere to surfaces and that inhibition of the nitrifying organisms may occur from simple competition for space. Inhibition of nitrification is also thought to occur in situations of high C : N ratios, the rapid growth of the heterotrophs limiting the availability of the ammonia. It is generally concluded therefore that high rates of filtration and nitrification are mutually exclusive because of the enhanced heterotrophic growth. This has been confirmed experimentally on a number of occasions, (Stanbridge 1954; Wishart and Wilkinson 1941; Lumb and Barnes 1948; Bruce, Merkens and Macmillan 1970; Joslin, Sidwick, Greene and Shearer 1971; Water Research Centre 1974; Bruce, Merkens and Hynes 1975).

To avoid any progressive accumulation of adsorbed or stored material within the filter there mustbe a dynamic equilibrium between this material and its rate of oxidation. Normally domestic sewage contains the necessary trace materials as well as the macronutrients required to provide a nutritionally complete substrate for microbial metabolism. This means that the rate of metabolism is a function of the substrate concentration, available oxygen and ambient temperature. It is not directly influenced by the residence time of the filter. When the film is in equilibrium the overall rate of metabolism must however equal the rate of adsorption, otherwise organic matter would accumulate in the filter. Renn (1956), in considering the biophysical processes which occur in filter film, proposed that fluctuations in the relative rates of metabolism and adsorption of organic matter were the major factors controlling film accumulation. If the rate of metabolism was impaired for long periods then the adsorbed and stored material would accumulate until all the adsorption sites were filled, when performance would begin to fall off due to the loss in removal. What proportion of the metabolism of the organic matter is due to catabolism and what proportion to anabolism and which is the most sensitive to changes within the filter is uncertain. Sawyer (1956) reported that he thought about half the organic matter was respired and the other half converted into biomass of the film, but the proportions will be subject to a considerable number of variables, notably the identity of the dominant organisms, ambient temperature, and the type and mode of application of the waste.

The rate of metabolism is increased by an increase in substrate concentration. If the strength or rate of application of the sewage is increased then the rate of BOD removal also increases, and so therefore must the rate of metabolism. What the maximum rate of metabolism is, in quantitative terms is uncertain. As the strength of the waste increases other factors become limiting. Hawkes (1963) notes that with sewage strengths of over 350 mgl^{-1} the oxygen demand becomes so great as to generate anaerobic conditions within the filter. (If on the other hand the rate of irrigation is increased, this actually reduces the available organic matter for metabolism by limiting the adsorption of solids by the film.)

Even prior to the evolution of the percolating filter aeration was known to be vital to the purification process, and while a number of early British workers concentrated on improving ventilation by reducing the film accumulation (reviewed in section 5.1) a number of American workers investigated the possibility of improving ventilation by physical means. Levine, Nelson and Goresline (1934) found that the performance was severely reduced when the ventilation was restricted with screens around the base of the filter. Levine, Leubbers, Galligan and Vaughan (1936) proposed the use of synthetic media with more open structures to facilitate improved ventilation. Unfortunately the cost of the synthetic media was so high as to make its use uneconomic. Halvorson, Savage and Piret (1936) also recognised that restrictions in ventilation were a major feature in reducing the performance of filtration and noted that growths of fungi were primarily responsible for this accumulation. Halvorson _et al._ hoped to apply the sewage at such a rate as to control the fungal growth by the physical scouring action of the flow. The experiments were not a complete success and they failed to control the fungal growth, but did conclude that the situation might be improved by forced ventilation. A full scale filter incorporating assisted ventilation was subsequently built but unfortunately the sewage was extremely weak (60 mgl^{-1} BOD) which was insufficient to promote large growths of film, and the experiments were abandoned. In a later investigation into the aerodynamics of filters, Piret, Mann and Halvorson (1939) found a direct relationship between air flow through the filter and the difference in temperature between the inside and outside of the filter. If the air was cooled by the liquid and the filter, as was generally the case during the Summer months, its density was increased and the convection currents were downward. If the air was warmed it tended to rise and the air flow was upwards. In the experimental system they also found that the air flow was not significantly altered by increasing the rate of flow, nor was it significantly affected by changes in the relative humidity of the air. Piret, Mann and Halvorson did find however, that the air flow through the filter was affected by the direction and velocity of the wind. Calculations showed that the draught pressure caused by a 16 kph wind was 1.2 mm of water, whereas a 1°C created only a 0.5 mm of water change in pressure. In a report, the Water Research Centre (Water Pollution Research 1955) noted that with the structural provision of open channels in the drainage system, then with a thin film, a temperature difference of less than 1°C between the air and filter was sufficient to give adequate ventilation. Petru (1958) in a study on the affect of temperature and ventilation on the efficiency of filtration, also noted that small temperature differences were sufficient to promote adequate ventilation under ideal conditions. However because of the low voidage in the medium the air flow was susceptible to resistance created by even quite small accumulations of film. Mitchell and Eden (1963) investigated ventilation using radio-active tracers, and confirmed a number of Piret, Mann and Halvorson's original findings. They also found that the most important affects on ventilation were the wind velocity and direction, and the difference between air and filter temperatures. Other factors such as the humidity and composition of the air had a negligible affect on the ventilation.

In common with other chemical reactions metabolic rate increases exponentially with increases in temperature, a ten degree rise in temperature approximately doubling the rate of reaction. Percolating filters are however not normally exposed to such wide fluctuations in temperature. The temperature of conventional filters has been shown, with the exception of the upper surface of the filter, to depend on the temperature of the waste. Reynoldson (1939) observed that the temperature variation within a percolating filter was less than one third of the change which normally occurred in ambient temperature. Reynoldson noted that this was due to a much smaller seasonal difference in sewage temperatures and the metabolic activity of the film. A number of other workers have reported a similar relationship, (Lloyd 1945; Mills 1945b; Tomlinson and Hall 1950; Hawkes 1963). With reference to synthetic media with a greater voidage Bayley and Downing (1963) reported that although ambient temperature and the rate of flow of air through the filter may possibly influence the temperature of the voidage of the medium the temperature of the sewage was the main factor in determining the temperature of the wetted microbial film.

Hawkes (1963) also emphasised the relatively wide temperature optima of the micro-organisms constituting the film, and indicated that some adaption to changes in temperature was likely. Typically therefore lower ambient temperatures produce an indirect effect on filter performance, the lower temperatures restricting the life cycles of the grazing organisms, increasing the accumulation of organic matter within the filter (Solbe, Ripley, and Tomlinson 1974; Shephard and Hawkes 1976).

With higher rates of filtration however there is evidence that ambient temperature has a more profound effect, both Levine *et al.* (1936) and Halvorson *et al.* (1936) reported that the performances of their high rate filters were markedly affected by changes in temperature. A similar difference has been noted in more recent investigations into high rate filtration (Tomlinson and Hall 1950; Eden, Truesdale and Mann 1966; Bruce, Merkens and Macmillan 1970). Bruce *et al.* found a 20% fall in performance during the Winter months when compared with the Summer performance. A Canadian group (Jank, Drynan and Sylveston 1969) on the other hand found, despite rather more severe environmental conditions (temperature range -24.5° to 30.5° sewage temperature 9 to 21°C) there was rather less difference between Summer and Winter (7%). Howland (1952) also observed a difference in the response to temperature according to organic loading. Howland proposed that this was due to the affect of temperature on dissolved oxygen. In weaker sewages the (albeit small) dissolved oxygen concentration was increased by the reduction in temperature which tended to counteract the direct affect of temperature reduction on metabolism. In stronger sewages the dissolved oxygen was so low that temperature changes made no difference. Wilson (1960) provided an alternative explanation. Noting that the affect of rises in temperature on nutrient transfer rates were not as great as the direct affect on metabolism

(Q_{10} about 20%), Wilson proposed that in nutrient limiting conditions (weak sewages and low rates of irrigation), the obvious effect of a rise in temperature would be on the transfer rates, giving only a small response to temperature. In conditions where the nutrients were not limiting (strong sewages and high irrigation rates) then the direct affect of temperature on reaction rate would be more important giving the exponential rise in reaction rate.

Despite the complexity of the reactions occurring in a biological filter, the overall reaction can be represented;

$$\text{Organic matter} + O_2 \rightarrow CO_2 + H_2O + \text{inorganic salts}$$

All kinetic interpretations of this expression have found a pseudo first order rate equation can be used to express the relationship between the rate of reaction and concentration of the substrate.

$$-\frac{d\,[C]}{dt} = k\,[C]$$

A large number of mathematical expressions of varying complexity have emerged since the application of this expression to biological filter systems by Velz (1948) (originally proposed by Streeter and Phelps 1925 as the law of biological oxidation). Some of the proposed expressions use empirical residence time data as the time function (Tomlinson and Hall 1950; Eden, Brendish and Harvey 1964; Meltzer 1962). Others interpret residence time mathematically in terms of the depth and hydraulic loading (Howland 1952; Rohde 1961, Eckenfelder 1961) or in terms of depth, surface area, and hydraulic loading (Lamb and Owen 1970; Bruce and Boon 1971; Bruce and Merkens 1973). Most of the proposed formulae successfully describe the quantitative relationships between performance and the main design variables in the situation they were derived. They have been used variously to describe the efficiency of wetting of the available surface area (Bruce and Merkens 1973), the rate limiting factors under different loading conditions (Jank, Drynan and Sylveston 1969; Ross 1970) and the rate limiting factors under different conditions of temperature (Howland 1952; Jank _et al._ 1969). The expressions and resulting rate constants still however show a wide disparity between each other and cannot yet be used for design purposes (Behn 1963; Bruce and Boon 1971). The problem relates to the different environments from which the data was gathered. Each sewage has a different treatability, each site is controlled by different meteorological conditions, and normally each filter contains medium of different origins. If a mathematical model is ever to be used successfully in general design and operation, then further knowledge about the interrelationships of the rate determining factors is required.

To summarise therefore, past work has shown that high rate filtration is normally incompatible with the production of high quality effluents. Evidence exists to suggest that this is due to a reduction in the adsorption of the suspended material of the sewage by the film. Changes in the design of the medium which produce a thin flow of sewage, over a larger surface area of medium, can to a certain extent counteract this effect.

6.2 RESULTS WITH DISCUSSION

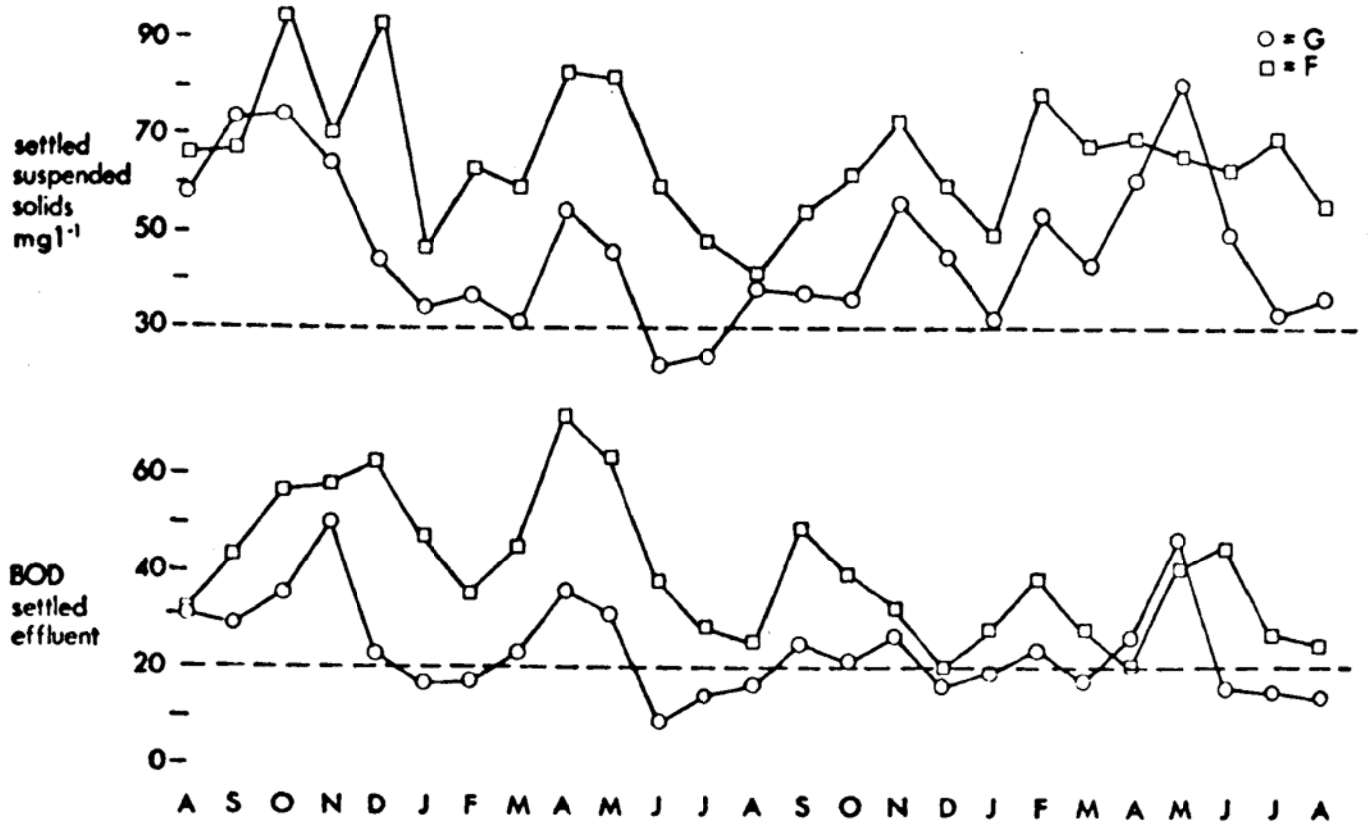
6.2.1 Presentation of Results

The chemical data, BOD removal, temperature, and suspended solids are the monthly means of twelve samples. Appendix 4 contains statistical analysis of the data recorded. Results of the soluble BOD components, filtered BOD, synthetic detergent, ammonia and nitrate are the monthly means of four samples; Appendix 4 contains the raw data.

Unfortunately facilities were not available for the regular examination of sludge characteristics and the results presented are those from an intensive investigation over a short time. The sludge production figures are derived from the effluent suspended solids (table 6.1).

6.2.2 Effects of Temperature

In conventional percolating filters 60% of the volume is solid, heat retaining, material and it is now known that, with the exception of the surface directly exposed to the atmosphere, the temperature of the film is controlled by the temperature of the waste flowing over the filter (reviewed 6.1). Although the mean air temperature may vary between 0 and 20°C during the year the change in sewage temperature is normally less than a third of this value. Fig. 6.1 shows the variation in air and sewage temperatures recorded during two years of the project. The variation in the temperature is similar to that recorded by other workers (reviewed 6.1). Temperature losses in excess of those normally associated with biofiltration were recorded through the experimental filters. Fig. 6.2 shows the temperatures of the effluents of the two filters in relation to the air temperatures. Unlike conventional filters the effluent temperatures are directly related to the air temperature. It was assumed that this, as in the other synthetic media, was due to much greater voidage giving rise to excessive ventilation. Past work has shown (reviewed 6.1) that wind direction and force play a major role in the ventilation of filters. So in an attempt to reduce the wind induced ventilation the bottom of the filters were screened on the three exposed sides in February 1974 (detailed in Section 3). This was not successful and effluent temperatures remained



mean effluent quality 1973-75 (figs 5.13 and 5.14)

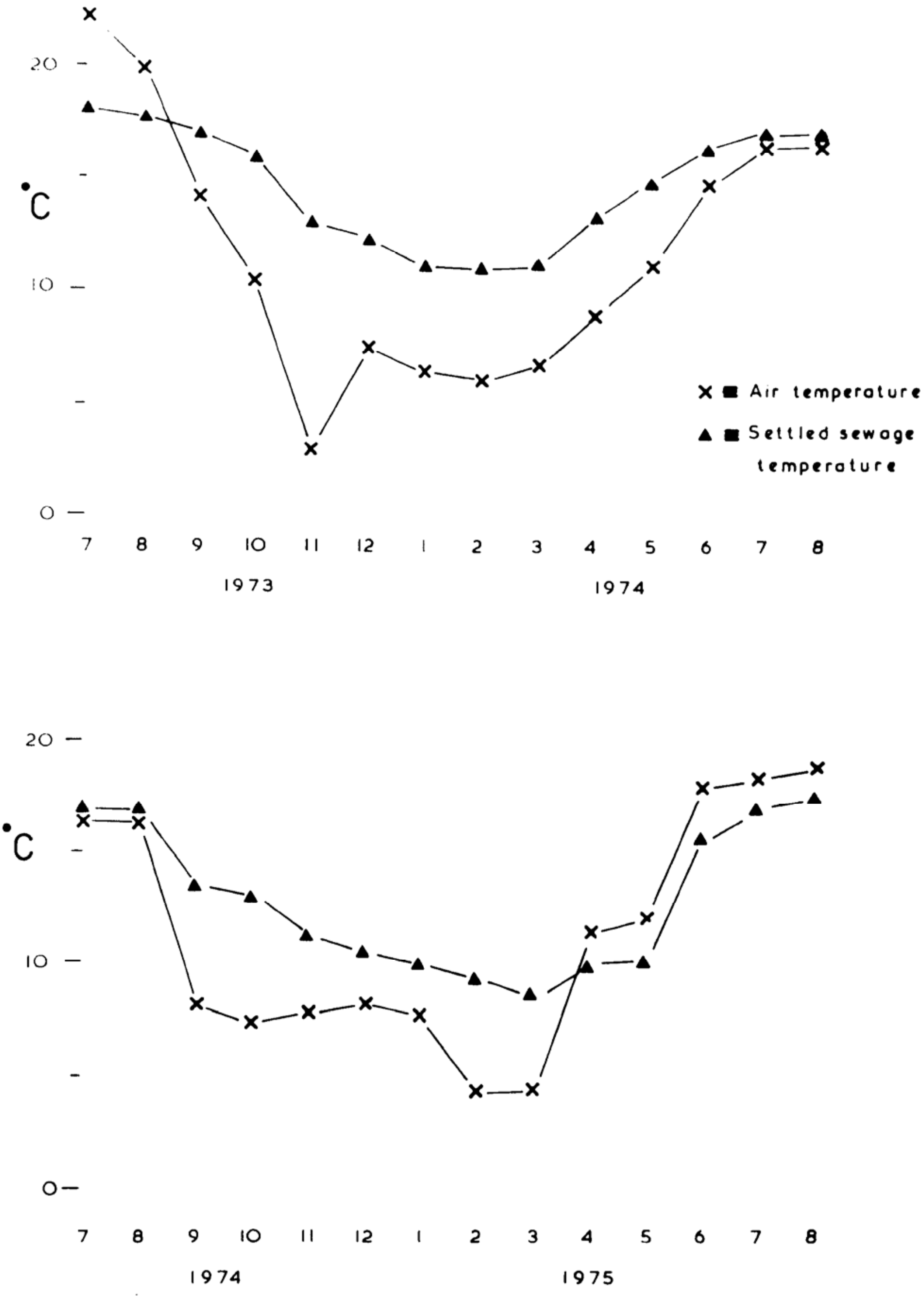


Fig 6.1 Seasonal change in sewage temperature

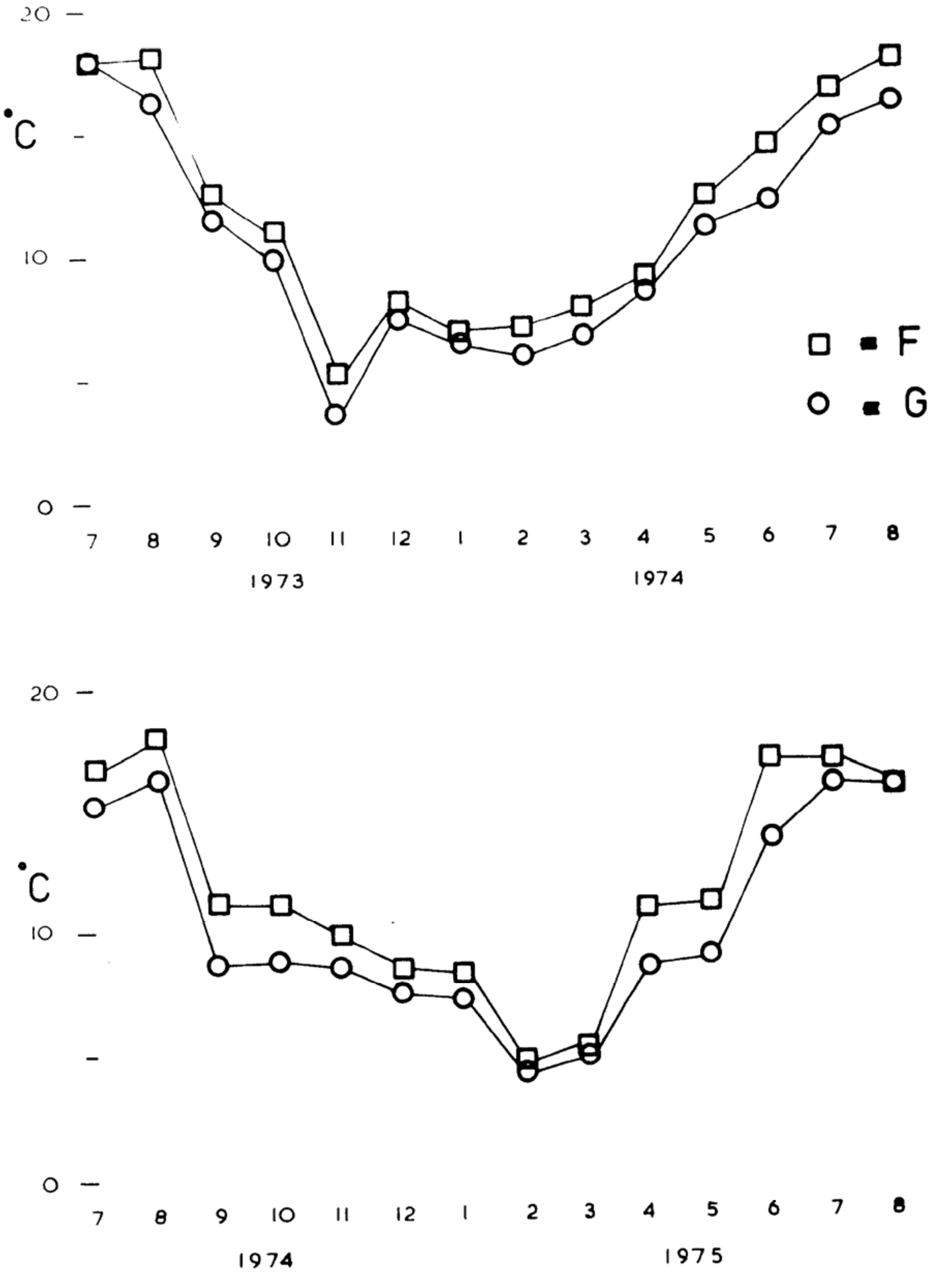


Fig 6.2 Seasonal change in filter effluent temperatures

virtually at air temperatures, (fig. 6.2). Another possibility was related to the structure of the pilot plant; the total amount of solid material provided by the medium was relatively small and afforded little heat retention to compensate for high heat losses through the exposed walls of the filters. For further insulation the walls of the pilot plant were covered with a 25 mm layer of expanded polyurethane to improve heat retention (detailed in section 3). This procedure was also unsuccessful and the temperature losses continued to be in excess of 5°C. Investigation of the temperature of the effluents from different levels down the filter revealed a complex seasonal temperature pattern (fig. 6.3). In Winter the temperature loss occurred in the surface layers of the filters. Effluent from the first draw-off point (0.5 m) showed a big drop in temperature, with little further cooling in the lower sections. Most of the heat was probably lost in the fall from the distribution system to the surface of the medium, about 600 mm, despite the fact that this was within the walls of the filter (plate 3.3). In milder weather there was normally some warming in the first 0.5 m of the filter, presumably due to the microbial activity in the surface of the filter; Reynoldson (1939) noted a similar effect. Again there was only a small loss in the remainder of the filter. In this case the major loss occurred between the second level and the filter effluent collected from the sump; so the heat

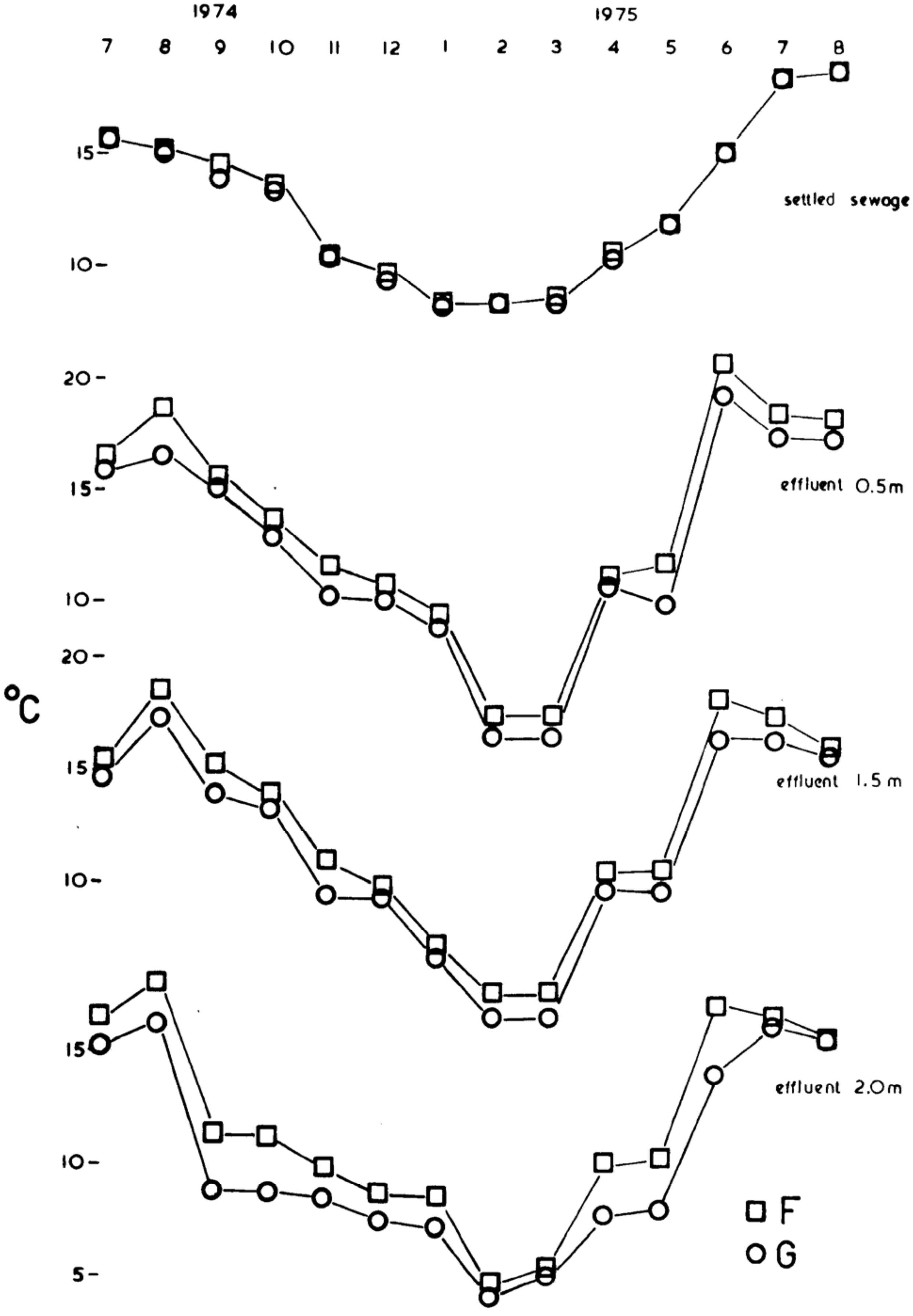


Fig 6.3 Seasonal change in temperature through the filters

losses appeared to occur in the fall from the bottom of the filter to the sump (fig. 3.3). The sump was uninsulated and stood 300 mm above ground level and could have been subject to cooling by air currents beneath it. Even during the Summer months when warming of the sewage was expected as it passed through the filter, effluent temperatures below that of the incoming sewage were not uncommon. A twenty four hour temperature survey indicated this to be due to the sampling times (fig. 6.4). Normally sampling took place in the morning and as the results show there was a lag between the effluent temperature and the air temperature. This sensitivity to temperature was aggravated by the small scale of the plant. It is significant that the losses from the high rate filter (F) were less than those of the low rate filters (G) and it seems that by virtue of its greater size and flow, a large scale plant would not be subject to such losses. Generally the worst performances corresponded to the lowest ambient temperatures, the notable exceptions to this occurring at the end of each Spring (May) when the worst annual performances were recorded (discussed in 5.2.4).

The difference in performance between the Summer and Winter expressed as BOD removal was 4% in the low rate filter (G) and 10% in the high rate filter (F) (figs. 5.11 and 5.12). A wide range of values for the temperature coefficient of filtration are reported in the literature.

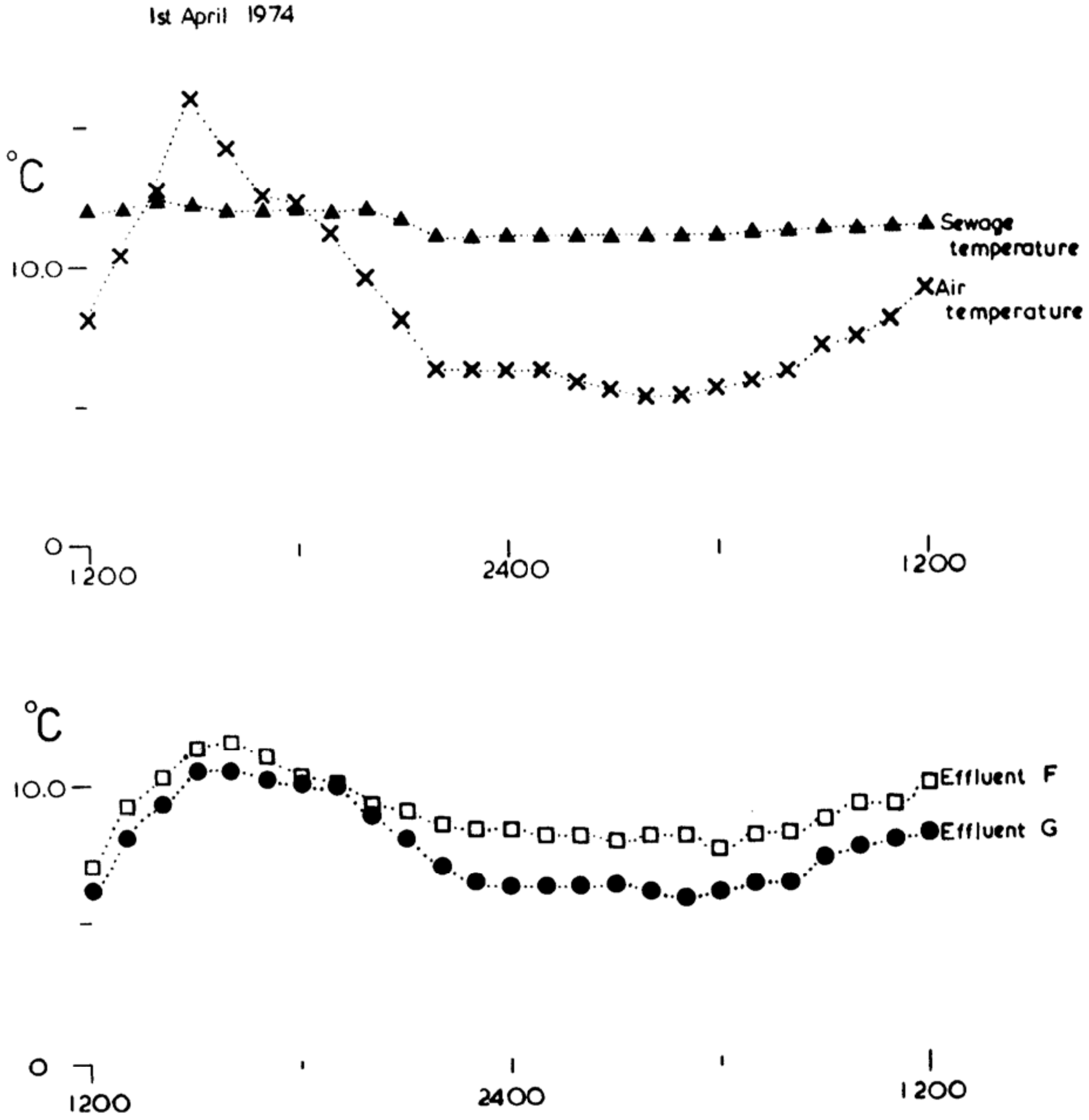


Fig 6.4 diurnal change in air, sewage and effluent temperatures

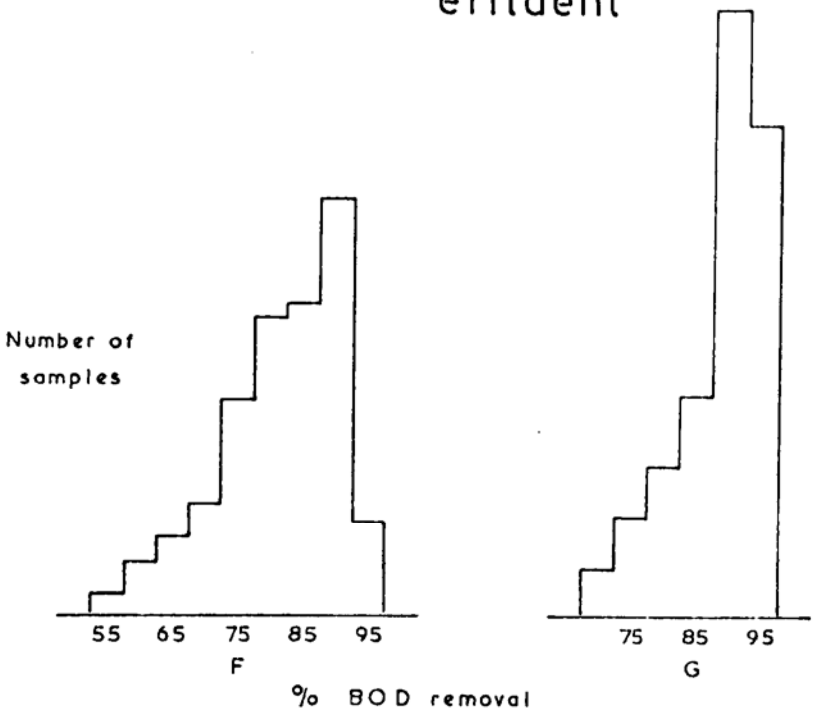
It has been shown for example, that the coefficient varies with the temperature range (Bruce and Merkens 1973), and with the loading of the filter (Howland 1952; Wilson 1960). Wilson (1960) proposed that the affect of temperature on the rate of filtration could be used to differentiate between nutrient limiting conditions and limiting rates of oxidation (discussed in section 6.1). In the experimental filters, because of the difficulty of determining the temperature of the active film, the response to temperature is obscure. If however it is assumed that the temperature of the film is almost air temperature then the response by both filters is small which therefore may indicate that nutrients are limiting the rate of removal.

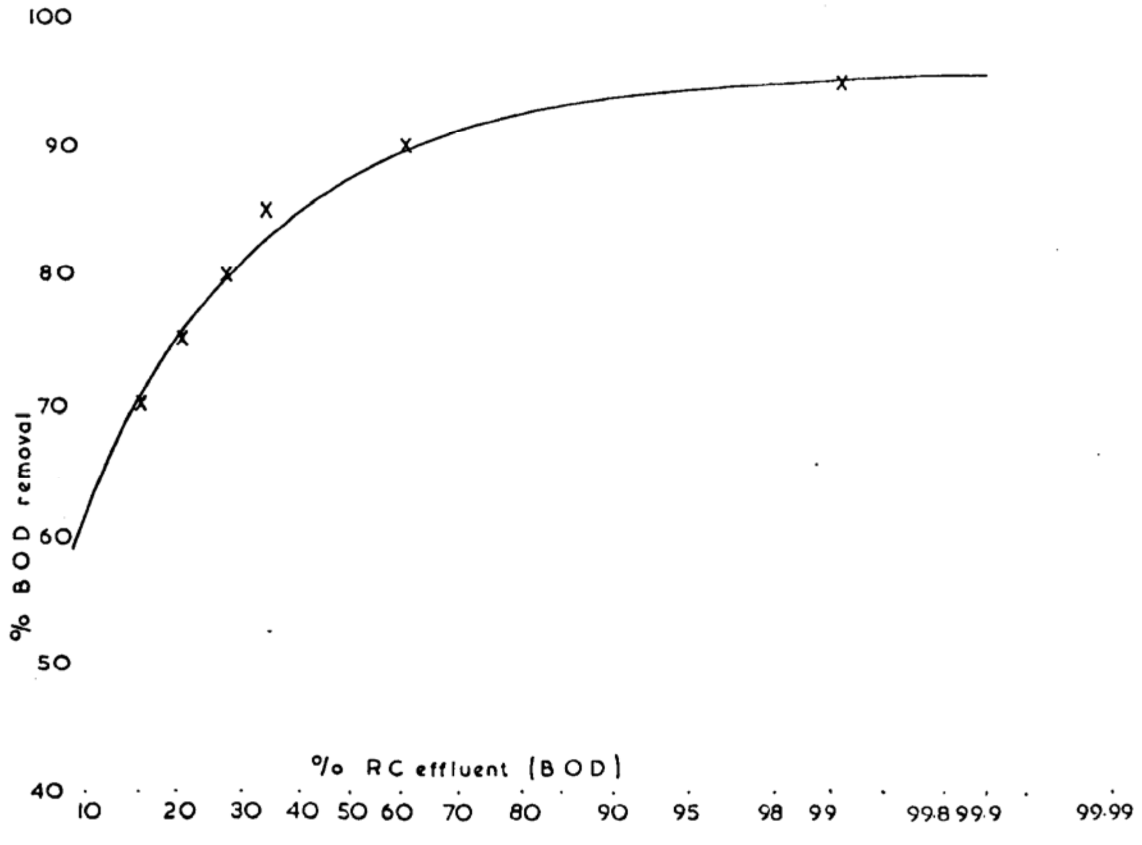
To achieve a Royal Commission standard effluent (99.0% probability) required a mean 95% BOD removal (fig. 6.5). This figure was achieved only during the warmest months of the year (figs. 5.11 and 5.12) by the low rate filter (G), ($1.2 m^3 m^{-3} day^{-1}$) and not at all by the high rate filter (F), ($2.4 m^3 m^{-3} day^{-1}$). Figs 5.13, 5.14 show the seasonal variation in effluent quality.

6.2.3 Mode of BOD Removal

As the rate of irrigation is increased some of the more sensitive of the removal stages in filtration are eliminated. One of these stages is the adsorption of suspended material by the film of the filter, thus high

Fig 6.5 Probability of Royal Commission effluent



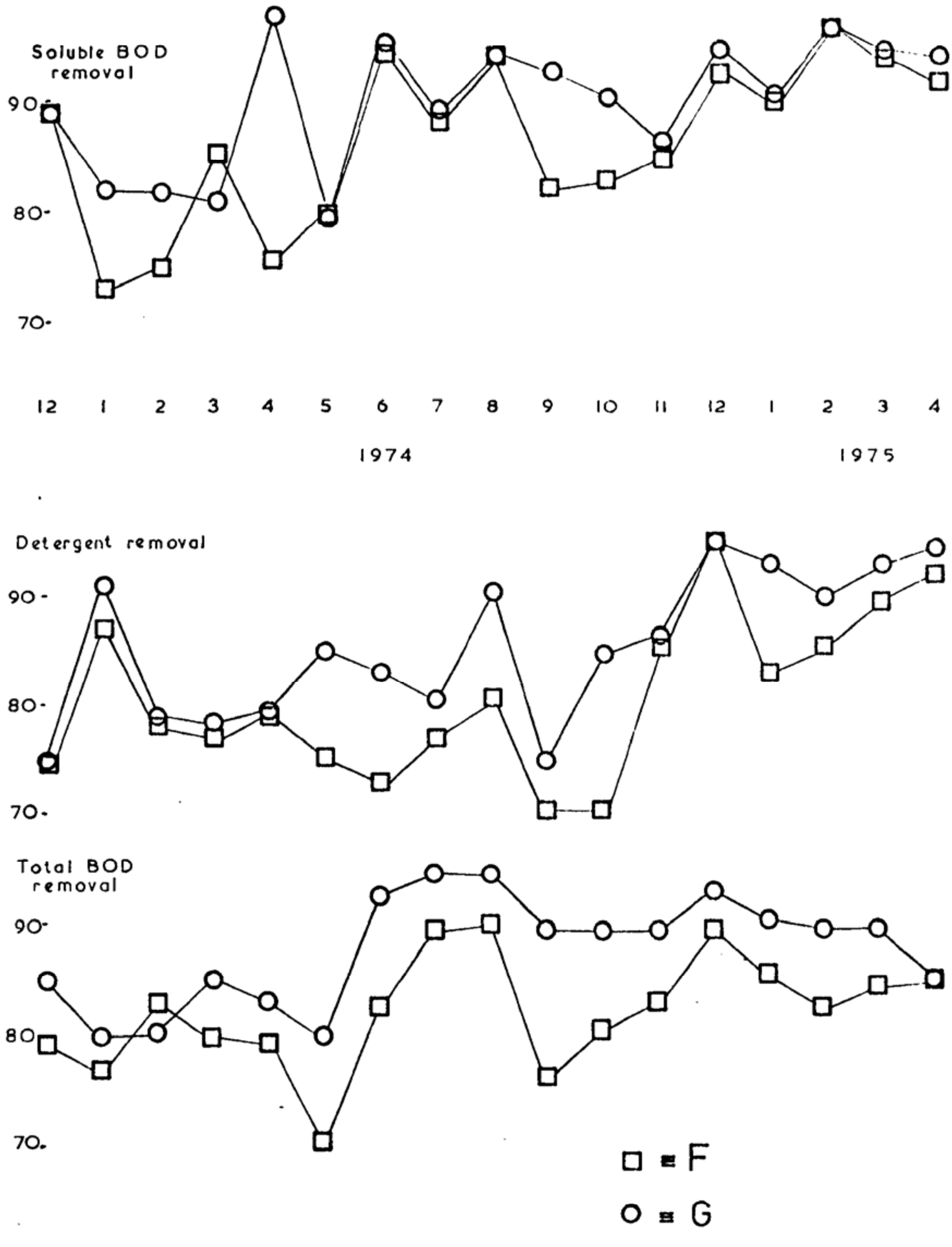


rates of filtration primarily remove dissolved BOD (reviewed 6.1).

The BOD of filtered samples (GFC papers removing suspended matter larger than 0.5 μm) were carried out once a week (fig. 6.6). About half the total BOD of the sewage was attributable to material in solution. Bruce, Merkens and Macmillan (1970), Sorrels and Zeller (1955), and Painter, Viney and Bywaters (1961) found a similar proportion in investigations into the composition of domestic sewage. The results show that performance expressed as soluble BOD removal was significantly greater than the total BOD removal. Bruce, Merkens and Macmillan (1970) found a similar pattern. Transfer between the phases in the metabolism of the filter makes it impossible to prove that the soluble proportion is the most easily removed. Bruce, Merkens and Macmillan (1970) investigated individual soluble components to correlate with their total soluble BOD data. They found that the efficiency of removal of acetates (common soluble and easily metabolised components Painter and Viney 1959) in high rate filtration was similar to that achieved in low rate filtration.

In this investigation facilities were available for measuring only the detergent, but the results did show that the removal of the detergent, although less than the total soluble BOD removal, was better than the total BOD removal (fig. 6.6). Bruce _et_ _al_. (1970) found that the

Fig 6.6 Soluble BOD removal



differential rate of removal between the soluble and total removals was fairly closely maintained in respect to changes in the overall efficiency of the filters. The differential was not well maintained, in the experimental filters the soluble BOD removal was affected by seasonal changes in performance. The figures for the settled effluent (figs. 5.13 and 5.14) show that the suspended solids were consistently higher than those normally associated with high quality effluents, and although this was another feature aggravated by the small scale of the plant (the use of centrifugal pumps may well have led to the breaking up of flocs for example), the poor settling characteristics of the effluent were a result of the incomplete removal of suspended BOD. The removal of ammonia did not follow this simple pattern.

In the experimental filters the removal of BOD was often greater than 90% which indicates that the medium and the associated film did offer sufficient physical resistance to adsorb nearly all the suspended organic material though not consistently. Fluctuations in the transfer or the oxidation of adsorbed material due to temperature may have been responsible for the changes in the performance.

The other feature often associated with high rates of filtration is a reduction in the diversity of the grazing organisms. This may be linked with certain changes in the characteristics of the sludge (reviewed 6.1) which instead of being primarily the result of grazing activity of the organisms in the filter becomes the debris of the primary population of the film. This produces more sludge in quantitative terms, increases the organic content and makes the sludge more difficult to dewater. Table 6.1 shows the weight of BOD removed in relation to the sludge produced (dry solids 105°C). There was considerable variation in the production from both filters with the greatest sludge production following accumulations of film. The figures were generally higher in the first year of operation and in excess of those normally associated with high rate filtration suggesting the filters were still maturing.

Another unusual feature was the consistently greater sludge production from the low rate filter (G). Previous work has indicated (reviewed 6.1) that lower rates of filtration produce less sludge. One explanation could be that the rates of filtration used were rather less than previous work on high rate filtration. Larger numbers of grazing organisms were recorded in the high rate filter (F) which might account for the lower primary solids content, but this was not consistent with the organic matter contained in the sludges.

MONTH	1973-1974		1974-1975	
FILTER	F	G	F	G
AUGUST	0.38	0.48	0.39	0.34
SEPTEMBER	0.76	2.70	0.45	0.14
OCTOBER	0.39	1.02	0.54	0.51
NOVEMBER	0.60	0.35	0.66	0.78
DECEMBER	0.50	1.68	0.83	1.54
JANUARY	2.41	3.05	0.55	0.67
FEBRUARY	1.85	1.34	0.31	0.35
MARCH	1.07	1.32	0.30	0.45
APRIL	0.41	1.08	0.84	0.98
MAY	1.01	2.68	0.42	0.42
JUNE	0.28	0.67	0.47	0.66
JULY	0.42	0.45	0.54	0.68
AUGUST	0.39	0.34	0.07	0.24
MEAN	0.80	1.32	0.50	0.59

TABLE 6.1 : Sludge production in kilograms dry solids per kilogram BOD removed

The organic matter of the sludge is shown in table 6.2. The mean for the high rate filter (F) was 72% and for the low rate filter (G) 62%. This indicates a more stable sludge from the low rate filter (G). Bruce and Boon (1971) found that 60% was typical from a low rate filter and 80% from a high rate filter.

The capillary suction time of the sludge of the two filters are shown in table 6.3. It is not possible to equate these values with specific resistance to filtration because the corresponding measurements of the solids content were not made at the same time. The large variation in the CST may reflect the difference in the solids content of the samples taken at different times. The CST values of the high rate filter (F) sludge are four times those of the low rate filter sludge (G).

The anomalous sludge production results may have arisen as a result of being derived from the effluent suspended solids rather than the actual sludge collected in the humus tank which is the normal method of quantifying sludge production.

In the second year of operation the annual average sludge production was almost half that of the first year of operation (table 6.1). Bruce and Boon (1971) found that an average of 0.2 kg kg^{-1} BOD removed was typical of low rate filtration and 0.8 kg kg^{-1} BOD removed of high rate filtration.

	ORGANIC MATTER		SOLIDS CONTENT	
FILTER	F	G	F	G
1.	74.5	67.0	2.0	1.0
2.	61.0	67.7	2.0	1.0
3.	75.0	53.4	1.4	0.1
4.	71.8	64.7	2.0	1.0
5.	76.6	65.5	1.4	0.1
6.	74.8	59.9	1.4	0.2
7.	66.4	57.9	0.7	0.5
8.	69.7	57.3	1.8	0.8
9.	74.4	63.8	2.1	1.4
10.	72.9	59.4	2.5	0.2
MEAN	71.7	61.6	1.7	0.6

TABLE 6.2 : The organic matter and dry solids content of the sludges, results expressed in percent.

	C.S.T. TIME	
FILTER	F	G
1.	133.7	29.7
2.	165.4	83.3
3.	76.6	14.5
4.	124.1	29.6
5.	285.9	49.6
6.	73.5	37.7
7.	229.6	26.7
8.	103.8	29.3
9.	124.5	25.1
10.	246.3	44.1
11.	237.0	51.1
MEAN	163.7	38.2
DRY SOLIDS	1.7%	0.6%

TABLE 6.3 : Cappillary suction time of the sludges, results in seconds. (Each value is the mean of three values.)

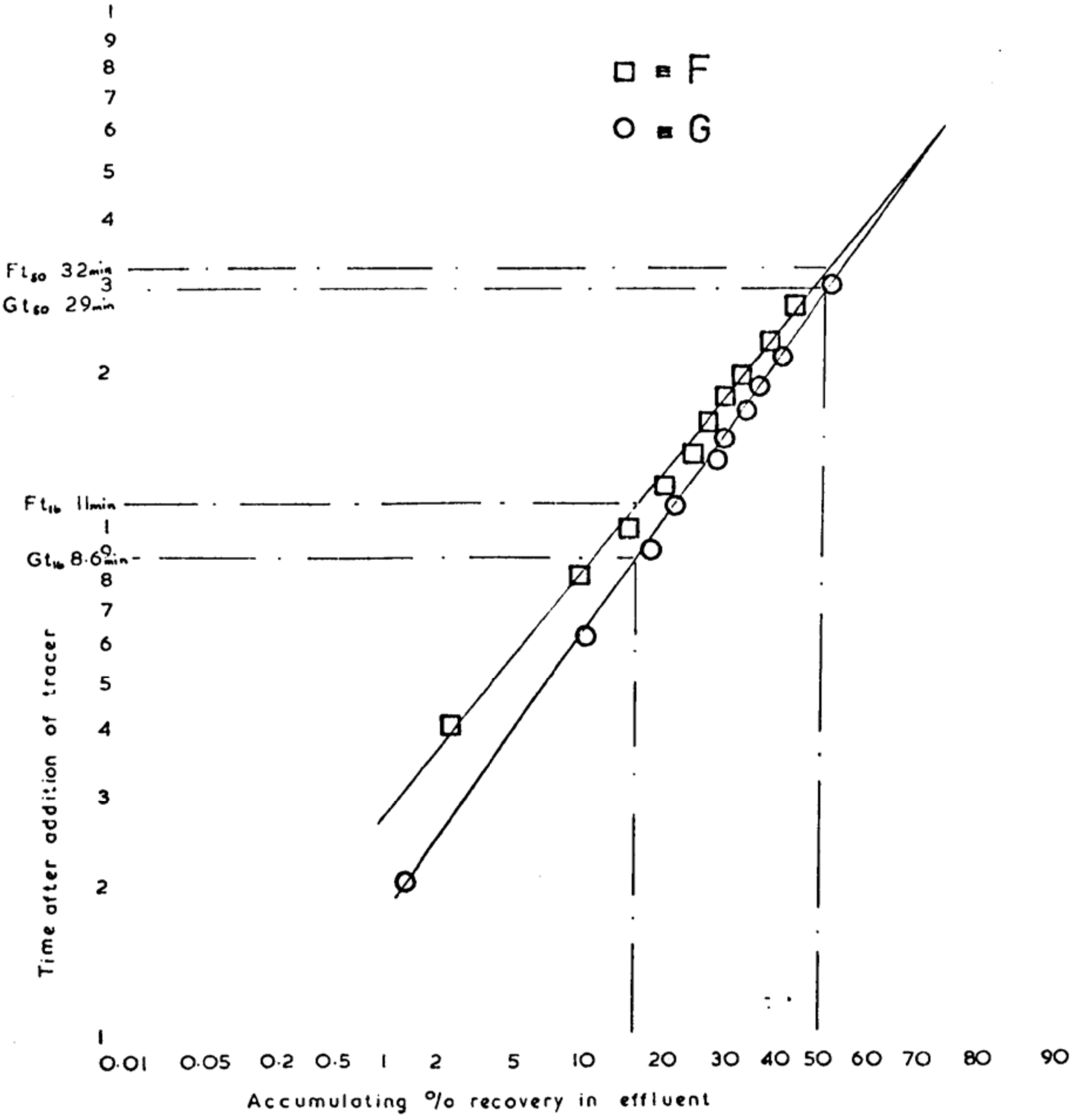
6.2.4 Performance in Relation to Load

Previous investigations into biofiltration have linked residence time (reviewed 6.1) directly to efficiency of filtration. Figures 6.7, 6.8, 6.9 and 6.10 show the residence time of the filters as determined by the tracer studies. In every case the high rate filter (F, 2.4m^3m^{-3} day^{-1}) had a significantly longer residence time than the low rate filter (G, 1.2 $m^3m^{-3}day^{-1}$). In the experimental filters therefore the measured residence time was not directly correlated with performance. To allow optimum biochemical exchange of organic matter across the interphase, the liquor must flow as a very thin film over the biologically active surface (Dorst-Hansen 1965). Larger bodies of water generated by less than ideal distribution or reservoirs of water within the medium are thought to reduce the efficiency of this exchange (Eden Brendish and Harvey 1964). One possibility therefore was that the higher hydraulic loading was increasing the amount of liquor held in pools in the large voidage filter. Since the body of the liquor would not then be in contact with the active surface, material in the centre of these reservoirs would not be in contact with the active film. Observations of the media in use indicated that pools of sewage and effluent did collect within the media in a horizontal or near horizontal position, but there was no evidence to suggest that the size of the pools of the liquor, were affected by the rate of flow or were

Fig 6.7

Tracer test April 1973

Tracer test clean media trough distribution system



Tracer test 18th June 1974

Fig 6.8 Tracer test media with growth trough distribution system

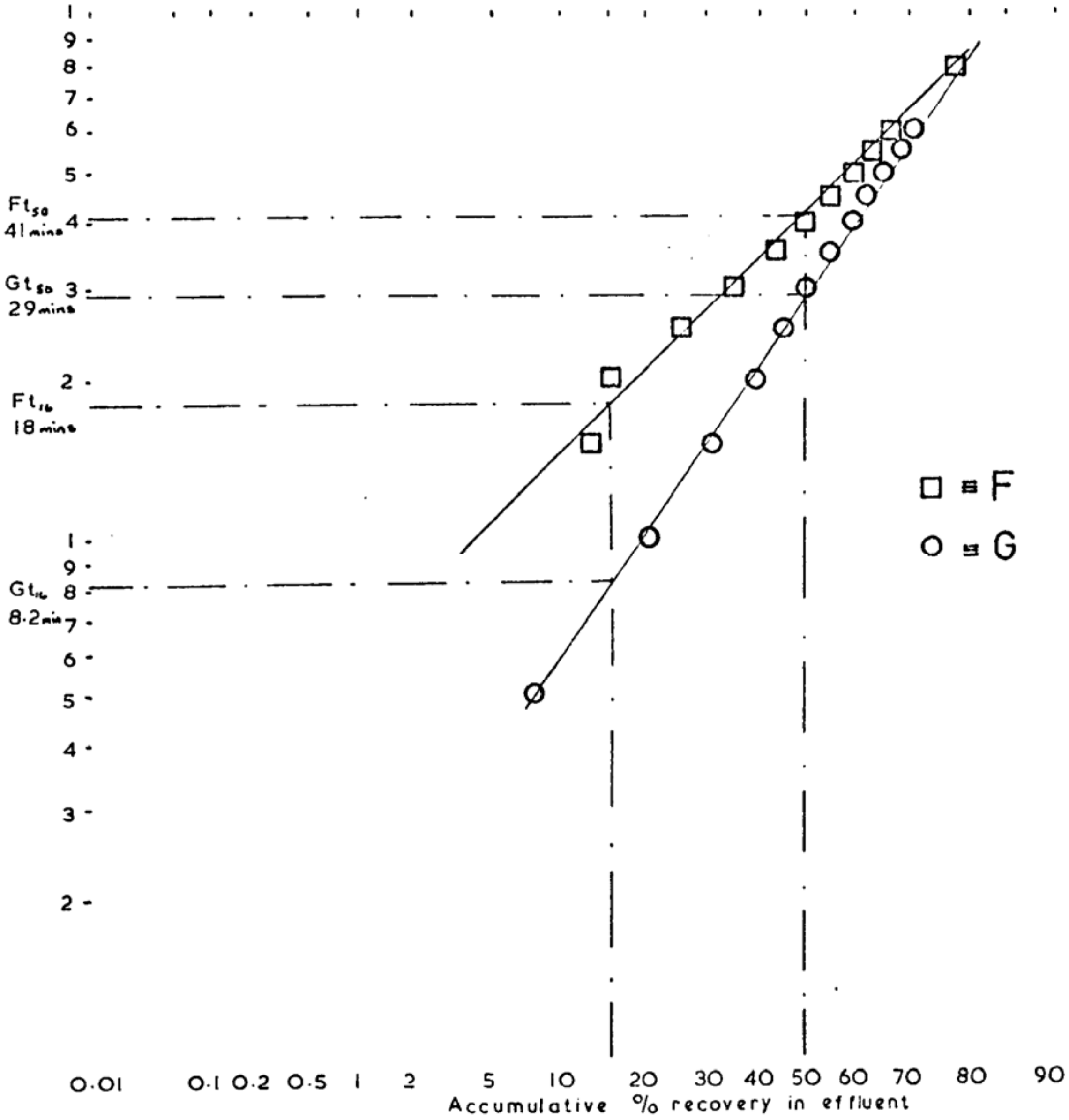


Fig 6.9

Tracer test 17 January 1975

Tracer test media with growth reciprocating distribution system

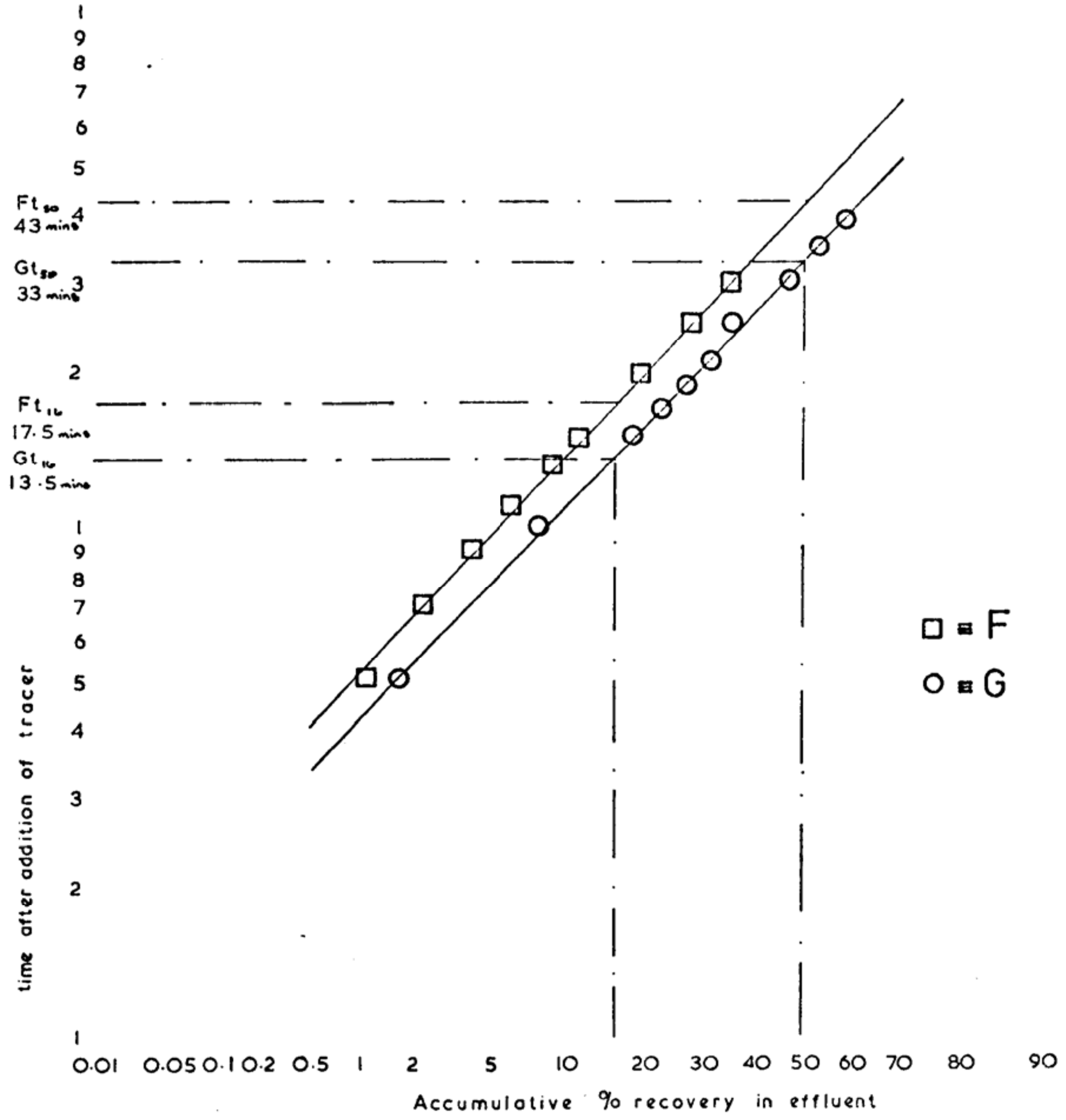
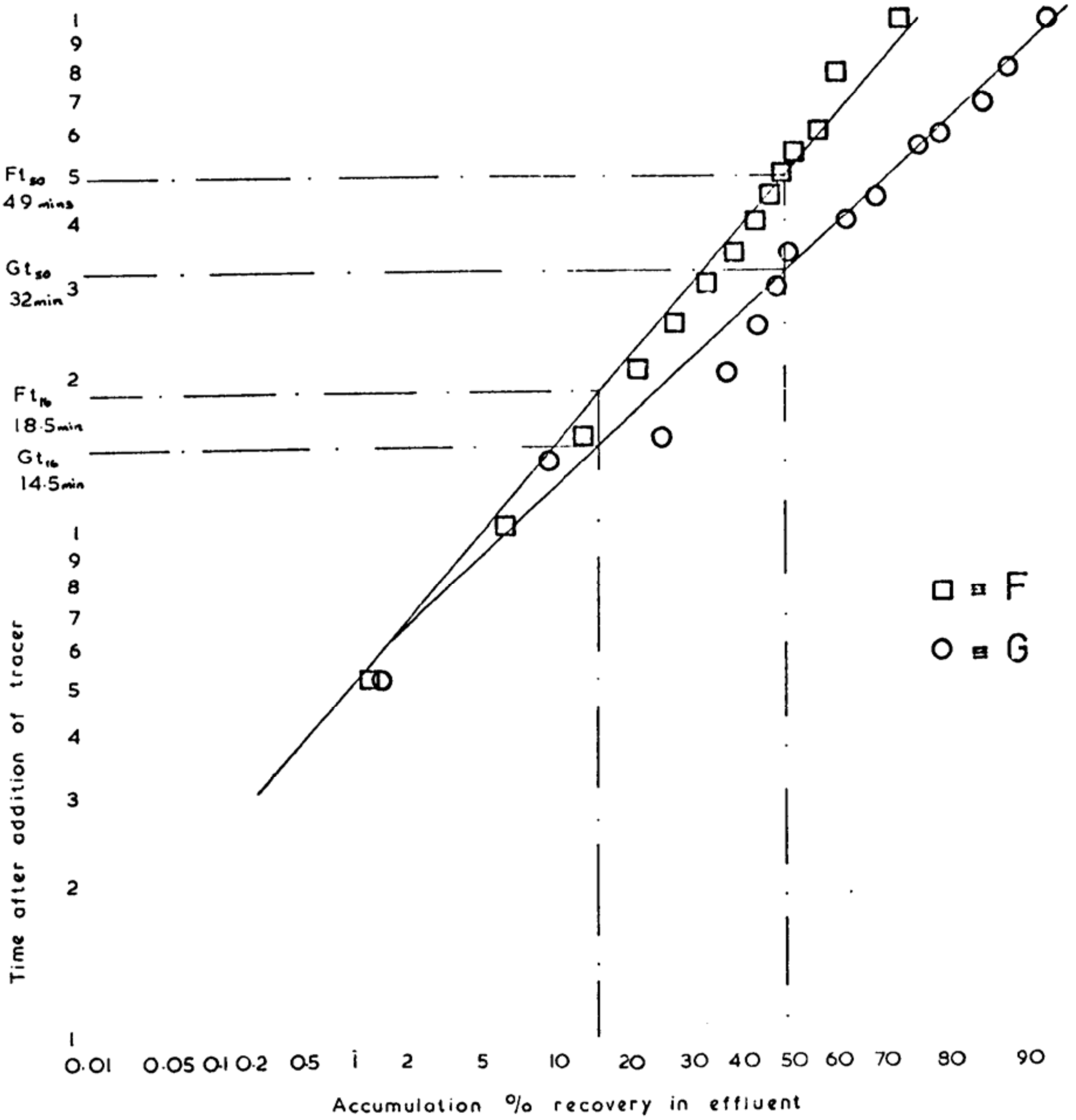


Fig 6.10

Tracer test 18th July 1975

Tracer test, with growth reciprocating distribution system



sufficiently large to interfere with the exchange of material. A second possibility was that the high rate of irrigation was inducing some turbulence of flow, so that although the residence time of the filter was increased the turbulence at the interphase between liquid and film actually reduced the time of contact between film and nutrients. It was not possible to observe any significant turbulence at the flows used in the experiments.

The retention time data was related to the dispersion of flow. Fig.6.7 shows the residence time as measured just after the beginning of irrigation with the medium free of biological growth, with both filters at the same irrigation rate, (1.2 m^3m^{-3} day for maturation section 5.3.1). The residence times are similar. Fig. 6.8 shows the residence time at the final irrigation rates and the high rate filter has a significantly longer residence time. Fig. 6.9 shows the residence times three months after the fitting of the new distribution system (reciprocating system with splash plates instead of the trough system originally fitted); in this case the residence times are increased although only marginally. This is consistent with the only marginal increase in the dispersion of flow caused by the splash plates. Fig. 6.10 shows the residence time after the fitting of the distribution nozzles to the high rate filter (F); the residence time of the high rate filter was significantly increased while that of the low rate filter was virtually the same. This is presumably due to the increased dispersion of flow promoted by the nozzles. Optimum flow dispersion occurs when the liquor is completely homogenized in respect of droplet size (Lee 1932). Dispersion can be improved in two ways, either an increase in the velocity of flow at an impact point, or an increase in pressure in the distribution system. Both are brought about by an increase in the flow. The greater flow rate of the high rate filter (F) and later the greater pressure produced by the distribution nozzles produced a visibly better dispersion of the flow than in the low rate filter. This was confirmed by the residence times. Eden, Brendish and Harvey (1964) proposed that the better distribution and increased wetting as a result of the higher rates of flow was one of the major factors in the increased efficiency of ADF and recirculation. In view of this anomalous behaviour predicting the performance of the filters using a mathematical model of the conventional type would not have been valid. Part of the problem is likely to be intermediate rates of application as the irrigation rate is increased eventually a peak residence time would have been attained and thereafter the residence time would presumably decrease.

An alternative possibility was that the higher organic load to the high rate filter was reducing the percentage BOD removal. The results from the samples taken from 0.5 m and 1.5 m depth down the filter (table 6.4)

	BOD				NH_3			
DEPTH	0.5		1.5		0.5		2.0	
FILTER	F	G	F	G	F	G	F	G
AUGUST	86.7	90.2			30.0	40.5	35.0	36.0
SEPTEMBER	85.5	84.0			65.0	72.5	28.0	46.0
OCTOBER	78.2	85.5			16.0	59.0	38.0	64.0
NOVEMBER	82.0	78.0			16.0	34.0	25.0	53.0
DECEMBER	86.5	87.5			0.0	50.0	20.5	65.0
JANUARY	83.0	85.5			0.0	18.0	0.0	55.5
FEBRUARY	90.0	88.0			0.0	23.0	25.5	50.5
MARCH	84.0	86.0			0.0	30.0	3.6	41.0
APRIL	80.0	71.0			0.0	6.6	2.6	30.6
MAY	85.0	87.0	93.0	90.0				
JUNE	87.0	89.0	93.0	97.0				
JULY	84.0	85.0	92.0	90.0				
AUGUST	96.0	90.0	90.0	99.0				
MEAN	85.2	85.2	92.0	94.0				

TABLE 6.4 : Mean removals in relation to the depth of the filter, through the period 1974-1975. The results are expressed as a percentage of the total removal.

show that on average 85% of the total BOD occurred in the surface layers of both filters. The surface removals were subject to quite a wide variation but the similarity between the two filters was closely maintained. The micro-organisms of the surface film, governed by the available surface area, might have been removing a constant proportion of concentration applied. The larger amounts of nutrient available in the high rate filter may have enabled the preferential removal of specific components in the sewage more readily metabolised by the film. This would leave a residue of more difficult organic matter to remove lower in the filter.

6.2.5 Nitrification

The removal of ammonia in relation to the applied BOD load is shown in figs 6.11 and 6.12. Although showing a trend towards improved nitrification, generally removal of ammonia was poor. Inhibition of nitrification by polypropylene has been noted (Forster 1975) but because of the occasional good nitrification this was not thought to be a problem with this PVC medium. For the reasons discussed (section 6.1) nitrifying bacteria normally flourish in the lower regions of percolating filters. In high rate filters because of the lower overall BOD removal heterotrophic growth occurs throughout the depth of the filter thus eliminating the autotrophic bacteria. The results from the lower levels of the experimental filters indicate that in both cases the removal of BOD in the first 0.5m (table 6.4) were 85% and with dissolved oxygen concentration in the filter effluents are very close to saturation. Examination of the film of the medium in the lower regions of the filter showed that it was largely aggregated humus material rather than microbial growth. It was therefore thought unlikely that there was inhibition of nitrifying activity by either a reduction in the oxygen in the lower levels of the filter or a lack of available surface. The results in fact indicate that nitrification was directly related to sewage strength rather than the expected inverse relationship. One possibility therefore was that there was insufficient ammonia consistently present in the settled sewage to

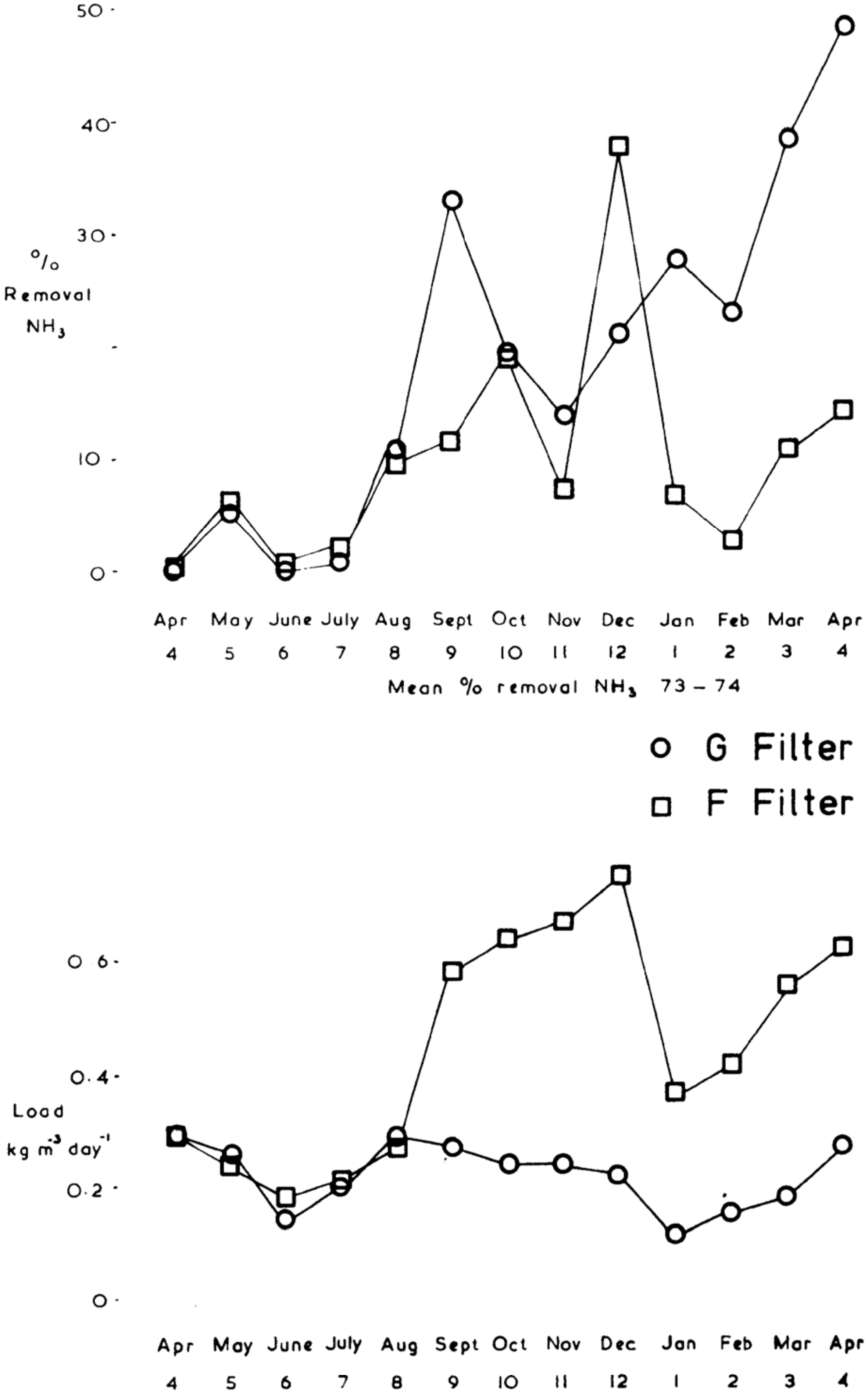


Fig 6.11 Seasonal Removal of Ammonia 1973 – 74

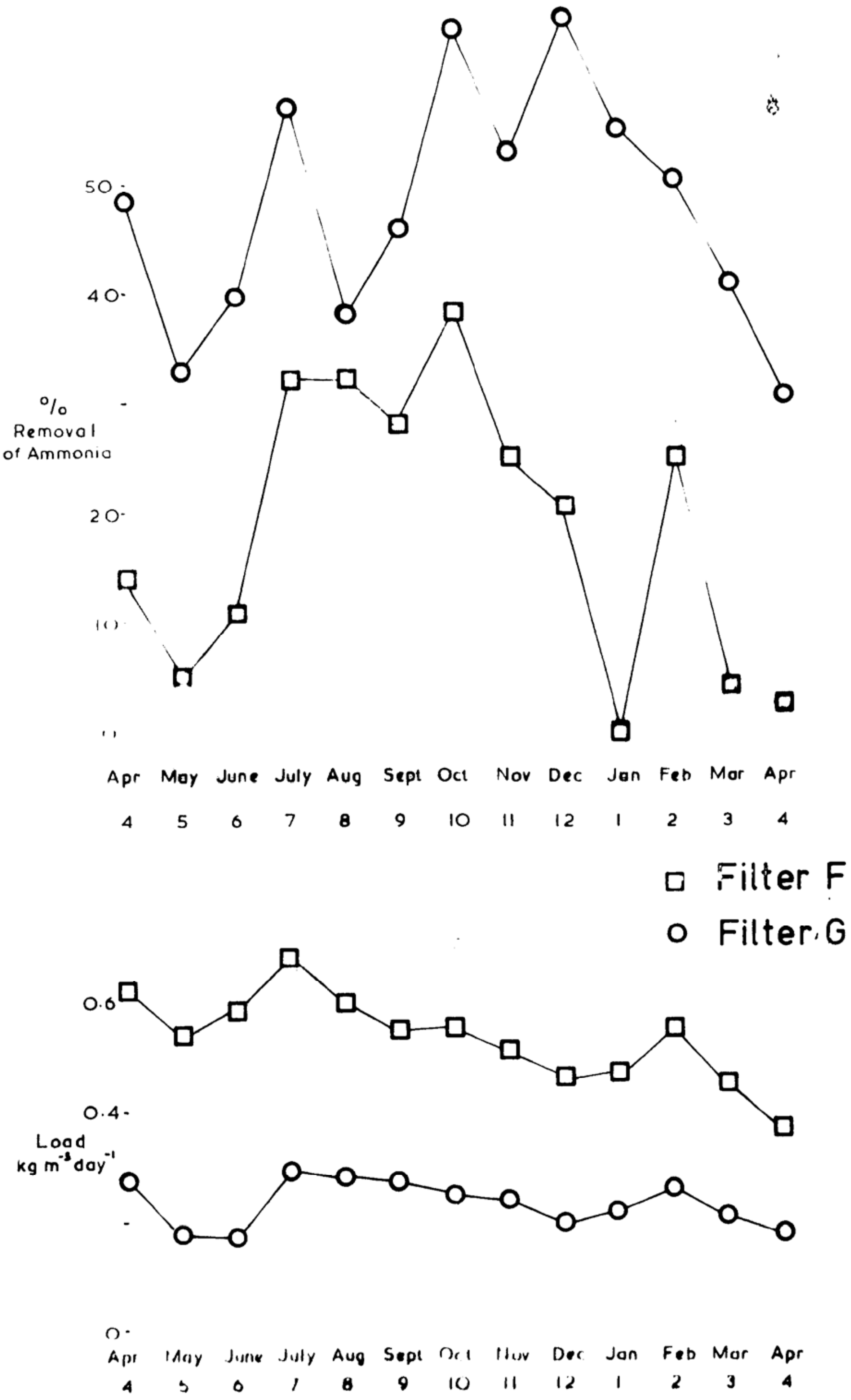


Fig 6.12 Seasonal Removal of Ammonia 1974 – 75

sustain the necessary population for full nitrification. Knowles, Downing and Barret (1965) reported a very rapid loss in nitrifying activity at low concentration of ammonia. Two 24 hour surveys show little diurnal variation in the concentration of ammonia (table 6.5) and although there was a very wide range in ammonia concentration in the settled sewage (table 2.1; range 7.5 - 71.0) normally it was between 25.0 and 45.0 mgl^{-1}. It therefore seems unlikely that the ammonia was below a critical level needed to maintain an active nitrifying population. The low nitrification figures also corresponded to periods when there was a high concentration of nitrate in the sewage feed. In a number of samples taken from both filters, but particularly the high rate filter (F), the nitrate between the sewage influent and the first effluent level (0.5 metres) was reduced while the ammonia increased. Many bacteria reduce nitrate as a method of respiration in time of temporary oxygen shortage, producing nitrite or rarely ammonia and this could occur in thick film. Species capable of full denitrification (forming nitrogen gas) might also be active in conditions of oxygen shortage. Nitrate reduction also occurs as a result of nitrogen assimilation by bacteria. A number of bacteria use nitrate as a nitrogen source in cell synthesis, thus the disappearance of nitrate in the surface layers could have been brought about by several metabolic pathways.

Painter (1970) reports three potential sources of ammonia in metabolism; the deamination of organic nitrogen compounds, the formation of ammonia from endogenous respiration, and the release of ammonia from cell lysis. Normally it is assumed that the relatively small quantities of ammonia so produced are used in cell synthesis (Painter 1970). In low fluctuating C : N ratios, ammonia in excess of that required for growth may be formed by these routes.

To investigate these possibilities the sewage feed was diluted by recirculated effluent to reduce the ammonia and return nitrate to the feed. The tests were carried out during dry months when the sewage strength and concentration of ammonia were high. The low rate filter (G) was selected for the test since it was consistently nitrifying, and a survey of the changes in inorganic nitrogen carried out with no recirculation as a control (6th June 1975). Ammonia, nitrite and nitrate were determined in the effluents from four levels down the depth of the filter at two hourly intervals for 24 hours (composites of one hour samples). When suitable conditions were repeated effluent was recirculated (sewage to effluent 8 : 1) and after an acclimatization period (four days) a second survey was carried out (25th July). The results are shown in tables 6.5 and 6.6. No significant nitrite was recorded in the surveys.

The results were looked at in relation to flow, and changes in the nitrogen balance in the feed (fig.3.5, table 6.5) and although changes in the ammonia to nitrate ratio were reflected in the results the overall patterns remained the same.

Fig. 6.13 and table 6.6 show the rate of change of ammonia and nitrate. In the filter with no recirculation the rate of removal of ammonia and gain in nitrate were equal when balanced over the first metre depth of the filter. Over the next metre depth the removal of ammonia fell to zero while the rate of increase in nitrate was first halved and then over the last 0.5m there was a substantial loss in nitrate. This might have been due to either denitrification or cell uptake.

In the filter with recirculation there was no removal of ammonia in the first half metre but a 9mg increase in ammonia with a small increase in nitrate. In the second metre the rate of removal of ammonia and increase in nitrate were approximately equal and similar to those of the first metre of the filter without recirculation. Recirculation of effluent therefore had two effects. Firstly it increased heterotrophic deamination of organic nitrogen compounds; there was an overall $19mgl^{-1}$ increase in inorganic nitrogen compared with only a $3.5mgl^{-1}$ gain in the filter without recirculation. This may have been caused by the reduction in feed strength either changing the microbial composition of the film or alter ing the metabolism of the existing population. Unfortunately BOD was not measured during the survey and further experiments on the removal of ammonia in relation to the feed

CONTROL	NH_3				NO_3			
	DEPTH (metres)				DEPTH (metres)			
TIME	0.0	0.5	1.5	2.0	0.0	0.5	1.5	2.0
1200	57.5	35.7	21.7	28.0	0.3	13.2	27.0	24.0
1400	60.2	42.0	29.4	28.0	0.3	8.0	33.0	22.0
1600	57.4	42.0	26.6	30.1	0.3	7.6	33.5	23.0
1800	53.2	31.5	16.8	25.9	1.0	18.8	60.0	31.0
2000	48.3	38.5	32.9	30.1	0.8	12.0	24.5	24.5
2200	52.5	33.6	30.8	28.7	0.7	8.8	25.0	24.5
2400	51.1	32.9	21.0	25.9	0.7	11.2	48.5	33.5
0200	51.8	37.8	33.6	28.0	0.7	9.2	21.5	27.0
0400	49.7	42.7	32.9	30.1	0.8	9.5	28.0	29.5
0600	54.6	45.5	21.0	28.0	0.7	9.2	63.0	37.5
0800	53.9	45.5	40.6	29.4	0.9	9.2	36.5	34.5
1000	61.6	47.6	32.9	30.1	0.5	10.4	32.0	35.5
1200	63.0	42.0	29.4	36.4	1.1	20.4	51.5	46.0
EXPERIMENTAL								
1200	43.7	61.0	49.7	44.8	0.1	1.2	11.5	18.9
1400	46.2	59.8	51.1	45.8	0.1	2.8	12.6	22.5
1600	47.5	59.5	46.2	41.8	0.9	3.7	15.5	30.0
1800	46.1	56.7	50.3	43.6	0.8	2.1	10.3	16.2
2000	44.9	56.4	46.8	40.5	0.4	2.3	16.2	18.9
2200	42.0	48.0	49.7	40.5	0.4	3.6	13.2	20.1
2400	44.7	46.9	55.3	40.1	0.7	2.8	12.3	18.9
0200	46.9	56.7	48.2	40.7	0.6	3.8	13.8	21.0
0400	40.7	37.8	40.7	30.1	0.5	6.7	17.1	29.7
0600	46.1	55.3	53.1	41.3	1.0	6.3	19.8	21.0
0800	49.3	62.3	57.4	51.7	0.6	7.3	17.4	18.9
1000	51.9	60.1	56.0	49.0	1.5	3.1	8.3	19.5
1200	52.5	59.5	51.6	49.6	1.6	3.2	12.5	18.9

TABLE 6.5 : Ammonia survey control, without recirculation and experimental, with recirculation. (results in mgl^{-1})

CONTROL								
	NH_3				NO_3			
	DEPTH (m)				DEPTH (m)			
	0.0	0.5	1.5	2.0	0.0	0.5	1.5	2.0
MEAN	54.98	39.79	28.45	29.13	0.67	11.19	37.23	30.19
S.D.	4.67	5.23	6.69	2.63	0.28	3.71	13.90	7.04
C.V.	8.00	13.00	23.00	9.00	41.00	33.00	37.00	23.00
S.E.	1.29	1.44	1.85	0.72	0.0	1.02	3.85	1.95
EXPERIMENTAL								
MEAN	46.34	55.38	50.46	43.03	0.70	3.76	13.88	21.11
S.D.	3.52	7.08	4.61	5.57	0.46	1.86	3.20	4.18
C.V.	7.00	12.00	9.00	12.00	65.00	49.00	23.00	19.00
S.E.	0.97	1.96	1.28	1.54	0.10	0.50	0.88	1.15

TABLE 6.6 : Analysis of results of the ammonia survey (mgl^{-1} NH_3N)

BOD are required to confirm this.

Secondly the production of nitrate moved lower down the filter indicating the nitrifying organisms were no longer able to nitrify in the surface metre of the filter.

Normally nitrification is improved by recirculation (Lumb and Eastwood 1958; Hawkes 1961) which may indicate that the results are due to the higher organic and hydraulic loadings.

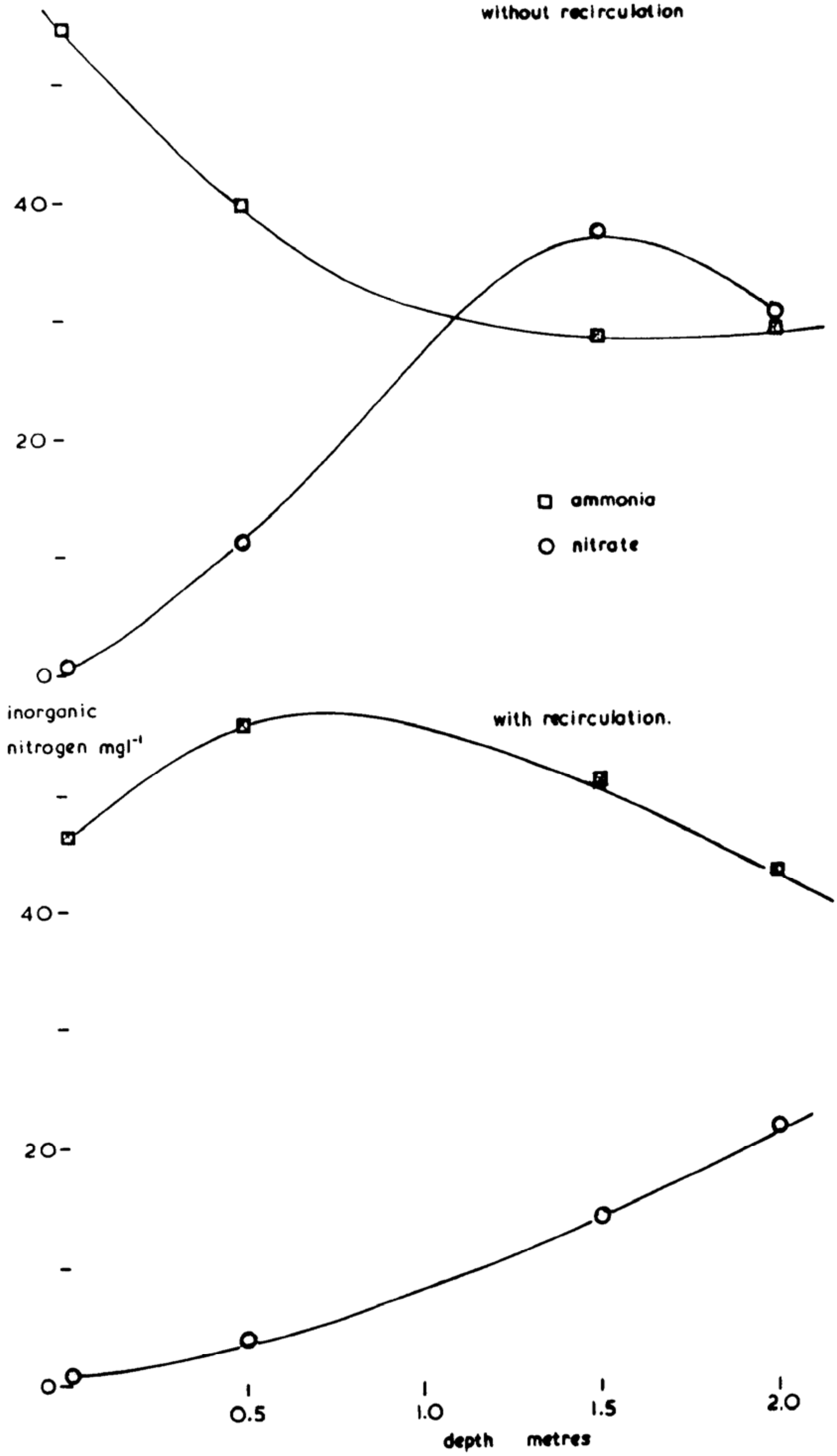


Fig 6.13 ammonia survey

SECTION SEVEN

CONCLUSIONS

SECTION 7

CONCLUSIONS

7.1 PHYSICAL NATURE OF THE MEDIUM

1. The new medium has a specific surface area of $320m^2m^{-3}$ three times that of conventional media, a void space of 94%, twice that of conventional media, and weighs less than 10% of the weight of conventional media.

2. The medium was found to be stable under varying conditions of pH, and not to release significant amounts of metals under normal operating conditions. Compression tests on the medium showed a 1% compression occurred with every 500 kgm^{-2} load applied.

3. Investigations on the wetting characteristics of the medium showed that significant redistribution of the flow occurred within the medium, and that biological growth was possible on virtually all the surface of the medium. It was concluded the medium was physically suitable for high efficiency filtration.

(The results and discussion on the physico-chemical nature of the medium are presented in section two.)

7.2 BIOLOGICAL INVESTIGATIONS

1. The maturation period (as determined by performance) was long in relation to experience with conventional filters started in summer, but to what extent mechanical breakdowns were responsible for this is not known. There was evidence that although the filters had been in operation for two and a half years ecological stability was yet to be reached.

2. The main macro-invertabrates in the first year of operation were psychoda flies and mites. Psychoda and Enchytraeidae were the dominant grazers in the second. The major microfauna in both years of operation were Opercularia and nematodes.

3. The number of grazing organisms was directly linked to the level of organic matter in the filter. The numbers of microfauna were high at times of film unloading and also at times when the numbers of macrofauna were low.

4. There was significant vertical stratification of the film and fauna down the depth of the filter, the largest numbers of macrofauna occurred in the middle of the filters. The mites and collembolans were restricted to the lower levels of the filters; collembolans were not recorded in significant numbers in the high rate filter. Nematodes and Opercularia were found throughout both the filters but the

holotrichous and spirotrichous protozoa were largely restricted to the lower levels of the filters.

5. There were differences in the composition of the film of the two filters at the different hydraulic loadings. Fungi and bacteria dominated the surface film of the high rate filter (F) and algae and bacteria the surface of the low rate filter (G).

6. No single factor was found to directly influence film weight but it was thought to be controlled by an interaction of factors namely, ambient temperature, sewage strength, mode of application of the sewage, the microbial characteristics of the film and grazing activity.

7. The amount of film in both filters was normally low and could not be linked to changes in the performance of the filters. The maximum accumulated film was 4.0 kgm^{-3} (as volatile matter) about half that reported to cause ponding in conventional 50 mm medium. At this level of film, tests showed that the film still occupied less than 5% of the available void space.

8. No major differences were observed between the ecology of the plastic filter medium under test and that reported in mineral media.

(The results and discussions on ecology are in section five.)

7.3 THE PERFORMANCE OF THE FILTERS

1. The seasonal changes in ambient temperature affected the performances of the filters, the best performances were obtained during the warmer months of the year. The low rate filter (G) was irrigated at $1.2m^3m^{-3}day^{-1}$ ($0.25kg\ BODm^{-3}day^{-1}$) three times the recommended Royal Commission loadings. The low rate filter achieved an average 87% BOD removal. While this did not produce a consistant Royal Commission standard effluent it came sufficiently close to suggest that a large scale plant could reach this standard at this loading. The high rate filter (F) was irrigated at twice this loading $2.4m^{-3}m^{-3}day^{-1}$ ($0.55\ kg\ BODm^{-1}day^{-1}$) and produced an average 83% BOD removal.

2. Higher rates of filtration are known to restrict a number of processes within the filter; notably a change in sludge characteristics, depression of nitrification, and a more even BOD removal down the depth of the filter.

   The sludge production and dewatering figures although inconclusive showed a general tendancy to fall. The organic matter contained in the sludges of both filters (72% and 62% for the high and low rate filters respectively) was consistant with that produced by low rate filters.

Nitrification was not good but ammonia in the effluent also showed a general tendancy to fall. It is possible that it could be maintained in the long term at least at the lower flow. Experiments indicated that the removal was proportional to the strength of the incoming sewage feed.

An average of 85% of the total BOD removal in both filters occurred in the first 0.5m of filter depth. It was concluded that the filters were behaving as low rate filters.

3. Although subject to variation the filters were not consistently more efficient at removing the soluble BOD fraction of the applied sewage a feature noted with high rate filtration.

4. The retention times of the filters were found to be proportional to the dispersion of flow produced by the distribution system. The mean residence time of the high rate filter was 40 minutes ($2.4m^3m^{-3}day^{-1}$) and 30 minutes for the low rate filter ($1.2m^3m^{-3}day^{-1}$), compared with 40 minutes for 60 mm mineral media irrigated at $0.6m^3m^{-3}day^{-1}$. It was concluded that the filters were behaving as low rate filters.

(The results and discussion on performance are in section six.)

Suggestions for further work

Physical nature of the medium

1. There have been recent suggestions that vinyl monomer is released from PVC and chromotographic determination of the leached monomer would indicate the amount and significance of the release.
2. Compression tests on the medium as it is removed from the filters would indicate to what extent ageing had affected its mechanical strength.

Biological Investigations

1. Longer term studies on maturation in relation to ecology would indicate whether the populations had reached stability.
2. A more intensive quantitative study on microfauna is desirable and might give an insight into its role in controlling film accumulation.

Performance

1. Thermocouples embedded in the plastic media would enable accurate film temperature measurements to be made. This could improve the understanding of the relationships between temperature and performance.

2. Sludge treatment is often the major problem on a sewage works routine measurements of the sludge production and characteristics would provide information on its treatability.

3. Increased frequency of measurements of residence time by a more rapid method (conductivity, chloride probe) would indicate the seasonal changes in residence time and its affect on performance.

4. Further work on the nitrogen balance of filters, in relation to the BOD load would assist in determining the important sources of nitrogen in the filter and how these vary seasonally and with film weight.

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APPENDIX

APPENDIX ONE

Cost equivalents for treating 90Kg BOD day^{-1} in 1972

	Natural Medium Filter	Random Flocor Medium
Load	$0.07kgm^{-3}day^{-1}$	$0.2Kgm^{-3}day^{-1}$
Volume of medium	$1200m^3$	$400m^{-3}$
Cost m^{-3}	£4.50	£30.00
total	£5,500.00	£12,000.00
Cost of civil engineering works	£13,000.00	£6,000.00
TOTAL	£18,500.00	£18,000.00

APPENDIX TWO

Results from the test samples from different widths through the filter.

Volatile solids are expressed as kgm^{-3}, invertebrates as counts m^{-3} and the microfauna as counts per 20 fields of view (x 100), calculated to represent 8.6×10^{-3}mls.

	WIDTH OF FILTER SAMPLED	
Depth 0.5m	0-600mm	600-1200mm
Volatile Solids (kgm^{-3})	0.20	0.12
INVERTEBRATES		
OLIGOCHAETA		
Enchytraeidae		
NEMATODA	4	3
INSECTA		
Psychoda 1.	24	25
ARACHNIDA		
mites	5	5
CILIATEA		
PERITRICHIA		
Opercularia	21	10
Depth 1.5m		
Volatile Solids (kgm^{-3})	0.40	0.21
INVERTEBRATES		
OLIGOCHAETA		
Enchytraeidae		
NEMATODA	2	5
INSECTA		
Psychoda 1.	48	32
ARACHNIDA		
mites	7	5
CILIATEA		
PERITRICHIA		
Opercularia	16	12

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	WIDTH OF FILTER SAMPLED	
Depth 0.5m	0-600mm	600-1200mm
Volatile Solids (kgm^{-3})	0.62	1.00
INVERTEBRATES		
OLIGOCHAETA		
Enchytraeidae		
NEMATODA	5	5
INSECTA		
Psychoda l.	44	52
ARACHNIDA		
mites	2	6
CILIATEA		
PERITRICHIA		
Opercularia	5	5
Depth 1.5m		
Volatile Solids (kgm^{-3})	0.72	0.70
INVERTEBRATES		
OLIGOCHAETA		
Enchytraeidae		
NEMATODA	5	5
INSECTA		
Psychoda l.	31	12
ARACHNIDA		
mites	13	10
CILIATEA		
PERITRICHIA		
Opercularia	2	5

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	WIDTH OF FILTER SAMPLED	
Depth 0.5m	0-600mm	600-1200mm
Volatile Solids (kgm^{-3})	1.48	1.60
INVERTEBRATES		
OLIGOCHAETA		
Enchytraeidae		
NEMATODA	4	1
INSECTA		
Psychoda l.		
ARACHNIDA		
mites	10	
CILIATEA		
PERITRICHIA		
Opercularia	1	1
Depth 1.5m		
Volatile Solids (kgm^{-3})	1.22	1.01
INVERTEBRATES		
OLIGOCHAETA		
Enchytraeidae	10	2
NEMATODA	3	1
INSECTA		
Psychoda l.	12	13
ARACHNIDA		
mites		1
CILIATEA		
PERITRICHIA		
Opercularia	5	7

SEPTEMBER 1974 F

	WIDTH OF FILTER SAMPLED	
Depth 0.5m	0-600mm	600-1200mm
Volatile Solids (kgm^{-3})	1.01	1.11
INVERTEBRATES		
OLIGOCHAETA		
Enchytraeidae	19	30
NEMATODA	3	6
INSECTA		
Psychoda l.	10	10
ARACHNIDA		
mites		
CILIATEA		
PERITRICHIA		
Opercularia	3	2
Depth 1.5m		
Volatile Solids (kgm^{-3})	0.95	1.20
INVERTEBRATES		
OLIGOCHAETA		
Enchytraeidae	15	12
NEMATODA	3	4
INSECTA		
Psychoda l.	10	11
ARACHNIDA		
mites		
CILIATEA		
PERITRICHIA		
Opercularia	2	6

SEPTEMBER 1974 G

	WIDTH OF FILTER SAMPLED	
Depth 0.5m	0-600mm	600-1200mm
Volatile Solids (kgm^{-3})	1.51	1.06
INVERTEBRATES		
OLIGOCHAETA		
Enchytraeidae	950	1070
NEMATODA	2	5
INSECTA		
Psychoda l.	40	52
ARACHNIDA		
mites		
CILIATEA		
PERITRICHIA		
Opercularia	3	5
Depth 1.5m		
Volatile Solids (kgm^{-3})	0.48	0.53
INVERTEBRATES		
OLIGOCHAETA		
Enchytraeidae	20	103
NEMATODA	5	5
INSECTA		
Psychoda l.	120	110
ARACHNIDA		
mites		
CILIATEA		
PERITRICHIA		
Opercularia	2	1

MARCH 1975 F

	WIDTH OF FILTER SAMPLED	
Depth 0.5m	0-600mm	600-1200mm
Volatile Solids (kgm^{-})	0.61	1.32
<u>INVERTEBRATES</u>		
OLIGOCHAETA		
Enchytraeidae	80	107
NEMATODA	1	1
INSECTA		
Psychoda l.	110	112
ARACHNIDA		
mites		
<u>CILIATEA</u>		
PERITRICHIA		
Opercularia	6	5
Depth 1.5m		
Volatile Solids (kgm^{-})	1.39	1.36
<u>INVERTEBRATES</u>		
OLIGOCHAETA		
Enchytraeidae	180	212
NEMATODA	5	10
INSECTA		
Psychoda l.	60	127
ARACHNIDA		
mites		
<u>CILIATEA</u>		
PERITRICHIA		
Opercularia	3	10

<u>**MARCH 1975 G**</u>

APPENDIX THREE

Survey of the differences between automatically and manually taken samples - 18th March 1972

Rainfall 2.0mm

Mean Temperature 7.0°C

PARAMETER	BOD		PV		SS		NH_3	
TIME	A	M	A	M	A	M	A	M
09.30	144.5	112.5	43.2	41.5	146	138	34.7	41.7
10.30	141.0	116.2	48.0	41.0	134	134	41.3	43.7
11.30	168.9	135.2	52.6	45.5	130	100	50.7	51.1
12.30	215.5	169.0	56.0	47.3	196	146	41.3	59.7
13.30	164.4	133.5	53.7	49.2	162	146	55.0	53.2
14.30	186.7	139.4	53.5	52.6	144	118	53.5	51.8
15.30	220.8	133.1	56.2	54.8	174	134	50.9	52.2
16.30	160.3	151.0	55.5	53.2	164	140	50.8	46.9
17.30	215.2	156.8	56.5	54.5	172	150	47.3	46.3

(Results in mgl^{-1} A ≡ automatic sample

M ≡ manual sample)

APPENDIX FOUR

Invertebrate and microfauna counts, the scoring of surface microorganisms and the chemical data.

The invertebrates are expressed as counts m^{-3} of medium, the microfauna and surface microorganisms score counts, as per 20 fields of view (x 100 equivalent to 8.6×10^{-3}mls). The chemical data is in mgl^{-1} except where noted.

	F			G			F			G		
MONTH	Depth(m) 0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
8	0.55	0.23	0.76	0.36	0.26	0.42	0.98	0.83	0.77	0.89	0.84	0.46
9	0.95	1.87	0.90	0.57	0.52	0.86				1.78	1.88	0.63
10	1.19	1.63	1.55	1.08	0.93	0.62	0.89	2.02	1.77	1.73	2.12	1.55
11							1.27	0.65	0.43	0.97	0.94	0.81
12	1.54	0.20	0.41	0.50	0.62	0.72						
1	1.23	0.67	1.35	0.72	0.59	0.63	1.19	0.80	0.59	0.83	0.64	0.56
2	1.19	0.65	0.95	1.20	0.49	0.95	0.89	0.41	0.55	1.48	0.74	0.75
3	0.73	0.69	0.47	1.53			0.70	0.37	0.45	1.19	0.81	0.73
4							1.31	0.52	0.30	1.71	1.00	1.60
5	1.15	0.61	0.54	1.54	0.78	1.01	0.74	0.55	0.36	1.30	0.32	0.57
6	0.82	0.48	0.28	0.82	0.24	0.22						
7	0.69	0.75	0.90	0.57	0.58	0.53	0.28	0.39	0.44	0.48	0.31	0.24

VOLATILE SOLIDS kgm^{-3} 1973 - 74

	F			G			F			G		
MONTH	Depth(m) 0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
8	0.86	1.24	0.99	0.76	1.24	0.58	0.91	1.01	0.79	0.87	0.69	0.33
9	1.79	1.48	1.22	1.24	1.01	0.95						
10	2.73	2.43	2.40	1.83	1.95	1.23	3.84	2.50	1.82	1.62	1.58	1.25
11	3.25	2.76	2.22	3.58	3.25	2.49	3.94	3.12	2.69	3.30	2.65	1.63
12	3.08	1.11	1.00	3.17	2.10	1.20						
1	2.01	1.38	0.47	2.01	1.15	0.71	2.24	1.99	0.43	3.16	1.31	1.06
2	2.39	1.32	0.42	2.89	1.49	1.28	2.28	1.18	0.41	1.99	1.44	0.97
3	2.21	1.51	0.48	1.49	0.61	1.39						
4							1.56	1.69	0.43	1.24	0.56	1.15
5	1.21	0.52	0.36	0.72	0.52	0.37						
6							1.35	1.09	0.49	0.84	0.41	0.34
7	1.00	0.73	0.51	0.81	0.38	0.34						
8	1.39	1.03	0.82	0.81	0.51	0.30						

VOLATILE SOLIDS kgm^{-3} 1974 - 75

AUGUST 1973

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
BACTERIA												
Zoogloeal forms	2			2			4			3		
Sphaerotilus								1				
Beggiatoa												
Thiothrix												
FUNGI												
Subbaromyces		2		2	2	1	2	4	1	2	2	
ALGAE												
Chlorella	1			6			1			6		
Stigeoclonium												
Phormidium												

August 1973

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
OLIGOCHAETA												
Enchytraeidae												
Lumbricillus lineatus												
Enchytraeus albidus												
INSECTA												
Collembola												
Hypogastrura												
Diptera												
Psychoda												
larvae	63	65	32	272	42	90	226	74	66	11	24	6
pupae												
flies												
Chironomidae												
larvae	20		3	2		10	20		5	6		28
flies												
ARACHNIDA												
Mites (Mesostigmatidae)		6						2				
CRUSTACEA												
Canthocamptidae												

August 1973

FILTER	F			G			F			G		
DEPTH (m)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
PROTOZOA: CILIOPHORA												
HOLOTRICHIA												
Trachelophyllum pusillum												
Paramecium caudatum		4	6		5	3		6	14		6	8
Colpidium colpoda	1											
Glaucoma scintillans	17	27	30	4	12	1	22	52	41	7	7	1
Colpoda inflata												
Chilodonella uncinata												
PERITRICHIA												
Vorticella sp.												
Telotrochs of Vorticella												
Opercularia coarctata	6	15	10	7	10	3	5	17	20	6	11	7
SPIROTRICHIA												
Aspidisca costata					2	1					7	1
Oxytricha sp.												
Stylonychia sp.												
PROTOZOA : MASTIGOPHORA												
Euglena sp.												
NEMATODA	6	5	5	20	6	4	7	5	5	11	3	4
ROTIFERA	3	5	1	2			6	4	8			

AUGUST 1973

DATE	FILTER	TEMPERATURE °C			LOAD	SETTLED BOD mgl^{-1}				SUSPENDED SOLIDS mgl^{-1}			
		INF	EFF	AIR	Kgm^{-3}	INF	EFF	FINAL	% rem	INF	EFF	FINAL	% rem
1st	F	18.9	18.4	21.0	0.19	167.0	60.5	27.2	84	146	118	45	69
	G	18.5	18.0		0.19	170.0	53.5	32.8	84	110	138	50	55
4th	F	18.0	17.0	21.0	0.29	256.0	61.5	17.3	97				
	G	18.0	17.0		0.24	213.0	70.0	23.0	93				
10th	F	18.0	17.0	21.0	0.21	177.0	53.8	43.0	76				
	G	18.0	17.0		0.13	115.0	30.8	28.0	76				
15th	F	18.5	19.0	21.0	0.39	344.0	136.0	41.5	88	140	102	87	64
	G	18.5	18.0		0.38	333.0	177.0	41.5	87	189	88	63	49
24th	F			19.0									
	G	19.0	16.0		0.42	374.0	84.0	24.0	67	210	124	92	56
30th	F												
	G	15.5	13.0	18.3	0.43	378.0	111.0	41.0	73	96	150	28	70

	BOD					SUSPENDED SOLIDS			
	INF	EFF	FINAL	% rem	LOAD	INF	EFF	FINAL	% rem
F MEAN	236.0	64.4	32.2	86	0.27	165.3	114.6	74.6	63
S.D	82.3	40.6	12.2	8.7	0.09	38.8	11.4	25.8	4.9
C.V	34.7	63.1	37.9	10.1	33.5	23.5	9.9	34.6	7.7
S.E	41.1	18.2	6.1	4.3	0.04	22.4	6.6	14.9	2.8
G MEAN	263.8	87.7	31.7	83.3	0.29	110.0	125.3	47.0	58.0
S.D	112.7	51.4	8.1	7.5	0.12	14.0	32.8	17.7	10.8
C.V	42.7	58.7	25.7	9.0	43.0	12.7	26.2	37.6	18.6
S.E	46.0	21.0	3.3	3.0	0.05	8.0	18.9	10.2	6.2

AUGUST 1973

FILTER	DATE	SOLUBLE BOD			AMMONIACAL NITROGEN			OXIDISED NITROGEN		PERMANGANATE VALUE			DETERGENT (as manoxol)		
		INF	EFF	%R	INF	EFF	%R	INF	EFF	INF	EFF	%R	INF	EFF	%R
1st	F	111.0	14.5	87	43.8	33.4	24	2.6	2.4	65.5	24.0	63	16.0	2.2	86
	G	95.2	18.1	81	43.8	33.2	24	2.4	5.2	64.0	25.4	60	13.4	2.2	84
10th	F	82.0	6.5	92	32.2	30.6	5	1.4	3.4	32.2	19.5	40			
	G	67.0	18.1	73	32.8	26.5	16	1.8	4.6	34.3	20.5	40			
15th	F	197.0	73.2	63	52.4	58.4	-	1.4	3.6	60.0	48.4	20			
	G	189.0	50.5	65	49.0	58.4	-	1.4	3.0	66.5	43.4	34	8.6	2.2	80
30th	F														
	G	117.0	38.5	70	42.2	38.2	9	2.4	7.4	84.0	37.3	55			

FILTER	DATE	TEMPERATURE ^{o}C		AMMONIACAL NITROGEN			OXIDISED NITROGEN			B.O.D.			SUSPENDED SOLIDS		
	Depth(m)	0.0	0.5	0.0	0.5	%R	0.0	0.5	2.0	0.0	0.5	%R	0.0	0.5	2.0

SEPTEMBER 1973

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
BACTERIA												
Zoogloeal forms	4	1		4			2			2		
Sphaerotilus												
Beggiatoa												
Thiothrix												
FUNGI												
Subbaromyces	1	1		1			1	1		1		
ALGAE												
Chlorella	1			6			1			6		
Stigeoclonium												
Phormidium												

September 1973

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
OLIGOCHAETA												
Enchytraeidae												
Lumbricillus lineatus												
Enchytraeus albidus												
INSECTA												
Collembola												
Hypogastrura												
Diptera												
Psychoda												
larvae	112	16	20	16	10	8	10	4	8	14	5	19
pupae												
flies												
Chironomidae												
larvae	10		3	6	2	2	6	1	5	4		5
flies												
ARACHNIDA												
Mites (Mesostigmatidae)		5						10			3	
CRUSTACEA												
Canthocamptidae												

September 1973

FILTER	F			G			F			G		
DEPTH (m)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
PROTOZOA: CILIOPHORA												
HOLOTRICHIA												
Trachelophyllum pusillum												
Paramecium caudatum			6					5	25		11	3
Colpidium colpoda											2	
Glaucoma scintillans	11	21	15				32	18	30	3	1	1
Colpoda inflata												
Chilodonella uncinata										1		
PERITRICHIA												
Vorticella sp.												
Telotrochs of *Vorticella*												
Opercularia coarctata	6	5	5	3	7	5	3	3	3	5	1	4
SPIROTRICHIA												
Aspidisca costata					6	5	1	3	1		3	
Oxytricha sp.									1			
Stylonychia sp.						1			1			1
PROTOZOA : MASTIGOPHORA												
Euglena sp.												
NEMATODA	2	8	9	6	2	5	7	3	3	6	7	3
ROTIFERA	2	2		1	2	1	4	6	3	1	1	1

SEPTEMBER 1973

DATE	FILTER	TEMPERATURE °C			LOAD	SETTLED BOD mgl^{-1}				SUSPENDED SOLIDS mgl^{-1}			
		INF	EFF	AIR	Kgm^{-3}	INF	EFF	FINAL	% rem	INF	EFF	FINAL	% rem
17th	F	20.0	18.0	24.0	0.60	328	88.4	29.5	90				
	G	20.0	17.0		0.35	278	29.0	16.5	96				
19th	F	17.0	12.5	12.5	0.35	140.5	25.8	41.0	70	116	221	31	73
	G	17.0	12.0		0.17	136.0	50.0	35.0	74	139	284	22	84
21st	F	18.0	13.0	16.0	0.55	232.0	71.5	26.8	89				
	G	18.0	12.0		0.25	221.0	92.0	23.4	89				
22nd	F	18.0	13.0	14.0	0.55	231.0	90.0	81.5	65				
	G	18.0	13.0		0.26	231.0	66.5	46.0	80				
26th	F	17.0	12.0	12.0	0.75	339	58	53.5	84	222	208	80	64
	G	17.0	12.0		0.30	262	116	44.0	83	182	360	67	63
27th	F	17.0	12.0	11.0	0.70	302	99	68.4	77	222	208	80	64
	G	17.0	12.0		0.32	280	107	8.9	97	182	360	67	63

		BOD					SUSPENDED SOLIDS			
		INF	EFF	FINAL	% rem	LOAD	INF	EFF	FINAL	% rem
F	MEAN	262.1	79.6	50.1	79	0.58	169.0	214.5	55.5	68.5
	S.D	75.5	28.9	21.8	10.3	0.17	74.9	9.2	34.6	6.3
	C.V	28.8	36.3	43.5	12.9	29.00	44.3	4.3	62.4	9.3
	S.E	30.8	10.9	8.9	4.2	0.00	53.0	6.5	24.5	4.5
G	MEAN	234.6	71.0	28.9	86.5	0.27	160.5	322.0	44.5	73.5
	S.D	54.1	29.9	15.1	9.1	0.0	30.4	53.7	31.8	14.8
	C.V	23.0	42.1	52.2	10.5	0.0	18.9	16.7	71.5	20.2
	S.E	22.0	12.2	6.2	3.7	0.0	21.5	38.0	22.5	10.5

SEPTEMBER 1973

FILTER	DATE	SOLUBLE BOD			AMMONIACAL NITROGEN			OXIDISED NITROGEN		PERMANGANATE VALUE			DETERGENT (as manoxol)		
		INF	EFF	%R	INF	EFF	%R	INF	EFF	INF	EFF	%R	INF	EFF	%R
F	19th	93	19.6	79	24.2	18.6	23	7.2	10.2	48.5	15.2	68			
G		126	44.5	65	45.0	25.1	44	12.4	20.0	62.0	29.5	53			
F	27th	275	108	61	51.0	55.0		1.0	1.0	79.0	36.0	54			
G		250	96	62	53.2	35.8	33	1.0	13.6	76.4	52.0	32			

FILTER	DATE	TEMPERATURE °C		AMMONIACAL NITROGEN			OXIDISED NITROGEN			B.O.D.			SUSPENDED SOLIDS		
	Depth(m)	0.0	0.5	0.0	0.5	%R	0.0	0.5	2.0	0.0	0.5	%R	0.0	0.5	2.0

OCTOBER 1973

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
<u>BACTERIA</u>												
Zoogloeal forms	2			2			10		2	4		
Sphaerotilus	2											
Beggiatoa												
Thiothrix												
<u>FUNGI</u>												
Subbaromyces							8					
<u>ALGAE</u>												
Chlorella	2											
Stigeoclonium												
Phormidium												

October 1973

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
OLIGOCHAETA												
Enchytraeidae												
Lumbricillus lineatus												
Enchytraeus albidus												
INSECTA												
Collembola												
Hypogastrura									1			
Diptera												
Psychoda												
larvae	29	42	59	54	33	10	40	55	47	50	74	20
pupae	4		7	3	3		4		4	2	1	2
flies				1			6					
Chironomidae												
larvae	6		16	3		10	23		1	3		20
flies	2						7			1		6
ARACHNIDA												
Mites (**Mesostigmatidae**)								51			50	
CRUSTACEA												
Canthocamptidae												

October 1973

FILTER	F			G			F			G		
DEPTH (m)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
PROTOZOA: CILIOPHORA												
HOLOTRICHIA												
Trachelophyllum pusillum												
Paramecium caudatum	1	17	8		7	1		10	14	1	8	4
Colpidium colpoda												
Glaucoma scintillans	1	3	5	13	10	7	1		4	12	9	10
Colpoda inflata												
Chilodonella uncinata		2				3			2			
PERITRICHIA												
Vorticella sp.												
Telotrochs of Vorticella												
Opercularia coarctata	6	4	1	18	4	10	12	3	1	6	5	9
SPIROTRICHIA												
Aspidisca costata	3	12	19		7	2		8	16	2	10	1
Oxytricha sp.	1	3	4					3	3		3	
Stylonychia sp.												
PROTOZOA : MASTIGOPHORA												
Euglena sp.	2											
NEMATODA	27	26	6	7	2	1	33	28	9	12	3	8
ROTIFERA	1	1				2	2	1				2

OCTOBER 1973

DATE	FILTER	TEMPERATURE °C			LOAD	SETTLED BOD mgl^{-1}				SUSPENDED SOLIDS mgl^{-1}			
		INF	EFF	AIR	Kgm^{-3}	INF	EFF	FINAL	% rem	INF	EFF	FINAL	% rem
2nd	F	16.5	13.0	11.0	0.70	293	67.6	67	77				
	G	16.0	12.0		0.34	297	80.0	67	77				
4th	F	17.0	16.0	14.5	0.70	350	89.0	50.5	85	220	321	83	62
	G	18.0	15.0		0.32	289	57.5	49.5	83	222	224	70	68
7th	F	17.5	14.0	13.0	0.84	352	102	37.0	87				
	G	17.0	13.0		0.32	283	58	28.8	98				
10th	F	17.5	15.0	15.0	0.84	352	106.8	84.0	76				
	G	17.0	14.5		0.22	192.5	35.0	51.5	73				
12th	F	15.5	8.0	4.0	0.58	241.0	76.4	52.5	78	314	744	150	52
	G	15.0	7.0		0.27	235.8	50.5	35.0	85	206	204	110	47
13th	F	16.0	10.0	11.0	0.63	262	117	52.7	80				
	G	16.0	10.0		0.30	268	70.6	21.5	98				
17th	F	15.5	10.0	11.0	0.66	278	69.5	91.5	67	169	184	46	73
	G	15.5	8.0		0.28	250	62.5	37.4	85	204	175	41	80
18th	F	14.5	9.5	5.5	0.45	189	55.5	55.6	70				
	G	14.3	4.5		0.19	170	45.4	47.2	72				
19th	F	15.5	11.0	13.5	0.47	194.7	72.6	22.0	89	220	224	114	48
	G	15.0	10.0		0.11	90.6	30.4	22.0	77	200	368	59	70
24th	F	15.0	10.0	7.0	0.43	176.5	68.5	44.6	75	200	258	67	66
	G	14.0	9.0		0.13	80.5	25.1	25.7	69	114	260	75	33
25th	F	16.0	14.0	17.0	0.65	274.2	62.2	62.0	77				
	G	16.5	13.0		0.19	161.9	17.5	14.4	89				
26th	F	15.0	9.0	5.0	0.75	324	40.6	61.7	80	402	388	109	73
	G	13.5	6.5		0.25	186.1	22.2	24.8	87	444	254	91	79

	BOD					SUSPENDED SOLIDS			
	INF	EFF	FINAL	% rem	LOAD	INF	EFF	FINAL	% rem
F MEAN	273.7	77.3	56.7	78	0.64	254.3	234.7	94.8	62.3
S.D	64.2	22.3	19.7	6.4	0.13	87.1	193.0	37.2	10.5
C.V	23.4	28.8	34.8	8.2	21.7	34.3	57.7	39.2	16.9
S.E	18.5	6.4	5.9	1.9	0.04	35.6	72.9	15.2	4.3
G MEAN	208.6	46.0	35.2	83	0.24	231.7	247.5	74.3	62.8
S.D	74.2	20.3	15.5	9.5	0.07	110.9	66.9	24.1	18.8
C.V	35.6	44.2	44.0	11.5	31.3	47.8	27.0	32.4	29.9
S.E	21.4	5.9	4.5	2.7	0.02	45.3	27.3	9.8	7.7

OCTOBER 1973

FILTER	DATE	SOLUBLE BOD			AMMONIACAL NITROGEN			OXIDISED NITROGEN		PERMANGANATE VALUE			DETERGENT (as manoxol)		
		INF	EFF	%R	INF	EFF	%R	INF	EFF	INF	EFF	%R	INF	EFF	%R
F	4th	259	82.7	69	52.6	34.0	24	1.0	16.0	61.0	37.2	49			
G		280	61.0	80	45.0	46.0		3.0	6.0	63.0	32.7	47			
F	12th	191.1	65.4	76	35.5	31.8	11	1.5	4.2	51.0	21.1	59			
G		179.9	58.8	68	34.3	28.3	18	1.8	5.2	53.0	28.0	47			
F	18th	150	58.0	61	42.4	36.6	14	1.0	5.0	56.6	26.7	53			
G		150	41.7	75	38.0	29.6	24	1.5	2.2	50.5	27.6	45			
F	26th	122.0	70.1	42	45.0	32.6	28	2.2	7.3	58.5	23.2	60			
G		28.8	8.3	71	36.0	23.2	35	4.2	19.4	43.0	20.4	49			

FILTER	DATE	TEMPERATURE °C		AMMONIACAL NITROGEN			OXIDISED NITROGEN			B.O.D.			SUSPENDED SOLIDS		
	Depth(m)	0.0	0.5	0.0	0.5	%R	0.0	0.5	2.0	0.0	0.5	%R	0.0	0.5	2.0

NOVEMBER 1973

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
BACTERIA												
Zoogloeal forms	1			2								
Sphaerotilus		2										
Beggiatoa		1										
Thiothrix		8		2								
FUNGI												
Subbaromyces	8	2	1		6	2						
ALGAE												
Chlorella	1			1								
Stigeoclonium												
Phormidium												

November 1973

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
OLIGOCHAETA												
Enchytraeidae												
Lumbricillus lineatus												
Enchytraeus albidus												
INSECTA												
Collembola												
Hypogastrura												
Diptera												
Psychoda												
larvae							75	66	34	16	22	15
pupae							4	10	4	1	5	3
flies							2	1	1		1	
Chironomidae												
larvae							24		3	4		6
flies							3			1		
ARACHNIDA												
Mites (Mesostigmatidae)								110	23		220	4
CRUSTACEA												
Canthocamptidae												

November 1973

FILTER	F			G			F			G		
DEPTH (m)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
PROTOZOA: CILIOPHORA												
HOLOTRICHIA												
Trachelophyllum pusillum												
Paramecium caudatum								5	16		2	
Colpidium colpoda												
Glaucoma scintillans							2	41	34	9	4	2
Colpoda inflata												
Chilodonella uncinata										1		
PERITRICHIA												
Vorticella sp.												
Telotrochs of Vorticella												
Opercularia coarctata							6	15	9	8	4	4
SPIROTRICHIA												
Aspidisca costata								5	8		3	2
Oxytricha sp.												
Stylonychia sp.												
PROTOZOA : MASTIGOPHORA												
Euglena sp.							1			4		
NEMATODA							4	6	4	5	5	10
ROTIFERA												1

NOVEMBER 1973

DATE	FILTER	TEMPERATURE °C			LOAD	SETTLED BOD mgl^{-1}				SUSPENDED SOLIDS mgl^{-1}			
		INF	EFF	AIR	Kg m^{-3}	INF	EFF	FINAL	% rem	INF	EFF	FINAL	% rem
1st	F									190	210	76	60
	G									142	156	50	65
14th	F	14.0	8.0	7.0	0.58	224	91.0	88.0	61	248	94	97	61
	G	12.5	6.0		0.17	144	27.2	16.7	98	104	349	26	77
15th	F	13.0	8.0	9.0	0.60	252	36.0	24.4	97				
	G	13.0	6.0		0.19	172	28.6	5.4	97				
16th	F	14.0	5.0	6.0	0.75	363	43.0	30.6	92				
	G	14.0	5.0		0.37	318	32.7	20.9	94				
20th	F	13.0	2.5	0.0	0.65	272	85.0	42.0	84	228	235	53	77
	G	9.0	2.5		0.17	148	34.8	47.4	68	108	72	44	60
21st	F	13.0	3.5	-1.0	0.60	251	85.4	63.0	75	196	76	51	74
	G	13.0	1.0		0.13	112.8	52.6	54.6	53	194	176	49	75
22nd	F	13.0	6.0	3.0	0.76	317.8	52.5	66.0	79	246	148	62	75
	G	9.0	6.0		0.13	113.8	33.6	43.0	62	178	230	83	53
27th	F	12.0	3.0	-1.0	0.64	306	85.5	91.0	70	200	210	87	56
	G	10.5	2.0		0.30	266	84.0	95.0	64	188	198	90	52
28th	F	12.0	1.0	-1.0	0.70	310	143	81.0	74	216	232	63	70
	G	10.0	1.0		0.40	242	71.5	92.5	65	162	102	105	35
29th	F	13.0	10.0	7.0	0.77	328	187	36.7	88	204	380	71	71
	G	13.0	2.0		0.35	309	63.2	74.7	76	202	268	73	72

		BOD					SUSPENDED SOLIDS			
		INF	EFF	FINAL	% rem	LOAD	INF	EFF	FINAL	% rem
F	MEAN	291.5	89.8	58.0	80	0.67	218.5	198.1	64.7	68
	S.D	44.4	48.5	28.4	11.4	7.5	26.9	95.7	27.2	7.9
	C.V	15.2	53.9	43.8	14.2	11.1	12.3	48.3	42.1	11.6
	S.E	14.8	16.2	8.4	3.8	2.4	9.5	33.8	9.6	2.7
G	MEAN	202.8	47.6	50.0	75.2	0.24	159.7	192.9	70.2	61
	S.D	81.7	21.0	32.5	16.9	10.8	38.1	89.5	17.9	14.1
	C.V	40.3	44.1	65.0	22.5	44.2	23.8	46.4	25.5	23.2
	S.E	27.2	7.0	10.0	5.6	3.6	13.4	31.7	6.7	5.0

NOVEMBER 1973

FILTER	DATE	SOLUBLE BOD			AMMONIACAL NITROGEN			OXIDISED NITROGEN		PERMANGANATE VALUE			DETERGENT (as manoxol)		
		INF	EFF	%R	INF	EFF	%R	INF	EFF	INF	EFF	%R	INF	EFF	%R
F	16th	160	24.2	85	40.2	33.6	16	2.0	6.0						
G		134	22.2	83	34.3	27.4	20	3.0	8.0						
F	22nd	126	34.6	72	39.8	41.6		1.8	2.8	69.5	26.6	62			
G		59	36.2	40	36.6	38.6		3.5	4.1	40.0	23.3	42			
F	29th	170	60.5	65	57.9	54.6	6	1.2	10.1	61.0	26.5	57			
G		142	23.7	86	57.0	45.4	21	2.9	21.0	48.5	20.3	58			

FILTER	DATE	TEMPERATURE °C		AMMONIACAL NITROGEN			OXIDISED NITROGEN			B.O.D.			SUSPENDED SOLIDS		
	Depth(m)	0.0	0.5	0.0	0.5	%R	0.0	0.5	2.0	0.0	0.5	%R	0.0	0.5	2.0

DECEMBER 1973

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
<u>BACTERIA</u>												
Zoogloeal forms	1	2		2								
Sphaerotilus			2	1		2						
Beggiatoa			2	1								
Thiothrix	2			3								
<u>FUNGI</u>												
Subbaromyces	9											
<u>ALGAE</u>												
Chlorella	1		1									
Stigeoclonium												
Phormidium												

December 1973

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
OLIGOCHAETA												
Enchytraeidae												
Lumbricillus lineatus												
Enchytraeus albidus												
INSECTA												
Collembola												
Hypogastrura												
Diptera												
Psychoda												
larvae		24	48	31	44	21						
pupae	7				1	1						
flies	2											
Chironomidae												
larvae	1											
flies		1										
ARACHNIDA												
Mites (Mesostigmatidae)		5	7		2	13						
CRUSTACEA												
Canthocamptidae												

December 1973

FILTER	F			G			F			G		
DEPTH (m)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
PROTOZOA: CILIOPHORA												
HOLOTRICHIA												
Trachelophyllum pusillum												
Paramecium caudatum		2	5		2							
Colpidium colpoda	6		3	10								
Glaucoma scintillans	2	39	52	2	1	5						
Colpoda inflata						6						
Chilodonella uncinata			1	3	3							
PERITRICHIA												
Vorticella sp.					1							
Telotrochs of Vorticella												
Opercularia coarctata	18	21	16	5	5	2						
SPIROTRICHIA												
Aspidisca costata												
Oxytricha sp.					2	4						
Stylonychia sp.												
PROTOZOA : MASTIGOPHORA												
Euglena sp.					2							
NEMATODA	4	4	2	6	5	5						
ROTIFERA			1	2	1	2						

DECEMBER 1973

DATE	FILTER	TEMPERATURE °C			LOAD	SETTLED BOD mgl^{-1}				SUSPENDED SOLIDS mgl^{-1}			
		INF	EFF	AIR	Kgm^{-3}	INF	EFF	FINAL	% rem	INF	EFF	FINAL	% rem
5th	F	13.0	10.5	10.5	0.86	360	41	29.7	92	343	224	93	73
	G	13.0	9.0		0.12	101.5	4.5	4.5	95	142	402	53	63
6th	F	12.5	7.0	7.0	0.87	362.0	98	85	76	242	222	127	48
	G	13.0	6.0		0.33	285	36.7	22.2	96	222	160	51	51
7th	F	13.5	10.0	10.5	0.84	374	84.7	57	83	224	440	96	57
	G	14.0	10.0		0.35	306	33.0	27.4	90	200	608	23	88
11th	F	12.0	8.0	6.0	0.68	283	36.8	52.5	81	228	125	54	76
	G	10.0	7.0		0.15	130	28.6	11.5	91	192	197	29	85
12th	F	12.0	6.0	3.0	0.61	256	48.0	61.0	76	224	120	95	58
	G	11.0	5.0		0.11	100	46.5	53.5	46	180	108	86	52
13th	F	11.0	7.0	8.0	0.64	268	121	78	71	194	178	93	52
	G	11.0	7.0		0.24	227	73.7	14.7	97	212	396	24	89

		BOD					SUSPENDED SOLIDS			
		INF	EFF	FINAL	% rem	LOAD	INF	EFF	FINAL	% rem
F	MEAN	294.2	71.6	62.4	80	0.75	242.5	218.2	93.0	58
	S.D	60.7	34.7	16.4	7.3	11.9	51.7	117.6	23.2	10.7
	C.V	20.6	48.4	26.2	9.1	15.9	21.3	53.9	24.9	18.4
	S.E	24.8	14.1	6.7	3.0	4.9	21.1	48.0	9.5	4.8
G	MEAN	191.6	37.2	22.3	86.2	0.22	191.3	311.8	44.5	75.5
	S.D	93.1	22.7	17.3	19.9	11.1	28.3	190.1	24.3	15.0
	C.V	48.6	61.1	77.4	23.1	51.4	14.8	60.9	54.9	20.0
	S.E	38.0	9.3	7.0	8.1	4.5	11.5	77.6	9.9	6.1

DECEMBER 1973

FILTER	DATE	SOLUBLE BOD			AMMONIACAL NITROGEN			OXIDISED NITROGEN		PERMANGANATE VALUE			DETERGENT (as manoxol)		
		INF	EFF	%R	INF	EFF	%R	INF	EFF	INF	EFF	%R	INF	EFF	%R
F	5th	222	18.2	92	125.4	52.6	58	1.4	13.2	67.5	24.6	64			
G		57	12.9	77	36.2	23.5	35	9.4	28.7	30.0	19.0	37			
F	11th	149	22	85	38.2	31.4	18	1.2	10.1	29.7	16.3	55			
G		98	8.8	90	27.8	20.0	28	5.2	19.8	26.7	13.8	48			

FILTER	DATE	TEMPERATURE °C		AMMONIACAL NITROGEN			OXIDISED NITROGEN			B.O.D.			SUSPENDED SOLIDS		
	Depth(m)	0.0	0.5	0.0	0.5	%R	0.0	0.5	2.0	0.0	0.5	%R	0.0	0.5	2.0

JANUARY 1974

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
BACTERIA												
Zoogloeal forms	2			2			4	3	1	2		
Sphaerotilus												
Beggiatoa	1						1					
Thiothrix	2			1			4					
FUNGI												
Subbaromyces	9	5	7				5	4	1			
ALGAE												
Chlorella	2			1			1			1		
Stigeoclonium												
Phormidium	2						2					

January 1974

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
OLIGOCHAETA												
Enchytraeidae												
Lumbricillus lineatus												
Enchytraeus albidus												
INSECTA												
Collembola												
Hypogastrura												
Diptera												
Psychoda												
larvae	15	41	110	19	36	1	20	85	76	15	50	50
pupae	2	12	3		8		1	11	4	5		
flies		5	3	3	5		1	4	1			
Chironomidae												
larvae	3						1			1		
flies												
ARACHNIDA												
Mites (Mesostigmatidae)		20	10		250	50		40			200	70
CRUSTACEA												
Canthocamptidae												

January 1974

FILTER	F			G			F			G		
DEPTH (m)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
PROTOZOA: CILIOPHORA												
HOLOTRICHIA												
Trachelophyllum pusillum												
Paramecium caudatum			5			1			5	5	4	4
Colpidium colpoda					1		11		3	15	3	30
Glaucoma scintillans	3	20	2				2	16	120	6	60	25
Colpoda inflata		2				1	31	6	1	5		
Chilodonella uncinata			5			2		5				
PERITRICHIA												
Vorticella sp.												
Telotrochs of Vorticella						5					20	3
Opercularia coarctata	3	9	8	15	5	2	17	10	13	10	4	6
SPIROTRICHIA												
Aspidisca costata										1		6
Oxytricha sp.		5	5		5	6				4	4	5
Stylonychia sp.												
PROTOZOA : MASTIGOPHORA												
Euglena sp.											1	
NEMATODA	10	2	1	6	3	1	8	1	1	5	1	1
ROTIFERA	2	2	8	1			2	2	8	1	5	1

JANUARY 1974

DATE	FILTER	TEMPERATURE °C			LOAD	SETTLED BOD mgl^{-1}				SUSPENDED SOLIDS mgl^{-1}			
		INF	EFF	AIR	Kgm^{-3}	INF	EFF	FINAL	% rem	INF	EFF	FINAL	% rem
9th	F	9.5	4.5	2.0	0.36	148	45.0	35.7	76	82	419	55	33
	G	9.0	4.5		0.17	145	50.0	33.2	77	106	310	67	37
10th	F	10.0	4.0	4.0	0.25	106	38.8	23.1	78	184	356	59	68
	G	8.5	4.0		0.05	45.6	14.7	23.1	50	152	65	35	77
11th	F	8.5	5.0	4.0	0.13	56.5	24.7	23.2	60	230	1028	34	85
	G	8.0	4.5		0.08	72.0	18.2	23.2	68	312	306	22	86
16th	F	9.5	8.5	8.0	0.14	60.1	27.6	10.8	82	244	1416	31	87
	G	9.5	8.5		0.07	66.2	12.2	7.6	88	78	332	36	54
18th	F	14.0	10.0	10.0	0.25	104.2	7.2	10.6	90	176	190	25	86
	G	13.5	9.0		0.07	64.7	3.0	7.1	89	198	111	14	93
19th	F	13.0	10.0	11.5	0.49	204.1	28.8	30.9	85	154	546	31	80
	G	13.0	9.0		0.20	173.8	16.8	15.2	91	170	121	15	91
23rd	F	11.0	10.0	10.0	0.44	185.0	9.9	5.7	69	152	314	76	50
	G	13.5	9.0		0.14	118.4	6.5	3.0	75	166	114	34	80
24th	F	11.5	8.0	6.5	0.41	171.1	60.1	63.1	63	88	143	54	40
	G	13.0	6.0		0.19	169.7	37.0	34.8	80	136	136	20	85
25th	F	11.5	8.0	6.0	0.53	222.0	60.0	43.2	80	166	562	58	65
	G	13.0	7.0		0.20	178	18.4	11.8	97	212	462	75	65
29th	F	10.5	5.0	2.0	0.49	205	33.8	10.9	96	166	378	66	60
	G	7.0	3.0		0.13	110	21.0	2.5	97	82	71	64	26
30th	F	10.5	7.0	7.0	0.42	175	40.1	44.2	75	188	1259	34	82
	G	11.0	7.0		0.17	152	33.6	29.6	80	192	574	20	90
1st	F	11.5	8.0	8.0	0.43	178	36.8	45.1	75	160	130	39	75
	G	11.5	8.0		0.13	117	21.2	9.4	92	112	542	12	90

		BOD					SUSPENDED SOLIDS			
		INF	EFF	FINAL	% rem	LOAD	INF	EFF	FINAL	% rem
F	MEAN	151	28.9	46.8	77	0.36	158.2	560	46.8	67
	S.D	56.4	17.9	16.4	10.4	13.6	51.4	433.1	16.4	17.8
	C.V	37.3	61.9	35.1	13.4	37.8	32.5	77.3	35.1	26.3
	S.E	16.3	5.1	4.7	3.0	3.9	14.8	125.0	4.7	15.1
G	MEAN	117,7	16.7	34.5	80	0.11	159.6	262.0	24.5	74
	S.D	46.9	11,6	22.7	12.8	6.0	65.4	188.9	22.3	24.1
	C.V	39.9	69.7	64.5	15.9	55.2	40.9	72.1	64.5	32.7
	S.E	13.5	3.4	6.4	3.9	1.7	18.9	54.3	6.4	6.9

JANUARY 1974

FILTER	DATE	SOLUBLE BOD			AMMONIACAL NITROGEN			OXIDISED NITROGEN		PERMANGANATE VALUE			DETERGENT (as manoxol)		
		INF	EFF	%R	INF	EFF	%R	INF	EFF	INF	EFF	%R	INF	EFF	%R
F	11th	46.2	8.5	81	49.2	36.2	27	55.8	98.8	18.0	22.0				
G		47.4	18.2	62	46.9	21.4	54	60.6	87.3	14.0	23.0				
F	16th	43.3	10.5	75	53.8	93.6		30.0	37.8	31.6	22.0	30			
G		22.8	1.0	95	53.9	61.2		54.3	82.6	27.6	14.0	50			
F	25th	88.5	26.0	70	16.7	16.7		13.4	15.0	50.0	24.5	66			
G		66.0	42.0	96	16.2	10.5	30	9.0	15.0	44.1	16.9	62			
F	30th	95.2	31.3	67	20.5	23.2		6.4	6.0	42.6	21.3	50			
G		79.5	19.6	75	21.4	15.0	30	5.0	13.8	40.6	20.2	52			

FILTER	DATE	TEMPERATURE °C		AMMONIACAL NITROGEN			OXIDISED NITROGEN			B.O.D.			SUSPENDED SOLIDS		
	Depth(m)	0.0	0.5	0.0	0.5	%R	0.0	0.5	2.0	0.0	0.5	%R	0.0	0.5	2.0

FEBRUARY 1974

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
BACTERIA												
Zocgloeal forms	6		1	8			12	5		4	5	3
Sphaerotilus		1	1									
Beggiatoa										2		
Thiothrix	4		1									
FUNGI												
Subbaromyces	1	5	9		2	2	5	6	3		1	2
ALGAE												
Chlorella	2			4						3		
Stigeoclonium												
Phormidium	4											

February 1974

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
OLIGOCHAETA												
Enchytraeidae												
Lumbricillus lineatus												
Enchytraeus albidus												
INSECTA												
Collembola												
Hypogastrura												
Diptera												
Psychoda												
larvae	19	100	194	42	29	18			3	50	22	5
pupae		14	12	1	1	2						
flies	1	2	1		3				1			
Chironomidae												
larvae	40		3	5								
flies												
ARACHNIDA												
Mites (Mesostigmatidae)		123	10		184	210						
CRUSTACEA												
Canthocamptidae												

February 1974

FILTER	F			G			F			G		
DEPTH (m)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
PROTOZOA: CILIOPHORA												
HOLOTRICHIA												
Trachelophyllum pusillum												
Paramecium caudatum					7	1		10			6	1
Colpidium colpoda				1	5	1						
Glaucoma scintillans	120	15	70	14	13	2	20	18	28	7		2
Colpoda inflata			1				1		5	2	1	1
Chilodonella uncinata									7	5		19
PERITRICHIA												
Vorticella sp.	3				1							
Telotrochs of *Vorticella*					7	6	3	21	2		4	5
Opercularia coarctata	9	15	6	8	4	4	8	37	12	9	6	7
SPIROTRICHIA												
Aspidisca costata					2					1	2	1
Oxytricha sp.			7		1	5			2		1	5
Stylonychia sp.												
PROTOZOA : MASTIGOPHORA												
Euglena sp.												
NEMATODA	18	4	3	10		4	2	2	4	8	3	5
ROTIFERA			4						4			

FEBRUARY 1974

DATE	FILTER	TEMPERATURE °C			LOAD	SETTLED BOD mgl^{-1}				SUSPENDED SOLIDS mgl^{-1}			
		INF	EFF	AIR	Kgm^{-3}	INF	EFF	FINAL	% rem	INF	EFF	FINAL	% rem
5th	F	10.5	5.5	3.0	0.30	124.2	33.6	27.5	78	164	380	69	58
	G	10.0	3.0		0.09	87.5	14.7	25.2	71	120	139	60	50
8th	F	10.0	5.0	2.0	0.54	225.8	84.4	76.0	66	138	117	84	40
	G	10.0	3.0		0.19	168.0	50.1	42.4	75	134	88	39	71
9th	F	10.0	9.0	9.0	0.24	102.8	12.7	12.7	88	102	400	47	54
	G	11.5	7.0		0.19	146.4	11.0	16.9	64	110	57	34	69
13th	F	10.5	9.0	8.5	0.36	149.0	26.9	14.2	77	100	516	12	88
	G	11.0	8.0		0.33	284.0	5.8	6.5	90	132	206	9	95
14th	F	10.5	6.0	4.0	0.27	113.8	22.2	15.8	86	105	231	58	42
	G	10.0	4.0		0.12	104.0	4.9	8.5	92	83	112	47	43
15th	F	10.5	7.0	8.5	0.40	167.0	33.9	22.1	86	147	690	28	81
	G	10.5	7.5		0.10	92.1	25.2	12.7	86	99	408	17	83
19th	F	10.5	7.0	6.0	0.57	238.0	76.4	22.5	90				
	G	11.0	5.0		0.21	185.3	25.2	18.9	90				
21st	F	11.5	12.0	13.0	0.50	207.9	57.5	39.4	81				
	G	16.0	12.0		0.08	74.4	19.0	8.1	89				
22nd	F	11.0	9.5	9.5	0.39	163.1	65.3	16.9	90	238	238	87	63
	G	12.5	9.0		0.15	132.9	30.1	15.0	89	142	97	45	68
26th	F	12.0	8.0	6.0	0.61	254.0	88.2	80.0	68	338	111	196	42
	G	12.0	7.0		0.25	225.8	27.4	33.2	85	368	396	46	87
27th	F	14.0	4.0	3.0	0.59	247.5	111.0	58.8	76	210	188	61	71
	G	13.0	3.0		0.17	146.4	48.3	23.1	84	230	334	57	75
28th	F	11.5	4.0	1.5	0.51	210.2	184.6	170.8	16	166	148	97	41
	G	9.5	3.0		0.11	96.5	38.9	34.4	65	88	129	25	72

	BOD					SUSPENDED SOLIDS			
	INF	EFF	FINAL	% rem	LOAD	INF	EFF	FINAL	% rem
F MEAN	173.9	51.8	30.5	83.1	0.41	152.2	323	60.3	63
S.D	53.0	33.6	21.3	7.8	0.12	48.4	189.7	27.9	19.1
C.V	30.4	64.8	69.6	9.4	30.7	31.8	58.7	46.3	30.4
S.E	16.7	11.2	6.7	2.4	0.04	16.1	63.2	9.3	6.0
G MEAN	138.5	23.7	17.0	81.7	0.15	126.4	174.4	37.0	69.5
S.D	69.6	15.5	11.1	9.4	0.08	43.9	120.1	17.4	15.6
C.V	50.2	65.3	64.7	11.5	53.7	34.7	68.8	47.1	22.4
S.E	23.2	4.9	3.4	2.9	0.02	14.6	40.0	5.8	5.2

FEBRUARY 1974

FILTER	DATE	SOLUBLE BOD			AMMONIACAL NITROGEN			OXIDISED NITROGEN		PERMANGANATE VALUE			DETERGENT (as manoxol)		
		INF	EFF	%R	INF	EFF	%R	INF	EFF	INF	EFF	%R	INF	EFF	%R
F	5th	56.4	25.4	55	35.3	34.1		2.8	2.6	45.4	28.5	43	84.0	22.8	73
G		21.0	10.9	55	35.4	29.1	18	4.6	8.9	29.3	25.7	49	96.0	32.0	67
F	13th	78.6	11.6	88	20.8	34.8		14.4	11.6	44.3	20.2	53	18.8	4.0	79
G		64.7	4.3	93	18.3	20.5		15.5	20.3	36.8	14.8	61	20.0	8.5	58
F	22nd	74.7	15.0	80	31.6	40.3		7.4	11.5	59.0	22.8	61	22.0	8.2	73
G		74.7	6.0	91	29.4	19.8	33	8.1	16.1	47.0	22.6	52	13.6	4.2	70
F	27th	88.2	29.4	67	67.1	60.0	10	4.0	4.0	91.0	57.0	37	55.6	8.2	85
G		95.3	21.0	78	56.9	32.0	44	4.7	11.0	78.6	23.6	70	39.2	5.8	86

FILTER	DATE	TEMPERATURE °C		AMMONIACAL NITROGEN			OXIDISED NITROGEN			B.O.D.			SUSPENDED SOLIDS		
	Depth(m)	0.0	0.5	0.0	0.5	%R	0.0	0.5	2.0	0.0	0.5	%R	0.0	0.5	2.0

MARCH 1974

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
<u>BACTERIA</u>												
Zoogloeal forms	10	3		8	1		14			8	1	
Sphaerotilus												
Beggiatoa												
Thiothrix	2							1				
<u>FUNGI</u>												
Subbaromyces	6	3	4	1			2	3	6			
<u>ALGAE</u>												
Chlorella	2			4			2			5		
Stigeoclonium				2						1		
Phormidium	2						2					

March 1974

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
OLIGOCHAETA												
Enchytraeidae												
Lumbricillus lineatus												
Enchytraeus albidus												
INSECTA												
Collembola												
Hypogastrura												
Diptera												
Psychoda												
larvae	1		31		2	1	3		40			
pupae		2										
flies		5	49									
Chironomidae												
larvae												
flies												
ARACHNIDA												
Mites (Mesostigmatidae)		23	3		22	15	2	139	50		17	187
CRUSTACEA												
Canthocamptidae												

March 1974

FILTER	F			G			F			G		
DEPTH (m)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
PROTOZOA: CILIOPHORA												
HOLOTRICHIA												
Trachelophyllum pusillum												
Paramecium caudatum		3			2	2		1			1	15
Colpidium colpoda	8		5	4	7	1						
Glaucoma scintillans	70	24	30	5	2	2	100	23	21	5	7	
Colpoda inflata	4	4		4			1					2
Chilodonella uncinata			1				4			1	1	
PERITRICHIA												
Vorticella sp.												1
Telotrochs of *Vorticella*	10	12	28	1	5	11	12	16	26	1		10
Opercularia coarctata	12	8	9	14	6	14	9	8	11	15	6	18
SPIROTRICHIA												
Aspidisca costata	1		7						2			
Oxytricha sp.			13		6	16			10		5	6
Stylonychia sp.			2									
PROTOZOA : MASTIGOPHORA												
Euglena sp.	1				1	1				1		
NEMATODA	10	7		5	6	9	10	9	3	3	5	10
ROTIFERA			1									

MARCH 1974

DATE	FILTER	TEMPERATURE °C			LOAD	SETTLED BOD mgl^{-1}				SUSPENDED SOLIDS mgl^{-1}			
		INF	EFF	AIR	Kgm^{-3}	INF	EFF	FINAL	% rem	INF	EFF	FINAL	% rem
6th	F	10.0	5.5	1.0	0.53	221.8	56.8	54.7	74	328	148	41	87
	G	11.0	3.5		0.23	200.0	46.3	29.6	85	158	198	37	77
7th	F	11.5	8.5	8.0	0.58	282.0	76.6	49.4	82	202	182	76	73
	G	14.5	8.0		0.27	233.8	25.2	19.9	91	374	125	29	98
8th	F	10.5	4.0	3.0	0.57	238.2	92.5	46.4	77				
	G	9.0	4.0		0.18	105.1	28.1	23.1	87				
11th	F	10.0	5.0	4.0	0.60	287.5	136.0	57.5	80	178	242	90	49
	G	8.0	3.5		0.25	220.0	66.0	16.0	92	152	155	29	81
13th	F	11.5	6.0	5.0	0.43	179.2	38.4	48.3	75	194	108	87	55
	G	13.0	7.5		0.18	158.4	37.2	27.6	82	134	72	29	78
16th	F	12.0	10.5	12.5	0.57	238.1	55.0	18.3	92	348	860	29	91
	G	12.0	10.0		0.19	171.8	38.8	9.5	95	332	382	19	94
20th	F	11.0	8.0	9.5	0.59	246.5	65.2	24.9	90	164	220	60	63
	G	13.0	6.5		0.19	163.4	3.8	6.2	95	158	488	29	80
21st	F	10.5	6.0	5.0	0.58	243.5	80.0	19.7	92	218	416	38	82
	G	11.5	4.0		0.18	154.0	35.7	7.5	95	158	284	17	89
22nd	F	10.5	8.0	3.0	0.43	178.3	92.0	67.5	62	182	144	89	51
	G	9.0	7.0		0.14	125.6	35.0	25.2	80	102	164	40	78
27th	F	11.0	8.0	6.0	0.59	246.1	38.2	45.3	80	148	100	33	77
	G	9.5	7.0		0.13	115.0	58.4	51.3	68	70	56	40	40
28th	F	10.0	7.0	5.0	0.68	284.0	65.4	69.4	76	208	236	50	76
	G	9.0	6.0		0.14	122.2	43.7	40.0	77	70	73	42	40
30th	F	15.0	14.0	19.0	0.50	209.0	34.4	43.0	79				
	G	15.0	14.0		0.12	89.2	29.4	21.2	76				

		BOD					SUSPENDED SOLIDS			
		INF	EFF	FINAL	% rem	LOAD	INF	EFF	FINAL	% rem
F	MEAN	237.9	69.0	45.5	80	0.55	217	256.6	59.3	64
	S.D	68.1	28.3	19.7	8	0.12	67.1	227.8	24.4	18
	C.V	30.8	40.5	40.0	10.7	22.7	30.9	85.8	41.1	29
	S.E	19.6	8.1	5.6	2.5	0.03	21.2	72.0	7.7	5.6
G	MEAN	154.8	41.1	23.1	85	0.18	170.8	199.7	31.1	75.0
	S.D	52.7	15.3	16.8	8.8	0.04	102.4	143.5	8.6	24.4
	C.V	35.1	41.6	68.8	10.4	26.1	60.0	71.8	27.8	26.5
	S.E	15.2	4.4	4.8	2.5	0.0	32.4	45.4	2.7	6.3

MARCH 1974

FILTER	DATE	SOLUBLE BOD			AMMONIACAL NITROGEN			OXIDISED NITROGEN		PERMANGANATE VALUE			DETERGENT (as manoxol)		
		INF	EFF	%R	INF	EFF	%R	INF	EFF	INF	EFF	%R	INF	EFF	%R
F	6th	140	22.3	84	27.5	32.4		9.7	7.2	45.4	15.8	65	47.8	10.4	78
G		123	25.4	71	23.8	30.8		10.0	12.0	41.0	14.2	65	26.8	4.4	83
F	13th	93.5	15.6	83	39.4	27.5	43	2.8	5.4	46.0	22.1	54	34.0	11.8	65
G		77.1	16.7	78	38.5	18.3	52	3.3	11.4	42.0	17.8	65	25.2	6.0	76
F	20th	76.6	10.7	86	38.6	39.3		2.5	10.0	49.6	22.0	56	43.0	5.8	87
G		60.9	2.1	96	28.9	12.0	58	2.2	22.0	35.8	12.2	66	38.0	6.0	84
F	28th	147.2	13.3	91	43.0	49.6		3.5	6.9	54.4	35.2	35	46.8	10.9	77
G		47.0	10.4	78	33.6	18.6	45	4.5	12.9	41.0	15.2	63	25.2	7.4	71

FILTER	DATE	TEMPERATURE °C		AMMONIACAL NITROGEN			OXIDISED NITROGEN			B.O.D.			SUSPENDED SOLIDS		
	Depth(m)	0.0	0.5	0.0	0.5	%R	0.0	0.5	2.0	0.0	0.5	%R	0.0	0.5	2.0

APRIL 1974

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
<u>BACTERIA</u>												
Zoogloeal forms	4	5		6								
Sphaerotilus												
Beggiatoa												
Thiothrix												
<u>FUNGI</u>												
Subbaromyces	7	3	1									
<u>ALGAE</u>												
Chlorella	2			2								
Stigeoclonium				7								
Phormidium	1											

April 1974

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
OLIGOCHAETA												
Enchytraeidae												
Lumbricillus lineatus												
Enchytraeus albidus												
INSECTA												
Collembola												
Hypogastrura												
Diptera												
Psychoda												
larvae							4	3				
pupae												
flies												
Chironomidae												
larvae												
flies												
ARACHNIDA												
Mites (Mesostigmatidae)								72	25		65	112
CRUSTACEA												
Canthocamptidae												

April 1974

FILTER	F			G			F			G		
DEPTH (m)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
PROTOZOA: CILIOPHORA												
HOLOTRICHIA												
Trachelophyllum pusillum												
Paramecium caudatum											2	11
Colpidium colpoda												
Glaucoma scintillans							9	10	5	1	1	2
Colpoda inflata									3			
Chilodonella uncinata										1		4
PERITRICHIA												
Vorticella sp.												
Telotrochs of *Vorticella*							1	7	4	1	2	1
Opercularia coarctata							8	7	4	7	7	12
SPIROTRICHIA												
Aspidisca costata								2				
Oxytricha sp.									5		2	20
Stylonychia sp.										1		
PROTOZOA : MASTIGOPHORA												
Euglena sp.										1		
NEMATODA							1	9	6	12	10	15
ROTIFERA										6	2	1

APRIL 1974

DATE	FILTER	TEMPERATURE °C			LOAD	SETTLED BOD mgl^{-1}				SUSPENDED SOLIDS mgl^{-1}			
		INF	EFF	AIR	Kgm^{-3}	INF	EFF	FINAL	% rem	INF	EFF	FINAL	% rem
24th	F	13.5	8.0	8.5	0.58	244.0	59.0	84.2	66	232	146	80	65
	G	13.0	8.0		0.26	225.5	61.2	63.2	72	114	724	62	45
25th	F	13.0	8.0	8.0	0.58	241.0	56.6	83.7	65	156	127	95	39
	G	13.0	8.0		0.26	225.8	70.6	55.7	75	114	239	50	56
26th	F	13.0	7.0	8.0	0.72	300.0	41.0	32.7	89	238	227	42	82
	G	13.5	6.5		0.29	255.5	19.5	2.3	91	232	90	27	82
27th	F	14.5	11.0	10.5	0.60	249	80	105	60	186	212	125	33
	G	14.0	10.5		0.24	208	44	45.5	78	170	161	50	70
1st	F	13.0	11.5	8.0	0.53	220.1	69.5	63.0	71	148	127	82	45
	G	13.0	10.0		0.19	167.0	19.7	3.0	98	126	167	58	54
3rd	F	13.0	9.0	8.5	0.91	379	98.8	52.7	86	308	144	73	76
	G	13.0	9.0		0.32	282	39.1	46.5	83	242	105	80	74

	BOD					SUSPENDED SOLIDS			
	INF	EFF	FINAL	% rem	LOAD	INF	EFF	FINAL	% rem
F MEAN	272.2	67.5	70.2	73	0.65	211.3	163.8	83	57
S.D	58.6	20.2	25.9	12	0.14	60.3	65.9	27	20
C.V	21.5	30.0	36.9	16	1.53	28.5	49.9	33	36
S.E	23.9	8.2	10.6	5	0.05	24.6	26.9	11	8
G MEAN	222.3	42.3	36.0	82.8	0.26	166.3	247.6	54.5	63
S.D	39.5	20.9	26.6	14.7	0.04	58.6	239.2	17.4	14
C.V	17.4	49.6	73.9	18.1	16.7	35.2	96.6	31.9	22
S.E	16.1	8.6	10.9	6.0	0.0	23.9	97.7	7.1	6

APRIL 1974

FILTER	DATE	SOLUBLE BOD			AMMONIACAL NITROGEN			OXIDISED NITROGEN		PERMANGANATE VALUE			DETERGENT (as manoxol)		
		INF	EFF	%R	INF	EFF	%R	INF	EFF	INF	EFF	%R	INF	EFF	%R
F	26th	141.5	43.5	69	47.3	35.0	26	2.7	11.5	59.3	23.2	61	58.4	13.0	78
G		136.0	9.7	97	45.7	19.5	57	3.2	18.5	50.0	18.0	66	54.2	12.0	78
F	1st	127.2	21.0	83	41.1	40.4	2	3.1	4.8	52.6	28.8	55	57.6	11.2	80
G		100.0	2.5	98	34.1	20.4	40	3.5	19.7	30.8	24.0	22	53.6	11.0	80

FILTER	DATE	TEMPERATURE °C		AMMONIACAL NITROGEN			OXIDISED NITROGEN			B.O.D.			SUSPENDED SOLIDS		
	Depth(m)	0.0	0.5	0.0	0.5	%R	0.0	0.5	2.0	0.0	0.5	%R	0.0	0.5	2.0

MAY 1974

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
BACTERIA												
Zoogloeal forms	6			6			5			6		
Sphaerotilus												
Beggiatoa												
Thiothrix												
FUNGI												
Subbaromyces	14						1					
ALGAE												
Chlorella	2			5			2			1		
Stigeoclonium				5						8		
Phormidium												

May 1974

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
OLIGOCHAETA												
Enchytraeidae												
<u>Lumbricillus lineatus</u>												
<u>Enchytraeus albidus</u>												
INSECTA												
Collembola												
<u>Hypogastrura</u>												
Diptera												
<u>Psychoda</u>												
larvae	2	4	30	1	1	2	3	166	52	4	75	5
pupae		1						6			3	
flies							3	10	4	3	5	2
Chironomidae												
larvae												
flies												
ARACHNIDA												
Mites (Mesostigmatidae)		225	100		30	50		210	80		42	150
CRUSTACEA												
Canthocamptidae												

May 1974

FILTER	F			G			F			G		
DEPTH (m)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
PROTOZOA: CILIOPHORA												
HOLOTRICHIA												
Trachelophyllum pusillum												
Paramecium caudatum					1	4						2
Colpidium colpoda												
Glaucoma scintillans	10	13	10		4		10	14	36		5	3
Colpoda inflata												
Chilodonella uncinata		2		1								
PERITRICHIA												
Vorticella sp.												
Telotrochs of Vorticella											2	2
Opercularia coarctata	7	3	10	2	3	1	9	5	11	1	17	1
SPIROTRICHIA												
Aspidisca costata			2									
Oxytricha sp.					2	3					1	6
Stylonychia sp.									1			
PROTOZOA : MASTIGOPHORA												
Euglena sp.				7						1		
NEMATODA	5	1	1	15	15	18	4	1	1	5	6	30
ROTIFERA				8	1	3				10		6

MAY 1974

DATE	FILTER	TEMPERATURE °C			LOAD	SETTLED BOD mgl^{-1}				SUSPENDED SOLIDS mgl^{-1}			
		INF	EFF	AIR	Kgm^{-3}	INF	EFF	FINAL	% rem	INF	EFF	FINAL	% rem
8th	F	14.0	9.0	11.5	0.58	242	70.5	42.2	82	188	251	74	60
	G	16.0	9.5		0.22	187	44.3	21.5	88	142	814	51	65
9th	F	14.0	10.0	10.5	0.62	259	67.2	58.8	77	236	270	88	63
	G	14.0	10.0		0.20	175	53.0	42.0	76	190	246	53	72
10th	F	16.0	10.5	12.5	0.39	162	55.6	76.6	53	236	204	104	56
	G	15.5	10.0		0.16	142	16.2	42.0	70	176	246	75	57
14th	F	14.0	14.0	15.5	0.44	184	61.2	97.5	47	180	149	105	42
	G	15.0	12.0		0.15	132	47.0	41.0	68	136	262	79	56
16th	F	14.0	13.5	12.5	0.49	206	58.3	69.4	66	146	223	73	50
	G	15.0	12.0		0.21	180	35.8	39.1	79	124	154	60	52
17th	F	15.0	14.0	15.0	0.51	213	62.6	63.6	70	260	708	70	73
	G	15.5	14.0		0.09	76	50.0	9,7	87	212	1420	32	85
22nd	F	16.0	12.0	13.0	0.51	214	57.9	51.4	76	108	192	70	35
	G	16.0	11.0		0.18	154	34.5	39.6	75	75	167	54	36
23rd	F	15.0	13.0	11.0	0.57	236	89.5	67.0	72	134	124	93	30
	G	15.0	10.0		0.17	144	46.6	25.2	82	88	96	35	60
24th	F	14.0	12.0	11.0	0.44	195	64.3	54.7	71	206	136	73	65
	G	16.0	10.5		0.09	74	10.7	18.9	78	152	118	29	81
29th	F	15.0	14.0	13.5	0.79	328	86.4	52.7	84	418	414	84	80
	G	15.0	10.0		0.30	259	53.0	5.3	98	260	324	45	82
30th	F	13.0	15.5	17.0	0.63	262	67.2	62.3	76	168	147	63	62
	G	19.0	12.0		0.26	226	29.4	26.0	88	160	131	21	87
31st	F	15.0	12.0	12.5	0.57	235	52.5	59.4	75	162	120	83	50
	G	15.5	12.0		0.20	176	35.8	15.4	92	148	440	19	87

	BOD					SUSPENDED SOLIDS			
	INF	EFF	FINAL	% rem	LOAD	INF	EFF	FINAL	% rem
F MEAN	228	66.1	63.2	71.0	0.54	188	243.5	81.6	62
S.D	43.3	11.5	14.0	11.0	10.7	82.2	167	13.6	16.9
C.V	19.0	17.3	22.2	15.4	19.7	43.7	68.6	16.7	27.4
S.E	12.5	3.3	4.0	3.2	3.1	23.7	48.2	3.9	4.8
G MEAN	160.4	39.4	31.2	81.5	0.18	156.0	371.8	46	68
S.D	53.5	14.3	13.6	9.1	0.06	49.6	383.5	19.6	16.4
C.V	33.4	36.2	43.6	11.2	32.7	31.7	103.1	42.5	24.1
S.E	15.4	4.1	3.9	2.6	0.01	14.3	110.7	5.6	4.7

MAY 1974

FILTER	DATE	SOLUBLE BOD			AMMONIACAL NITROGEN			OXIDISED NITROGEN		PERMANGANATE VALUE			DETERGENT (as manoxol)		
		INF	EFF	%R	INF	EFF	%R	INF	EFF	INF	EFF	%R	INF	EFF	%R
F	10th	114	24.2	79	39.3	36.6	7	4.6	6.6	53.4	42.5	20	47.8	6.3	87
G		80	17.9	77	36.6	9.0	75	17.4	42.7	45.4	24.4	46	4.6	5.5	88
F	17th	76.4	16.4	78	52.0	49.1	5.5	3.6	9.8	58.8	42.0	15	42.6	9.5	78
G		75.9	14.3	81	50.0	41.0	18.0	6.5	16.6	50.4	33.6	33	36.8	7.6	80
F	24th	90.3	21.5	76	33.0	38.5	-	3.4	3.5	42.5	22.6	47	43.4	17.4	60
G		32.0	9.1	72	30.3	20.7	32	8.0	24.7	25.6	22.6	12	33.2	6.3	81
F	31st	132.9	19.2	85	49.0	45.5	7.0	7.1	4.5	54.0	27.2	50	54.4	10.9	80
G		99.5	14.5	85	32.1	30.0	7.0	9.1	15.0	33.3	17.2	65	50.0	5.0	90

FILTER	DATE	TEMPERATURE °C		AMMONIACAL NITROGEN			OXIDISED NITROGEN			B.O.D.			SUSPENDED SOLIDS		
	Depth(m)	0.0	0.5	0.0	0.5	%R	0.0	0.5	2.0	0.0	0.5	%R	0.0	0.5	2.0

JUNE 1974

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
<u>BACTERIA</u>												
Zoogloeal forms	8			3								
Sphaerotilus												
Beggiatoa												
Thiothrix												
<u>FUNGI</u>												
Subbaromyces	5	4	1									
<u>ALGAE</u>												
Chlorella	2			6								
Stigeoclonium				4								
Phormidium												

June 1974

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
OLIGOCHAETA												
Enchytraeidae												
Lumbricillus lineatus												
Enchytraeus albidus						1						
INSECTA												
Collembola												
Hypogastrura												
Diptera												
Psychoda												
larvae	20	43		4	9	4						
pupae		2			1							
flies	21	13										
Chironomidae												
larvae				1								
flies												
ARACHNIDA												
Mites (Mesostigmatidae)		2	2									
CRUSTACEA												
Canthocamptidae												

June 1974

FILTER	F			G			F			G		
DEPTH (m)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
PROTOZOA: CILIOPHORA												
HOLOTRICHIA												
Trachelophyllum pusillum												
Paramecium caudatum					2	2						
Colpidium colpoda												
Glaucoma scintillans		10	24	8	33	8						
Colpoda inflata												
Chilodonella uncinata						7						
PERITRICHIA												
Vorticella sp.												
Telotrochs of Vorticella		8										
Opercularia coarctata	1	2	18	9	11	2						
SPIROTRICHIA												
Aspidisca costata												
Oxytricha sp.			5									
Stylonychia sp.												
PROTOZOA : MASTIGOPHORA												
Euglena sp.	7			5								
NEMATODA	1	2	1	4	5	4						
ROTIFERA				6	1	4						

JUNE 1974

DATE	FILTER	TEMPERATURE °C			LOAD	SETTLED BOD mgl^{-1}				SUSPENDED SOLIDS mgl^{-1}			
		INF	EFF	AIR	Kgm^{-3}	INF	EFF	FINAL	% rem	INF	EFF	FINAL	% rem
4th	F	16.0	16.0	18.0	0.53	221	58.8	52.6	73	242	160	69	71
	G	17.5	13.5		0.16	142	4.3	5.2	96	130	127	27	79
6th	F	16.5	12.0	12.5	0.52	218	42.6	38.5	82	134	112	66	51
	G	17.0	9.5		0.21	188	18.4	16.2	91	122	79	22	82
7th	F	15.0	13.5	12.0	0.65	273	41.6	38.5	86	172	88	62	64
	G	16.0	10.0		0.10	88.2	7.2	12.8	85	150	90	19	87
12th	F	16.0	16.0	15.0	0.69	236	40.3	31.9	88	156	102	47	70
	G	17.0	14.0		0.22	190	6.7	2.5	98	96	178	17	82
13th	F	17.0	13.0	14.0	0.52	216	19.4	32.3	85	144	109	47	67
	G	18.0	13.0		0.11	92.4	13.0	8.7	90	104	67	20	81
14th	F	17.0	15.0	18.5	0.61	256	35.2	36.3	86	144	119	65	53
	G	19.0	14.0		0.20	175	17.6	12.1	97	138	68	34	75

	BOD					SUSPENDED SOLIDS			
	INF	EFF	FINAL	% rem	LOAD	INF	EFF	FINAL	% rem
F MEAN	236	39.6	38.3	83	0.58	165	115	59.3	63
S.D	23.2	12.6	7.5	5.4	7.3	39.7	24.4	9.8	8
C.V	9.8	31.8	19.7	6.5	12.6	24.0	21.2	16.5	13.0
S.E	9.4	5.1	3.0	2.2	3.0	16.2	9.9	4.0	3.3
G MEAN	145.8	11.1	9.6	93	0.16	123.3	101.5	23.1	81.0
S.D	46.3	5.8	5.1	5.0	0.05	20.4	43.4	6.3	3.9
C.V	31.7	52.3	53.0	5.4	31.7	16.5	42.8	27.2	4.8
S.E	18.9	2.3	2.1	2.0	0.0	8.3	17.7	2.5	1.6

JUNE 1974

FILTER	DATE	SOLUBLE BOD			AMMONIACAL NITROGEN			OXIDISED NITROGEN		PERMANGANATE VALUE			DETERGENT (as manoxol)		
		INF	EFF	%R	INF	EFF	%R	INF	EFF	INF	EFF	%R	INF	EFF	%R
F	12th	145.4	10.0	97	51.7	46.6	10	3.0	4.5	59.2	29.2	51	52.6	6.0	88
G		89.0	1.6	98	43.2	24.1	44	2.4	16.5	45.2	16.2	64	38.6	5.8	83
F	7th	130.6	10.5	92	54.8	48.7	11	1.8	3.5	66.6	23.6	65	44.8	18.3	60
G		42.0	1.9	95	37.6	24.4	35	4.7	15.3	37.8	20.8	37	25.4	8.5	47

FILTER	DATE	TEMPERATURE °C		AMMONIACAL NITROGEN			OXIDISED NITROGEN			B.O.D.			SUSPENDED SOLIDS		
	Depth(m)	0.0	0.5	0.0	0.5	%R	0.0	0.5	2.0	0.0	0.5	%R	0.0	0.5	2.0

JULY 1974

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
<u>BACTERIA</u>												
Zoogloeal forms	20			5	1	1	26			1		
Sphaerotilus	5											
Beggiatoa												
Thiothrix												
<u>FUNGI</u>												
Subbaromyces	2	5	3	1			2	1	1			
<u>ALGAE</u>												
Chlorella	5			5			3			4		
Stigeoclonium				1						2		
Phormidium				1								

July 1974

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
OLIGOCHAETA												
Enchytraeidae												
Lumbricillus lineatus												
Enchytraeus albidus									10			20
INSECTA												
Collembola												
Hypogastrura												
Diptera												
Psychoda												
larvae	10	1	10		5	1	5		60	20	10	3
pupae			8					10				
flies	500	30	10			10						
Chironomidae												
larvae												
flies												
ARACHNIDA												
Mites (Mesostigmatidae)		40	5					3				10
CRUSTACEA												
Canthocamptidae												

July 1974

FILTER	F			G			F			G		
DEPTH (m)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
PROTOZOA: CILIOPHORA												
HOLOTRICHIA												
Trachelophyllum pusillum		2	5			28		1	5		100	33
Paramecium caudatum		1	1		1	2		1	1		3	1
Colpidium colpoda		1	1		1						1	5
Glaucoma scintillans		1			4	5	30	150	100	10	35	18
Colpoda inflata												
Chilodonella uncinata												
PERITRICHIA												
Vorticella sp.				50	6	2						
Telotrochs of *Vorticella*	1						3					
Opercularia coarctata	2	1	5	10	10		2	11	1	11	11	
SPIROTRICHIA												
Aspidisca costata			30	1	6	1		13	35	3	70	11
Oxytricha sp.					6	8			5		33	10
Stylonychia sp.				1		3					5	15
PROTOZOA : MASTIGOPHORA												
Euglena sp.							2			3		
NEMATODA	32	7	10	6	9	2	35	10	10	8	7	47
ROTIFERA					2	6				1		2

JULY 1974

DATE	FILTER	TEMPERATURE °C			LOAD	SETTLED BOD mgl^{-1}				SUSPENDED SOLIDS mgl^{-1}			
		INF	EFF	AIR	Kgm^{-3}	INF	EFF	FINAL	% rem	INF	EFF	FINAL	% rem
10th	F	16.5	16.0	14.5						204	198	96	50
	G	15.5	15.0							192	111	32	83
11th	F	17.0	16.5	16.0	0.72	300	61.7	30.5	90	212	225	34	84
	G	17.0	14.0		0.30	259	26.6	19.2	93	202	142	20	90
13th	F	17.0	17.5	20.0	0.52	260	93.2	19.8	92	204	222	44	78
	G	17.0	16.5		0.32	279	11.8	4.9	98	218	138	14	94
16th	F	16.5	16.0	14.8	0.60	251	58.0	59.0	75	130	148	75	42
	G	16.0	14.5		0.27	234	37.0	3.0	97	152	55	34	77
17th	F	16.5	15.0	17.5	0.69	288	18.9	25.2	91	206	107	37	82
	G	16.5	13.8		0.22	191	3.5	14.7	92	194	45	24	88
19th	F	17.0	17.5	18.0	0.65	270	50	17.0	94	212	118	31	85
	G	17.0	15.5		0.29	250	11	5.0	98	200	175	10	95
24th	F	17.0	16.5	15.0	0.73	303	62	54.4	82	234	68	42	82
	G	17.0	15.5		0.34	293	18.5	24.8	93	210	130	35	85
25th	F	17.0	17.0	18.0	0.89	370	39.2	28.6	92	358	166	53	85
	G	17.0	14.5		0.19	164	25.2	23.3	86	242	107	19	92
26th	F	17.0	16.8	17.0	0.85	356	32.6	27.0	92	270	214	32	89
	G	17.0	16.2		0.38	335	30.1	25.2	92	294	182	22	92
30th	F	17.3	17.3	17.0	0.58	244	84.3	24.7	80	314	108	53	83
	G	17.2	16.0		0.30	260	56.0	12.6	95	298	171	30	90
31st	F	17.0	17.0	15.5	0.66	277	28.4	20.2	93	174	136	47	73
	G	17.0	15.0		0.30	274	10.9	17.2	94	168	134	26	84
1st	F	17.0	18.5	16.8	0.68	282	12.7	8.5	97	214	145	34	84
	G	17.0	15.5		0.31	277	18.3	18.3	93	200	160	23	88

	BOD					SUSPENDED SOLIDS			
	INF	EFF	FINAL	% rem	LOAD	INF	EFF	FINAL	% rem
F MEAN	291.1	45.7	28.6	88.9	0.68	227	154.5	48.2	76.4
S.D	40.3	24.2	15.2	6.8	0.10	61	51.2	19.5	14.8
C.V	13.8	52.9	53.0	7.2	0.15	27	33.1	40.5	19.4
S.E	12.1	7.6	4.6	2.0	0.03	17.6	14.7	5.6	4.2
G MEAN	264.9	20.9	14.7	94.0	0.29	216.2	129.2	25.0	87.8
S.D	42.5	7.9	7.5	3.5	0.52	44.7	43.9	8.2	5.3
C.V	16.0	37.8	51.2	3.7	0.17	20.7	34.0	33.1	6.0
S.E	12.8	2.5	2.3	1.0	0.01	12.9	12.7	2.4	1.5

JULY 1974

FILTER	DATE	SOLUBLE BOD			AMMONIACAL NITROGEN			OXIDISED NITROGEN		PERMANGANATE VALUE			DETERGENT (as manoxol)		
		INF	EFF	%R	INF	EFF	%R	INF	EFF	INF	EFF	%R	INF	EFF	%R
F	17th	172.2	6.3	96	46.7	18.9	54	2.0	9.0	68.0	17.7	74	41.8	19.3	55
G		110.4	1.5	98	40.9	14.0	66	4.5	15.2	56.2	16.0	72	41.8	12.0	71
F	25th	161.1	17.6	89	62.6	41.4	34	4.5	23.0	78.8	34.8	56	47.2	8.0	94
G		76.8	15.5	80	46.6	28.7	38	8.5	13.0	50.6	24.2	52	39.6	4.7	88
F	30th	125.9	27.0	80	52.0	47.2	10	2.2	10.2	56.5	39.0	31	42.8	7.9	82
G		111.5	12.0	90	50.0	16.3	67	2.0	23.8	55.4	34.0	40	41.6	5.8	86

FILTER	DATE	TEMPERATURE °C		AMMONIACAL NITROGEN			OXIDISED NITROGEN			B.O.D.			SUSPENDED SOLIDS		
	Depth(m)	0.0	0.5	0.0	0.5	%R	0.0	0.5	2.0	0.0	0.5	%R	0.0	0.5	2.0

AUGUST 1974

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
<u>BACTERIA</u>												
Zoogloeal forms	8	4		8			12	1		6	5	1
Sphaerotilus										3		
Beggiatoa	3	2				1	2			3		
Thiothrix	1											
<u>FUNGI</u>												
Subbaromyces	4	4										
<u>ALGAE</u>												
Chlorella	5			5			1			12		
Stigeoclonium				3						10		
Phormidium				1								

August 1974

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
OLIGOCHAETA												
Enchytraeidae						30		10			30	30
Lumbricillus lineatus												
Enchytraeus albidus												
INSECTA												
Collembola												
Hypogastrura												
Diptera												
Psychoda												
larvae	30			11			52	10	20	31	10	21
pupae	10				10		13		10	5		
flies	30						40			10		30
Chironomidae												
larvae						10						20
flies												
ARACHNIDA												
Mites (Mesostigmatidae)		30					10	10	40		20	10
CRUSTACEA												
Canthocamptidae												

August 1974

FILTER	F			G			F			G		
DEPTH (m)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
PROTOZOA: CILIOPHORA												
HOLOTRICHIA												
Trachelophyllum pusillum		4	21	1	16	6		5	27		30	12
Paramecium caudatum		1	10		1	8		2	10		2	7
Colpidium colpoda		1						4	10			4
Glaucoma scintillans	6	8	20	4	1	6	4	12	27	5	12	30
Colpoda inflata											1	
Chilodonella uncinata												
PERITRICHIA												
Vorticella sp.			1	4	1	3		5		1	2	2
Telotrochs of *Vorticella*	1	2	2			8	1	9	20			2
Opercularia coarctata	12	25	10	1	1	3	14	40	10	10	11	22
SPIROTRICHIA												
Aspidisca costata		73	25		58	13		19	60		60	12
Oxytricha sp.		1	2		1			2	19			2
Stylonychia sp.		1	4			1		2	3			2
PROTOZOA : MASTIGOPHORA												
Euglena sp.								1		1		
NEMATODA	17	20	11	10	4	11	12	23	17	11	5	13
ROTIFERA					1	4			8		1	4

AUGUST 1974

DATE	FILTER	TEMPERATURE °C			LOAD	SETTLED BOD mgl^{-1}				SUSPENDED SOLIDS mgl^{-1}			
		INF	EFF	AIR	Kgm^{-3}	INF	EFF	FINAL	% rem	INF	EFF	FINAL	% rem
7th	F	17.0	17.0	15.6	0.60	284.5	27.5	32.1	90	210	112	72	66
	G	17.0	15.5		0.26	231.2	14.2	16.5	93	226	147	49	78
8th	F	17.2	18.1	18.0	0.54	225.5	29.6	29.4	87	148	154	45	70
	G	17.2	17.2		0.26	230.0	20.6	14.9	93	98	103	32	67
9th	F	17.2	17.8	17.0	0.61	254.0	22.3	24.9	90	162	134	30	81
	G	17.2	16.3		0.29	254.0	11.7	11.8	95	198	111	33	83
13th	F	17.0	16.7	13.6	0.44	185.0	25.5	16.1	91	192	97	54	73
	G	17.0	16.3		0.21	182.0	21.3	16,9	91	204	83	55	71
16th	F	17.4	19.3	17.3	0.49	202.0	15.3	15.0	93				
	G	17.4	17.6		0.24	210.2	22.9	3.3	98				
20th	F	16.0	17.3	16.0	0.67	281.0	46.4	33.6	90	168	115	37	78
	G	16.0	14.4		0.28	242.0	34.3	21.2	91	170	112	36	79
21st	F	16.5	18.0	17.2	0.69	328.0	24.8	34.9	91	238	104	29	88
	G	16.5	16.5		0.38	333.0	27.3	27.3	92	212	87	34	84
22nd	F	16.8	19.5	18.5	0.75	319.0	18.7	20.4	93	280	200	33	88
	G	16.8	16.0		0.36	18.0	29.2	22.4	93	272	172	49	82

	BOD					SUSPENDED SOLIDS			
	INF	EFF	FINAL	% rem	LOAD	INF	EFF	FINAL	% rem
F MEAN	259.8	26.3	25.8	90	0.60	194.2	131.1	42.0	78
S.D	52.6	9.4	7.9	1.90	0.10	46.0	33.4	14.7	7.9
C.V	20.2	35.7	30.6	2.1	17.5	23.7	25.5	34.9	10.2
S.E	18.6	3.3	2.8	0.6	0.03	16.3	11.8	5.2	2.8
G MEAN	250.0	22.7	16.5	93.3	0.28	198.3	112.1	38.7	79.0
S.D	51.5	7.5	7.2	2.3	0.05	37.5	29.2	10.8	7.0
C.V	20.6	33.2	3.4	2.4	20.4	18.8	26.0	27.8	8.9
S.E	18.2	2.7	2.6	0.8	0.02	13.2	10.3	3.8	2.5

AUGUST 1974

FILTER	DATE	SOLUBLE BOD			AMMONIACAL NITROGEN			OXIDISED NITROGEN		PERMANGANATE VALUE			DETERGENT (as manoxol)		
		INF	EFF	%R	INF	EFF	%R	INF	EFF	INF	EFF	%R	INF	EFF	%R
F	8th	121.1	8.4	93	45.8	22.7	50	1.0	12.5	48.6	16.0	67	52.6	5.2	90
G		127.4	8.9	92	45.5	18.8	60	1.4	11.9	48.4	16.4	66	35.4	3.6	90
F	16th	90.6	4.2	95	43.5	23.4	48	1.5	12.3	51.0	22.4	56	40.8	7.9	83
G		84.5	4.3	95	44.7	19.4	55	1.6	17.0	51.0	14.0	73	34.2	7.4	77
F	22nd	158.0	8.4	95	31.2	28.1		1.6	14.8	66.0	20.2	69	29.6	7.4	75
G		150.0	8.4	94	30.6	30.0		1.5	17.5	67.0	20.2	70	35.4	0.4	99

FILTER	DATE	TEMPERATURE °C		AMMONIACAL NITROGEN			OXIDISED NITROGEN			B.O.D.			SUSPENDED SOLIDS		
	Depth(m)	0.0	0.5	0.0	0.5	%R	0.0	0.5	2.0	0.0	0.5	%R	0.0	0.5	2.0

SEPTEMBER 1974

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
BACTERIA												
Zoogloeal forms	8			6	3							
Sphaerotilus												
Beggiatoa					1							
Thiothrix												
FUNGI												
Subbaromyces	10											
ALGAE												
Chlorella	2			3								
Stigeoclonium				3								
Phormidium	1											

September 1974

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
OLIGOCHAETA												
Enchytraeidae												
Lumbricillus lineatus												
Enchytraeus albidus			10		19	15						
INSECTA												
Collembola												
Hypogastrura												
Diptera												
Psychoda												
larvae	34		12	24	10	10						
pupae	10			30								
flies				10		10						
Chironomidae												
larvae												
flies												
ARACHNIDA												
Mites (Mesostigmatidae)		10										
CRUSTACEA												
Canthocamptidae		10										

September 1974

FILTER	F			G			F			G		
DEPTH (m)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
PROTOZOA: CILIOPHORA												
HOLOTRICHIA												
Trachelophyllum pusillum		43	250		5	41						
Paramecium caudatum		14	43		3	5						
Colpidium colpoda		2			2							
Glaucoma scintillans	2	25	15	5	2	10						
Colpoda inflata												
Chilodonella uncinata		2	2									
PERITRICHIA												
Vorticella sp.												
Telotrochs of Vorticella		3	8			14						
Opercularia coarctata	7	1	5	2	3	2						
SPIROTRICHIA												
Aspidisca costata		35	20		26	29						
Oxytricha sp.		1	21									
Stylonychia sp.		1			1							
PROTOZOA : MASTIGOPHORA												
Euglena sp.					2							
NEMATODA	2	4	3	7	3	3						
ROTIFERA		1	3		2	1						

September 1974

DATE	FILTER	TEMPERATURE °C			LOAD	SETTLED BOD mgl^{-1}				SUSPENDED SOLIDS mgl^{-1}			
		INF	EFF	AIR	Kgm^{-3}	INF	EFF	FINAL	% rem	INF	EFF	FINAL	% rem
24th	F									226	214	52	77
	G									298	107	32	90
25th	F	14.5	13.5	9.5	0.60	251.0	46.7	64.2	74	162	104	50	69
	G	14.5	11.0		0.36	316.7	28.8	22.2	93	150	70	48	68
26th	F	14.5	13.0	10.0	0.46	195.3	40.4	46.5	76	208	120	73	64
	G	14.5	10.0		0.24	210.4	5.3	16.7	92	152	86	49	69
27th	F	13.5	8.2	6.9	0.50	207.9	38.2	49.0	76	168	215	36	79
	G	13.5	7.2		0.24	208.0	10.1	20.3	92	138	21	24	83
30th	F	13.5	11.2	7.5						244	135	70	71
	G	13.5	7.5							242	70	22	91
1st	F	14.0	12.0	10.0						154	89	35	77
	G	14.0	8.5							190	47	14	93
2nd	F	14.0	12.0	6.5	0.80	330.2	77.6	50.6	83	256	87	67	74
	G	14.0	10.0		0.37	325.5	61.3	39.0	88	252	79	59	77
3rd	F	13.5	11.0	10.0	0.47	194.5	54.1	44.1	77	170	118	52	69
	G	13.5	9.0		0.21	179.2	34.0	27.5	85	170	59	55	68
4th	F	12.0	9.5	6.5	0.47	195.0	37.3	43	78	148	109	47	68
	G	12.0	7.0		0.23	205.0	35.7	24.3	88	154	52	31	80

	BOD					SUSPENDED SOLIDS			
	INF	EFF	FINAL	% rem	LOAD	INF	EFF	FINAL	% rem
F MEAN	228.9	49.0	49.5	77.3	0.55	198.5	135.2	54.3	72.5
S.D	54.1	15.3	7.7	3.0	0.13	40.2	51.4	14.6	5.1
C.V	23.6	31.3	15.5	3.9	24.1	20.2	38.0	26.8	7.0
S.E	22.1	6.3	3.1	1.2	0.05	14.2	18.2	5.2	1.8
G MEAN	241.6	29.2	25.0	89.6	0.27	199.0	64.9	37.6	79.7
S.D	61.9	20.1	7.7	3.1	0.07	58.2	27.7	17.0	10.9
C.V	25.6	69.0	31.0	3.5	25.7	29.2	42.7	45.3	13.7
S.E	25.3	8.2	3.1	1.2	0.02	20.5	9.8	6.0	3.8

SEPTEMBER 1974

FILTER	DATE	SOLUBLE BOD			AMMONIACAL NITROGEN			OXIDISED NITROGEN		PERMANGANATE VALUE			DETERGENT (as manoxol)		
		INF	EFF	%R	INF	EFF	%R	INF	EFF	INF	EFF	%R	INF	EFF	%R
F	26th	124.0	15.5	87	34.8	29.7	26	1.9	9.0	50.0	19.7	60	22.4	6.0	73
G		103.0	7.2	93	35.4	20.5	42	3.1	13.4	48.3	15.3	68	18.6	5.1	73
F	3rd	107.5	13.6	77	55.0	38.1	31	3.0	13.0	58.1	25.4	56	22.4	8.0	64
G		112.8	7.2	93	54.2	31.1	43	4.8	14.5	58.6	28.8	51	22.8	5.2	77

FILTER	DATE	TEMPERATURE °C		AMMONIACAL NITROGEN			OXIDISED NITROGEN			B.O.D.			SUSPENDED SOLIDS		
	Depth(m)	0.0	0.5	0.0	0.5	%R	0.0	0.5	2.0	0.0	0.5	%R	0.0	0.5	2.0
F	26th	14.5	15.0	34.8	34.1	46	1.9	3.2	9.0	195.3	80.4	92	208	168	120
G		14.5	13.0	35.4	27.6	55	3.1	7.3	13.4	210.4	36.2	91	152	150	86
F	3rd	13.5	12.0	55.0	41.0	84	3.0	10.0	13.0	194.5	77.7	79	170	186	118
G		13.5	12.0	54.2	38.2	90	4.0	10.8	14.5	179.2	67.0	77	170	222	59

OCTOBER 1974

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
BACTERIA												
Zoogloeal forms	4			10			4			5		
Sphaerotilus												
Beggiatoa												
Thiothrix												
FUNGI												
Subbaromyces	12	4					16	5				
ALGAE												
Chlorella	1			2			3			2		
Stigeoclonium												
Phormidium												

October 1974

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
OLIGOCHAETA												
Enchytraeidae												
Lumbricillus lineatus		68	14			9		27	3		12	7
Enchytraeus albidus		10	6			12		15	2		12	10
INSECTA												
Collembola												
Hypogastrura												
Diptera												
Psychoda												
larvae	10	1	4	30			32		6	21		
pupae									1	21		
flies	10											2
Chironomidae												
larvae												
flies												
ARACHNIDA												
Mites (Mesostigmatidae)		1							2		1	2
CRUSTACEA												
Canthocamptidae		57	6					21	3		10	20

October 1974

FILTER	F			G			F			G		
DEPTH (m)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
PROTOZOA: CILIOPHORA												
HOLOTRICHIA												
Trachelophyllum pusillum		100	100		14	40		9	70		38	144
Paramecium caudatum		17	25					15	90			
Colpidium colpoda		1							11			
Glaucoma scintillans	5	20	22				5	50	20			
Colpoda inflata		1										
Chilodonella uncinata												
PERITRICHIA												
Vorticella sp.		1				1		1				3
Telotrochs of *Vorticella*		10	10		6	14		1	8		7	10
Opercularia coarctata	6	10	2	10	4	3	12	1	7	8	5	5
SPIROTRICHIA												
Aspidisca costata		40	40		14	10		19	13		6	30
Oxytricha sp.												
Stylonychia sp.					4	1		4			27	51
PROTOZOA : MASTIGOPHORA												
Euglena sp.	2						1					
NEMATODA		7	6	10	7	5	6	5	9	10	5	2
ROTIFERA				1					3			

OCTOBER 1974

DATE	FILTER	TEMPERATURE °C			LOAD	SETTLED BOD mgl^{-1}				SUSPENDED SOLIDS mgl^{-1}			
		INF	EFF	AIR	Kgm^{-3}	INF	EFF	FINAL	% rem	INF	EFF	FINAL	% rem
8th	F	13.5	10.5	8.5	0.62	260.5	34.0	36.8	86	162	126	25	85
	G	13.5	8.5		0.29	250.5	30.7	27.7	89	166	105	37	78
9th	F	14.0	12.0	10.5	0.62	203.4	54.5	26.8	87	172	232	35	80
	G	14.0	8.0		0.17	151.1	12.8	11.0	93	166	278	24	86
10th	F	13.5	11.5	7.0	0.65	315.0	55.8	42.1	86	192	170	51	74
	G	13.5	10.0		0.31	271.0	30.6	28.2	90	194	165	46	76
15th	F	13.5	13.5	9.5	0.70	291.0	128.7	92.7	68	160	139	97	55
	G	12.0	10.0		0.37	325.5	13.3	17.3	95	212	143	36	77
16th	F	13.0	12.5	9.0	0.63	261.8	31.0	43.4	83	252	192	55	78
	G	13.0	11.5		0.29	249.5	11.4	15.8	94	290	183	43	85
17th	F	13.5	13.0	8.0	0.37	152.0	28.6	36.8	76	94	95	44	58
	G	13.5	11.0		0.18	157.0	11.1	12.8	92	104	122	36	65
20th	F	13.0	8.5	6.0	0.60	251.2	69.3	10.3	96	110	135	49	56
	G	13.0	6.5		0.28	241.0	48.4	9.3	96	120	153	27	78
23rd	F	12.5	9.0	7.5	0.53	220.2	40.8	49.0	78	148	118	67	55
	G	12.5	7.0		0.25	215.4	12.5	13.7	93	186	69	20	86
25th	F	12.5	11.5	8.5	0.44	182.4	20.1	45.6	75				
	G	12.5	10.5		0.21	182.4	15.1	31.6	83				
30th	F	12.0	9.0	4.0	0.48	200.0	54.9	59.5	70	108	145	79	27
	G	12.0	4.5		0.22	189.0	36.4	40.8	78	142	68	39	72
31st	F	12.0	11.0	5.5	0.40	165.6	38.5	41.3	75	156	88	74	53
	G	12.0	6.0		0.19	169.0	3.4	24.2	83	144	218	32	78
1st	F	12.0	11.5	7.2	0.61	253.8	39.0	45.4	82	224	216	106	53
	G	12.0	10.0		0.27	238.1	20.2	26.5	89	210	118	65	69

	BOD					SUSPENDED SOLIDS			
	INF	EFF	FINAL	% rem	LOAD	INF	EFF	FINAL	% rem
F MEAN	229.7	42.4	39.7	81.3	0.55	161.6	162.3	62.0	68
S.D	50.5	14.4	12.7	7.3	0.10	48.4	46.0	25.2	12.4
C.V	22.0	34.2	31.9	9.0	19.4	29.9	28.3	40.7	18.2
S.E	14.5	4.3	3.8	2.2	0.03	14.5	13.8	7.6	3.7
G MEAN	220.0	19.6	21.5	89.6	0.25	175.8	131.4	36.3	77
S.D	52.2	14.1	9.7	5.5	0.06	51.3	50.1	11.7	6.8
C.V	23.7	71.7	44.9	6.2	23.7	29.3	38.1	32.3	8.7
S.E	15.0	4.0	2.8	1.6	0.01	15.5	15.0	3.4	2.0

CCTOBER 1974

FILTER	DATE	SOLUBLE BOD			AMMONIACAL NITROGEN			OXIDISED NITROGEN		PERMANGANATE VALUE			DETERGENT (as manoxol)		
		INF	EFF	%R	INF	EFF	%R	INF	EFF	INF	EFF	%R	INF	EFF	%R
F	9th	92.4	6.6	93	41.7	25.0	40	0.0	5.1	20.2	17.5	63	18.0	9.0	50
G		82.2	0.8	98	41.3	15.3	63	0.0	12.5	46.0	16.1	65	20.0	2.5	88
F	16th	135.4	14.8	89	40.0	21.7	46	1.0	2.0	54.0	17.6	67	27.6	5.8	79
G		127.7	4.1	97	38.8	12.4	69	2.5	10.9	53.6	10.8	80	27.2	2.6	90
F	25th	59.6	15.8	74	35.5	21.0	41	1.0	5.0	49.0	20.0	59	40.8	9.0	78
G		64.8	12.9	80	35.0	18.3	48	1.1	5.6	47.0	15.0	68	35.2	6.6	83
F	31st	76.3	18.2	76	42.0	30.5	27	1.4	6.2	54.2	14.2	74	38.6	8.2	79
G		68.2	7.2	90	40.2	11.4	78	2.5	12.4	53.8	9.5	82	31.0	8.2	74

FILTER	DATE	TEMPERATURE °C		AMMONIACAL NITROGEN			OXIDISED NITROGEN			B.O.D.			SUSPENDED SOLIDS		
	Depth(m)	0.0	0.5	0.0	0.5	%R	0.0	0.5	2.0	0.0	0.5	%R	0.0	0.5	2.0
F	9th	14.0	13.0	41.7	41.7		0.0	0.8	5.1	20.34	73.2	73	172	232	225
G		14.0	10.0	41.3	22.2	86	0.0	3.5	12.5	166.0	31.7	85	166	278	262
F	16th	13.0	13.0	40.0	36.2	22	1.0	0.8	2.0	261.8	99.0	77	252	228	192
G		13.0	12.0	38.8	22.2	64	2.5	4.2	10.9	127.7	31.0	94	290	108	183
F	25th	12.5	12.0	35.5	29.8	20	1.0	2.4	5.0	182.4	72.6	80			
G		12.5	10.0	35.0	29.2	24	1.1	3.2	5.5	182.4	60.0	80			
F	31st	12.0	11.0	42.0	39.3	22	1.4	3.0	6.2	165.6	73.0	75	156	174	88
G		12.0	7.0	40.2	21.2	62	2.5	4.7	12.4	169.0	42.4	83	144	296	218

NOVEMBER 1974

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
<u>BACTERIA</u>												
Zoogloeal forms				5	1					7	1	
Sphaerotilus	1				1	1	1			1		
Beggiatoa										1		
Thiothrix												
<u>FUNGI</u>												
Subbaromyces	15			1			10					
<u>ALGAE</u>												
Chlorella							3			4		
Stigeoclonium												
Phormidium	5											

November 1974

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
OLIGOCHAETA												
Enchytraeidae												
Lumbricillus lineatus		29	51			21	12	11			10	12
Enchytraeus albidus	10	5			10	11			10		30	
INSECTA												
Collembola												
Hypogastrura												
Diptera												
Psychoda												
larvae	10	3	8	20		40	15	9	20	14	2	3
pupae			10						20	10		
flies		10		10					20		20	20
Chironomidae												
larvae												
flies												
ARACHNIDA												
Mites (Mesostigmatidae)			10			10		10	20			10
CRUSTACEA												
Canthocamptidae	11	21	20	20		20				25	36	12

November 1974

FILTER	F			G			F			G		
DEPTH (m)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
PROTOZOA: CILIOPHORA												
HOLOTRICHIA												
Trachelophyllum pusillum		53	103		100	110		45	115		5	40
Paramecium caudatum		15	32						6		5	5
Colpidium colpoda												
Glaucoma scintillans	12	20	10	1		6	10	10	10	2	2	6
Colpoda inflata												
Chilodonella uncinata												3
PERITRICHIA												
Vorticella sp.									1			
Telotrochs of *Vorticella*		1	1		3	10		12	13		15	10
Opercularia coarctata	3	4	3	7	5	13	4	5	6	13	4	1
SPIROTRICHIA												
Aspidisca costata		23	13		12	1		25	27		9	9
Oxytricha sp.			2						1			20
Stylonychia sp.						1					1	1
PROTOZOA : MASTIGOPHORA												
Euglena sp.	2						1					
NEMATODA	9	1	3	15	14	10	21	7	7	25	18	27
ROTIFERA												

NOVEMBER 1974

DATE	FILTER	TEMPERATURE °C			LOAD	SETTLED BOD mgl^{-1}				SUSPENDED SOLIDS mgl^{-1}			
		INF	EFF	AIR	Kgm^{-3}	INF	EFF	FINAL	% rem	INF	EFF	FINAL	% rem
4th	F	12.0	10.5	7.0	0.64	265.5	30.8	29.7	89	170	117	58	66
	G	12.0	8.0		0.32	278.0	30.8	24.2	91	170	109	49	71
7th	F	12.0	11.2	9.0	0.70	292.2	35.9	46.7	84	208	289	75	64
	G	12.0	10.8		0.34	294.7	25.8	25.8	91	188	230	57	70
8th	F	12.0	12.0	10.5	0.57	237.9	47.4	64.9	73	256	140	103	60
	G	12.0	11.5		0.29	253.8	43.0	37.0	85	252	376	65	74
9th	F	12.0	11.5	10.0	0.53	222.2	68.2	91.0	70	172	195	132	32
	G	12.0	10.5		0.27	237.0	26.2	35.5	89	194	217	87	45
13th	F	11.5	8.5	7.5	0.45	187.0	53.3	43.6	76	224	198	34	85
	G	11.0	8.0		0.22	192.2	23.6	28.3	88	232	156	36	84
14th	F	11.0	9.5	9.0	0.55	231.6	19.9	19.4	92	98	202	85	13
	G	11.0	8.0		0.17	147.2	9.4	15.8	89	90	263	76	15
19th	F	11.0	8.0	5.0	0.53	220.0	29.9	33.0	85	180	122	45	75
	G	11.0	6.0		0.25	220.0	26.4	27.5	88	180	126	44	75
26th	F	10.5	8.5	6.0	0.37	154.0	18.1	22.5	85	120	207	49	60
	G	10.5	7.5		0.17	148.8	21.4	28.5	81	116	263	52	55
27th	F	10.5	10.0	8.0	0.38	157.0	24.5	24.5	84	164	220	85	45
	G	10.5	9.5		0.18	157.0	24.7	33.3	84	154	76	73	55
28th	F	10.0	8.0	6.0	0.35	140.6	11.5	13.6	90	154	207	57	61
	G	10.0	6.0		0.16	135.6	7.7	12.5	91	148	134	22	86

	BOD					SUSPENDED SOLIDS			
	INF	EFF	FINAL	% rem	LOAD	INF	EFF	FINAL	% rem
F MEAN	210.8	33.9	32.3	83	0.51	174.6	189.7	72.3	56
S.D	50.1	17.6	15.6	7.3	0.11	46.7	51.6	29.8	20.9
C.V	23.7	51.9	48.2	8.9	23.2	26.7	27.2	41.3	37.4
S.E	15.8	5.6	5.2	2.3	0.04	14.7	16.3	9.4	6.6
G MEAN	206.4	23.7	26.7	89	0.24	172.4	195.0	56.1	63
S.D	58.5	9.9	8.3	4.6	0.06	48.9	91.4	19.7	21.3
C.V	28.3	41.8	31.3	5.2	28.3	28.4	46.9	35.1	33.9
S.E	18.5	3.1	2.7	1.4	0.02	15.5	28.9	6.2	6.7

NOVEMBER 1974

FILTER	DATE	SOLUBLE BOD			AMMONIACAL NITROGEN			OXIDISED NITROGEN		PERMANGANATE VALUE			DETERGENT (as manoxol)		
		INF	EFF	%R	INF	EFF	%R	INF	EFF	INF	EFF	%R	INF	EFF	%R
F	8th	100	22	78	71.5	58.7	18	2.4	10.3	78.0	38.8	50	31.6	3.9	82
G		91	16.1	82	73.4	50.0	32	2.0	15.6				24.6	2.6	89
F	28th	44.0	4.1	91	24.0	16.2	32	2.0	11.3	38.0	12.3	68	17.6	1.7	90
G		42.0	3.5	92	23.5	6.1	74	2.0	14.0	38.5	7.8	80	19.8	2.8	86

FILTER	DATE	TEMPERATURE °C		AMMONIACAL NITROGEN			OXIDISED NITROGEN			B.O.D.			SUSPENDED SOLIDS		
	Depth(m)	0.0	0.5	0.0	0.5	%R	0.0	0.5	2.0	0.0	0.5	%R	0.0	0.5	2.0
F	8th	12.0	12.0	71.5	66.9	33	2.4	5.8	10.3	253.8	79.9	80	256	188	140
G		12.0	12.0	73.4	60.0	56	2.0	4.4	15.6	253.8	79.9	80	252	302	376
F	28th	10.0	8.0	24.0	30.2		2.0	3.2	11.3	140.6	31.9	86	154	207	135
G		10.0	7.0	23.5	20.1	12	2.0	3.3	14.0	135.6	43.3	75	148	134	117

DECEMBER 1974

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
<u>BACTERIA</u>												
Zoogloeal forms	15			8								
Sphaerotilus	1											
Beggiatoa	1											
Thiothrix												
<u>FUNGI</u>												
Subbaromyces	8					1						
<u>ALGAE</u>												
Chlorella	1											
Stigeoclonium												
Phormidium				1								

December 1974

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
OLIGOCHAETA												
Enchytraeidae												
Lumbricillus lineatus	50	25	67	10	10	10						
Enchytraeus albidus	30	34	32	32	11							
INSECTA												
Collembola												
Hypogastrura					30	63						
Diptera												
Psychoda												
larvae	26	50	120	23	10	17						
pupae		20	20	10		20						
flies						10						
Chironomidae												
larvae												
flies												
ARACHNIDA												
Mites (Mesostigmatidae)		20	20		10							
CRUSTACEA												
Canthocamptidae	10	20	43	76	50	21						

December 1974

FILTER	F			G			F			G		
DEPTH (m)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
PROTOZOA: CILIOPHORA												
HOLOTRICHIA												
Trachelophyllum pusillum		10	25		12	10						
Paramecium caudatum		2	10		1	2						
Colpidium colpoda												
Glaucoma scintillans	10	1	2	2	1	1						
Colpoda inflata												
Chilodonella uncinata					1							
PERITRICHIA												
Vorticella sp.					10	1						
Telotrochs of *Vorticella*		4	2		7	7						
Opercularia coarctata	3	22	9	10	4	6						
SPIROTRICHIA												
Aspidisca costata		5	10		9	1						
Oxytricha sp.												
Stylonychia sp.					2							
PROTOZOA : MASTIGOPHORA												
Euglena sp.	1											
NEMATODA	25	15	6	19	17	5						
ROTIFERA			2		1							

DECEMBER 1974

DATE	FILTER	TEMPERATURE °C			LOAD	SETTLED BOD mgl^{-1}				SUSPENDED SOLIDS mgl^{-1}			
		INF	EFF	AIR	Kgm^{-3}	INF	EFF	FINAL	% rem	INF	EFF	FINAL	% rem
4th	F	11.0	9.0	8.5	0.41	169.2	41.0	9.1	95	148	279	33	81
	G	11.0	7.5		0.18	159.0	15.7	13.8	91	168	180	53	68
5th	F	10.5	8.0	8.5	0.37	152.2	13.2	14.7	90	156	198	68	55
	G	10.0	6.0		0.17	145.0	11.0	13.0	91	152	176	45	70
7th	F	11.5	11.0	12.0	0.52	218.0	29.3	28.6	87	202	210	86	61
	G	11.5	10.5		0.24	213.4	12.9	11.3	95	220	334	62	70
11th	F	9.5	3.0	5.0	0.54	225.0	42.7	27.0	88	170	157	61	64
	G	8.5	2.0		0.24	212.8	26.2	19.8	94	160	358	33	79
12th	F	10.0	6.0	4.0	0.34	141.8	25.1	14.7	90	138	209	43	69
	G	9.0	7.0		0.18	156.9	8.2	15.0	90	146	440	45	69
13th	F	10.0	7.0	0.0	0.40	166.3	22.0	26.6	84	128	102	68	51
	G	9.5	3.0		0.19	169.0	13.4	22.2	87	134	362	34	73

	BOD					SUSPENDED SOLIDS			
	INF	EFF	FINAL	% rem	LOAD	INF	EFF	FINAL	% rem
F MEAN	175.7	28.8	20.1	89	0.43	157	192.5	59.8	63.5
S.D	34.6	11.3	8.2	3.6	0.08	26.3	59.2	19.0	10.7
C.V	19.3	39.3	41.0	4.1	18.8	16.7	30.7	31.9	16.0
S.E	14.1	4.6	3.3	1.5	0.03	10.7	24.2	7.7	4.4
G MEAN	176.0	14.6	15.8	91.3	0.20	163.3	308.3	45.3	71.5
S.D	29.7	6.2	4.2	2.8	0.03	30.1	107.0	11.1	4.03
C.V	16.8	42.7	26.7	3.1	15.8	18.4	34.7	24.5	5.00
S.E	12.1	2.5	1.7	1.1	0.01	12.3	43.7	4.5	1.64

DECEMBER 1974

FILTER	DATE	SOLUBLE BOD			AMMONIACAL NITROGEN			OXIDISED NITROGEN		PERMANGANATE VALUE			DETERGENT (as manoxol)		
		INF	EFF	%R	INF	EFF	%R	INF	EFF	INF	EFF	%R	INF	EFF	%R
F	5th	61.5	3.1	95	28.6	16.8	41	2.3	15.7	42.0	18.2	57	21.8	1.2	94
G		60.0	5.7	91	28.2	9.5	66	2.5	17.0	41.7	18.6	55	16.6	1.2	93
F	12th	67.4	3.5	95	27.2	30.0	-	2.0	10.0	36.0	17.6	52	26.0	1	95
G		58.8	3.5	94	26.5	9.6	64	2.1	11.6	34.6	6.8	80	22.8	1	95

FILTER	DATE	TEMPERATURE °C		AMMONIACAL NITROGEN			OXIDISED NITROGEN			B.O.D.			SUSPENDED SOLIDS		
	Depth(m)	0.0	0.5	0.0	0.5	%R	0.0	0.5	2.0	0.0	0.5	%R	0.0	0.5	2.0
F	5th	10.5	8.0	28.5	33.1		2.3	5.2	15.7	152.2	35.1	86	156	140	198
G		10.0	7.0	28.2	18.9	50	2.5	6.5	17.0	145.0	36.2	82	152	202	176
F	12th	10.0	8.0	27.2	33.7		2.0	2.9	10.0	141.8	38.0	87			
G		9.0	6.0	26.5	18.1	50	2.1	7.1	11.6	156.9	18.6	93			

JANUARY 1975

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
<u>**BACTERIA**</u>												
Zoogloeal forms	13			6			10			10		
Sphaerotilus	1			1			1			1		
Beggiatoa	1			1			1			1		
Thiothrix												
<u>**FUNGI**</u>												
Subbaromyces	3			1			9			1		
<u>**ALGAE**</u>												
Chlorella				1			1			1		
Stigeoclonium												
Phormidium	1											

January 1975

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
OLIGOCHAETA												
Enchytraeidae												
Lumbricillus lineatus	100	20	40	130	140	73	530	250	200	225	50	10
Enchytraeus albidus	10	130	10	10	74	110	7	90		26	42	56
INSECTA												
Collembola												
Hypogastrura					100	310					20	780
Diptera												
Psychoda												
larvae	70	21	50	140	24	110	13	360	440	31	13	10
pupae									10			
flies					10	10						
Chironomidae												
larvae												
flies												
ARACHNIDA												
Mites (Mesostigmatidae)			20									10
CRUSTACEA												
Canthocamptidae	10	10	20	74		112	10	10	16	33	10	52

January 1975

FILTER	F			G			F			G		
DEPTH (m)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
PROTOZOA: CILIOPHORA												
HOLOTRICHIA												
Trachelophyllum pusillum		12	21		2	7					1	6
Paramecium caudatum		10	5	1	2	2					3	3
Colpidium colpoda					4	10			5		2	1
Glaucoma scintillans	12		8	2	6	4	8		8			
Colpoda inflata					2						2	1
Chilodonella uncinata												
PERITRICHIA												
Vorticella sp.	2	2										2
Telotrochs of *Vorticella*				2	2						15	2
Opercularia coarctata	1	100	5	2	5		19	4	3	5	20	7
SPIROTRICHIA												
Aspidisca costata					9	1					1	1
Oxytricha sp.					3							
Stylonychia sp.					1							
PROTOZOA : MASTIGOPHORA												
Euglena sp.							1					
NEMATODA	11	1	1	39	52	4	13	10	1	21	9	6
ROTIFERA		1			1				1			

January 1975

DATE	FILTER	TEMPERATURE °C			LOAD	SETTLED BOD mgl^{-1}				SUSPENDED SOLIDS mgl^{-1}			
		INF	EFF	AIR	Kgm^{-3}	INF	EFF	FINAL	% rem	INF	EFF	FINAL	% rem
8th	F	11.0	7.0	5.5	0.67	278.3	60.9	49.3	83	226	270	58	74
	G	11.0	6.0		0.33	291.1	42.2	35.0	88	202	252	37	82
9th	F	11.0	9.0	8.5	0.51	215.5	37.2	35.7	84	376	151	70	81
	G	11.0	8.0		0.24	210.4	7.6	20.8	91	370	144	37	90
10th	F	11.0	8.5	8.0	0.67	280.4	51.9	28.2	90	272	196	40	85
	G	11.0	8.0		0.32	280.4	13.6	19.8	93	260	219	34	87
14th	F	10.5	8.0	8.5	0.60	250.8	42.9	40.7	84	142	115	57	60
	G	10.5	8.0		0.30	250.8	33.5	18.7	93	132	209	16	88
15th	F	10.5	9.0	11.0	0.45	186.7	25.3	28.6	85	144	97	45	69
	G	10.5	9.0		0.22	189.0	11.8	20.6	89	166	122	16	90
16th	F	10.5	4.5	3.0	0.51	214.5	65.5	20.4	90	186	162	29	84
	G	10.0	2.5		0.25	217.8	31.4	19.3	91	178	83	25	86
21st	F	9.5	7.0	6.0	0.49	204.1	23.7	26.4	87	124	54	54	55
	G	9.5	6.0		0.24	205.1	18.0	22.4	89	120	54	42	66
22nd	F	10.0	9.5	9.0	0.53	219.5	27.6	29.3	87	124	54	54	55
	G	10.0	9.0		0.22	192.2	21.6	26.5	86	170	117	36	79
23rd	F	9.0	7.5	5.0	0.34	141.0	15.7	18.8	87	134	78	38	72
	G	9.0	6.5		0.16	138.0	12.2	12.2	91	164	134	37	77
29th	F	8.5	6.5	3.5	0.31	133.1	22.0	18.2	86	134	124	53	60
	G	8.0	5.5		0.15	129.5	14.3	13.0	90	124	104	19	84
30th	F	9.5	10.5	11.5	0.31	130.9	19.4	25.2	80	65	182	203	40
	G	9.5	10.0		0.15	127.4	8.5	9.0	93	67	162	169	53
31st	F	9.0	9.0	8.0	0.31	129.8	24.1	26.2	83	140	105	57	60
	G	9.0	8.5		0.14	123.6	12.2	15.0	88	132	120	34	74

		BOD					SUSPENDED SOLIDS			
		INF	EFF	FINAL	% rem	LOAD	INF	EFF	FINAL	% rem
F	MEAN	198.7	34.7	28.6	85.5	0.47	183.7	142.6	49.9	69.2
	S.D	55.4	16.9	9.2	2.9	0.13	76.4	59.5	11.5	10.1
	C.V	27.8	48.6	32.5	3.4	28.2	41.6	41.7	23.0	14.5
	S.E	16.0	4.9	2.7	0.8	0.03	22.0	17.2	3.3	2.9
G	MEAN	196.3	18.9	19.3	90.1	0.22	182.3	143.3	32.1	80.8
	S.D	58.6	11.0	6.9	2.2	0.06	70.6	58.1	11.2	8.3
	C.V	29.8	58.4	35.7	2.5	29.9	38.7	40.5	34.7	10.3
	S.E	16.9	3.2	1.9	0.65	0.01	20.4	16.7	3.2	2.4

JANUARY 1975

FILTER	DATE	SOLUBLE BOD			AMMONIACAL NITROGEN			OXIDISED NITROGEN		PERMANGANATE VALUE			DETERGENT (as manoxol)		
		INF	EFF	%R	INF	EFF	%R	INF	EFF	INF	EFF	%R	INF	EFF	%R
F	10th	122.4	24.6	82	54.0	55.9	-	1.4	25.0	60.2	34.6	43	29.4	0.2	93
G		126.3	8.6	93	50.0	7.3	85	1.4	28.0	57.6	18.0	69	25.0	0.1	96
F	16th	107.2	28.0	74	30.8	49.5		2.5	9.5	45.0	29.6	34	26.0	0.2	93
G		98.0	6.6	93	31.0	17.3	44	2.5	16.6	43.4	20.4	53	22.8	0.2	92
F	23rd	59.8	12.7	79	15.7	18.1	-	6.0	8.1	35.0	11.4	74	21.8	0.2	90
G		51.7	4.6	91	16.5	12.7	41	6.1	12.0	35.0	9.0	74	15.4	0.1	85
F	30th	57.2	1.8	97	20.4	22.3	-	8.0	5.6	41.6	15.8	62	9.4	0.1	89
G		41.4	0.7	98	20.2	10.0	50	7.3	11.4	42.0	15.1	64	8.8	0.1	89

FILTER	DATE	TEMPERATURE °C		AMMONIACAL NITROGEN			OXIDISED NITROGEN			B.O.D.			SUSPENDED SOLIDS		
	Depth(m)	0.0	0.5	0.0	0.5	%R	0.0	0.5	2.0	0.0	0.5	%R	0.0	0.5	2.0
F	10th	11.0	10.5	54.0	68.5	-	1.4	2.6	25.0	280.4	75.3	82	272	172	196
G		11.0	10.0	50.0	37.2	30	1.4	7.2	28.0	280.4	55.9	82	260	162	219
F	16th	10.5	9.0	30.8	47.5	-	2.5	3.6	9.5	214.5	72.0	73	186	174	162
G		10.0	5.0	31.0	25.0	43	2.5	11.0	16.6	217.8	63.9	78	178	163	83
F	23rd	9.0	8.5	15.7	24.0	-	6.0	3.0	8.1	141.0	47.7	75	134	130	78
G		9.0	8.5	16.5	21.7	-	6.1	6.8	12.0	138.0	16.9	90	164	79	134
F	30th	9.5	10.5	20.4	28.6	-	8.0	2.2	5.6	130.9	23.8	100	182	103	203
G		9.5	11.0	20.2	23.0	-	7.3	5.9	11.4	127.4	27.3	88	162	123	169

FEBRUARY 1975

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
BACTERIA												
Zoogloeal forms	9			8			11			8		
Sphaerotilus			1				1			2		
Beggiatoa												
Thiothrix												
FUNGI												
Subbaromyces	5	2	2	4			3	5	1			
ALGAE												
Chlorella	1			1			1			1		
Stigeoclonium												
Phormidium												

February 1975

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
OLIGOCHAETA												
Enchytraeidae												
Lumbricillus lineatus	675	420	60	110	820	10	730	600	80	1940	800	70
Enchytraeus albidus					670	50	10			30	170	50
INSECTA												
Collembola												
Hypogastrura					50	90					30	400
Diptera												
Psychoda												
larvae	30	230	50	90	570	20	70	200	120	80	220	90
pupae												
flies			10									
Chironomidae												
larvae												
flies												
ARACHNIDA												
Mites (Mesostigmatidae)									10			
CRUSTACEA												
Canthocamptidae	11	10	15	36	70	20	36	7	32	160	150	20

February 1975

FILTER	F			G			F			G		
DEPTH (m)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
PROTOZOA: CILIOPHORA												
HOLOTRICHIA												
Trachelophyllum pusillum					11	7					9	6
Paramecium caudatum		2			2	1					1	1
Colpidium colpoda			2						6			
Glaucoma scintillans	10	2	20	6	25	10	12	1	8	4	7	11
Colpoda inflata												1
Chilodonella uncinata												
PERITRICHIA												
Vorticella sp.												
Telotrochs of *Vorticella*					12	1					10	8
Opercularia coarctata	13	16	6	10	10	4	5	22	7	11	2	1
SPIROTRICHIA												
Aspidisca costata									1			3
Oxytricha sp.			1		1	1						1
Stylonychia sp.					1	2						1
PROTOZOA : MASTIGOPHORA												
Euglena sp.												
NEMATODA	15	1	1	3	1	1	13	7	5	16	10	7
ROTIFERA												

February 1975

DATE	FILTER	TEMPERATURE °C			LOAD	SETTLED BOD mgl^{-1}				SUSPENDED SOLIDS mgl^{-1}			
		INF	EFF	AIR	Kgm^{-3}	INF	EFF	FINAL	% rem	INF	EFF	FINAL	% rem
4th	F	9.5	5.0	3.5	0.47	192.5	28.4	31.6	84	182	121	66	64
	G	9.0	4.0		0.22	195.2	23.7	19.3	90	178	140	42	77
5th	F	9.0	4.5	2.5	0.42	200.7	48.8	69.7	66	194	131	123	40
	G	8.5	3.0		0.23	199.2	30.1	24.7	88	202	113	42	79
6th	F	9.0	2.5	2.5	0.30	125.3	15.2	26.2	80	148	117	63	57
	G	8.0	2.5		0.15	133.5	9.8	11.2	92	146	87	41	72
9th	F	9.0	4.0	4.0	0.57	238.8	42.5	35.9	85	236	148	62	72
	G	8.0	3.0		0.28	243.4	19.4	17.6	93	226	83	34	87
13th	F	9.0	6.0	7.0	0.63	261.5	23.5	24.6	91	200	191	48	76
	G	8.0	5.0		0.29	251.3	22.4	19.1	92	198	149	43	78
21st	F	9.0	5.0	4.0	0.50	207.5	26.0	29.3	86	188	108	60	66
	G	9.0	6.0		0.23	197.3	23.8	24.9	87	178	161	77	57
22nd	F	9.5	6.5	8.5	0.77	319.1	31.6	32.6	91	224	162	67	73
	G	9.5	4.0		0.35	308.9	25.0	19.4	94	250	180	34	86
26th	F	9.0	5.5	3.5	0.56	266.3	59.5	25.6	90	222	137	90	57
	G	9.0	4.5		0.31	271.5	44.9	22.9	91	210	87	86	60
27th	F	9.0	6.0	0.0	0.59	240.0	47.6	43.8	82	194	146	87	55
	G	8.4	4.0		0.28	246.0	44.3	43.2	82	158	138	76	61
28th	F	9.5	8.5	8.0	0.70	291.8	77.9	67.9	77	232	112	120	46
	G	9.0	5.5		0.33	285.2	38.7	36.5	87	222	76	58	75

		BOD					SUSPENDED SOLIDS			
		INF	EFF	FINAL	% rem	LOAD	INF	EFF	FINAL	% rem
F	MEAN	235.2	40.1	38,7	83.2	0.55	202	137	78	61
	S.D	55.4	18.9	16.8	7.6	0.14	27.0	25.6	25.7	11.8
	C.V	23.6	47.4	43.5	9.1	24.7	13.3	18.6	32.8	19.4
	S.E	17.5	6.0	5.3	2.4	0.04	8.5	8.0	8.1	3.7
G	MEAN	233.2	28.2	23.9	89.0	0.26	197	121	53	73
	S.D	51.9	11.3	9.4	3.6	0.06	32.2	37.0	19.5	7.9
	C.V	22.3	40.0	39.5	4.0	22.5	16.3	30.5	36.6	10.9
	S.E	16.4	3.6	2.9	1.1	0.01	10.1	11.7	6.2	2.5

FEBRUARY 1975

FILTER	DATE	SOLUBLE BOD			AMMONIACAL NITROGEN			OXIDISED NITROGEN		PERMANGANATE VALUE			DETERGENT (as manoxol)		
		INF	EFF	%R	INF	EFF	%R	INF	EFF	INF	EFF	%R	INF	EFF	%R
F	6th	51.6	9.3	82	24.0	26.3		4.5	0.0	34.0	8.6	75	15.8	0.4	97
G		51.6	6.1	88	23.6	14.2	40	5.0	15.2	33.4	5.1	85	13.5	0.5	96
F	26th	136.3	15.6	89	36.5	17.9	51	2.7	5.5	51.6	23.4	55	15.8	0.1	98
G		143.5	12.2	91	36.1	14.2	61	2.7	21.0	52.0	18.8	64	13.5	0.1	98

FILTER	DATE	TEMPERATURE °C		AMMONIACAL NITROGEN			OXIDISED NITROGEN			B.O.D.			SUSPENDED SOLIDS		
	Depth(m)	0.0	0.5	0.0	0.5	%R	0.0	0.5	2.0	0.0	0.5	%R	0.0	0.5	2.0
F	6th	9.0	3.0	24.0	35.4		4.5	1.2	0.0	125.3	32.8	94	148	145	117
G		8.0	2.5	23.6	28.4		5.0	3.5	15.2	130.5	28.4	86	146	89	87
F	26th	9.0	7.5	36.5	41.8		2.7	2.5	5.5	266.3	56.2	88	222	148	137
G		9.0	6.5	36.1	26.0	47	2.7	8.0	21.0	271.5	40.0	93	210	153	87

MARCH 1975

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
BACTERIA												
Zoogloeal forms	6			8								
Sphaerotilus				3								
Beggiatoa				1								
Thiothrix												
FUNGI												
Subbaromyces	6	5		1	1	1						
ALGAE												
Chlorella	2			1								
Stigeoclonium												
Phormidium												

March 1975

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
OLIGOCHAETA												
Enchytraeidae												
Lumbricillus lineatus	260	950	20	190	50	50						
Enchytraeus albidus	20			80	30	130						
INSECTA												
Collembola												
Hypogastrura				50	45	50						
Diptera												
Psychoda												
larvae	10	40	120	80	110	60						
pupae												
flies			10									
Chironomidae												
larvae												
flies												
ARACHNIDA												
Mites (Mesostigmatidae)												
CRUSTACEA												
Canthocamptidae	5	11	10	25	45	30						

March 1975

FILTER	F			G			F			G		
DEPTH (m)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
PROTOZOA: CILIOPHORA												
HOLOTRICHIA												
Trachelophyllum pusillum						1						
Paramecium caudatum												
Colpidium colpoda		2		1	1							
Glaucoma scintillans	2		13	4	3	2						
Colpoda inflata		2		2								
Chilodonella uncinata												
PERITRICHIA												
Vorticella sp.												
Telotrochs of Vorticella	1				1	5						
Opercularia coarctata	6	3	2	11	6	3						
SPIROTRICHIA												
Aspidisca costata												
Oxytricha sp.						2						
Stylonychia sp.						1						
PROTOZOA : MASTIGOPHORA												
Euglena sp.												
NEMATODA	15	2	5	20	1	5						
ROTIFERA												

MARCH 1975

DATE	FILTER	TEMPERATURE °C			LOAD	SETTLED BOD mgl^{-1}				SUSPENDED SOLIDS mgl^{-1}			
		INF	EFF	AIR	Kgm^{-3}	INF	EFF	FINAL	% rem	INF	EFF	FINAL	% rem
5th	F	9.5	8.5	6.0	0.43	180.3	30.4	31.9	82	192	149	96	50
	G	9.5	7.0		0.19	164.4	32.3	26.3	84	162	288	57	65
6th	F	9.5	8.0	5.0	0.38	156.8	31.3	21.5	86	128	116	81	37
	G	10.0	5.0		0.18	156.8	9.3	17.7	89	130	105	30	77
8th	F	10.0	10.0	8.5	0.61	253.9	57.4	60.9	73	170	99	95	50
	G	10.0	8.0		0.30	253.9	26.3	22.3	91	194	146	46	76
13th	F	8.0	4.0	4.0	0.27	112.6	24.7	22.2	80	138	82	134	
	G	7.0	3.5		0.13	116.2	10.8	15.4	87	134	105	59	56
14th	F	7.0	3.0	2.5	0.48	199.5	13.5	10.3	95	40	48	37	
	G	6.5	3.0		0.22	189.2	9.5	9.1	95	32	22	35	
15th	F	8.0	3.5	4.0	0.44	183.6	18.7	5.6	90	152	61	41	73
	G	7.5	3.5		0.19	168.9	21.0	8.3	95	130	91	40	70
19th	F	8.0	0.0	1.0	0.52	215.5	50.0	40.0	81	196	193	26	87
	G	7.0	0.0		0.26	229.9	29.0	20.0	91	204	148	58	71
20th	F	8.0	3.5	4.5	0.44	184.4	44.2	38.3	79	170	221	58	66
	G	7.5	3.5		0.19	169.0	22.6	27.9	83	146	66	54	63
21st	F	8.5	4.0	4.5	0.53	220.8	22.2	22.1	90	174	71	44	75
	G	7.0	4.0		0.25	215.2	6.9	14.2	93	172	49	16	90

		BOD					SUSPENDED SOLIDS			
		INF	EFF	FINAL	% rem	LOAD	INF	EFF	FINAL	% rem
F	MEAN	189.7	32.5	28.1	84	0.45	151.1	115.5	68.0	49
	S.D	40.3	14.9	16.8	6.8	0.09	47.4	60.4	35.6	31.5
	C.V	21.3	46.0	60.0	8.1	21.3	31.4	52.3	52.4	64.7
	S.E	13.4	4.9	5.6	2.3	0.03	15.8	20.2	11.9	10.5
G	MEAN	184.8	18.6	17.9	89.7	0.21	144.8	113.3	43.8	63.1
	S.D	42.1	9.6	6.9	4.4	0.05	50.3	77.6	14.9	25.6
	C.V	22.7	51.7	38.7	4.9	23.9	34.7	68.4	33.9	40.5
	S.E	14.0	3.2	2.3	1.5	0.01	16.8	25.8	4.9	8.5

MARCH 1975

FILTER	DATE	SOLUBLE BOD			AMMONIACAL NITROGEN			OXIDISED NITROGEN		PERMANGANATE VALUE			DETERGENT (as manoxol)		
		INF	EFF	%R	INF	EFF	%R	INF	EFF	INF	EFF	%R	INF	EFF	%R
F	5th	68.2	5.9	91	42.9	39.8	11.0	2.4	5.9	38.6	14.0	64	16.6	0.2	98
G		82.5	2.8	97	42.6	22.5	52.0	2.5	18.2	38.6	13.6	65	15.4	0.1	98
F	14th	91.9	4.7	95	45.5	22.0	52	9.4	7.6	45.5	25.5	44	12.6	0.1	92
G		76.6	4.7	94	41.0	18.0	57	9.5	16.1	41.0	17.0	59	14.8	0.1	93
F	19th	85.5	15.9	81	29.0	23.8	12	9.4	11.2	50.2	21.8	57	25.6	0.2	91
G		84.2	10.6	87	28.6	15.4	46	9.5	12.1	51.6	13.8	73	22.2	0.1	95

FILTER	DATE	TEMPERATURE °C		AMMONIACAL NITROGEN			OXIDISED NITROGEN			B.O.D.			SUSPENDED SOLIDS		
	Depth(m)	0.0	0.5	0.0	0.5	%R	0.0	0.5	2.0	0.0	0.5	%R	0.0	0.5	2.0
F	5th	9.5	9.0	42.9	45.4		2.4	1.9	5.9	180.3	67.7	77	192	192	149
G		9.5	7.0	42.6	22.8	90	2.5	16.8	18.2	164.4	59.9	76	162	123	288
F	14th	7.0	3.0	45.5	17.7		9.4	2.2	7.6	199.5	18.6	86	40	101	48
G		6.5	3.0	41.0	16.2		9.5	10.2	16.1	189.2	35.5	89	32	77	22
F	19th	8.0	0.5	29.0	36.0		9.4	4.0	11.2	215.5	57.7	90	198	130	193
G		7.0	1.0	28.6	32.2		9.5	5.6	12.1	229.9	34.0	93	204	93	148

APRIL 1975

FILTER	**F**			**G**			**F**			**G**		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
BACTERIA												
Zoogloeal forms							6			4		
Sphaerotilus							2			2		
Beggiatoa												
Thiothrix												
FUNGI												
Subbaromyces							4	3				
ALGAE												
Chlorella							1			3		
Stigeoclonium							1			2		
Phormidium												

April 1975

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
OLIGOCHAETA												
Enchytraeidae												
Lumbricillus lineatus	150	610	25	200	90	60						
Enchytraeus albidus	10				10	20						
INSECTA												
Collembola												
Hypogastrura						10						
Diptera												
Psychoda												
larvae	80	290	200	20	180	50						
pupae		300			10							
flies												
Chironomidae												
larvae flies												
ARACHNIDA												
Mites (Mesostigmatidae)					10							
CRUSTACEA												
Canthocamptidae	1		5	10	20	8						

April 1975

FILTER	F			G			F			G		
DEPTH (m)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
PROTOZOA: CILIOPHORA												
HOLOTRICHIA												
Trachelophyllum pusillum												
Paramecium caudatum								3				
Colpidium colpoda											2	
Glaucoma scintillans								2	5	12	3	6
Colpoda inflata												
Chilodonella uncinata												
PERITRICHIA												
Vorticella sp.												
Telotrochs of *Vorticella*								1				1
Opercularia coarctata							15	1	1	3	5	8
SPIROTRICHIA												
Aspidisca costata												
Oxytricha sp.												
Stylonychia sp.												
PROTOZOA : MASTIGOPHORA												
Euglena sp.												
NEMATODA							18	1	3	6	1	3
ROTIFERA									1			1

APRIL 1975

DATE	FILTER	TEMPERATURE °C			LOAD	SETTLED BOD mgl^{-1}				SUSPENDED SOLIDS mgl^{-1}			
		INF	EFF	AIR	Kgm^{-3}	INF	EFF	FINAL	% rem	INF	EFF	FINAL	% rem
11th	F	8.5	8.0	7.0	0.57	236.2	28.3	41.4	82	196	166	94	52
	G	8.5	7.0		0.27	231.1	38.7	40.3	82	224	132	80	64
12th	F	9.5	10.5	12.0	0.56	233.8	39.2	27.5	72	228	218	107	53
	G	9.5	10.5		0.26	225.6	65.9	58.2	83	218	144	130	40
17th	F	10.0	11.0	10.0	0.45	188.6	39.0	27.9	85	202	255	100	50
	G	10.0	11.0		0.22	198.8	35.2	31.1	85	190	198	91	55
18th	F	9.5	10.5	12.0	0.24	100.0	6.8	7.9	92	116	188	48	60
	G	9.5	10.0		0.11	92.4	19.9	17.8	80	106	325	35	67
19th	F	10.0	11.5	16.0	0.23	95.0	10.2	10.2	89	134	119	61	55
	G	10.0	10.0		0.13	110.3	6.9	13.5	88	124	157	48	61
23rd	F	10.5	12.0	11.5	0.37	153.6	18.2	16.2	89	150	141	67	55
	G	10.5	11.0		0.19	163.8	13.4	17.4	89	92	124	39	60
24th	F	11.0	11.0	11.0	0.27	113.1	15.3	14.3	87	138	169	61	56
	G	10.5	11.0		0.12	107.1	15.9	16.5	85	134	155	43	68
25th	F	11.0	13.5	15.0	0.32	135.2	23.1	17.2	87	100	155	38	73
	G	11.0	12.5		0.15	135.2		13.3	90	142	112	37	63
30th	F	11.0	10.0	10.0	0.33	139.4	17.9	23.2	87	118	216	52	55
	G	11.0	7.0		0.16	144.5	21.2	31.9	85	146	251	47	68

	BOD					SUSPENDED SOLIDS			
	INF	EFF	FINAL	% rem	LOAD	INF	EFF	FINAL	% rem
F MEAN	154.9	22.6	20.6	85.5	0.37	153.5	180.8	70	57
S.D	53.5	11.5	10.5	5.7	0.12	44.5	42.7	24.6	6.7
C.V	34.5	50.7	50.8	6.7	34.7	29.0	23.6	35.3	11.9
S.E	17.8	3.8	3.5	1.9	0.04	14.8	14.2	8.2	2.2
G MEAN	156.5	27.5	26.6	85.1	0.17	153	177	61	61
S.D	51.7	17.4	15.2	3.4	0.06	47	69	32	9
C.V	33.0	63.2	56.9	4.0	33.5	31	39	53	14
S.E	17.2	5.8	5.0	1.1	0.02	16	23	11	3

APRIL 1975

FILTER	DATE	SOLUBLE BOD			AMMONIACAL NITROGEN			OXIDISED NITROGEN		PERMANGANATE VALUE			DETERGENT (as manoxol)		
		INF	EFF	%R	INF	EFF	%R	INF	EFF	INF	EFF	%R	INF	EFF	%R
F	17th	94.9	4.9	95	25.5	25.5		3.5	3.7	44.2	22.8	48	11.0	<0.1	91
G		93.9	6.1	93	35.5	18.7	27	3.3	10.1	44.2	20.8	53	9.0	<0.1	89
F	24th	46.1	4.4	90	23.0	21.2	8	6.5	8.0	41.4	15.6	62	19.6	0.1	95
G		40.1	5.5	86	21.9	17.5	20	5.9	11.7	40.6	14.8	64	15.2	0.1	93
F	30th	52.3	1.0	98	35.3	38.6		5.9	5.5	48.8	19.2	61	20.8	0.1	95
G		65.5	1.2	98	35.9	19.7	45	5.7	15.3	46.8	19.6	58	17.6	0.1	94

FILTER	DATE	TEMPERATURE °C		AMMONIACAL NITROGEN			OXIDISED NITROGEN			B.O.D.			SUSPENDED SOLIDS		
	Depth(m)	0.0	0.5	0.0	0.5	%R	0.0	0.5	2.0	0.0	0.5	%R	0.0	0.5	2.0
F	17th	10.0	11.0	25.5	29.3		3.5	2.0	3.7	188.6	54.2	83	202	210	255
G		10.0	11.0	25.5	29.3		3.3	2.7	10.1	198.8	73.9	71	190	200	198
F	24th	11.0	12.0	23.0	21.2		6.5	3.0	8.0	113.1	37.4	76	138	102	169
G		10.5	12.0	21.9	17.5	20	5.9	2.0	11.7	107.1	46.2	68	134	134	155
F	30th	11.0	11.0	35.3	45.7		5.9	1.9	5.5	139.4	41.9	80	118	135	216
G		11.0	12.0	35.9	35.0		5.7	4.3	15.3	144.5	53.4	74	146	138	251

MAY 1975

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
<u>BACTERIA</u>												
Zoogloeal forms	4			4			4	1		4		
Sphaerotilus												
Beggiatoa												
Thiothrix												
<u>FUNGI</u>												
Subbaromyces	8	3	1				8					
<u>ALGAE</u>												
Chlorella	2			4						4		
Stigeoclonium	2			4						4		
Phormidium												

May 1975

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
OLIGOCHAETA												
Enchytraeidae												
Lumbricillus lineatus	20	304	20	40	140	16						
Enchytraeus albidus		4		5		8						
INSECTA												
Collembola												
Hypogastrura												
Diptera												
Psychoda												
larvae	40	182	36	20	228	34						
pupae		4		4	16							
flies			12	8	8							
Chironomidae												
larvae			8									
flies												
ARACHNIDA												
Mites (Mesostigmatidae)					8	4						
CRUSTACEA												
Canthocamptidae				10		8						

May 1975

FILTER	F			G			F			G		
DEPTH (m)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
PROTOZOA: CILIOPHORA												
HOLOTRICHIA												
Trachelophyllum pusillum												
Paramecium caudatum		3										
Colpidium colpoda												
Glaucoma scintillans		1	15	100	3	6						
Colpoda inflata												
Chilodonella uncinata												
PERITRICHIA												
Vorticella sp.												
Telotrochs of Vorticella		1										
Opercularia coarctata	6	7	1	1	2	6						
SPIROTRICHIA												
Aspidisca costata			1									
Oxytricha sp.												
Stylonychia sp.			2									
PROTOZOA : MASTIGOPHORA												
Euglena sp.				6								
NEMATODA	7	1	5	4	2	5						
ROTIFERA												

MAY 1975

DATE	FILTER	TEMPERATURE °C			LOAD	SETTLED BOD mgl^{-1}				SUSPENDED SOLIDS mgl^{-1}			
		INF	EFF	AIR	Kgm^{-3}	INF	EFF	FINAL	% rem	INF	EFF	FINAL	% rem
7th	F	11.5	9.0	11.5	0.60	252.4	52.6	44.1	82	210	166	72	66
8th	G	11.5	9.5	8.5	0.23	200.1	56.1	61.0	70	160	127	97	40
16th	F	11.5	10.0	12.0	0.57	235.8	64.1	28.6	88	168	268	68	60
15th	G	11.5	6.5	7.0	0.19	171.5	33.6	38.2	78	143	148	67	53
21st	F	13.0	10.0	13.0	0.42	175.1	27.2	35.8	80	182	80	74	60
23rd	G	13.0	11.0	12.0	0.33	284.3	54.4	49.1	84	294	143	80	73
29th	F	12.5	10.5	8.0	0.46	189.9	62.3	56.3	70	186	130	52	72
	G	12.5	8.0		0.22	190.3	60.1	54.0	72	190	163	80	58

		BOD					SUSPENDED SOLIDS			
		INF	EFF	FINAL	% rem	LOAD	INF	EFF	FINAL	% rem
F	MEAN	213.3	51.5	41.3	80	0.51	186	138	66	64
	S.D	36.7		11.9	7.4	0.08	17	89	10	6
	C.V	17.2		28.8	9.3	16.9	9	65	15	9
	S.E	18.3		5.9	3.7	0.04	9	45	5	3
G	MEAN	211.5	51.0	47.2	76.0	0.24	197	145	81	56
	S.D	49.9		12.2	6.3	0.06	67	15	12	14
	C.V	23.6		25.8	8.3	25.1	34	10	15	24
	S.E	24.9		6.1	3.1	0.03	34	7	6	7

JUNE 1975

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
BACTERIA												
Zoogloeal forms	2			4			4			4		
Sphaerotilus												
Beggiatoa												
Thiothrix												
FUNGI												
Subbaromyces	10			2			12			6		
ALGAE												
Chlorella	2			4			1			1		
Stigeoclonium	2			2			1			1		
Phormidium												

June 1975

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
OLIGOCHAETA												
Enchytraeidae												
Lumbricillus lineatus							106	70	60	22	124	76
Enchytraeus albidus							7	10	15		4	4
INSECTA												
Collembola												
Hypogastrura									10			
Diptera												
Psychoda												
larvae							100	22	8	184	40	16
pupae							3			4		
flies												
Chironomidae												
larvae									11			7
flies												
ARACHNIDA												
Mites (Mesostigmatidae)												
CRUSTACEA												
Canthocamptidae												

June 1975

FILTER	F			G			F			G		
DEPTH (m)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
PROTOZOA: CILIOPHORA												
HOLOTRICHIA												
Trachelophyllum pusillum												
Paramecium caudatum												
Colpidium colpoda												
Glaucoma scintillans												
Colpoda inflata							10		100			
Chilodonella uncinata												
PERITRICHIA												
Vorticella sp.												
Telotrochs of Vorticella												
Opercularia coarctata							5	44	7			
SPIROTRICHIA												
Aspidisca costata								2	34			
Oxytricha sp.								1	3			
Stylonychia sp.												
PROTOZOA : MASTIGOPHORA												
Euglena sp.							1					
NEMATODA							1	7	4			
ROTIFERA												

JUNE 1975

DATE	FILTER	TEMPERATURE °C			LOAD	SETTLED BOD mgl^{-1}				SUSPENDED SOLIDS mgl^{-1}			
		INF	EFF	AIR	Kgm^{-3}	INF	EFF	FINAL	% rem	INF	EFF	FINAL	% rem
12th	F	15.0	18.0	22.0	0.77	324.0	54.2	40.5	87	202	113	36	82
11th	G	15.0	13.0	17.0	0.36	310.1	15.6	9.0	97	202	242	57	72
18th	F	15.0	15.0	16.0	0.64	266.7	21.4	38.3	86	228	193	94	60
13th	G	15.0	13.0	17.0	0.28	247.3	29.9	20.6	92	210	282	47	78
20th	F	15.0	17.0	18.0	0.76	318.5	60.5	43.4	86	296	237	58	80
19th	G	15.0	14.0	16.0	0.28	248.7	16.3	17.3	93	226	129	63	72
26th	F	16.5	18.0	22.0	0.58	242.2	55.0	58.8	85	170	171	67	60
25th	G	16.0	15.0	16.0	0.35	309.8	22.2	18.6	94	220	191	40	82

		BOD					SUSPENDED SOLIDS			
		INF	EFF	FINAL	% rem	LOAD	INF	EFF	FINAL	% rem
F	MEAN	287.8	47.7	45.2	86	0.68	224	178	64	70
	S.D	39.9	17.8	9.3	0.8	0.10	53	51	24	12
	C.V	13.0	37.0	20.0	0.0	14.0	23	28	37	17
	S.E	19.9	8.9	4.6	0.4	0.0	27	26	12	6
G	MEAN	278.9	21.0	16.4	94	0.31	214	211	50	76
	S.D	35.8	6.6	5.1	2.1	0.0	11	66	9	49
	C.V	12.0	31.0	31.0	2.0	0.0	4	31	16	6
	S.E	17.9	3.3	2.6	1.1	0.0	5	33	4	2

JULY 1975

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
BACTERIA												
Zoogloeal forms	2			2			4			4		
Sphaerotilus												
Beggiatoa												
Thiothrix												
FUNGI												
Subbaromyces	10	1		4			10	4		4		
ALGAE												
Chlorella	2			4			2			3		
Stigeoclonium	2			3			2			3		
Phormidium												

July 1975

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
OLIGOCHAETA												
Enchytraeidae												
Lumbricillus lineatus	78	128	20	8	20	6						
Enchytraeus albidus	6	4	4	1		1						
INSECTA												
Collembola												
Hypogastrura			8		4							
Diptera												
Psychoda												
larvae	492	140		80	16	4						
pupae	44	52		8	4	4						
flies	16	4										
Chironomidae												
larvae			44			17						
flies												
ARACHNIDA												
Mites (Mesostigmatidae)		4	4		4							
CRUSTACEA												
Canthocamptidae												

July 1975

FILTER	F			G			F			G		
DEPTH (m)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
PROTOZOA: CILIOPHORA												
HOLOTRICHIA												
Trachelophyllum pusillum												
Paramecium caudatum												
Colpidium colpoda												
Glaucoma scintillans	15	24	50	1	5	8						
Colpoda inflata												
Chilodonella uncinata												
PERITRICHIA												
Vorticella **sp.**												
Telotrochs of *Vorticella*												
Opercularia coarctata	1	3	2									
SPIROTRICHIA												
Aspidisca costata		5	1		15	4						
Oxytricha **sp.**			10		4							
Stylonychia **sp.**												
PROTOZOA : MASTIGOPHORA												
Euglena **sp.**												
NEMATODA	4	21	24	3	6	4						
ROTIFERA												

JULY 1975

DATE	FILTER	TEMPERATURE °C			LOAD	SETTLED BOD mgl^{-1}				SUSPENDED SOLIDS mgl^{-1}			
		INF	EFF	AIR	Kgm^{-3}	INF	EFF	FINAL	% rem	INF	EFF	FINAL	% rem
2nd	F	16.5	18.0	20.0	0.61	254.3	33.0	37.4	85	200	211	90	55
3rd	G	16.5	17.0	21.5	0.27	236.0	33.3	22.1	91	182	313	34	81
11th	F	17.0	17.0	16.5	0.73	306.2	22.9	21.2	93	192	166	53	73
10th	G	17.0	15.0	19.0	0.19	166.5	40.8	6.3	96	168	230	30	82
17th	F	17.5	19.0	19.0	0.77	322.7	31.3	30.8	90	254	190	70	78
16th	G	17.5	15.5	19.0	0.37	320.6	22.0	16.5	95	286	125	29	91
24th	F	17.0	14.0	15.5	0.47	197.8	28.4	20.2	90	228	244	67	71
23rd	G	17.0	16.0	17.0	0.33	286.9	7.9	17.7	94	176	87	43	75

		BOD					SUSPENDED SOLIDS			
		INF	EFF	FINAL	% rem	LOAD	INF	EFF	FINAL	% rem
F	MEAN	267.5	58.9	27.4	89.5	0.64	218	200	70	69
	S.D	57.7	4.4	8.2	3.3	0.13	28	33	15	10
	C.V	21.0	15.0	29.9	3.7	20.9	13	16	22	14
	S.E	28.8	2.2	4.1	1.6	0.06	14	16	8	5
G	MEAN	252.5	26.0	15.6	94	0.29	203	189	34	82
	S.D	67.0	14.3	6.7	2.1	0.07	56	102	6	7
	C.V	26.5	55.1	42.7	2.3	26.9	27	54	19	8
	S.E	33.5	7.2	3.3	1.0	0.03	28	51	3	3

AUGUST 1975

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
BACTERIA				6								
Zoogloeal forms												
Sphaerotilus												
Beggiatoa												
Thiothrix												
FUNGI												
Subbaromyces	10	7	1	2								
AIGAE												
Chlorella				3								
Stigeoclonium				5								
Phormidium												

August 1975

FILTER	F			G			F			G		
DEPTH (M)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
OLIGOCHAETA												
Enchytraeidae												
Lumbricillus lineatus	20		20			16						
Enchytraeus albidus	1	4	11									
INSECTA												
Collembola												
Hypogastrura			4		10	28						
Diptera												
Psychoda												
larvae	260	8	16	16		4						
pupae	40											
flies												
Chironomidae												
larvae			12			8						
flies												
ARACHNIDA												
Mites (Mesostigmatidae)												
CRUSTACEA												
Canthocamptidae												

August 1975

FILTER	F			G			F			G		
DEPTH (m)	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5	0.0	0.5	1.5
PROTOZOA: CILIOPHORA												
HOLOTRICHIA												
Trachelophyllum pusillum			40		2							
Paramecium caudatum												
Colpidium colpoda												
Glaucoma scintillans		1	2	3	16	1						
Colpoda inflata												
Chilodonella uncinata												
PERITRICHIA												
Vorticella sp.												
Telotrochs of *Vorticella*		1										
Opercularia coarctata	5	7	1	17	2							
SPIROTRICHIA												
Aspidisca costata		46	55		6	4						
Oxytricha sp.												
Stylonychia sp.			2									
PROTOZOA : MASTIGOPHORA												
Euglena sp.												
NEMATODA	3	1	2	1	3	4						
ROTIFERA		2	5		1							

AUGUST 1975

DATE	FILTER	TEMPERATURE °C			LOAD	SETTLED BOD mgl^{-1}				SUSPENDED SOLIDS mgl^{-1}			
		INF	EFF	AIR	Kgm^{-3}	INF	EFF	FINAL	% rem	INF	EFF	FINAL	% rem
1st	F	17.5	16.0	16.5	0.74	308.8	21.5	28.5	91	174	80	62	65
31st	G	17.5	15.5	18.0	0.26	231.2	31.5	14.5	94	192	89	44	77
7th	F	17.5	16.0	21.0	0.72	300.0	28.7	27.3	91	189	70	50	74
6th	G	17.5	16.5	20.0	0.29	250.0	20.1	15.2	94	200	89	30	85

	BOD					SUSPENDED SOLIDS			
	INF	EFF	FINAL	% rem	LOAD	INF	EFF	FINAL	% rem
F MEAN	304.4	27.9	25.1	91.0	0.73	181	75	56	69
S.D	6.2	0.8	5.0		0.01	11	7	8	6
C.V	2.0	3.0	20.3		1.9	6	9	15	9
S.E	4.4	0.6	3.6		0.01	7	7	5	6
G MEAN	240.6	25.8	14.7	94	0.27	196	89	37	81
S.D	13.2	8.0	0.3		0.02	6		10	6
C.V	5.5	31.2	2.4		8.1	3		27	7
S.E	9.4	5.7	0.2		8.0	4		7	4