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PROGRESS REPORT (PHASE II)

for the attention of the

UK OVERSEAS DEVELOPMENT ADMINISTRATION

'RURAL WATER TREATMENT PACKAGE PLANT'

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ABSTRACT

Following progress detailed in the first report for the UK Overseas Development Administration, a further eight months experimental and development work has been completed. Monitoring of the small scale protected slow sand filtration process has now been undertaken for both winter and summer operating conditions. This report therefore concludes the first phase of evaluation of the packaged water treatment plant at the University of Surrey Manor Farm site.

It should be noted that the raw water quality conditions throughout the period described in this report were again far from ideal, but that the process nevertheless achieved its target efficiencies, often exceeded them, and provided water of consistently potable quality from a heavily contaminated surface water source for prolonged periods.

Also accomplished during this phase was the successful transfer to Peru of the personnel and equipment involved in the water supply intervention.

This report includes description of the development of the treatment plant, including the design and production of treatment tanks, flow control devices, abstraction packages, underdrainage and distribution networks. Brief reviews of comparable technologies to those already adopted and under active consideration for augmentation of the U.O.S.-O.D.A. package are presented. Detailed analysis of the scientific data obtained during the period of operation April-October 1983 is included, together with further evidence of the efficiency of the concepts of prefiltration, filter fabric protection of slow sand filtration, and maintenance of continuity by semi-automatic flow control.

SECTION 1

Restatement of Project Philosophy and Research Priorities

The 1970 Community Water Survey of the US Public Health Service demonstrated that 50% of US communities of less than 500 persons received water supplies which failed to conform to the 1962 Public Health Service drinking water standards (USPHS, 1970). In 1980, the first major outbreak of waterborne disease in the UK for over 40 years occurred in the small Yorkshire town of Bramham. Over 1,000 people suffered a sharp attack of gastroenteritis (Lewis, 1983).

Perhaps it is unsurprising that those incidents of serious microbiological contamination of public water supplies which do occur in industrialised countries do so in small, usually rural communities. What is more pertinent however is the recognition by water authorities backed by surveys such as those of the USPHS that such incidents are becoming more frequent (Craun and McCabe, 1973) despite the introduction of increasingly automated process control. It is the contention of the authors that these incidents do not provide an argument for yet higher levels of technological intervention in the maintenance of safe water supplies for rural communities. On the contrary, it is arguable that reliance on single stage treatment processes in the absence of effective monitoring or communications represents a serious erosion of a fundamental principle of public water supply: the multiple barrier principle of protection against the transmission of waterborne disease.

The relevance of this argument to the development of appropriate water treatment processes for rural communities in the third world is quite clear. If the currently available technological barriers to waterborne and water washed disease have a poor record in many developing countries, it is axiomatic that the promotion of higher technology solutions to achieve acceptable levels of safety is probably of waste of time.

The failure of some water supply facilities in Peru may be attributable to the selection of inappropriate processes (if automated coagulation and disinfection occassionally fail in industrialised countries, how much more likely are they to fail in areas of the world where power supplies, the availability of chemicals and spare parts are unreliable or absent?). However, the most common cause of inefficiency and even paralysis of simple treatment plants in Peru and elsewhere is not one of inappropriate technology, it is one of inadequate support and a lack of basic training in operation and maintenance (Pardon et al , 1983; Grombach, 1965; Hespanhol, 1969). Fortunately some steps are now being taken to remedy this by the inception of in-country training schemes (IDRC, 1980, Clark, 1982).

It is conventional to describe the aforementioned multiple barrier principle in terms of those physical and biological processes which are most easily linked for efficiency of treatment and safety of water supplies - figure 1 (Lloyd, 1974). But there is considerable value in defining the principle in a much broader sense - to incorporate what may be termed organisational barriers to the transmission of waterborne and water washed disease. These barriers are of universal relevance and would include (in no particular order):

1: optimal source selection;
2: effective process supervision (operation and maintenance);
3: public health awareness of the operatives and consumers;
4: regular water quality monitoring of source, treated and supply waters;
5: effective communications between those responsible for maintenance, water quality inspection and consumers;
6: adequate provision of financial and human resources to rectify problems and undertake repairs.

The above features introduce concepts of communication and community participation which are essential in the successful prosecution of rural water supply programmes. However, Feacham (1980) has drawn attention to the

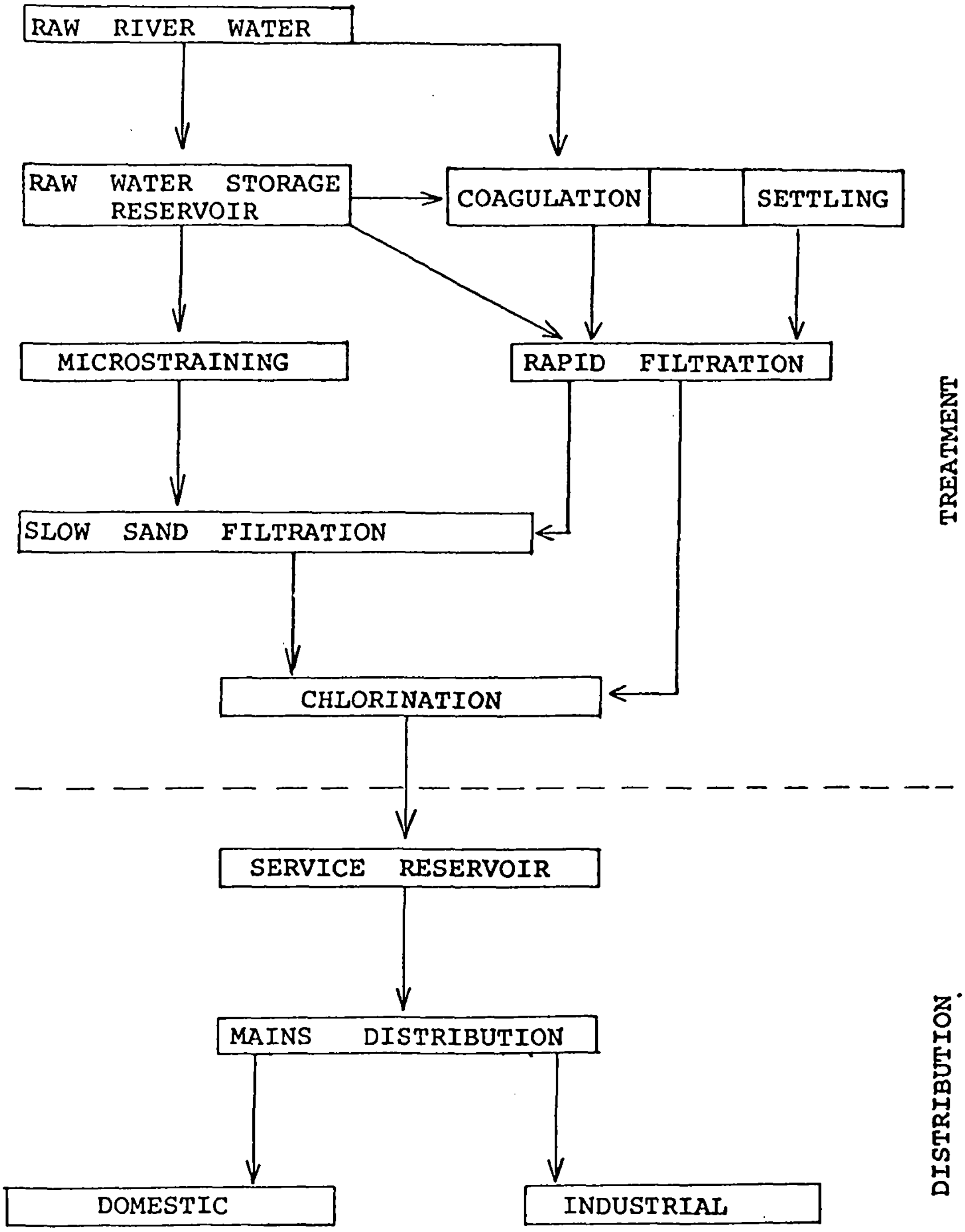

Figure 1. Flow Chart Demonstrating some of the Alternative Unit Processes for River Water Treatment, Applying the Multiple Barrier Principle

After Lloyd (1974)

dangers of a simplistic approach to appropriate technology and community participation. He takes the view that efficient bureaucrasies with standardised relationships between local (or national) government and the community are most likely to sustain successful, integrated water treatment projects. Community participation is vital in many areas eg. education, but it should not be assumed that it will guarantee maximum benefits or efficiency. Similarly, whilst the technology must be appropriate, taking full account of user preference and economic and social constraints, it will not in itself ensure acceptance - whatever the level of apparent suitability for the recipient community. Comprehensive approaches to the successful planning of water supply interventions are available (Cairncross *et al*, 1980; Reid and Coffey, 1978).

Whilst accepting these arguments and approaches and incorporating them within the broadened definition of the multiple barrier principle, there still remains an overwhelming responsibility on the part of the installing authorities, be they governmental or aid agency, to devote considerable efforts to the selection of those unit processes most likely to succeed on a technological level.

The reality in many rural areas of the developing countries is that treatments involving the addition of chemical agents are likely to be unreliable or unpopular due to the difficulties of maintaining supplies and achieving accurate dosing. Thus both coagulation and terminal disinfection are presently precluded from consideration on a village level in many circumstances. To retain the multiple barrier principle therefore, in both treatment processes and organisation, the following model may be considered (figure 2).

It is obvious that to be considered worthwhile in health terms the combination of processes selected must remove or reduce to acceptable levels those microorganisms responsible for diarrhoeal and other waterborne and

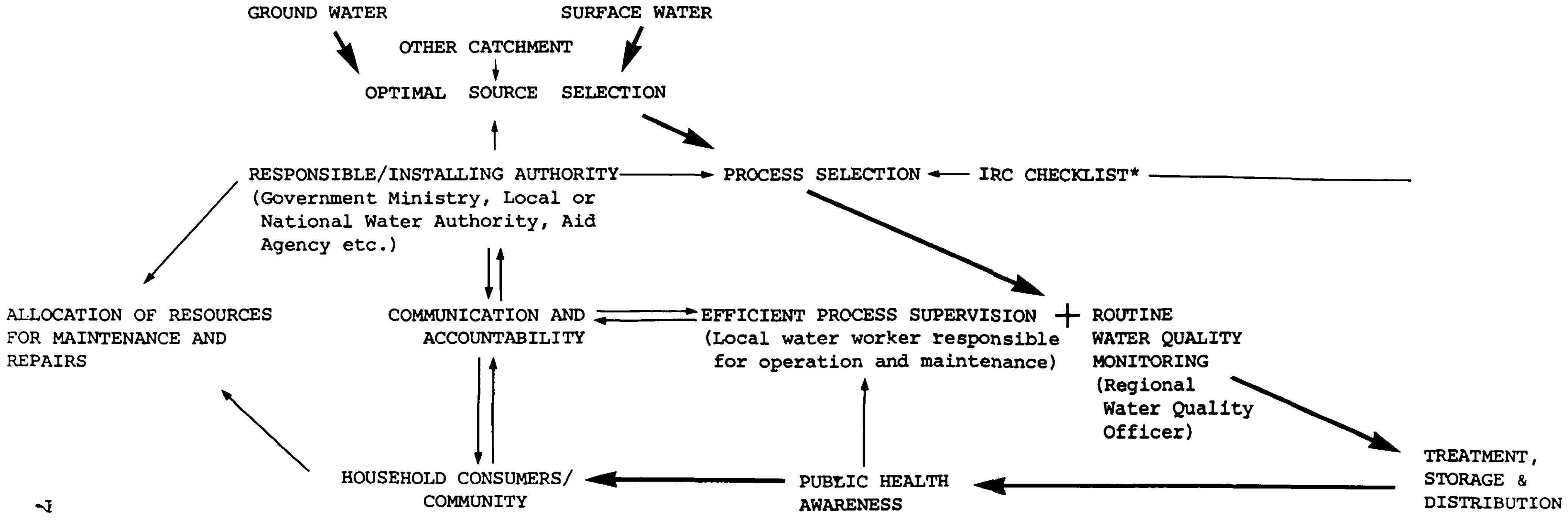

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FIGURE 2: Organisational barriers to the transmission of waterborne disease. * See over.

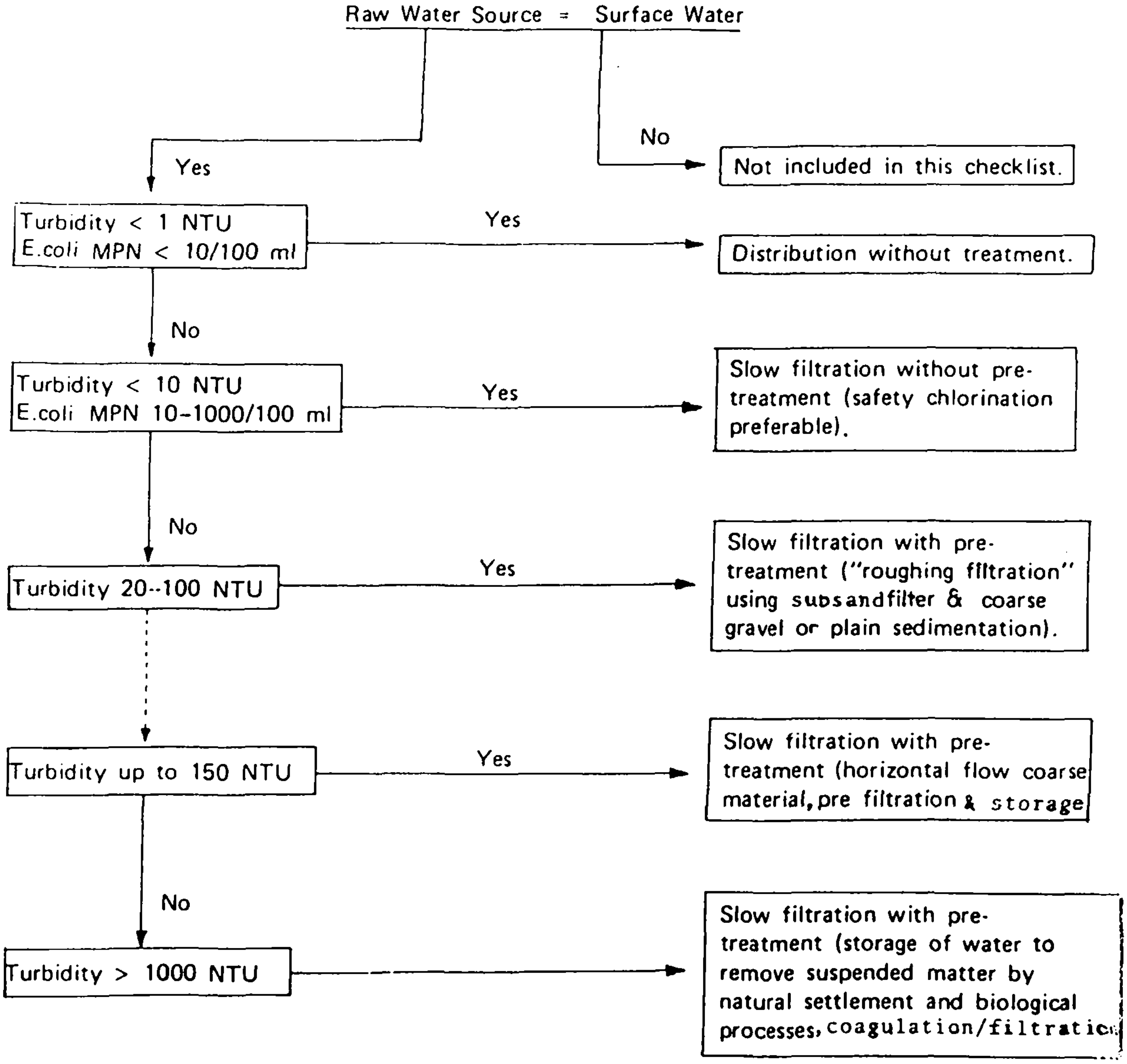


Figure 2 cont. IRC Checklist for the selection of water treatment processes suitable for the treatment of surface waters.

water washed disease. Where reliable terminal disinfection is practised this is not usually a problem, even where levels of contamination are gross. However, in the absence of disinfection, the efficient treatment of surface waters in rural locations in developing countries will almost invariably depend on a combination of processes which incorporates as its centre piece slow sand filtration. Thus, it is the central purpose of this research and demonstration project to establish:-

1: that slow sand filtration can be successfully scaled down and adapted for small rural communities in the third world;

2: that on that level, the process retains its cost-effectiveness, simplicity and flexibility for integration with other health and hygiene programmes;

3: that the process can effect substantial reductions in numbers of human enteric viruses - a major cause of diarrhoeal disease - a feature not sufficiently investigated on any scale to date.

SECTION 2

Slow Sand Filtration

It is not intended here to provide the usual review of the functional mechanisms, the advantages and applicability of slow sand filtration in the treatment of surface waters. These have been summarised in the project proposal document (Lloyd, 1982) and more comprehensive reviews of this nature are available (Huisman and Wood, 1974; Lloyd, 1974; Huisman, 1975). Similarly, it is not considered worthwhile to restate the design criteria for conventional slow sand filtration in developing countries which are dealt with in excellent detail by such authorities as the International Reference Centre for Community Water Supply and Sanitation (van Dijk and Oomen, 1978), and the Asian Institute of Technology (Thanh and Pescod, 1976). A detailed review of the mechanisms of slow sand filtration, in particular how they effect the removal of pathogenic bacteria and the human enteric viruses will be provided at a later date.

At this point it is considered more valuable to present a brief summary of the state of current research on small scale slow sand filtration and place the design, construction, operation and maintenance features of the UOS-ODA package water treatment plant in the context of other international initiatives. In this respect, the most encouraging developments have occurred at a time when the International Drinking Water Supply and Sanitation Decade has focussed global attention on the water treatment needs of rural village communities in developing countries. Seven countries, moreover, have been actively participating in the Slow Sand Filtration Demonstation Programme of WHO/IRC. They are India, Ghana, Kenya, Sudan, Colombia, Thailand and Jamaica and an appraisal of general progress is available (IRC, 1980).

Experience in these countries allowed the IRC to formulate general guidelines for planning, community contribution, design and construction, operation and maintenance, the operator, health education, impact studies and recommendations for further researches in slow sand filtration. The two topics of concern in this review are summarised below.

Design and Construction

The principle of flexibility and allowance for population growth is stressed, thus a sand filter system may be augmented towards the end of a 10-15 year design period by addition of more filtration area if community size and/or water use/expectations have increased. A minimum provision of two sand filters ensures continuity of treatment during cleaning. For villages of less than 800-1200 persons, pre-fabricated units are likely to be more economic than filters constructed conventionally on site. Optimal use should be made of gravity flow to minimise on-site costs for pumping. The minimum operational filter bed thickness should be 0.6-0.7 m i.e. 0.9-1.0 to allow for skimming. Builder grade sand has proven perfectly satisfactory as a substitute for graded sand.

Operation and Maintenance

Intermittent operation should be prohibited, but declining rate filtration (ie overnight reduction in supernatant head during the absence of the plant operator) may be tolerated. Cleaning should be accomplished by skimming when the design flow can no longer be maintained. Backfill water should be supplied from treated water storage tanks or an adjacent filter. A period of at least 24 hours must elapse before bringing a filter back into supply. Adequate records of flow rates and disinfectant doses (where practised) should be kept locally, and complete physico-chemical and bacteriological monitoring undertaken by regional laboratories on a periodic basis.

The above topics will now be discussed in greater detail with reference to the criteria adopted for the UOS-ODA package.

Design and Construction

Some of the most comprehensive investigations of small scale slow sand filtration in developing countries to date have been undertaken by the National Environmental Engineering Research Institute (NEERI), Nagpur, India. Two project reports are available (Sundaresan, B.B. and Paramasivam, R., 1982; NEERI, 1977) and particular attention has been devoted to design parameters such as filtration rate, discontinuous versus continuous operation, effect of covering, effect of pollution, and selection of filter medium (sand grade).

There is now general acceptance of the fact that flow rates for slow sand filtration may exceed 0.3-0.4 m/h without any deterioration in filtrate quality (physical or bacteriological). In fact, higher flow rates tend to reduce dissolved oxygen depletion and yield higher overall outputs of water per filter run (NEERI, 1977). Nevertheless, a law of diminishing returns operates where owing to the frequency of cleaning operations at high flow rates, there eventually results an unacceptably high proportion of down-time compared to running time (Kerkhoven, 1979). However, flow rates as high as 0.6 m/h have been recommended (Agarwal, undated) on economic grounds. The UK Thames Water Authority currently operates several of its largest slow sand filtration works at flow rates well in excess of 0.3 m/h - this represents a doubling of the design rate in some circumstances. Huisman and Wood (1974) consider flow rates between 0.1 and 0.4 m/h to be normal and reported no significant difference in efficiency of filtration at rates of 0.1, 0.25 and 0.45 m/h. The design flow of the UOS-ODA plant is 0.2-0.45 m/h.

The use of builder grade sand has been demonstrated to function at least as efficiently as optimally graded sand (Ives and Jain, 1971-74) and that in fact, longer filter runs may result from the use of coarser sands than conventionally recommended (NEERI, 1977; Bowles _et al_, 1983). THe UOS-ODA plant has allowed _in situ_ grading of the filter medium by a backwashing process, and whilst this has facilitated the production of a sand close to the optimal specifications (von Dijk and Oomen, 1978) the most important priority is the reduction of the silt content of the sand (Wheeler _et al_, 1983).

The depth of medium should not fall below 0.6 m (IRC, 1980). The UOS-ODA system incorporates a depth of sand and filter fabric of 0.6 m ie the lowest limit, but there is usually little necessity for skimming and consequent loss of material.

The selection of the principal filter medium is to a large extent governed by the availability of appropriate local materials. This will invariably be sand (usually ungraded) in many parts of the world, but other options are available. A dual filtration system based on shredded coconut husks (roughing filtration) and burnt rice husks was described by Frankel (1972 and 1974). This concept has since been developed (Thanh and Pescod, 1976; Frankel, 1981; Barnes and Mampitiyarachichi, 1983) with excellent results. Multi-medium filters have been used, employing gravel, sand and charcoal (Merchant, undated), and dual media filters also investigated (Renade _et al_ , 1976).

However, accepting that sand will usually be the preferred material, there are methods of optimising its efficiency as a biological filtration medium. The incorporation of synthetic filter fabrics as a top layer in slow sand filtration gives a dual medium function which can significantly improve filter run lengths and aid the maintenance of biological continuity. Recently this concept has been used to good effect in OXFAM's water treatment package for disaster relief (Lloyd _et al_ , 1983). Gould (1982) poses questions concerning the biological and physical nature of the filtration afforded by layers of synthetic fabric. The UOS-ODA system utilises sand filtration, protected and enhanced by the incorporation of a multi-layer of fabrics which alternate in density (Wheeler _et al_ , 1983; Pardon _et al_ ,1983). It is demonstrated later in this report how this configuration may be adapted to considerable advantage in terms of efficiency and ease of maintenance.

The effect of covering or shading on the efficiency of slow sand filtration is not great (NEERI, 1977). However, there is no doubt that on a small scale it is advisable. Firstly, because a small filter is very vulnerable to direct pollution eg by the defaecation of birds. Burman (1962) considered this factor to be one of the potential causes of poor filter performance immediately subsequent to cleaning. Secondly, the cover will prevent some heat loss in severe cold conditions (more important on a small scale). Thirdly, the growth of unicellular algae in the supernatant water will be inhibited thus avoiding premature blockage. Houghton (1970) quotes experience in Holland which indicated that covering of slow sand filters allowed a four-fold increase in filtration rates in certain circumstances. The UOS-ODA package incorporates a removable but integral fitted lid.

The need for flexibility means that for populations of less than 800 persons, it is almost certain that pre-fabricated units will prove most appropriate and economic. Such packages are available (Dhabadgaonkar, 1975; Korabelnikov, 1975; Alagarsamy and Gandhirajan, 1981) and usually include a terminal disinfection stage. Paramasivam et al., (1981) consider a modular design of treatment plant to be ideal in order to allow for expansion of the system. In this respect the UOS-ODA plant meets the requirements of flexibility, economy and reliability, being based on the concept of dual filtration by portable modules. The slow sand filters have a filtration area of 1.5 m^2 and will normally be linked in clusters of 2, 3 or 4 units to give a supply of 32-65 m^3/day (at the maximum flow rate of 0.45 m/h), sufficient for a population of up to 1000 persons (c.f. Wheeler et al, 1983). This allows for 50 litres treated water per capita per day and a population growth of 30% over the 15 year design period. In the event of a community eventually outgrowing this system and requiring conventional construction, the option of dismantling and removal to a smaller community is available (Appraisal recommendation 1.3.3., IRC, 1980).

Operation and Maintenance

Several important aspects of operation and maintenance have already been mentioned in the previous section on design and construction e.g. filtration rate and filter protection. However, a crucial aspect of the duties of the water treatment plant operative is the maintenance of continuity of 1) supply and 2) process efficiency. The provision of adequate training in good works practice is, of course, a pre-requisite if the operative is to achieve such continuity. Training should include not only practical details of mechanical maintenance but also sufficient briefing on the nature of the processes involved to ensure that operations such as filter cleaning, backfilling, sand washing and flow control are undertaken diligently and with care.

Guidelines for the successful operation and maintenance of slow sand filtration are available (Huisman, 1974; Huisman, 1975; van Dijk and Oomen, 1978; Hartong, 1978; Huisman _et al_ , 1981; Thanh and Hettiaratchi, 1982). The most frequently neglected aspect of sand filtration maintenance is regular cleaning. This is normally effected by a process termed 'skimming' where the raw water inlet to the filter is closed and the water in the filter allowed to drain down to approximately 10 cms below the sand surface. The top 2-3 cms of sand containing the majority of silt and biological growth (the schmutzdecke) are then physically removed; on a small scale blunt-nosed shovels are used, on a large scale powered vehicles with specially orientated blades may be employed. At this point a volumetric silt test of the newly exposed sand layer may be undertaken and provided that silt penetration has been low (ie the content is less than 10% by volume), no further skimming is indicated. The filter is then vacated and stored treated water is used to backfill the filter bed. If this step is omitted the filter may suffer from air entrapment with consequent loss of available filter medium. Sand which has been skimmed is not usually discarded but washed on site to be returned when the sand bed is nearing its minimum depth of 0.6-0.7 m.

The sand filter should be reset running at a low flow rate for a day before opening the outlet valve to allow the full design flow through the filter. The disturbance of the biological mechanisms of the bed by the fairly traumatic operation of skimming means that the filter may not recover its efficiency for several days - longer in low water temperatures. Thus it is very important to run the recently cleaned filter to waste for a period - particularly if no terminal disinfection is practised. It is also important therefore to operate at least two filters in parallel to avoid a cut in water supplies during this period and equally important that filters are cleaned in rotation - not all together.

Another misunderstood aspect in the maintenance of continuity is the avoidance of unnecessary fluctuations in flow rate and supernatant head level. The biological flora and fauna function most efficiently with uniform loading of nutrients ie water quality. Fluctuations disturb the balance of the microbiological populations and result in inefficiency. Thus, flow rates should be maintained as constant as possible - usually by daily adjustment of the outlet valve. Similarly, as much protection of the slow sand filter as possible should be afforded by the application of pretreatment stages which even out the 'peaks and troughs' of water quality.

Recognising these priorities, the UOS-ODA plant incorporates several novel 'process aids' which will significantly increase the likelihood of proper operation of the maintenance procedures. They have been described in some detail (Pardon et al, 1983) and that publication is reproduced in Appendix I.

SECTION 3

Prefiltration

Where raw surface water turbidities exceed 10 NTU, it is generally accepted that some form of pre treatment is advisable in order to avoid premature clogging of the slow sand filter and unacceptably short filter runs (Lloyd et al, 1983). The means of pre treatment most frequently employed include:- coagulation, rapid sand filtration, or micro-straining (mostly industrialised countries), reservoir storage, infiltration, roughing filtration and sub-sand abstraction (universal). Of these only the last four may be considered feasible in rural locations in developing countries. In most circumstances storage or infiltration will be precluded from consideration due to geographical, civil engineering and economic constraints. Thus in many cases, sub-sand abstraction or roughing filtration will present the likeliest options for the clarification of turbid waters prior to village scale slow sand filtration.

Whilst the UOS-ODA package was originally based on the concept of dual sand filtration, it is now recognised that gravel prefiltration may be as efficient as sub-sand abstraction, but that the process requires significantly less maintenance and in many cases obviates the need for pumping. Bearing in mind the recommendations (1.3.4) of the International Reference Centre for Community Water Supply (IRC, 1980) and the potential for maximising the benefit of gravity supply in the upland regions of South America, horizontal gravel filtration is now included as a pretreatment option.

Horizontal coarse medium filtration was employed as a protection to sand filtration by John Gibb (Paisley, Scotland) as early as 1804 (Baker, 1949). A 23 metre trench, 2.4 x 1.2 m section, provided roughing filtration and was operated at a flow rate of 0.43 m/h. Since then, the concept of roughing filtration has been somewhat neglected in industrialised countries, reliance being increasingly placed on reservoir storage, rapid sand filtration and latterly ie this century, micro-straining and chemical clarification. Nevertheless, interest in the processes of coarse filtration is currently being regenerated - most notably in developing countries.

Sevilla (1971) investigated on a laboratory scale the function of roughing filters with respect to optimum filtration rates and influent turbidity limits. It was concluded that a 'series filtration' system comprising prefiltration and slow sand filtration was most appropriate for the minimisation of labour and training costs in surface water treatment. Kuntschick (1976) described the efficiency of full-scale horizontal gravel filters operating at velocities of approximately 1.5-20 m/h. Even at the high flow rates, substantial reductions in suspended solids loading were achieved. Attention was drawn to the low frequency of maintenance (up to 60 months between cleaning) and the phenomenon of a maturation process which took approximately 14 days.

Lower flow rates are recommended by the WHO/IRC (van Dijk and Oomen, 1978); using filter bed depths of approximately 1 m and lengths of between 4 and 10 m, they suggest filtration rates of between 0.4 and 1.0 m/h. The use of alternating coarse and fine gravel is also recommended. Thanh (1978) employed an alternating series of gravel media and obtained turbidity removals of around 50% and coliform reductions of around 80% in filters 6 m x 2 m x 0.8 m operated at approximately 1.5 m/h. More recently, Thanh and Hettiaratchi (1982), whist retaining the principle of gravel size variation, recommended the lower flow rates of 0.5 m/h for influent turbidities in the range 15-50 NTU and 0.3 m/h for turbidities of up to 150 NTU. Turbidity and coliform reductions of 60-70% and 80% respectively may then be expected.

Huisman <u>et al</u>, (1981) suggest flow rates of 0.5-1 m/h for longitudinal gravel filtration, again with different gravel sizes in series. The general consensus is endorsed by CEPIS (1982) who have investigated the viability of horizontal prefiltration in South America. Using 3 stage gravel filtration (in decreasing size ranges) a 10 m filter was successfully operated at a flow rate of 0.5 m/h.

A detailed series of laboratory and field trials has been undertaken at the University of Dar es Salaam, Tanzania (Wegelin, 1980; Wegelin, 1980; Mbwette and Wegelin, 1982). Particularly encouraging were indications that with pretreatment by horizontal gravel roughing filtration (HRF) slow sand filter run lengths may be considerably prolonged.

Although long term operational data from the Tanzanian trials are not yet available, several interesting observations have been made. In general, it appears that efficiency increased both with increasing filter length and decreasing filtration rate. This implies that retention time may well be the most critical factor in optimal performance of horizontal gravel filtration. Again, in general the smaller the aggregate size, the more efficient the turbidity removal; this is not unexpected. Nevertheless the designs recommended include provision for three or four separate zones of filter medium with grain sizes in the range 2-40 mm. It is suggested that attaining high porosity by selecting media of high uniformity will further increase efficiency.

The converse of horizontal gravel filtration ie. upflow filtration is also discussed by both WHO/IRC and CEPIS, each recommending 3 layer gravel beds of 2 m and 0.8 m depth respectively. Cleaning of upflow filters is particularly simple and is effected by a rapid drain-down or gravity backwash. Possible filtration rates appear to vary widely within the range 0.25 to 20 m/h.

The use of river bed infiltration as a prefiltration step, usually using gravity percolation and collection via a network of underdrains is well known (van Dijk and Oomen, 1978; Thanh and Hettiaratchi, 1982). Methods for increasing the water availability from a small river bed site by sub-sand abstraction using a pump are also available (Cansdale, 1982). However, unless sited in a fairly fast flowing river these systems are not usually self cleaning and require maintenance on a periodic basis i.e. scraping or backwashing to overcome blockage.

The UOS-ODA package has provision for upflow gravel prefiltration as an intermediate stage between sub-sand abstraction and slow sand filtration. It is feasible that horizontal gravel prefiltration may be capable of replacing both prefilters in certain circumstances, since there would not be the requirement for the extra buffer during weekly or bi-weekly maintenance of the sub-sand unit.

SECTION 4

The Development of Hardware Specifications

Having run two small experimental slow sand filters (0.8 m^2), the first design-scale (1.5 m^2) slow sand filter was commissioned on May 9th 1983. This module was roughly cubic, 4'x4'x 4', constructed of polyethylene (medium density) and supported by a rigid frame (Plate 1). The tank was a commercially available unit (WCB Rotomoulding Ltd., Stalybridge, UK) but it was not entirely appropriate for our purposes. Following consultation with the manufacturers, it was apparent that using the rotation moulding process, an MDPE tank could be produced to our precise specifications at relatively low unit cost. One such unit was provided and installed on August 5 this year (Plates 1 and 2, Figure 3). Following initial testing and acceptance of the production model which included provision for covering, underdrainage, and filter fabric support, further tanks were produced for shipment to Peru.

The necessity for semi-automatic flow control to obviate the need for daily adjustment of flow rates (to account for filter blockage) was met by the design and development of a constant flow device based on the principle of the floating weir (Figures 4 & 5; Plate 3). This device was first installed in May 1983, and has proven its reliability to date. Eighteen such devices were manufactured for the Peruvian water supply intervention by Pendar Environmental Ltd., Bridgwater, U.K.

Specifications for abstraction and pumping packages were not substantially altered during the period April-September 1983, reliance still being placed on sub-sand abstraction and positive displacement pumping. However, independently powered portable pumps were developed by the manufacturers (Mono Pumps Ltd., Manchester, U.K.) to meet our requirements (Plates 4 & 5; Figure 6). More recently, an alternative form of primary treatment to sub-sand abstraction has been developed on the principle of longitudinal gravel filtration. The designs were not complete in time for

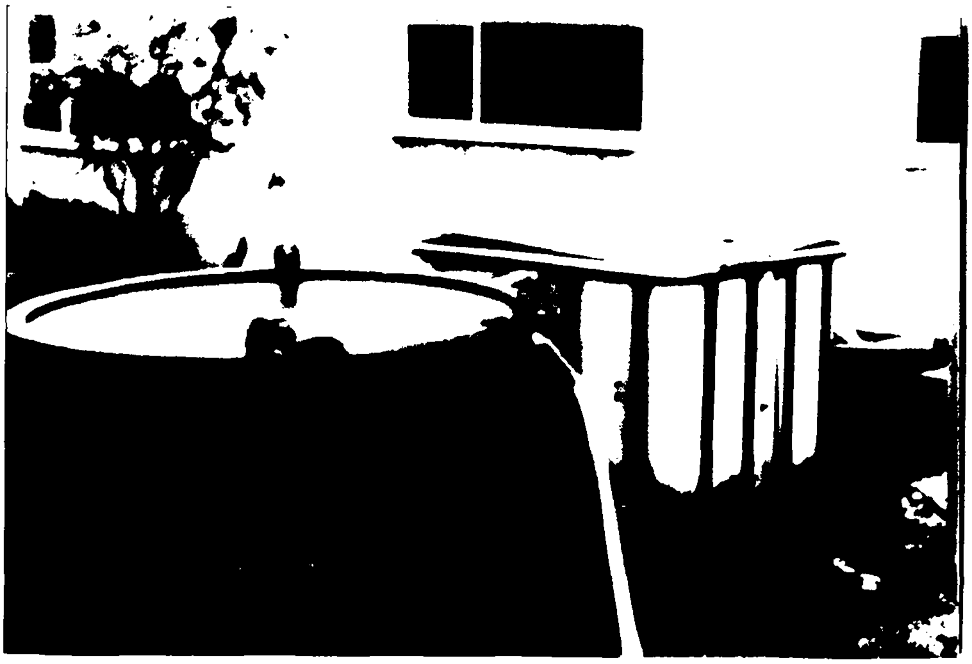


Plate 1. Experimental slow sand filter (white, in background) with design module (black, in foreground).

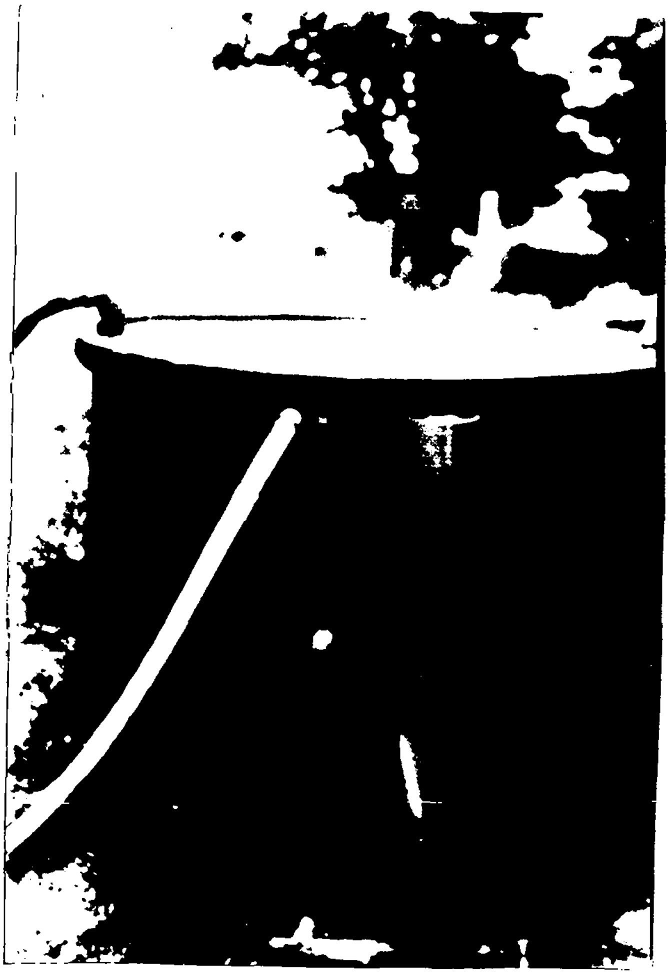


Plate 2. Design scale slow sand filter module with constant flow device.

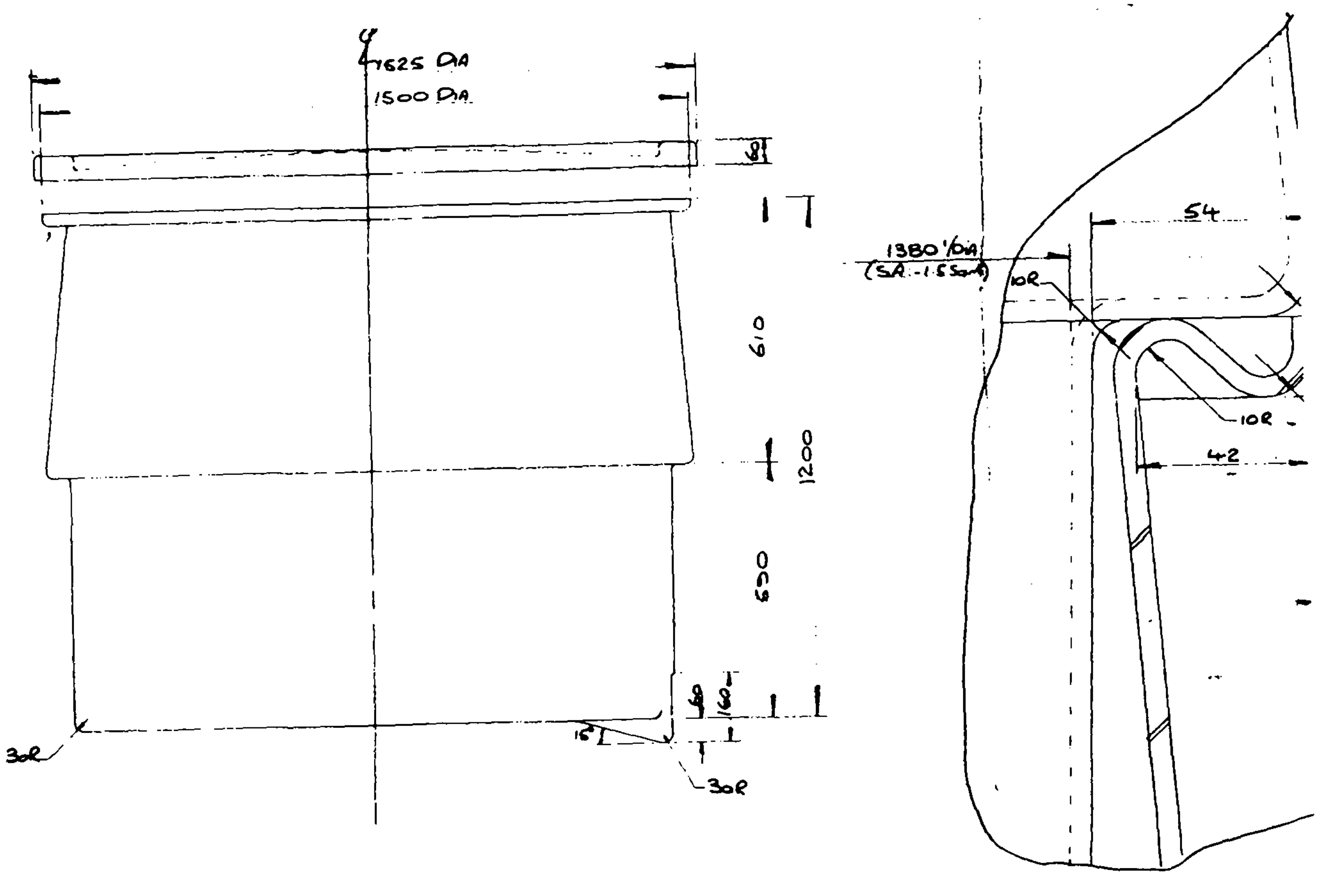


Figure 3. Engineering drawing of WCB slow sand filter module tank (MDPE construction).

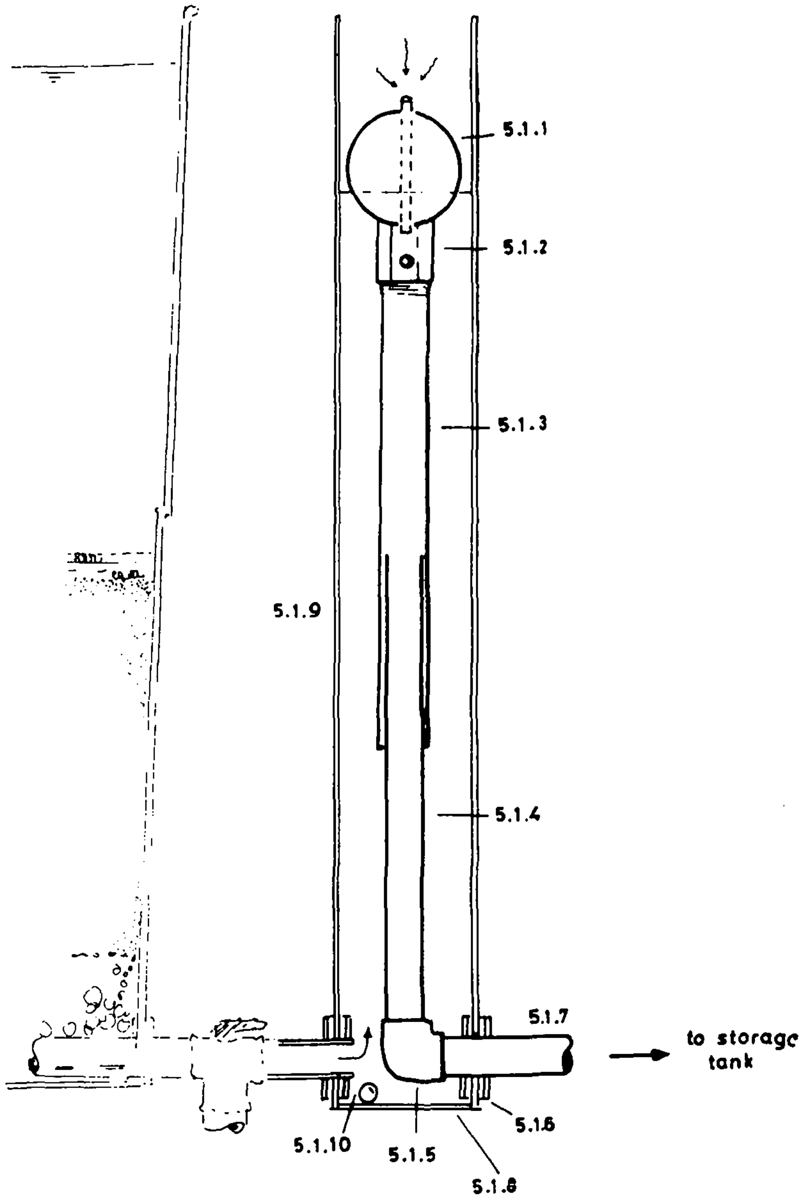
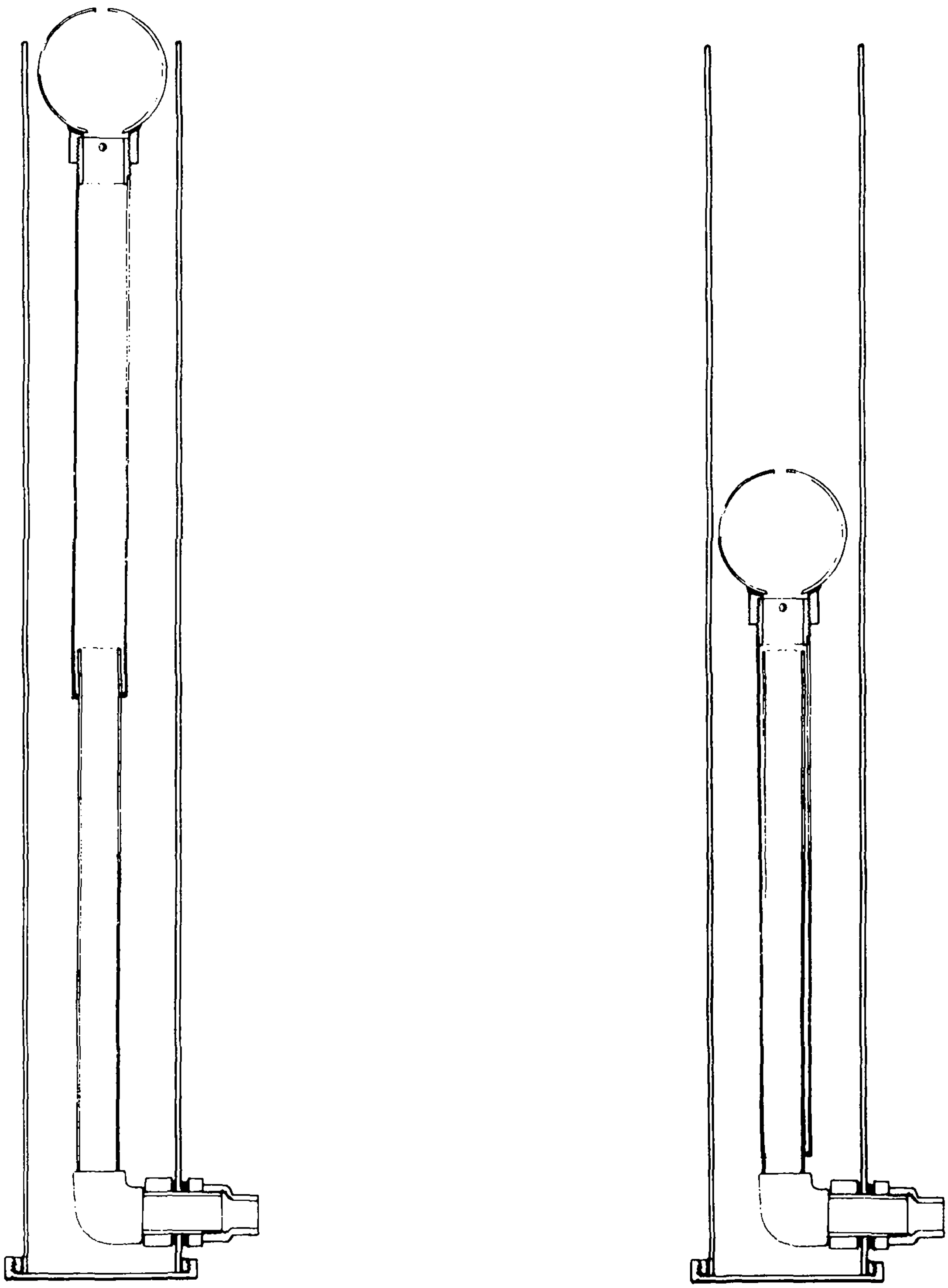


Figure 4. Orientation of constant flow device with respect to slow sand filtration module. Numbers refer to components list.



Start

Finish

Figure 5. Mode of operation of the constant flow device showing position of floating weir at start and finish of filter run.

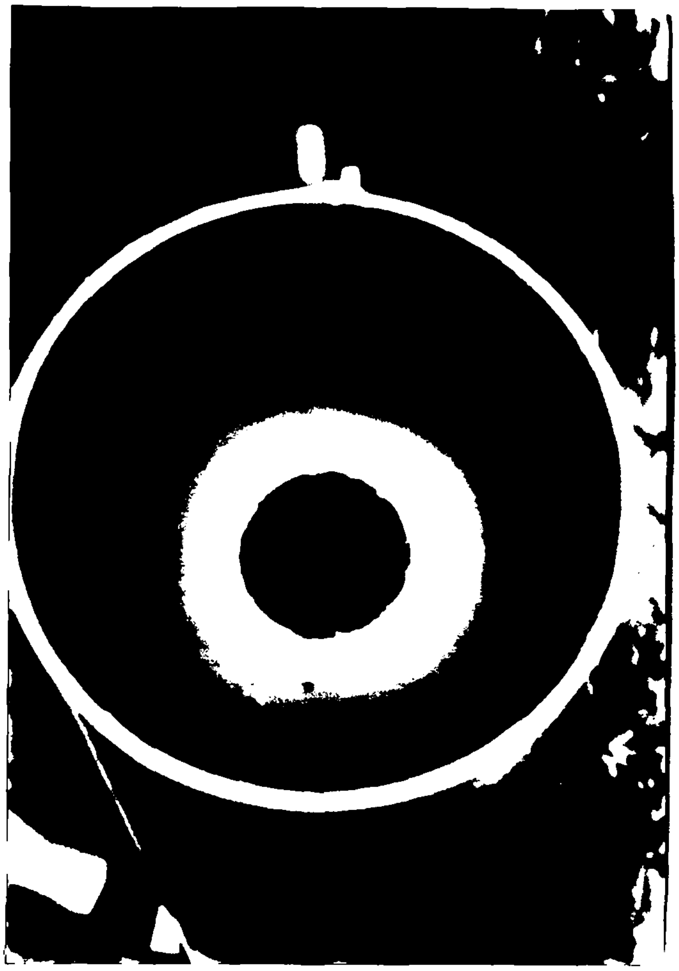


Plate 3. Aerial view of constant flow device showing position of floating weir (ball float) at the start of filter run.

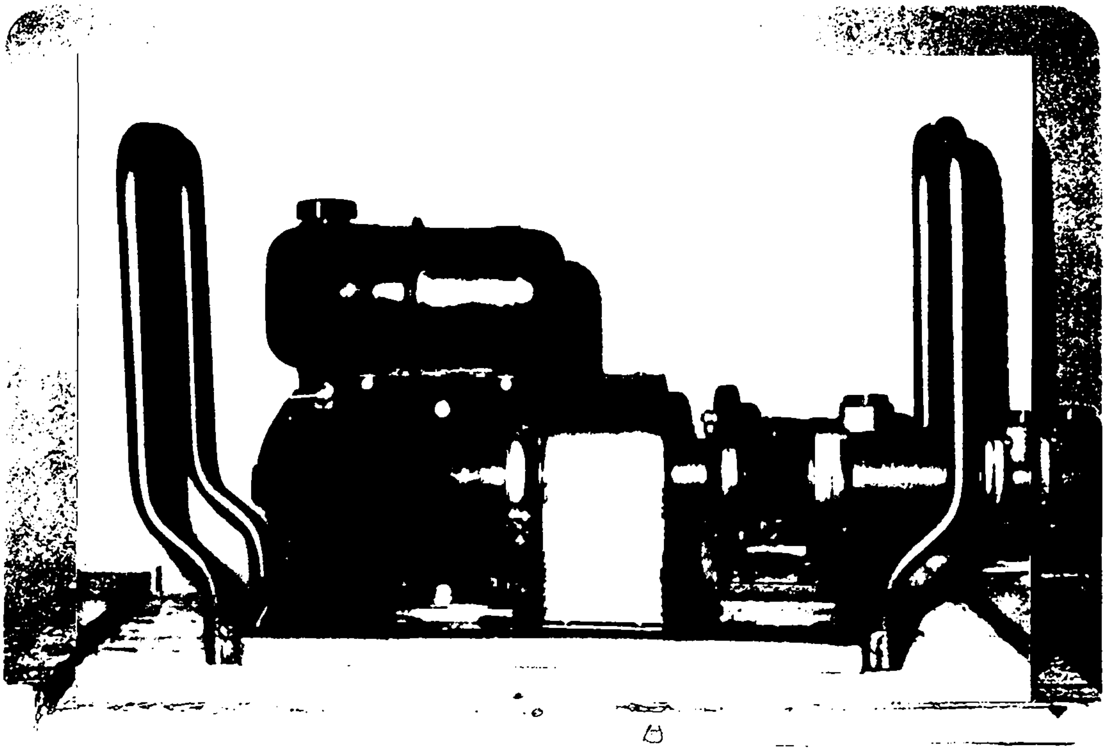


Plate 4. Portable development pump (MONO).

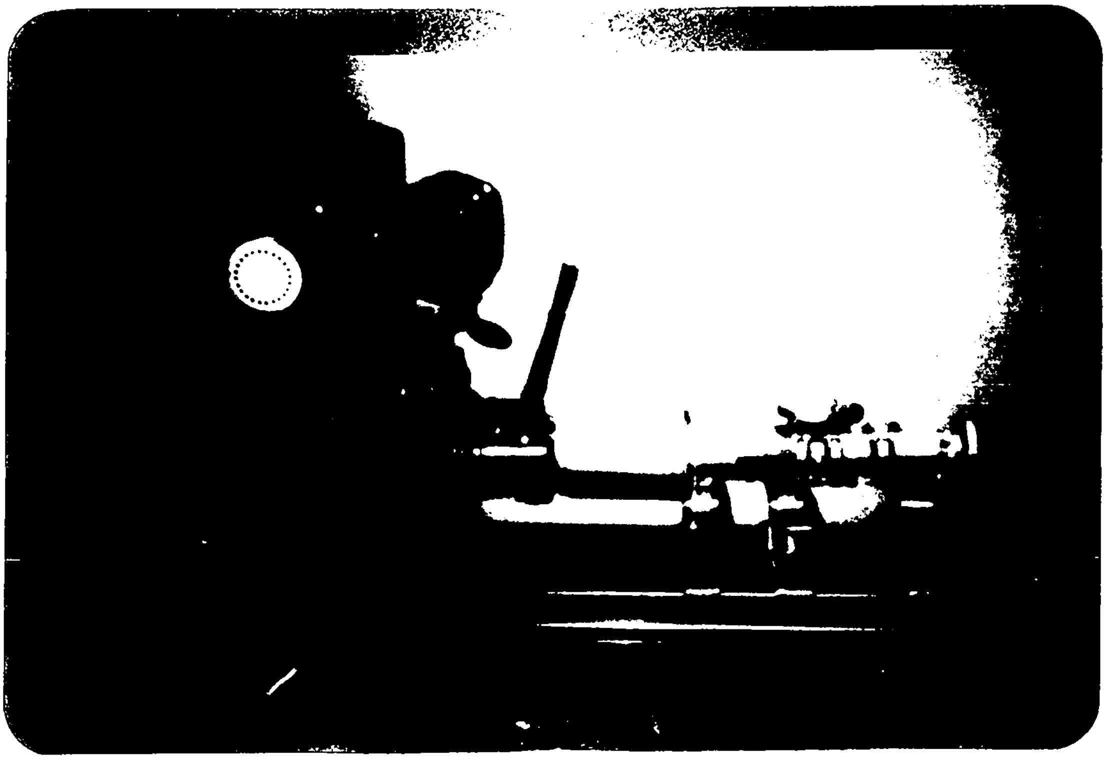


Plate 5. High-lift delivery pump (MONO).

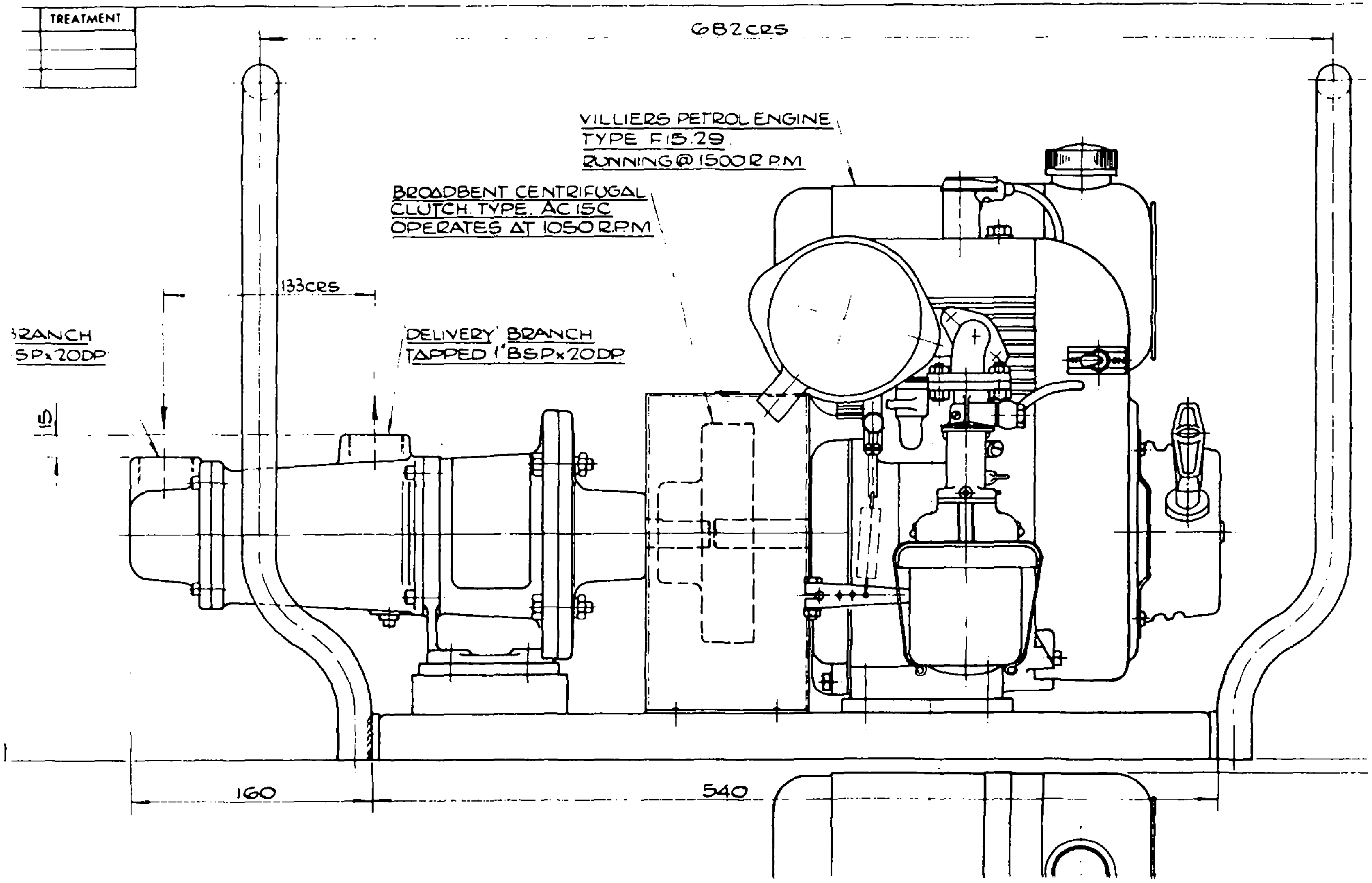


Figure 6. Engineering drawing of portable MONO development pump.

pre-fabrication and shipment to Peru, but the first module is now complete and beginning evaluation in the UK with the support of the Water Research Centre, Stevenage, UK (Plate 6; Figures 7 & 8).

Both underdrainage and distribution networks were designed for the Peruvian programme, but owing to their straightforwardness did not require testing or evaluation before shipment. Account was taken of the supreme need for flexibility in distribution systems and several options on networks, valves and taps are available. These systems were manufactured and supplied in collaboration with Pendar Environmental Ltd.,

The eventual conclusions on the use of filter fabrics led to the acceptance of the principle of the alternating density configuration. Assistance in the procurement and evaluation of fabrics was afforded by the suppliers (Universal Filters Ltd., London, U.K.)

The entire hardware package for the demonstration programme in Peru is detailed (figures 9-18). Specifications and approximate costings are also included.

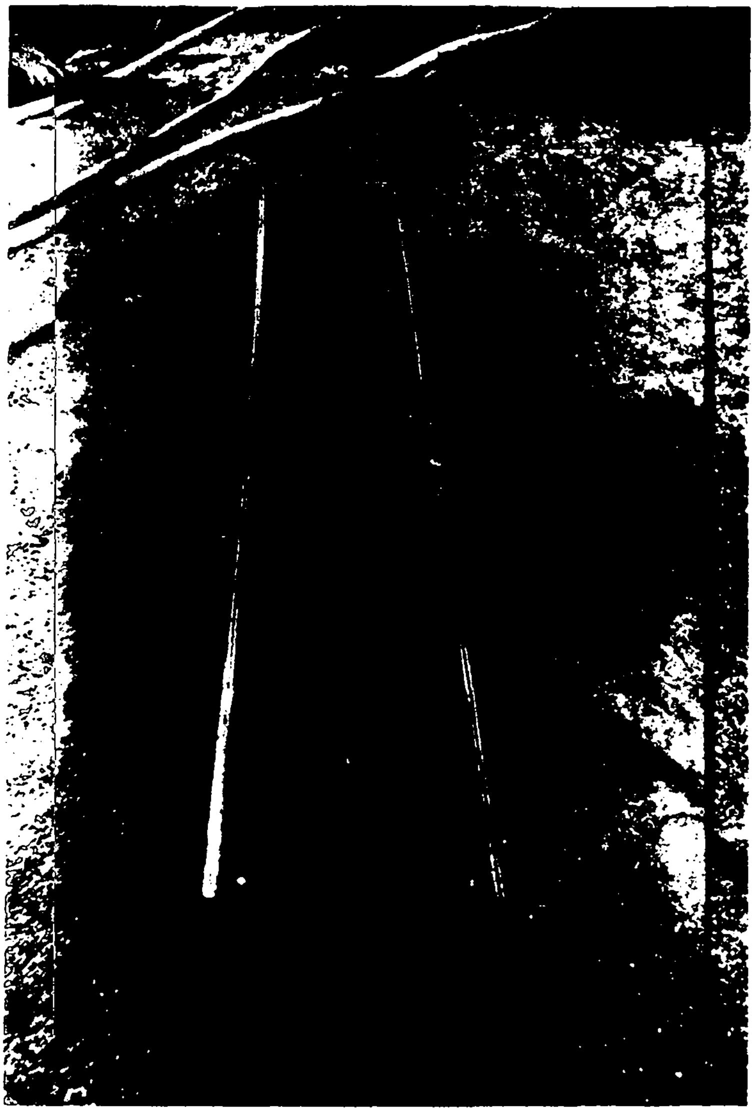


Plate 6. Prototype horizontal gravel prefilter with sampling ports.

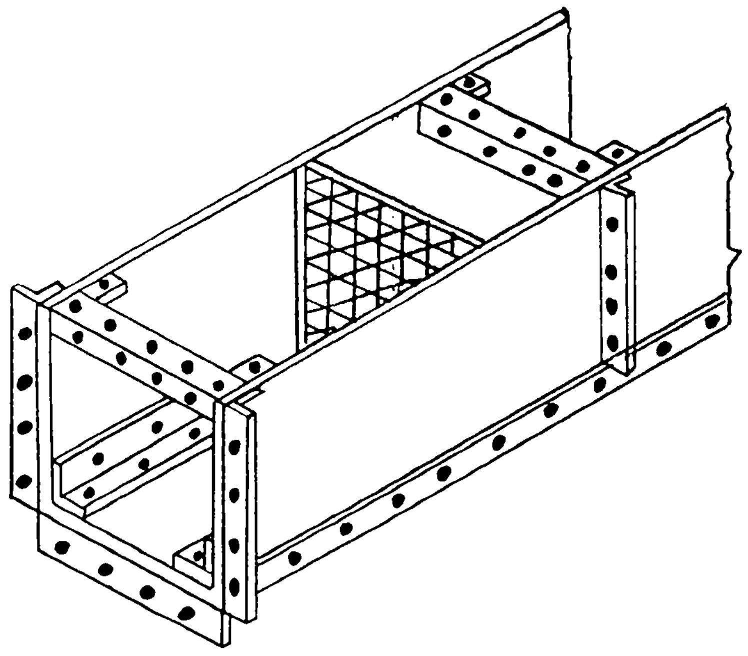
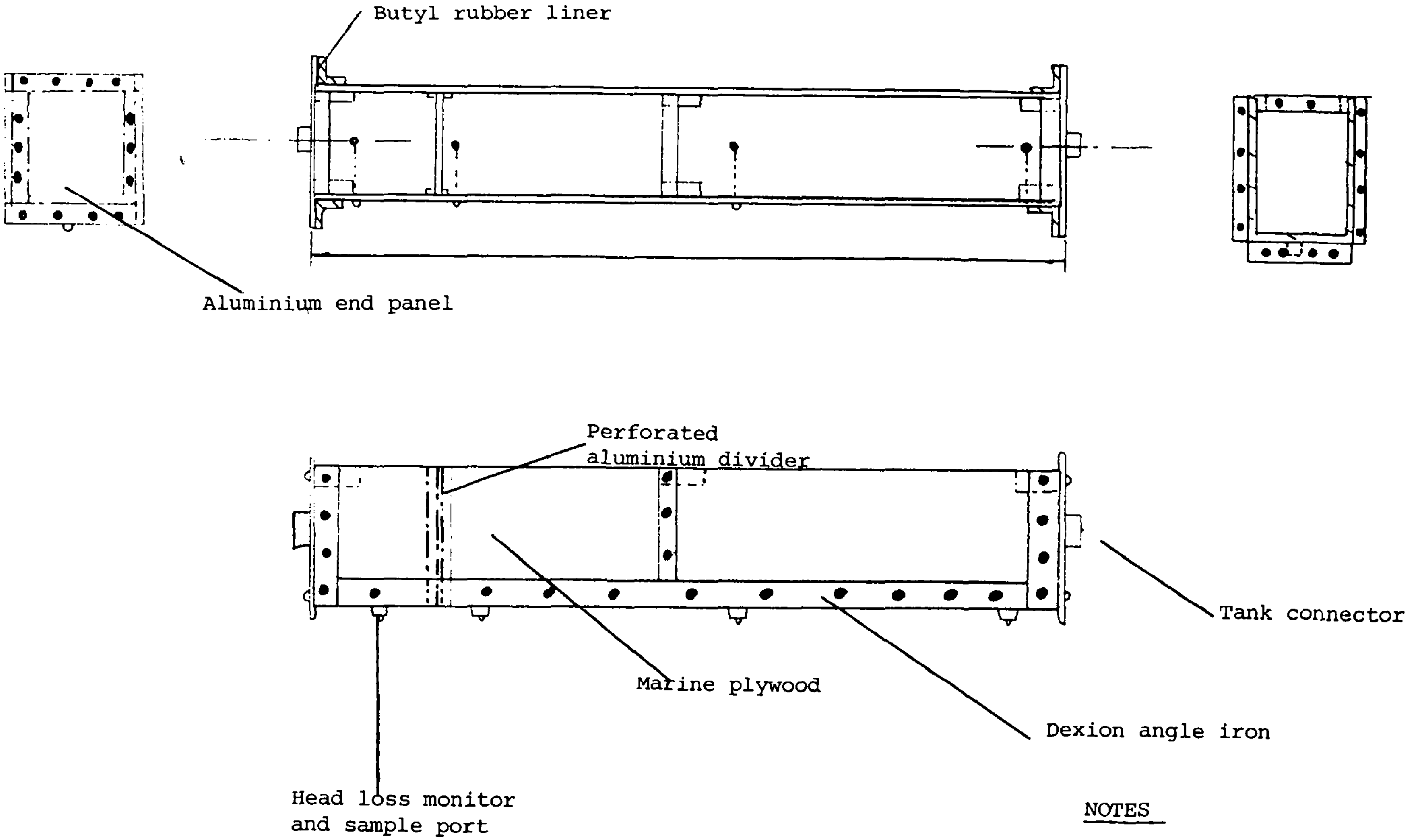


FIGURE 7 SCHEMATIC VIEW OF HORIZONTAL GRAVEL PRE-FILTER.



NOTES

1) 8ft. x 1ft. x 1ft channel
2) Head loss and sampling ports incorporate stainless steel and perspex tubing

FIGURE 8 GRAVEL PRE-FILTER

SPECIFICATIONS AND COSTINGS FOR PERUVIAN WATER TREATMENT PROJECT

Item No.	Description	Unit	Amount	Unit Cost	Total Cost
	COMPONENTS				
1.0	Abstraction from river beds using Cansdale Units	Global			293.50
2.0	Pumping system - considere a diesel motor appliance	Global			312.00
3.0	Header system	Global			58.00
4.0	Gravel prefilter	u	1	278.00	278.00
5.0	Secondary Filters	u	3	288.50	865.50
5.1	Constant flow devices	u	3	37.00	111.00
6.0	Ferrocement storage tank	u	2	152.50	305.00
7.0	Conduction line - based on 1000 mts piping and accessories	Global			1,625.00
7.1	Distribution system - based on 500 mts piping and 10 water points	Global			702.50
10.0	Concrete and masonry works for the system	Global			201.00
11.0	Flexible reinforces piping for 'short' distances	Global			100.00
				Total	£4,851.50
	SYSTEM A - comprises 1.0, 2.0, 3.0, 4.0, 5.0, 5.1.				£1,917.50
	SYSTEM B - comprises 1.0, 3.0, 4.0, 5.0 5.1				£1,605.50
	DISTRIBUTION AND CONDUCTION - comprises 6.0, 7.0, 7.1, 10.0, 11.0.				£2,933.50

NOTE: Labour costs are not considered in the analysis
Items 1 and 4 may be replaced by Horizontal Roughing Filtration

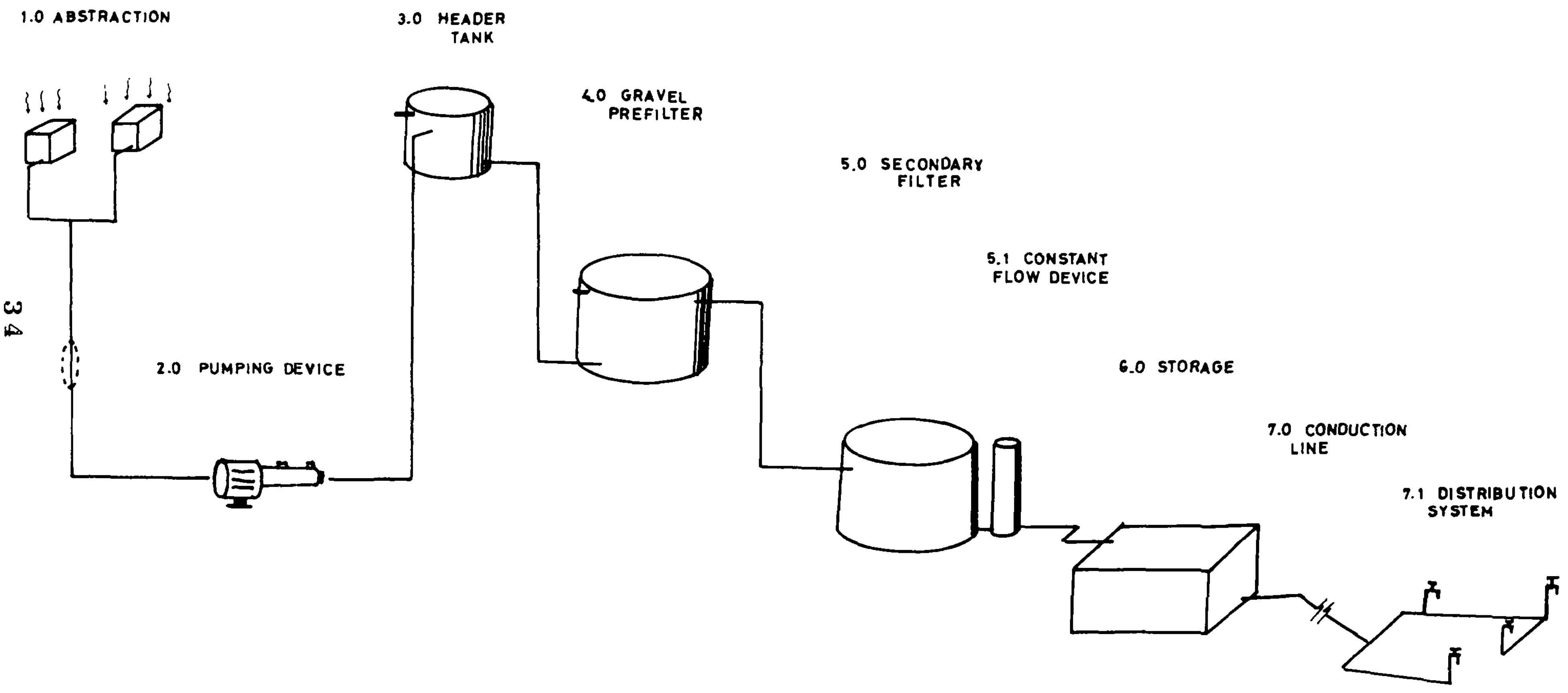


Figure 9. General Scheme

Item No.	Description	Unit	Amount	Unit Cost	Cost
1.0	<u>ABSTRACTION</u>				
1.0.1.	Cansdale abstraction units - including connector	u	3	80.00	240.00
1.0.2.	Plain Tee Ø 1½in.	u	3	1.00	3.00
	Plain hose connectors 1½in Ø	u	9	1.00	9.00
1.0.3.	Three way valves ; 1½in Ø	u	2	12.50	25.00
1.0.4.	Brass Gate Valves 1½ Ø	u	3	5.50	16.50
				Total	£ 293.50

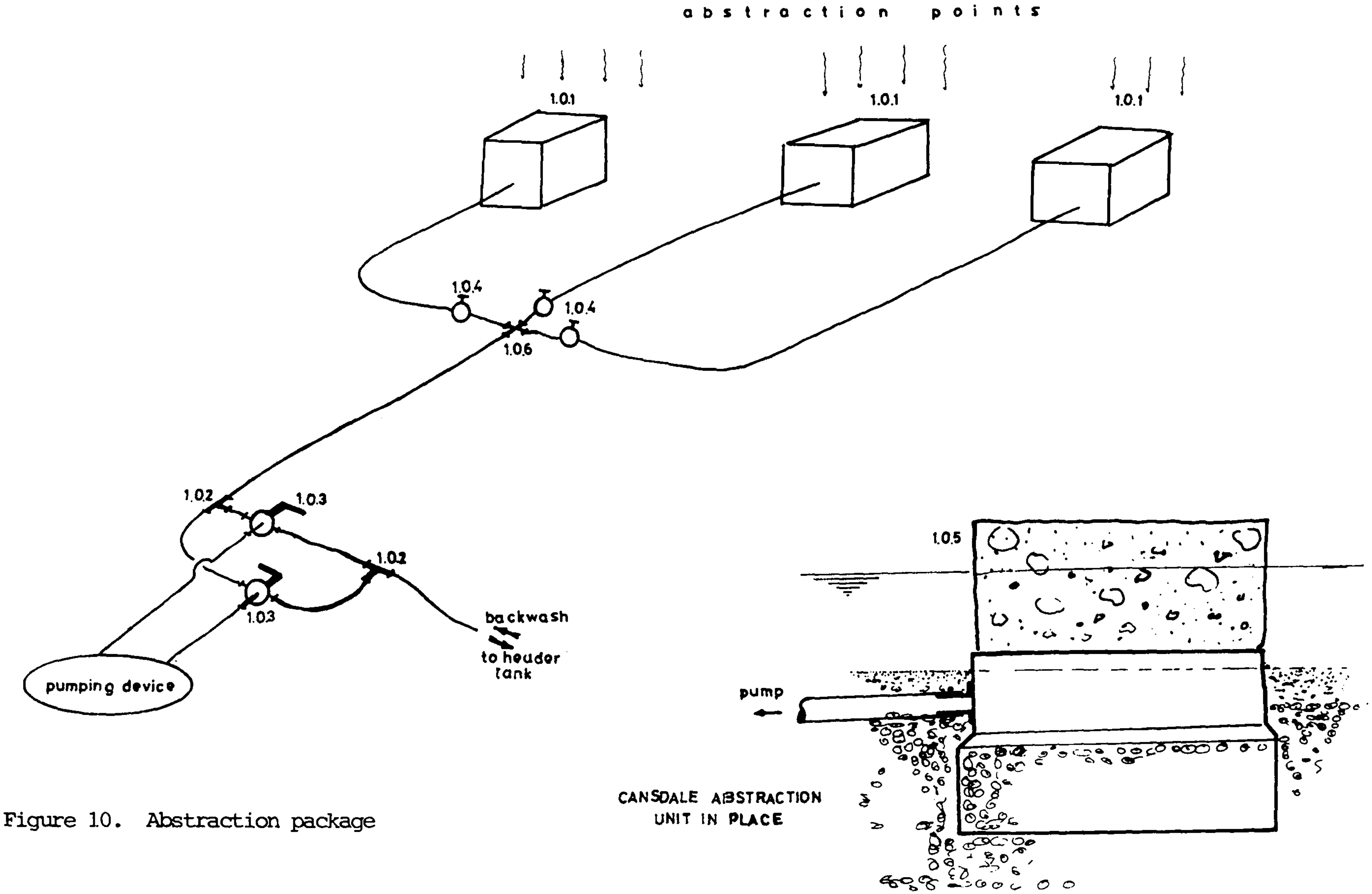


Figure 10. Abstraction package

Item No.	Description	Unit	Amount	Unit Cost	Cost
2.0	<u>PUMPING DEVICE</u>				
2.0.1.	Electric control box	u	1	20.00	20.00
2.0.2.	Electric cable	Global			200.00
2.0.3.	Electric Motor	u	1	150.00	150.00
2.0.5.	Mono pump - 2m^3/h capacity	u	1	70.00	70.00
2.0.6	Threaded nipples of G.I. Ø ¾in	u	4	1.00	4.00
2.0.7.	Threaded nipples of galvanised iron Ø 1in.	u	2	1.50	3.00
2.0.8.	Ø ¾in Elbows G.I.	u	2	1.50	3.00
2.0.9.	Reductions Ø ¾in to 1in	u	2	2.0	4.00
2.0.10.	Vacuum gauge range 0-30 in Hg	u	1	25.00	25.00
2.0.11	Fitting for vacuum gauge	u	1		.50
2.0.12	Plain hose adaptor 1½in Ø	u	2	1.00	2.00
2.0.13	Plain tee Ø 1½in.	u	1	1.00	1.00
				Total	£ 482.50
2.1	<u>ALTERNATIVE WITH DIESEL MOTOR</u>				
2.1.1.	Deisel motor	u	1	200.00	200.00
	Rest parts the same as case 2.0 with the exception of electric components 2.0.1, 2.0.2, and 2.0.3.				
				Total	£ 312.50

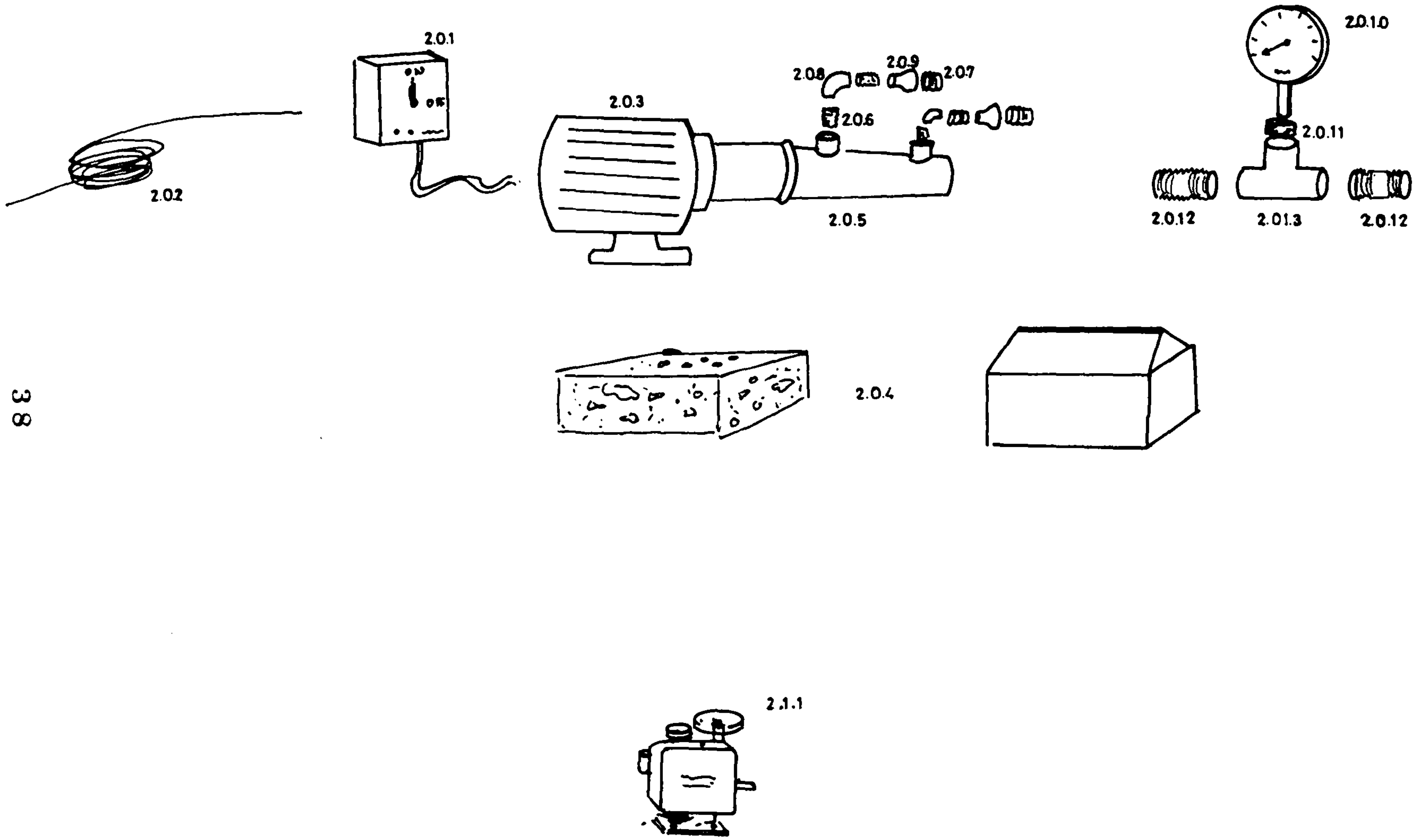


Figure 11. Pumping device.

Item No.	Description	Unit	Amount	Unit Cost	Cost
3.0	HEADER SYSTEM				
3.0.1.	50 gallon plastic tank	u	1	25.00	25.00
3.0.2.	Tank connectors 1½inØ	u	4	6 .00	24.00
3.0.3.	Plain tee Ø 1½in.	u	1	1.00	1.00
3.0.4.	Plain hose adaptor Ø 1½in.	u	3	1.00	3.00
3.0.5.	Lid for tank	u	2	5.00	5.00
				Total	£ 58.00

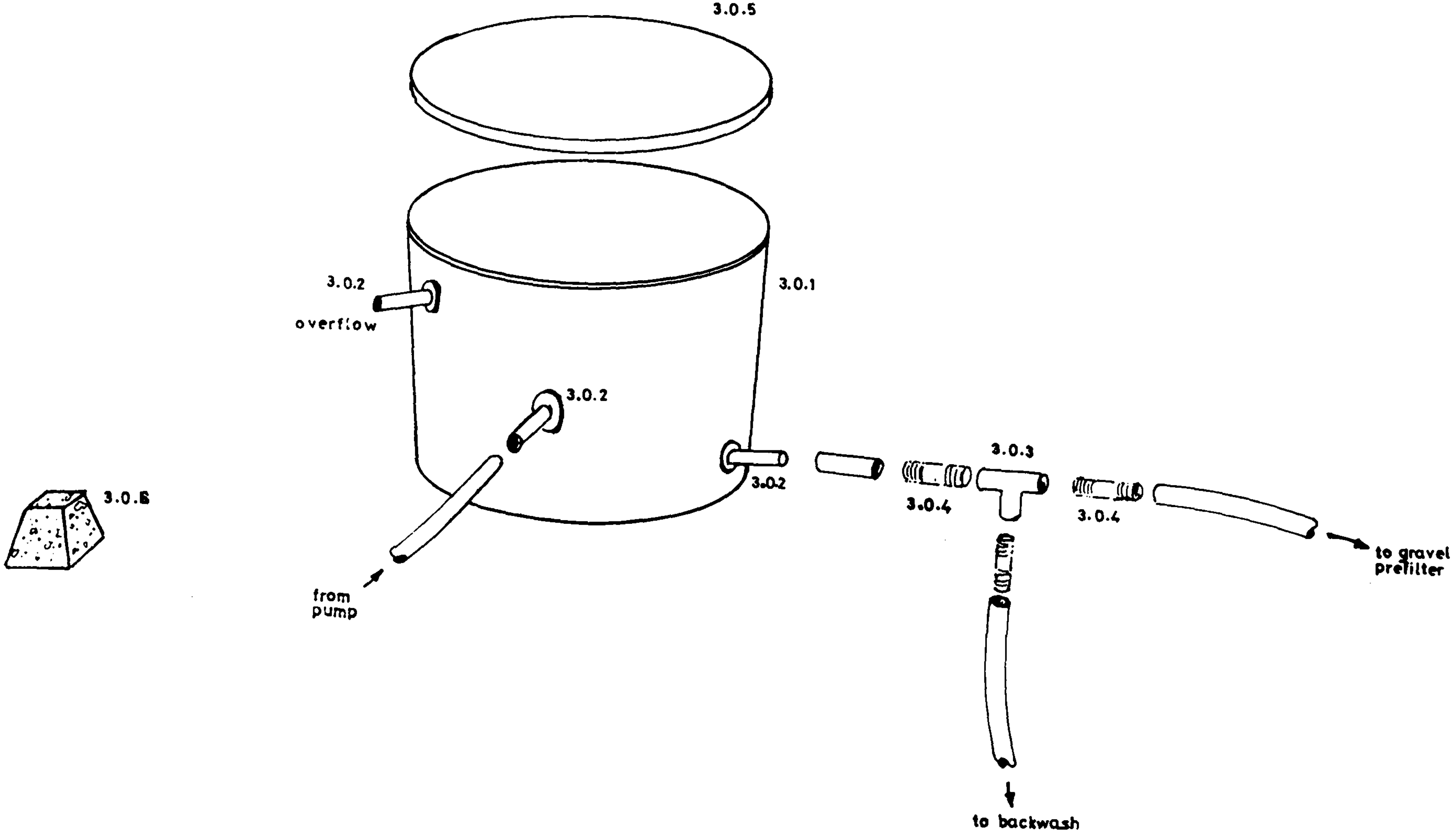


Figure 12. Header tank system.

Item No.	Description	Unit	Amount	Unit Cost	Cost
4.0	GRAVEL PREFILTER				
4.0.1.	WCB plastic tank 1.5m^2 x 1.2m	u	1	200.00	200.00
4.0.2.	Lid for tank	u	1	20.00	20.00
4.0.3.	Cross 1½in. plain (40mm)	u	1	3.50	3.50
4.0.4.	Tank connectors 1½in Ø	u	3	6.00	18.00
4.0.5.	Three-way valve	u	1	12.50	12.50
4.0.6.	Gravel ½in.	m^3	1.5	10.00	15.00
4.0.7.	Synthetic fabric	m^3	3.0	2.00	6.00
4.0.8.	Drain pipe 1½in. pvc (pressure pipe)	m	1.0	3.00	3.00
				Total	£278. 00

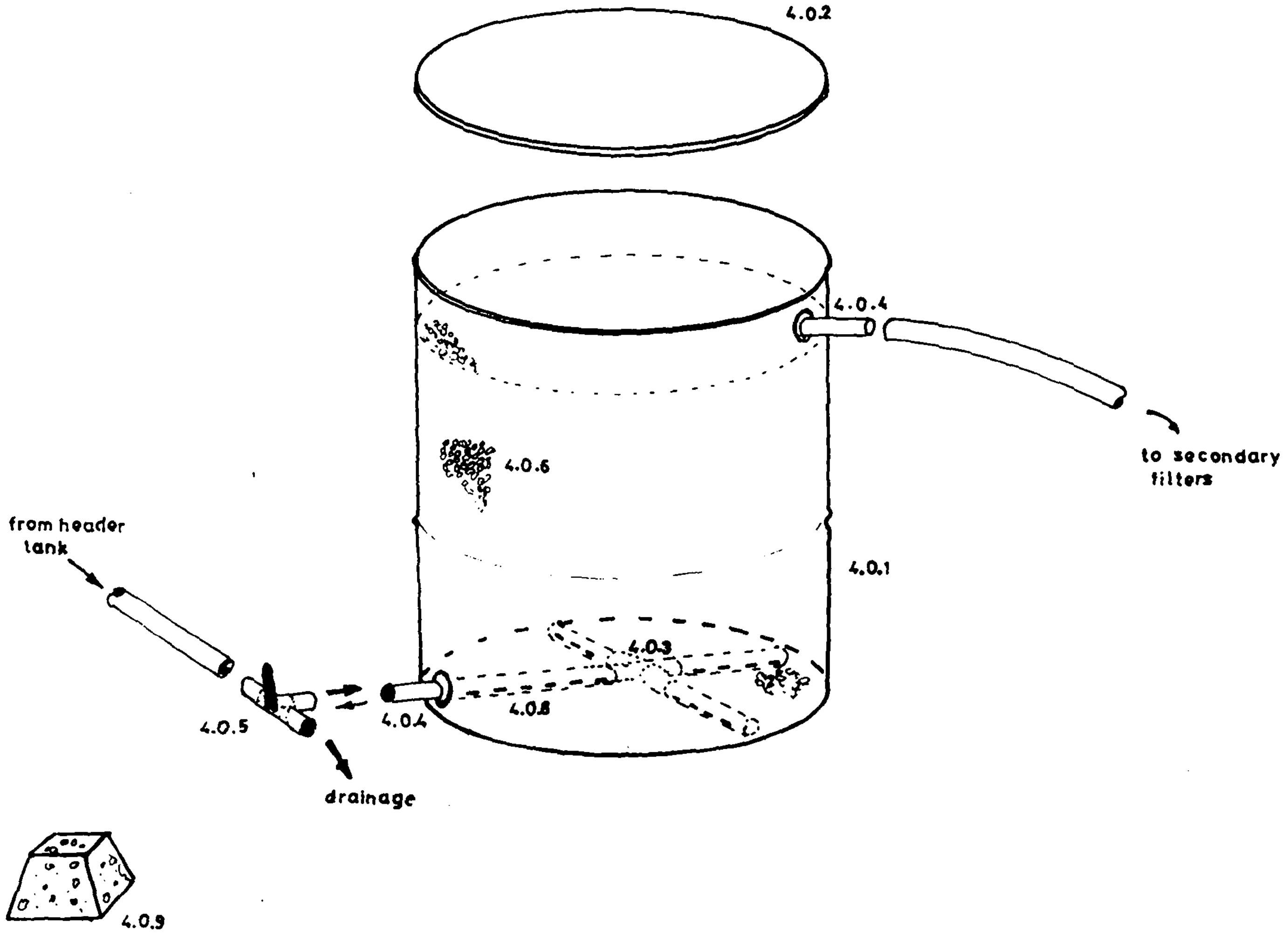


Figure 13. Upflow gravel prefilter.

Item No.	Description	Unit	Amount	Unit Cost	Cost
5.0	<u>SECONDARY FILTER</u>				
5.0.1.	WCB plastic tank 1.5 m^2 x 1.2m	u	1	200.00	200.00
5.0.2.	Lid for tank	u	1	20.00	20.00
5.0.3.	Under drain pipe Ø 1½in. (pressure pipe)	m	1.0	3.00	3.00
5.0.4.	Graded filtering material	m^3	0.7	10.00	7.00
5.0.5.	Multiple layers of synthetic fabric	m^2	6.0	2.00	12.00
5.0.6.	Tank connectors 1½in.	u	3	6.00	18.00
5.0.7.	Ball valves 5in. Ø	u	1	7.00	7.00
5.0.8.	Three-way valves 1½in.	u	1	12.50	12.50
5.0.9.	Italian connector 1½in.	u	1	5.00	5.00
5.0.10.	PVC cross 40mm	u	1	4.00	4.00
				Total	£288.50

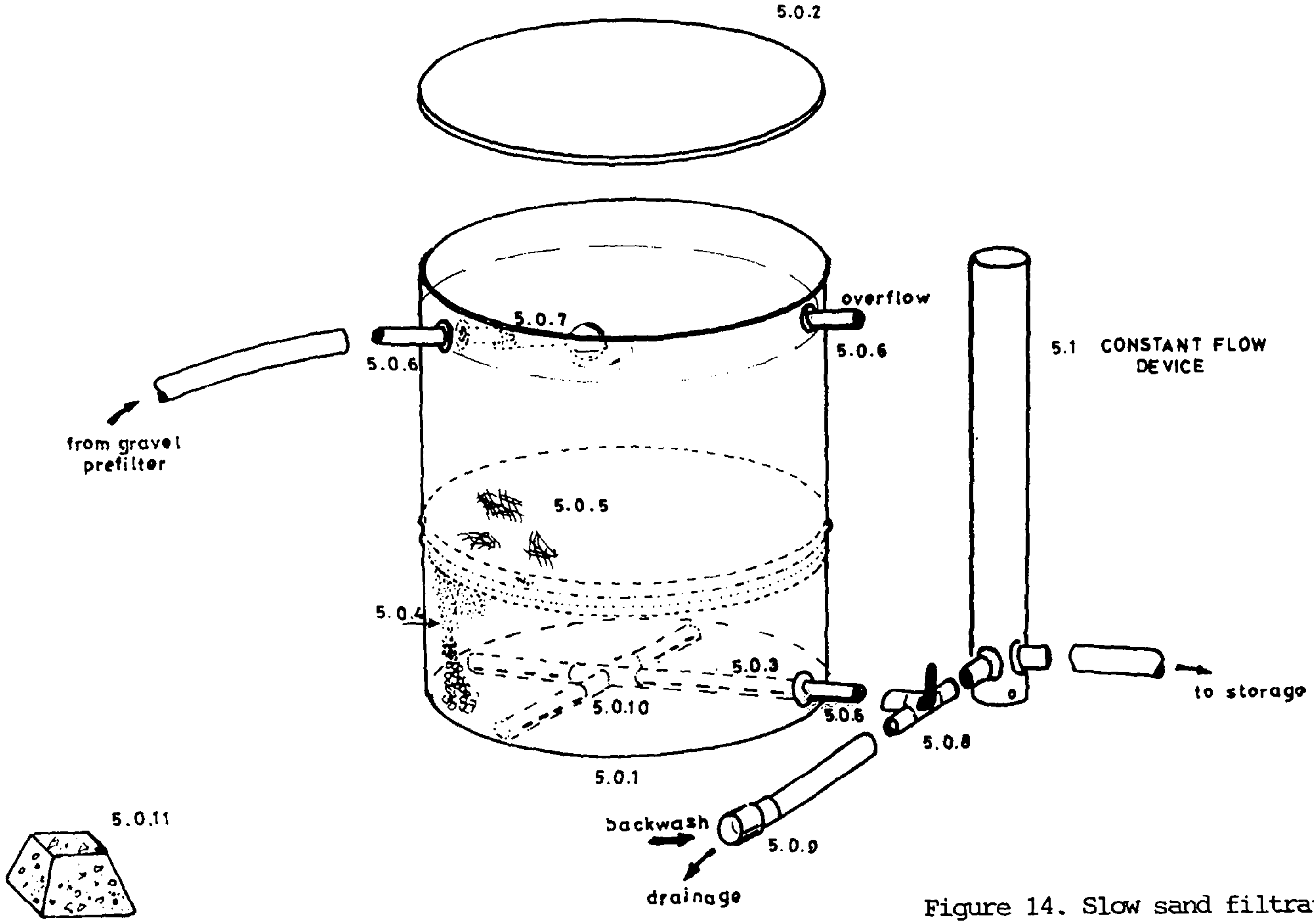


Figure 14. Slow sand filtration module.

Item No.	Description	Unit	Amount	Unit Cost	Cost
5.1	<u>CONSTANT FLOW DEVICE</u>				
5.1.1.	Ø 5in. plastic float	u	1	1.0	1.00
5.1.2.	Threaded socket Ø 2in.	u	1	2.50	2.50
5.1.3.	Pipe class C Ø 2in.	m	0.60	3.30	2.00
5.1.4.	Pipe class C Ø 1½in.	m	0.60	2.00	1.20
5.1.5.	Elbow Ø 1½in.	u	1	1.50	1.50
5.1.6.	Washer system	u	2	3.00	6.00
5.1.7.	Tank connectors with appropriate size nipples 1½in.	u	2	6.00	12.00
5.1.8.	Cap for Ø 6in. Osma D. pipe	u	1	3.00	3.00
5.1.9.	Osma drainage pipe Ø 6in	m	1.2	4.00	4.80
5.1.10	Tank connector with cap Ø ¾in.	u	1	3.00	3.00
				Total	£37.00

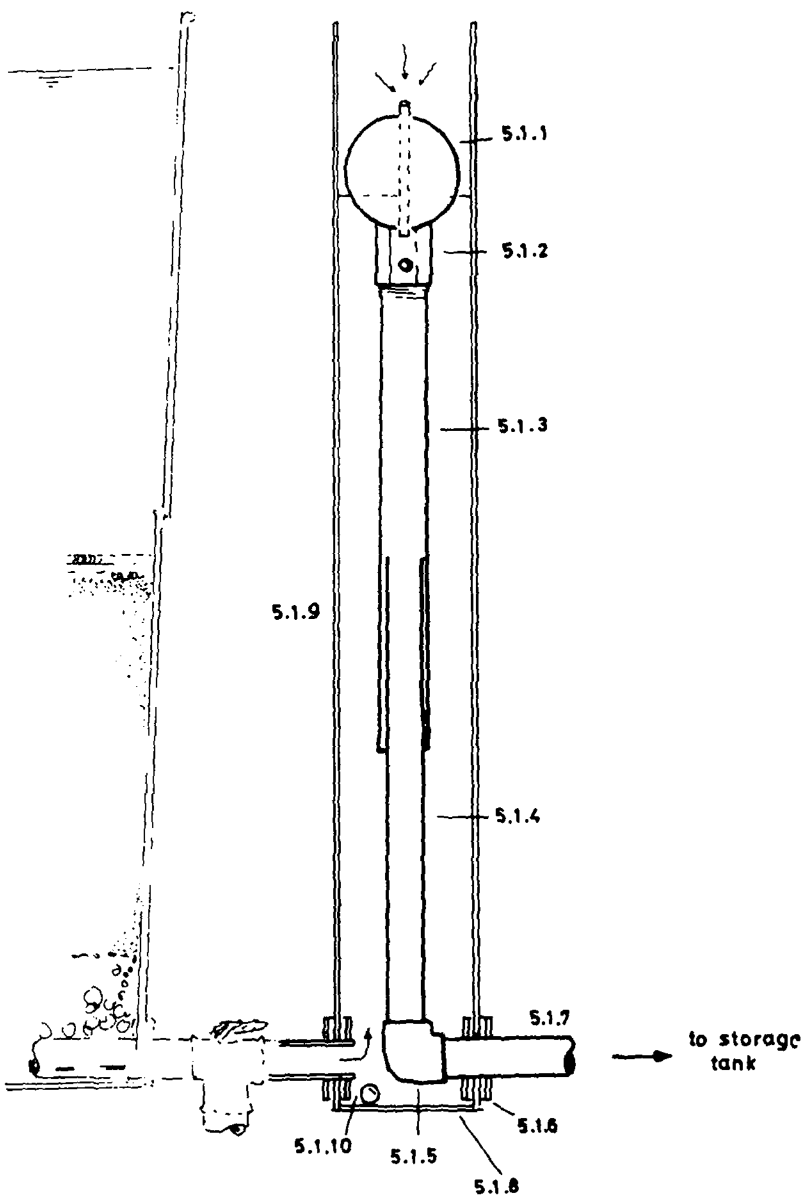


Figure 15. Constant flow device.

Item No.	Description	Unit	Amount	Unit Cost	Cost
6.0	<u>STORAGE (FERROCEMENT TANK)</u>				
	15^{m3} (30% total daily demand)				
6.0.1.	Ferrocement tank $15m^3$				
6.0.1.1.	Cement	kg	900	0.05	45.00
6.0.1.2.	Chicken mesh 1in. wide	m	24	1.00*	24.00
6.0.1.3.	Plain wire No. 8.	m	300	0.10*	30.00
6.0.1.4.	Water pipe 2in. bore	m	1	4.00	4.00
6.0.1.5.	Overflow pipe - 20 cm of 3in.Ø	u	1	2.00	2.00
6.0.1.6.	Galvanised iron sheet and angle for roof	Global		20.00*	20.00
6.o.1.7.	Sand	m^3	1.5	3.00	4.50
6.0.1.8.	Gravel	m^3	0.8	5.00	4.00
6.0.2.	Ball valve Ø 5in.	u	1	7.00	7.00
6.0.4	Nipples 1½in.	u	2	3.00	6.00
6.0.5.	Gate valve 1½in or 2in.	u	1	6.00	6.00
				Total	£152.00

NOTE Labour not considered

* Estimated Peruvian cost.

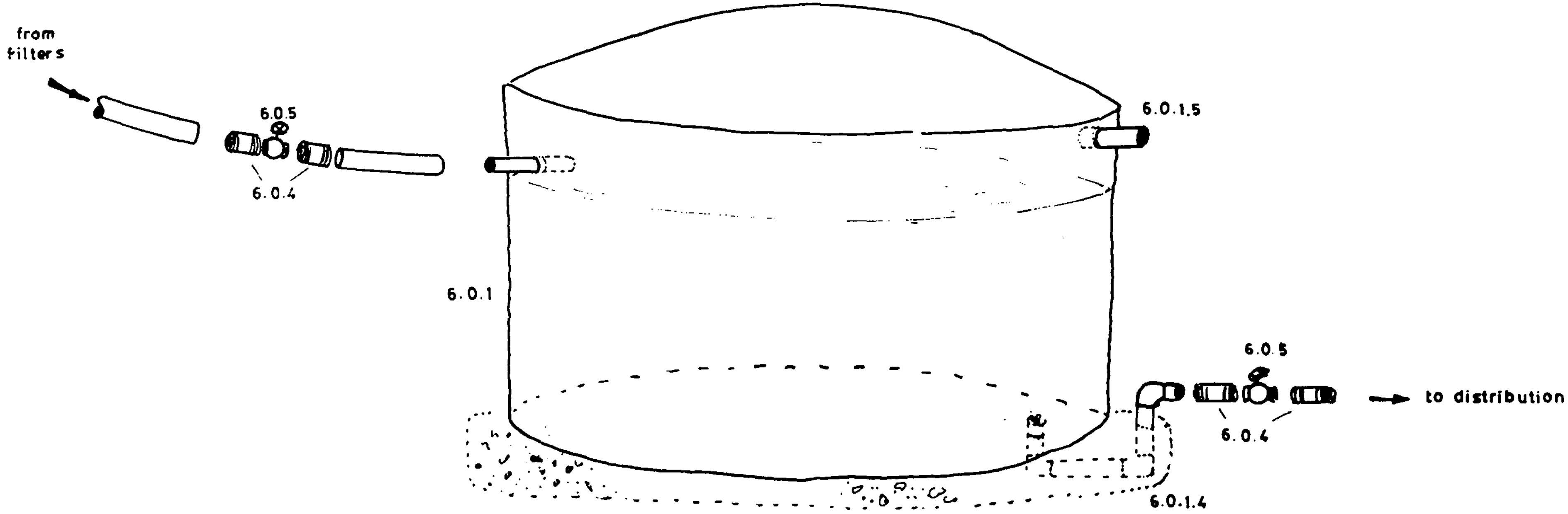


Figure 16. Ferrocement tank storage facility.

Item No.	Description	Unit	Amount	Unit Cost	Total Cost
7.0	<u>CONDUCTION LINE</u> *				
7.0.1.	High density polythene tube Ø 1¼in class C - 9 bar	m	700	1.61	1,127.00
	Low density polythene tube Ø 1¼in. class B - 6 bar	m	300	1.36	408.00
7.0.2.	Air release valve system for high points in conduction line, consists of:				
7.0.2.1.	Diaphragm valve Ø ½in.	u	1	6.00	
7.0.2.3.	Saddle 40 mm x ½in.	u	1	3.00	
7.0.2.4.	Threaded nipple Ø ½in.	u	1	1.00	
Total cost of accessories : £10.00					
assume maximum installation of 3 per system		u	3	10.00	30.00
7.0.3.	Water purge valve system for low points in conduction line, consists of :				
7.0.3.1.	Brass valve Ø 1¼in.	u	i	10.00	
7.0.3.2.	Threaded nippel Ø 1¼in	u	1	2.00	
7.0.3.3.	Tee - pvc plain threaded Ø 1¼in.	u	1	8.00	
Total cost of accessories: £20.00					
Assume maximum installation of 3 per system		u	3	20.00	60.00
					£1,625.00

NOTE: Masonry and labour considered separately.

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* Figures presented here correspond to a maximum expected in the field.

Item No.	Description	Unit	Amount	Unit Cost	Total Cost
7.0	<u>CONDUCTION LINE</u> *				
7.0.1.	High density polythene tube Ø 1¼in class C - 9 bar	m	700	1.61	1,127.00
	Low density polythene tube Ø 1¼in. class B - 6 bar	m	300	1.36	408.00
7.0.2.	Air release valve system for high points in conduction line, consists of:				
7.0.2.1.	Diaphragm valve Ø ½in.	u	1	6.00	
7.0.2.3.	Saddle 40 mm x ½in.	u	1	3.00	
7.0.2.4.	Threaded nipple Ø ½in.	u	1	1.00	
Total cost of accessories : £10.00					
assume maximum installation of 3 per system		u	3	10.00	30.00
7.0.3.	Water purge valve system for low points in conduction line, consists of :				
7.0.3.1.	Brass valve Ø 1¼in.	u	i	10.00	
7.0.3.2.	Threaded nippel Ø 1¼in	u	1	2.00	
7.0.3.3.	Tee - pvc plain threaded Ø 1¼in.	u	1	8.00	
Total cost of accessories: £20.00					
Assume maximum installation of 3 per system		u	3	20.00	60.00
					£1,625.00

NOTE: Masonry and labour considered separately.

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* Figures presented here correspond to a maximum expected in the field.

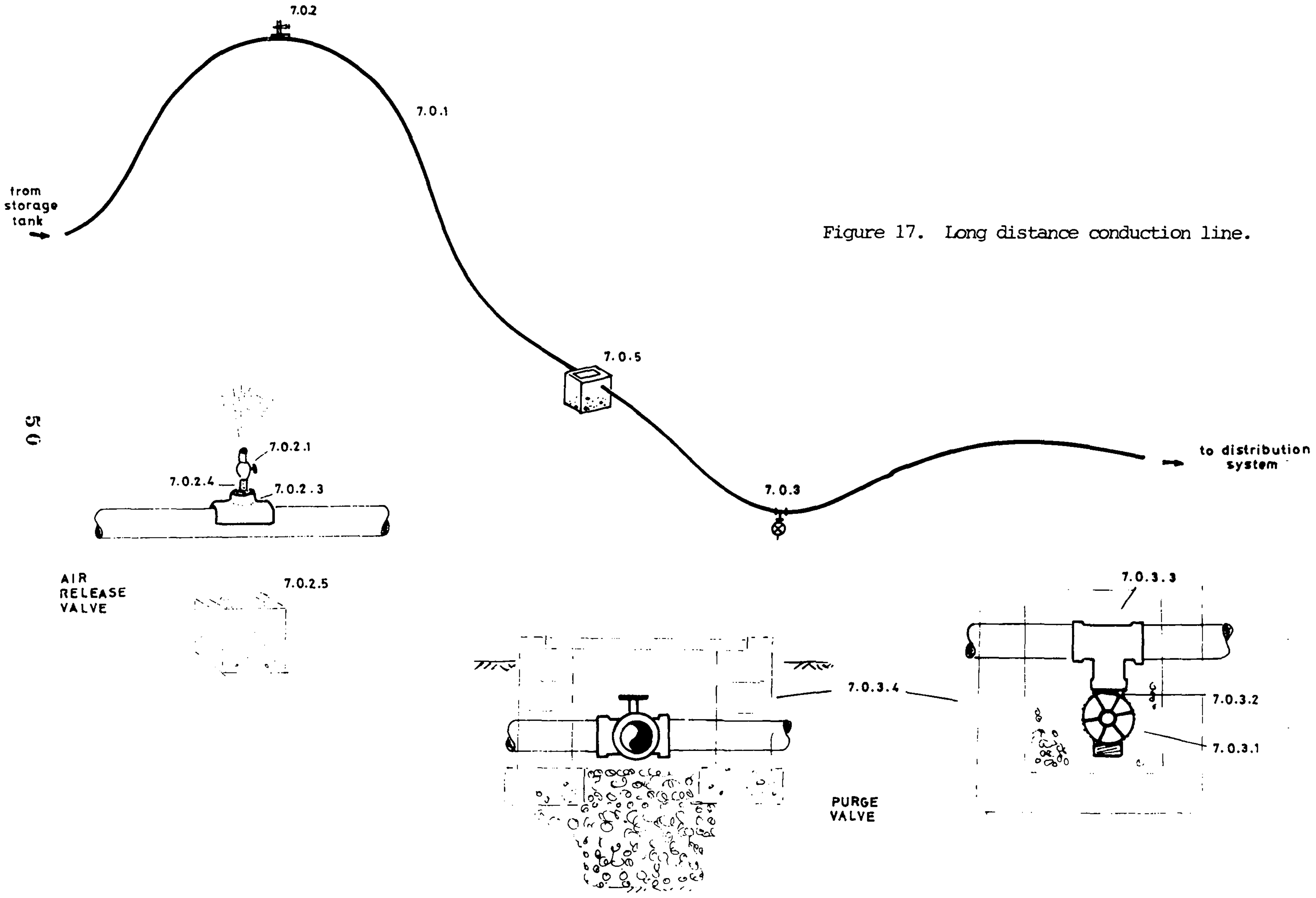


Figure 17. Long distance conduction line.

Item No.	Description	Unit	Amount	Unit Cost	Total Cost
7.1	DISTRIBUTION SYSTEM				
7.1.1.	Pipe for distribution system Ø ¾in. pvc or similar - minimum working pressure 90 mts 3 bar	m	500	0.65	325.00
7.1.2.	Brass gate valves Ø ¾in.	u	3	2.50	7.50
7.1.3.	Tee plain ¾in.Ø	u	10	0.80	8.00
7.1.4.	Water saving valves (metallic)	u	10	35.00	350.00
7.1.5.	Stand pipe and nipples	u	10	1.20	12.00
				Total	£702.50

NOTE Masonry and labour considered separately.

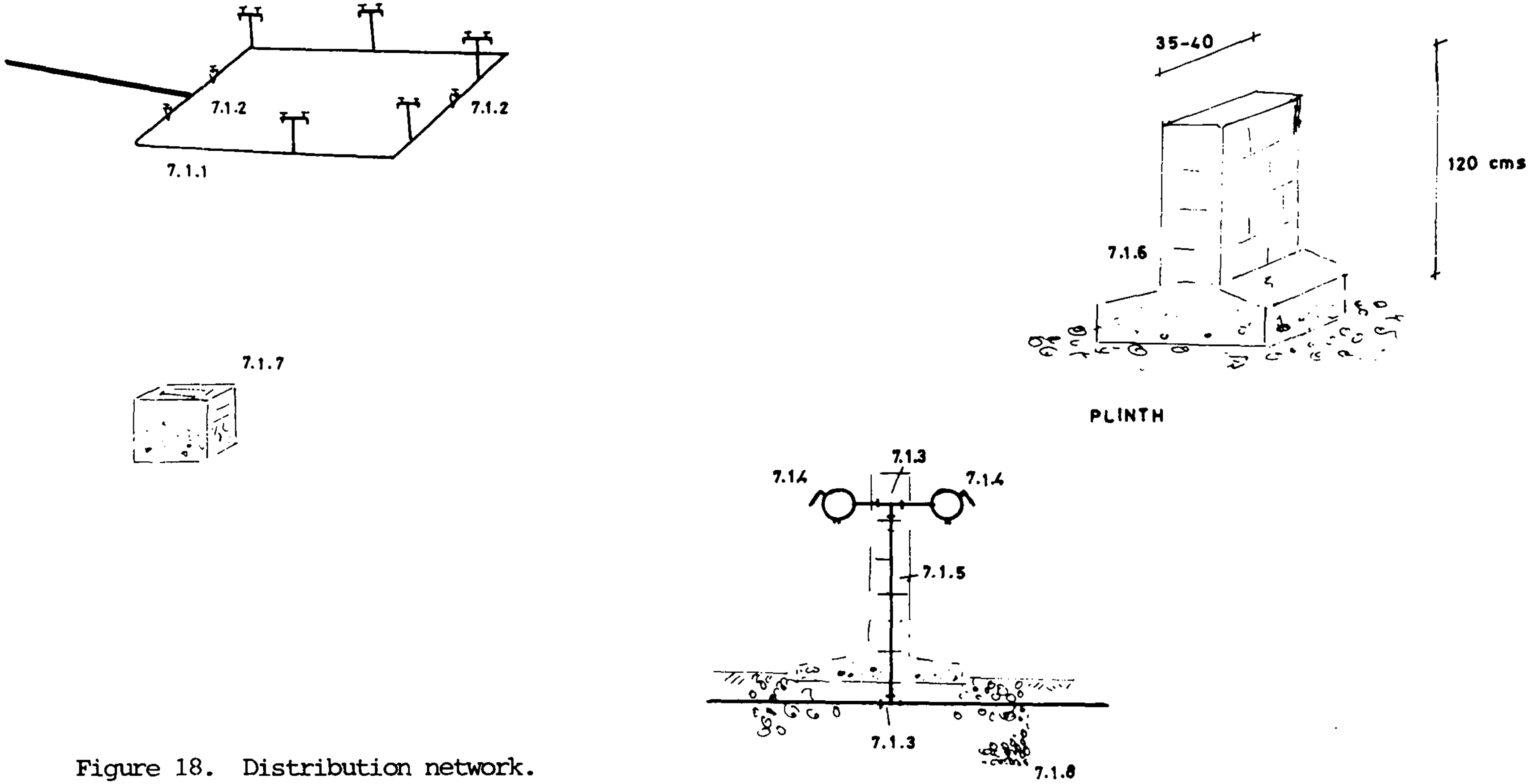


Figure 18. Distribution network.

Item No.	Description	Unit	Amount	Unit Cost	Total Cost.
	CONCRETE AND MASONRY WORKS				
1.0.5.	Concrete blocks to set over Cansdale units 20x15x40cm	u	3	2.00	6.00
2.0.4.	Shelter and base for pump	u	1	30.00	30.00
3.0.6.	Base (anchorage) for header system and drainage for overflow	u	1	10.00	10.00
5.0	Base for gravel prefilter and filter system 15m^2, include shelter for tools, Drainage system and 20 mts Ø 4in. concrete pipe	u	1	50.00	50.00
7.0	Conduction line : One pressure breaking chamber (7.0.5.) and a maximum of four boxes for air release values (7.0.2.5.) and purge valves (7.0.3.4.)	Global			35.00
7.1.	Distribution system: Masonry boxes for valves (7.1.7.) and plinths (7.1.6.)	Global			70.00
				Total	£201.00
	Flexible reinforced pipe Ø 1½in for short distance interconnections	m	60	1.50	90.00
	Jubilee clips for fittings	Global			10.00
				Total	£100.00

SECTION 5

METHODS

1. Water Analysis

Based on the data generated by the first report (Wheeler et al, 1983) it was decided to restrict routine microbiological analysis of filter performance to two parameters: faecal coliform and faecal streptococcus density reductions. Total coliform reductions followed those for faecal coliforms so closely in the first six months experimentation that their enumeration became redundant. General plate counts (37°C and 20°C) were performed on an occasional basis and returned typical results for sand filters but they are not quoted here.

Faecal coliforms and faecal streptococci were enumerated by standard membrane filter techniques (HMSO, 1969), filters were Gelman HC (0.7 μ pore size). Coliforms were recovered on membrane lauryl sulphate broth (Oxoid Ltd.) and streptococci on MF enterococcus agar (Gibco Ltd.) All results are based on the mean of duplicate samples.

Turbidimetric measurements were made on a conventional turbidimeter (HF Instruments). Suspended solids were determined infrequently, and results will not be quoted in this report but will eventually form part of a detailed appraisal of physical factors affecting filtration efficiency. This will also involve application of a filterability index and broad classification of water type according to the level of suspended organic and inorganic material (Appendix II).

Dissolved oxygen concentrations were derived by relating percentage saturation (determined by dissolved oxygen probe and meter) to temperature and atmospheric pressure. Results could then be expressed in mg/L.

2. Sand and Silt Analysis

Volumetric silt tests and sand gradings were undertaken according to the standard methods outlined in the first report.

3. Fabric Tests

Quantitative determinations of the efficiencies of filter fabrics in the removal of suspended solids were obtained by the technique described previously. In brief, this involved vigorous shaking of a standard fabric sample (usually 10 cms square) with water in a 500 ml thick walled glass vessel. Following 60 seconds shaking, the supernatant was quickly poured off into a settling vessel. Washing was repeated twice and the total silt liberated was drawn off from the settling vessel and quantified in a measuring cylinder.

SECTION 6

RESULTS AND DISCUSSION

Results from the series of experiments described in this report (phase 2) were obtained during a five month period when raw water temperatures ranged between 12 and 22°C, turbidities between 5 and 22 NTU, and faecal coliform densities fell mostly in the range 1,000-10,000 per 100 ml. In normal circumstances these conditions would have provided every chance for the dual filtration system to function optimally for the entire period. However, a serious pollution incident occurred in late May which affected the pond water source to the extent that filtration efficiency was severely disrupted for two months. This shortened the time available for experimentation quite considerably. However, whilst residual effects of the pollution were still in evidence in October, results obtained during the late summer demonstrated that high levels of efficiency could nevertheless be maintained without interruption.

Graphical data are expressed in a variety of ways - principally in terms of log reduction in bacterial densities and turbidity for each unit process, but also comparative levels in raw and treated waters and overall percentage reductions for the entire system. Where regression lines are plotted they represent the best fit for the available data and do not necessarily imply the existence of a definitive relationship. Linear and logarithmic regression yielded the highest correlation coefficients in all but one case where an exponential relationship provided the best fit.

Results are considered under the following headings: sub-sand prefiltration, slow sand filtration, overall performance, fabric efficiency, gravel prefiltration, observations on the pollution incident, and sand grading.

Sub-sand Prefiltration

The efficiency of the sub-sand abstraction units in warm water conditions is described in figures 19 to 24. Performance was generally superior to that attained in cold water conditions (phase 1). When water temperatures were in the range 0-10°C faecal coliform reductions barely reached 1 log i.e. 90% by the end of each filter run (signified by a head loss of around 23ft. water or 20in. Hg vacuum pressure on the suction side of the pump - normally reached after a period of 5-7 days). In contrast, 1 log reductions in both faecal coliform and faecal streptococcus densities were achieved within 1-2 days of the start of filter runs when water temperatures were in excess of 10°C (figures 19 and 21). Thereafter, efficiency continued to improve and where longer filter runs occurred due to good raw water quality (low turbidity) substantially higher reductions were obtained.

Once again, when blockage of filter beds caused vacuum pressures to exceed 20in. Hg, cavitation of the pump led to less smooth abstraction and a consequent reduction in the reliability of filtrate quality (figure 20).

Sand beds were completely changed before the summer experiments and so the observed improvement in the bacteriological performance of the filters cannot be ascribed to long term maturation. The improvement is therefore undoubtedly a result of enhanced biological activity in the filtration process in warm water conditions. This goes some way to endorsing the view that sub-sand abstraction functions in a similar fashion to slow sand filtration (Cansdale, 1982). The similarity is not absolute however, since pressure filtration by pumped abstraction is clearly more prone to breakthrough and erratic performance than slow, gravity percolation. This feature is apparent from the scatter of data points on figures 19 to 23.

The flow rates through the sand beds cannot be calculated accurately. Results were obtained with one abstraction bed operated with a pump rated at 1.1 m^3/h and an available filtration area restricted to 3.5 m^2. Two more beds were operated at a rate of 1.5 m^3/h and an available area estimated at 6

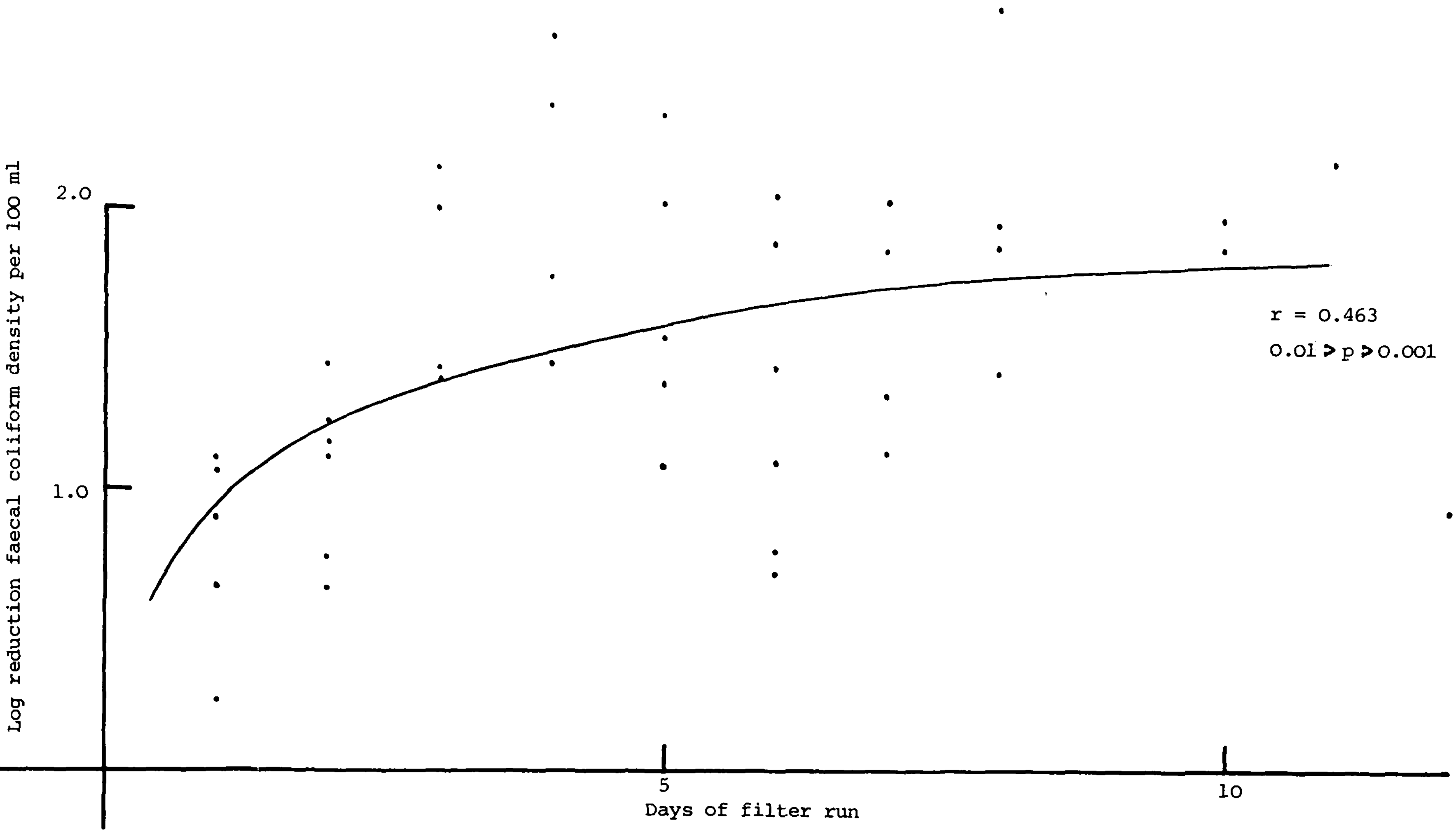


FIGURE 19 PRIMARY FILTRATION EFFICIENCY: FAECAL COLIFORM DENSITIES

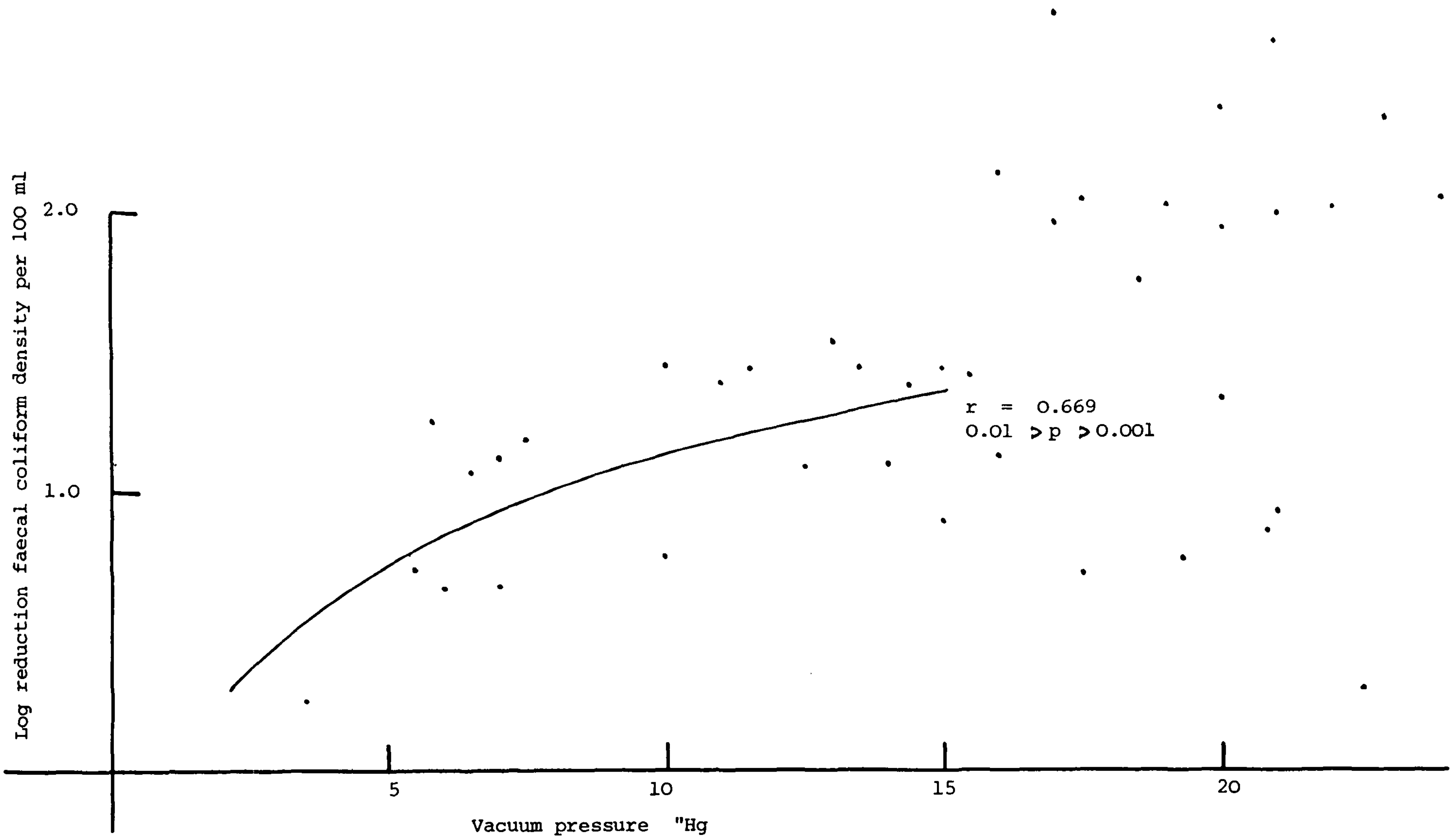


FIGURE 20 PRIMARY FILTRATION EFFICIENCY: FAECAL COLIFORM DENSITIES

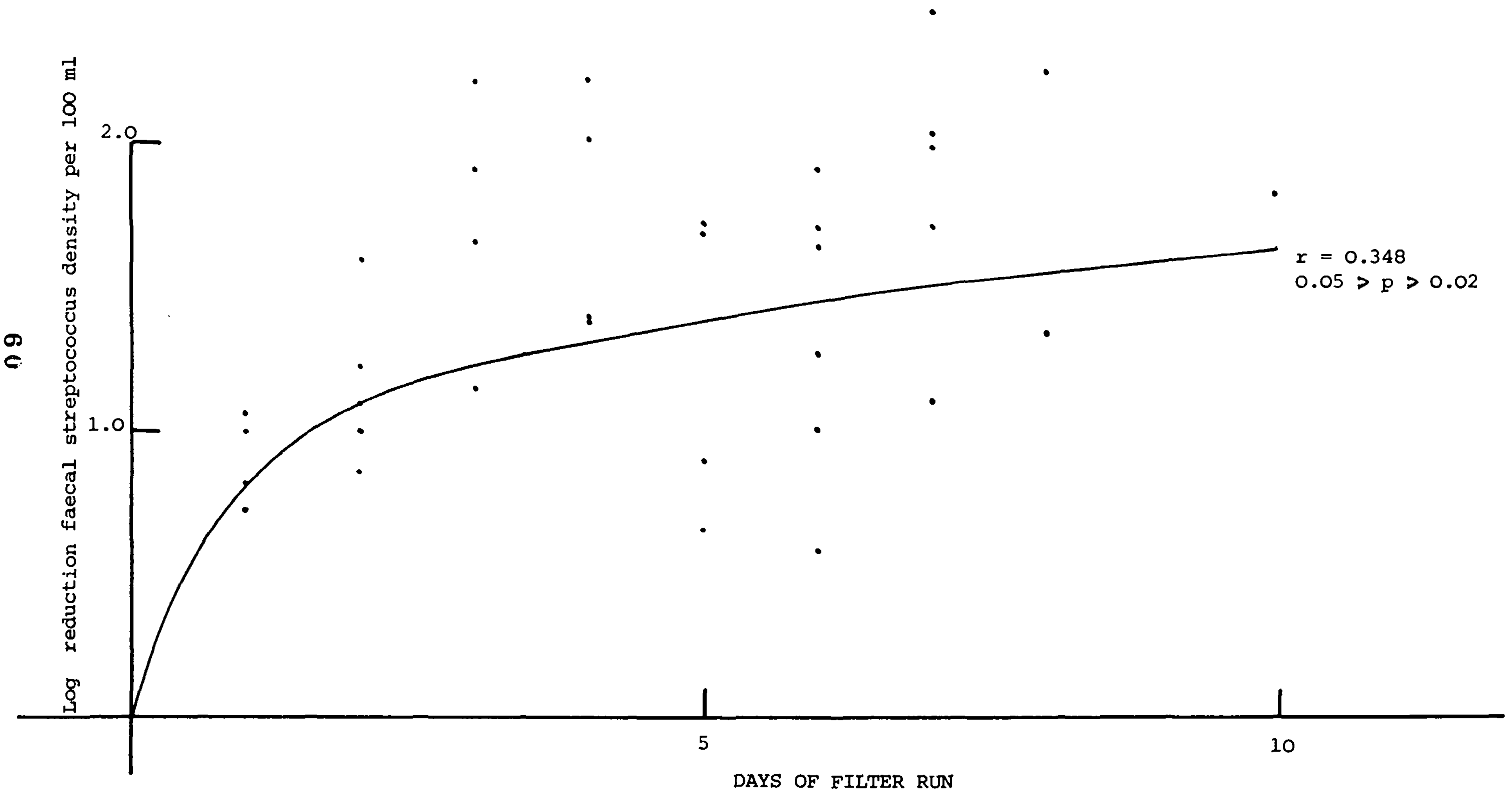


FIGURE 21 PRIMARY FILTRATION EFFICIENCY: FAECAL STREPTOCOCCUS DENSITIES

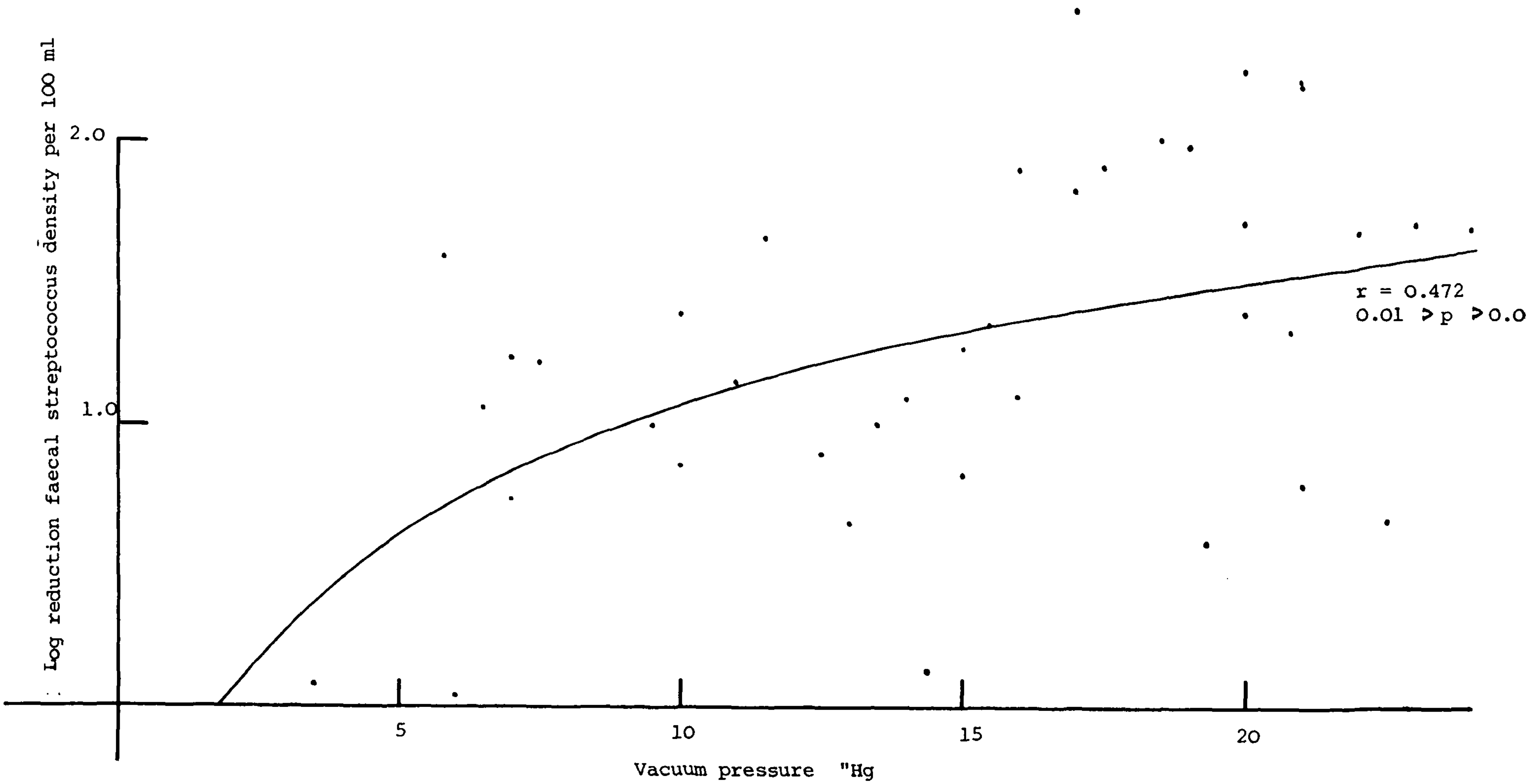


FIGURE 22 PRIMARY FILTRATION EFFICIENCY: FAECAL STREPTOCOCCUS DENSITIES

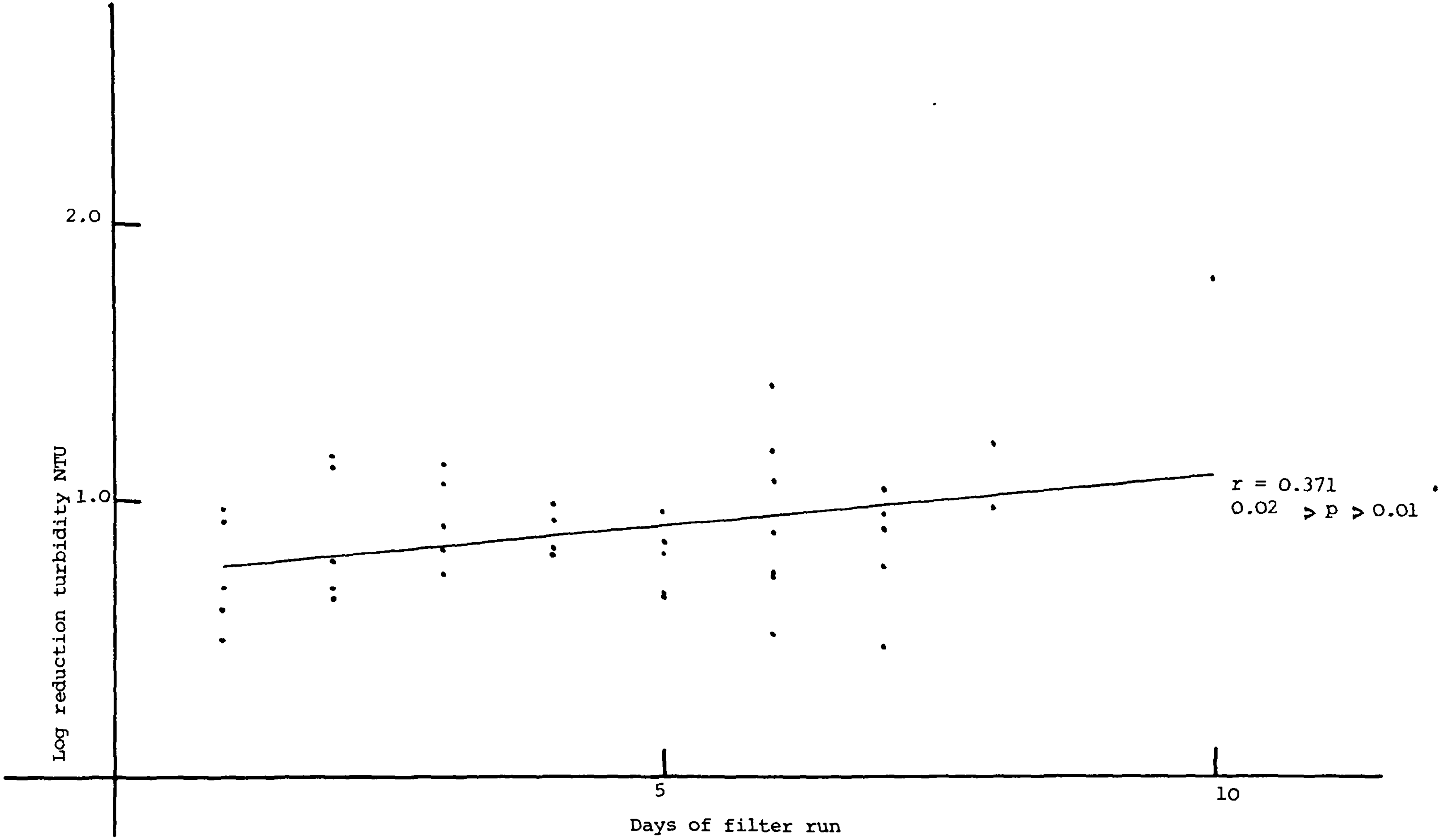


FIGURE 23 PRIMARY FILTRATION EFFICIENCY: TURBIDITY

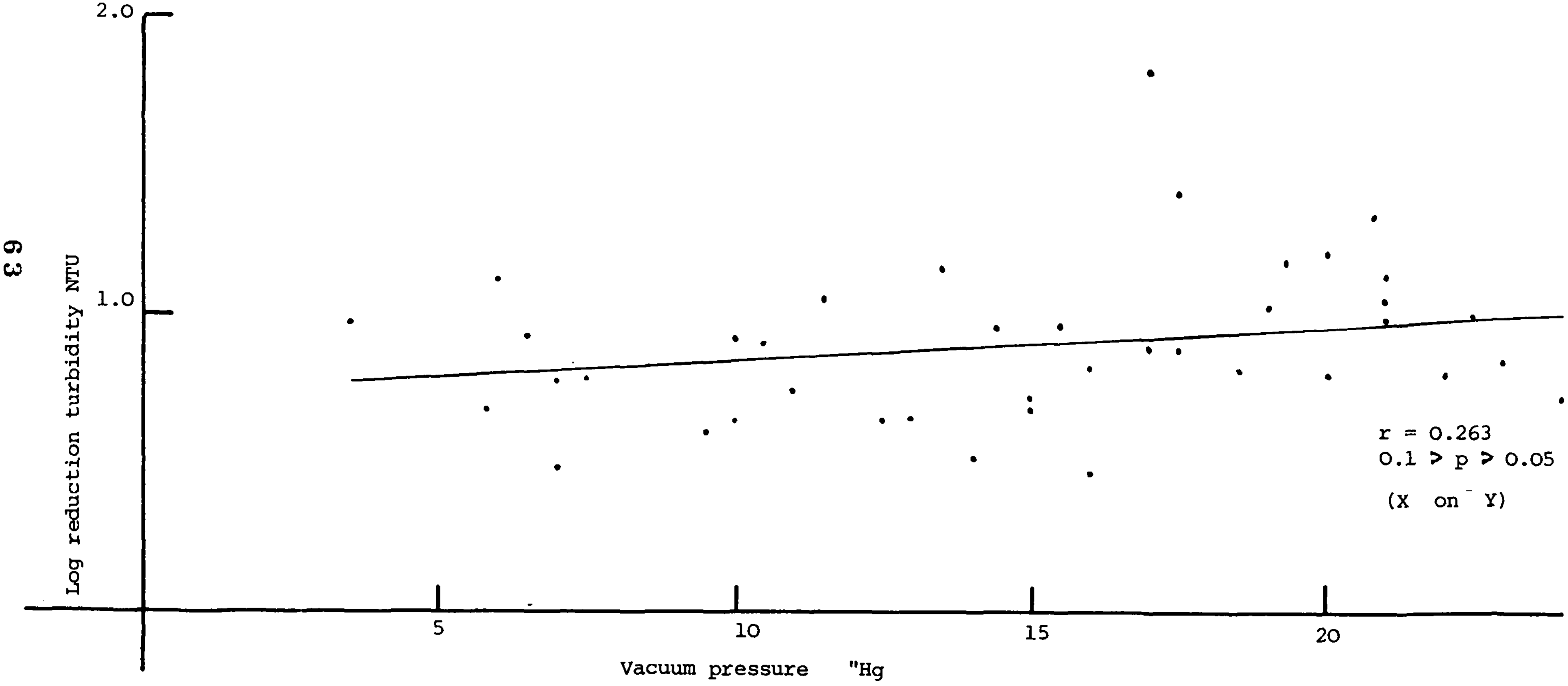


FIGURE 24 PRIMARY FILTRATION EFFICIENCY: TURBIDITY

m^2 each. However, with increasing head loss the amount of water delivered declined - usually to less than half the nominal pump capacity by the end of each filter run. This phenomenon rendered any attempt to compare process efficiency at different flow rates difficult. Nevertheless, the observations of this study suggest that at flow rates at the commencement of each filter run of the equivalent of 0.25-0.30 m/h valuable reductions in faecal bacterial levels can be achieved. These equivalent flow rates are based on uniform velocities across the available abstraction bed and do not take into account the likelihood that flow rates are substantially higher close to and directly above the abstraction unit than 1 or 2 metres away.

As well as the considerably improved microbiological performance of the sub-sand abstraction system with water temperatures in excess of 10°C, a generally higher level of physical performance was observed. Turbidity reductions in the first phase of experimentation were of the order of 0.5 log units after 3 days increasing to approximately 0.7 log units towards the end of filtration (8-10 days after commencement of the run). In comparison, turbidity reductions in the second phase of experiments were around 0.8 log units after 3 days increasing to more than 1 log i.e. 90% after 8 days (Figure 23).

It is not certain to what extent this increase in physical efficiency was due to a general improvement in biological filtration capability and to what extent it was due to qualitative differences in the suspended solids loading. Turbidities in the summer operating conditions were lower than in winter and there was usually a greater proportion of unicellular algae, rather than inorganic suspended solids, in the raw water. Since the algae are physically larger than most inorganic suspended solid particles it is feasible that the increased efficiency was purely a reflection of this factor.

It was apparent on cleaning the primary filters that large numbers of these algae were retained in the abstraction beds. During backwashing great clouds of green-brown material were liberated into the overlying water. Furthermore, there was very little carry-over of algal material onto the secondary slow sand filters - a factor which contributed significantly to ease of operation and maintenance.

Slow Sand Filtration

The ability of the slow sand filter modules to maintain high efficiencies of faecal bacterial removal was not really in doubt. There was no reason to suppose in fact that the filters would behave in anything other than an identical fashion to full scale slow sand filters. This implies the return of reliable reductions in faecal bacterial densities of 95-99% for sustained periods. Thus while it has been encouraging to demonstrate such performance in practice, of more practical concern has been i) the rate of maturation of newly commissioned filters, and ii) the maintenance of continuity of efficiency during and after cleaning procedures.

1: The maturation of filters is described in figures 25 to 28. On close inspection of maturation rates (figure 25) it is interesting to note that in the initial perid i.e. the first two weeks of operation, a velocity of 0.16 m/h yielded significantly faster improvements than were obtained at a rate of 0.32 m/h. At the lower flow rate 95% reductions in faecal coliform densities were attained in only 6 days. Figure 26 demonstrates that in warm water conditions, acceptable hygienic performance ie. greater than 95% reductions in faecal coliform density were achieved within 14 days at the higher flow rate; 99% (2 log) reductions were attained after approximately 28 days of operation. In the same period (figure 27) turbidity reductions also improved substantially achieving 0.5 log (approximately 70%) reductions within 21 days.

During installation it will be necessary to use the most readily available source of water for washing and preparing the sand bed, and this source will almost certainly be either the raw surface water (intended for treatment) or the prefiltered water (if the first stage of treatment has been installed first). In either case, the act of preparation will inevitably introduce a degree of contamination into the slow sand filter beds. Figure 28 shows the ability of both newly commissioned and re-commissioned filters to clear this contamination and return acceptable performance. Clearly

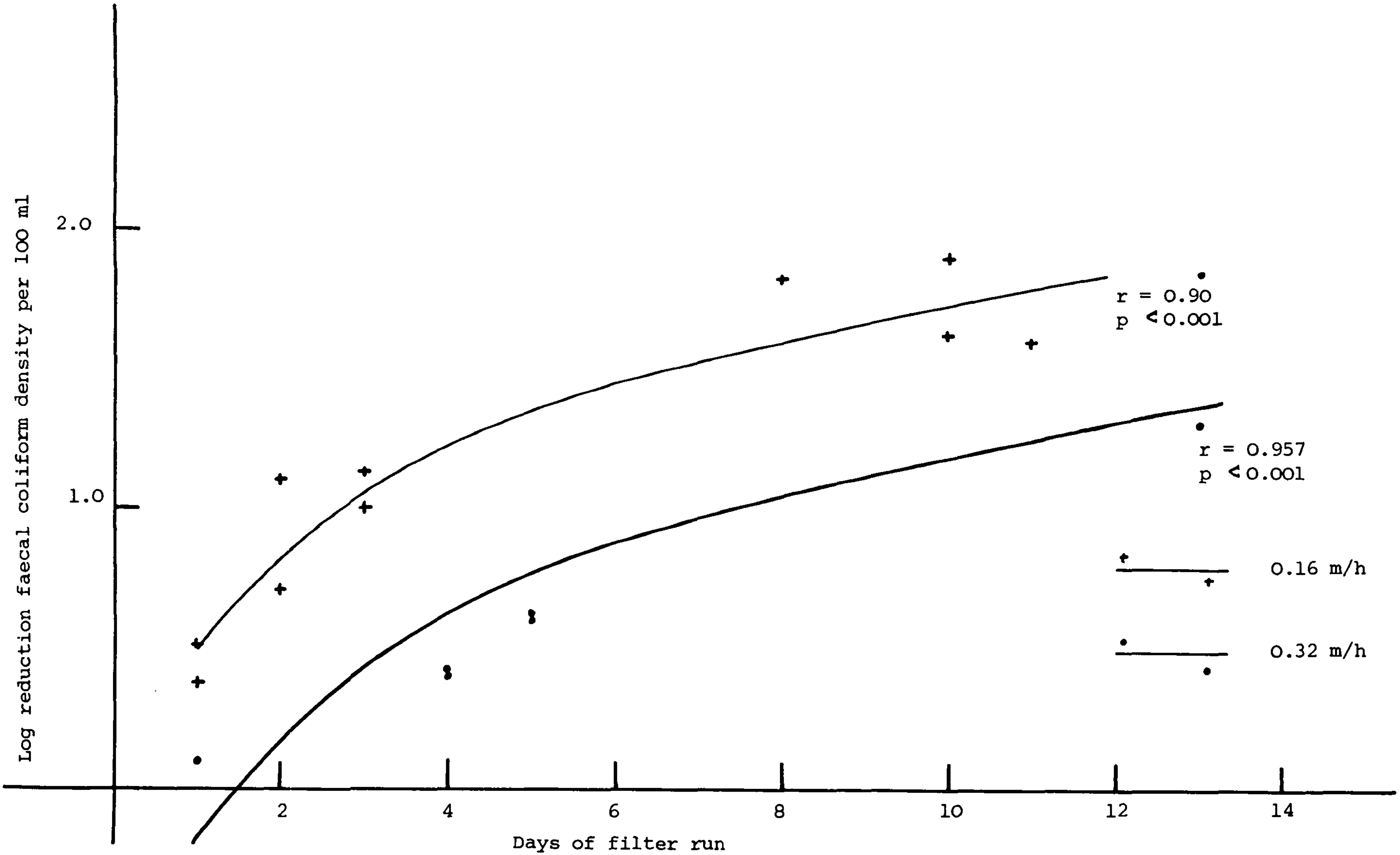


FIGURE 25 RATE OF MATURATION OF SLOW SAND FILTERS: FAECAL COLIFORM DENSITIES

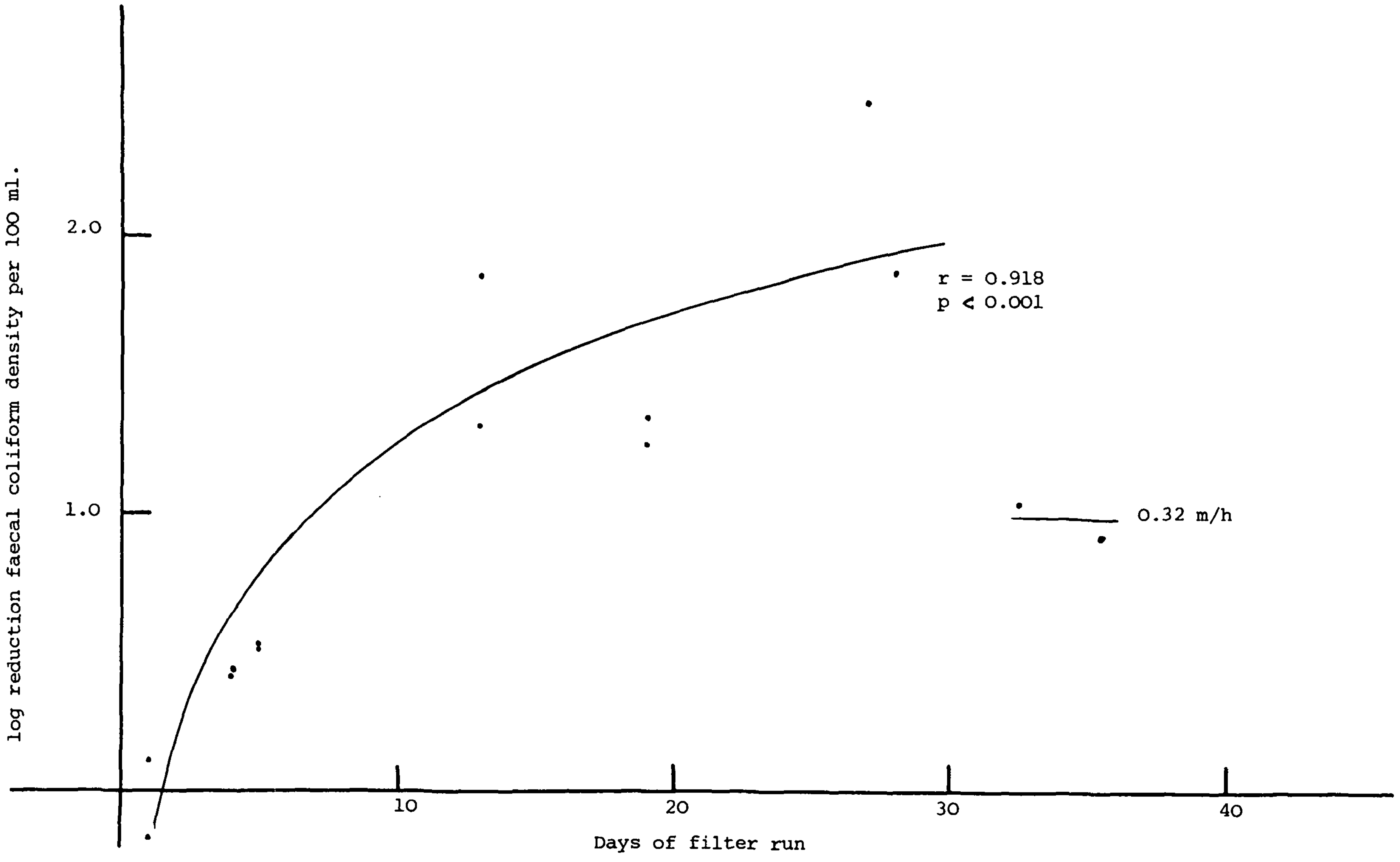


FIGURE 26 RATE OF IMPROVEMENT OF FAECAL COLIFORM REDUCTIONS BY SLOW SAND FILTERS FOLLOWING COMMISSIONING

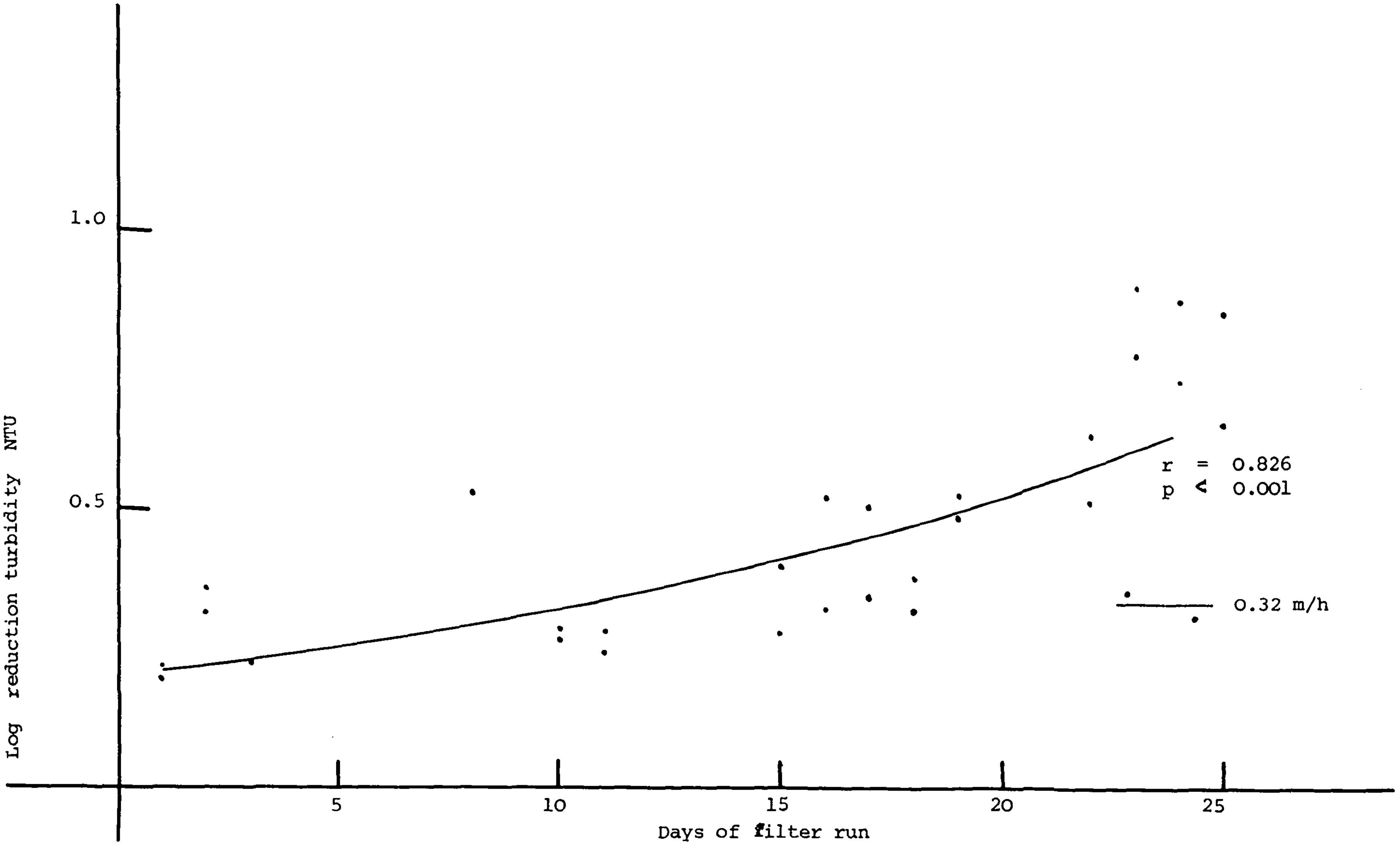


FIGURE 27 RATE OF IMPROVEMENT OF TURBIDITY REDUCTION BY SLOW SAND DILTERS FOLLOWING COMMISSIONING

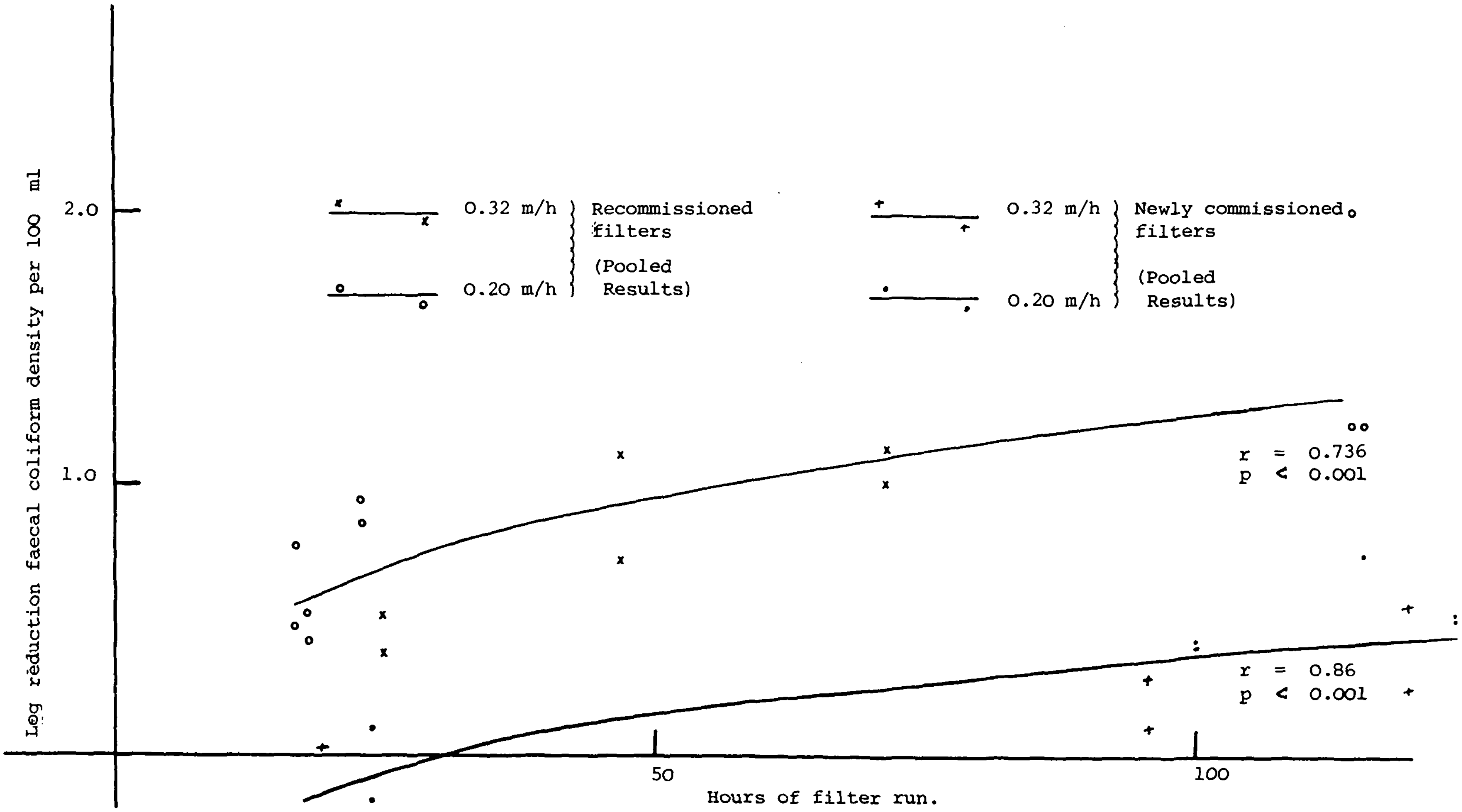


FIGURE 28 RATE OF IMPROVEMENT OF NEWLY COMMISSIONED AND RECOMMISSIONED SLOW SAND FILTERS FOLLOWING BACKWASHING WITH MODERATELY CONTAMINATED WATER.

filters which have been run for several months, de-commissioned and then re-commissioned mature relatively quickly after backwashing with moderately contaminated water whereas newly commissioned filters may take significantly longer.

2: With respect to the maintenance of efficiency during routine cleaning, two procedures have been adopted to minimise disruption of the functional biological populations. Firstly, the use of filter fabrics enables a significant proportion of these populations to be retained in place for re-introduction to the filter after cleaning the sand bed. One or two upper layers of fabric may be washed out but the lower layers are laid to one side with microflora and fauna undisturbed whilst the second procedure is undertaken. This is the gentle backflushing of the blocked filter with treated water - either from adjacent modules or from the storage tank. This backflushing is demonstrably less traumatic to the biological populations in the sand than draining down and skimming, but although it allows the recovery of head loss, it does not effect thorough cleaning of the bed. After backflushing, the fabrics are replaced, thereby immediately re-establishing the beneficial community of microorganisms. When more conventional cleaning procedures are indicated i.e. skimming, the retention of part of this community within fabric layers is of considerable benefit. This can be observed with reference to figure 29. Even though the recovery of the backflushed filter was marginally more rapid than the skimmed filter, the return to 1 log (90%) removal efficiency of faecal coliforms within approximately two days for both filters was creditable.

Similar effects were noted for both faecal streptococcus and turbidity reductions, though in both cases the expected efficiencies of removal are not as great as for coliforms (figures 30 and 31).

Compared to the use of final, treated water for the purposes of routine backflushing, the use of partially treated (prefiltered) water yields

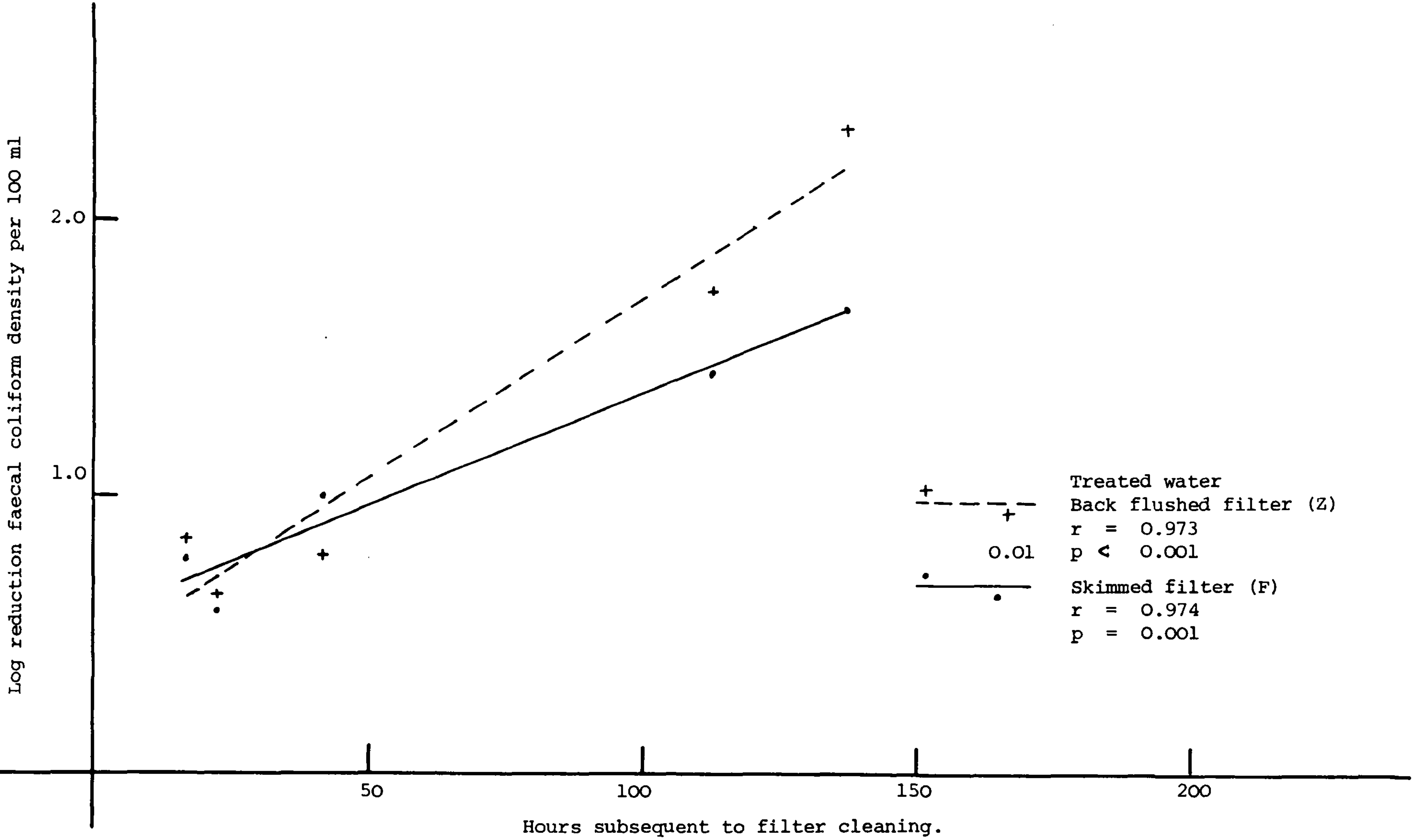


FIGURE 29 RECOVERY OF SLOW SAND FILTRATION EFFICIENCY SUBSEQUENT TO CLEANING: FAECAL COLIFORM DENSITY

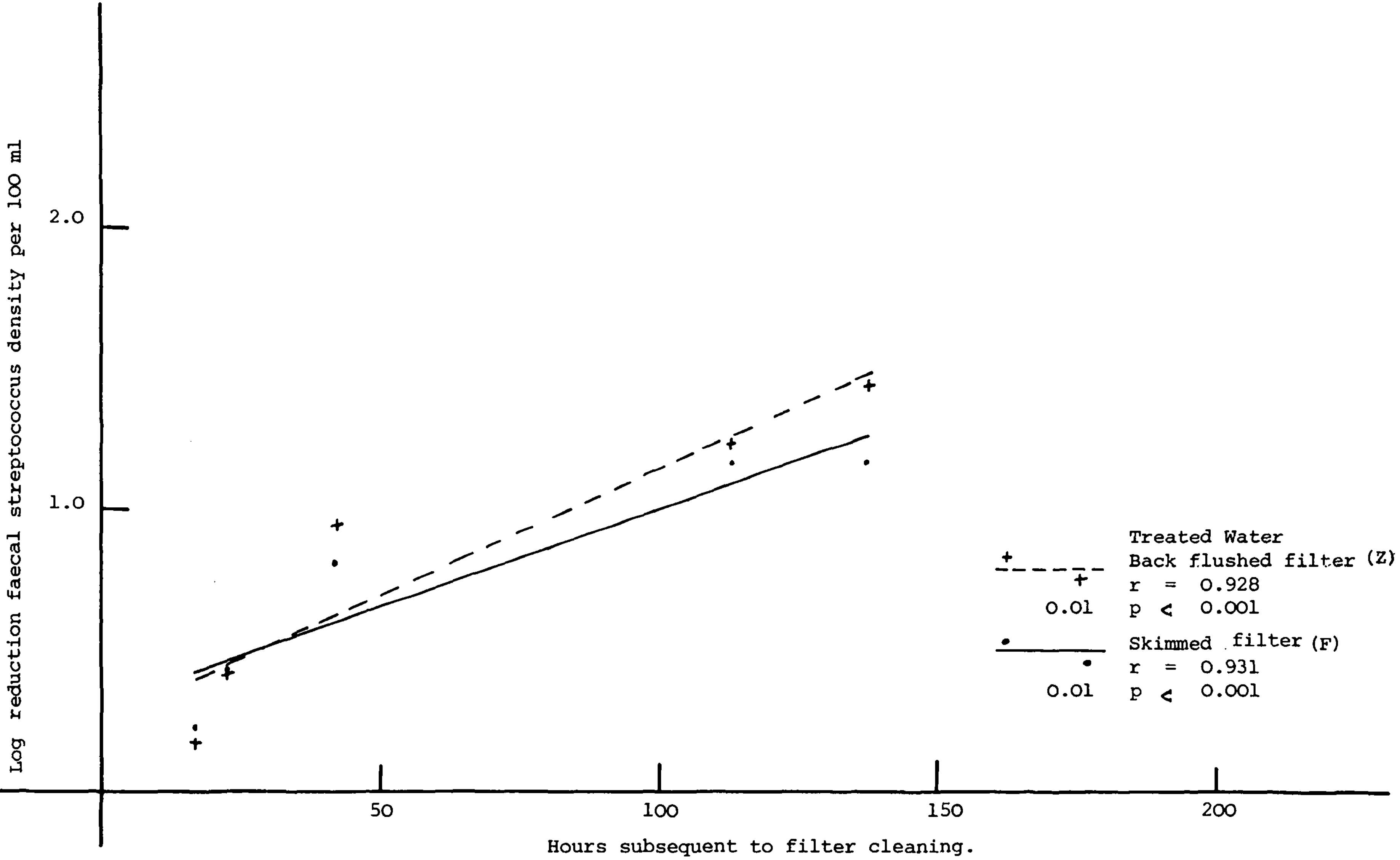


FIGURE 30 RECOVERY OF SLOW SAND FILTRATION EFFICIENCY SUBSEQUENT TO CLEANING: FAECAL STREPTOCOCCUS DENSITIES

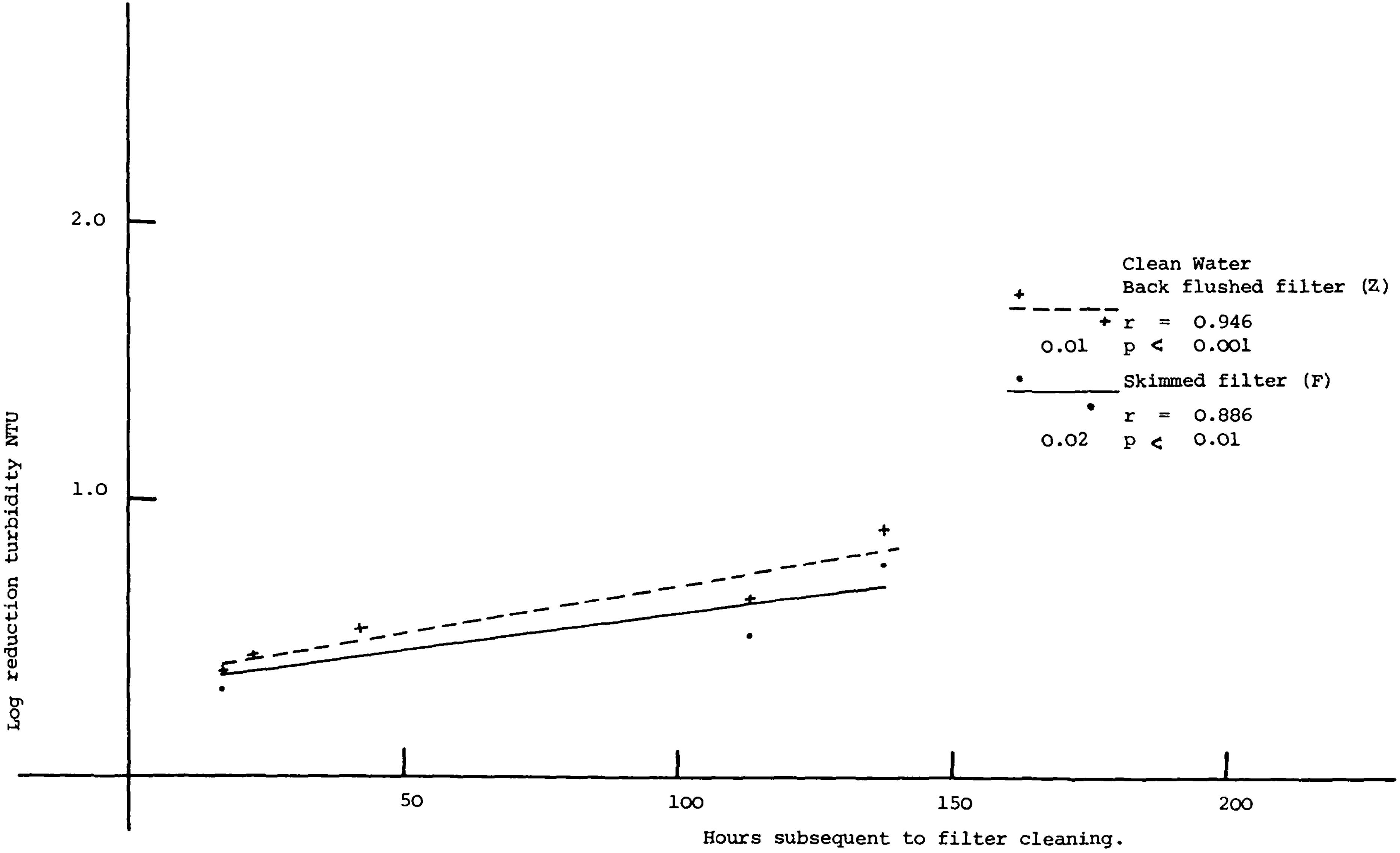


FIGURE 31 RECOVERY OF SLOW SAND FILTRATION EFFICIENCY SUBSEQUENT TO CLEANING: TURBIDITY

unacceptable results. Figure 32 demonstrates how cleaning with heads of 1m and 4m of sub-sand filtered water tends to retard the recovery of filter efficiency. This procedure might also have constituted an alternative to skimming when more vigorous cleaning than backflushing was necessary to remove entrapped silt and organic material from the top few centimetres of the sand bed. The availability of relatively large heads of prefiltered water would normally allow quite vigorous backwashing of the sand beds. However, it appears that the down-time of a filter cleaned by this method would be at least as long if not considerably longer than that following skimming. In any case it would be dubious hygienic practice to introduce partially treated water downstream of slow sand filtration however effective the cleaning method.

In marked contrast to the observed effect of flow rate on the rate of maturation of newly commissioned filters (figure 25), there was no apparent effect of flow rate on the efficiency of established filters. Figures 33 to 35 show the effect on filtrate quality of raising the flow rate of a slow sand filter module (F) from 0.16 to 0.35 m/h. A parallel filter (Z) remained at 0.16 m/h. The two filters were of comparable efficiency before the flow rate was raised, and with very little disturbance, filter F retained its bacteriological efficiency with respect to filter Z (figures 33 and 34). The turbidity reductions did reflect the difference in flow rates however, with the faster flow rate in filter F resulting in a slight diminution in observed efficiency (figure 35).

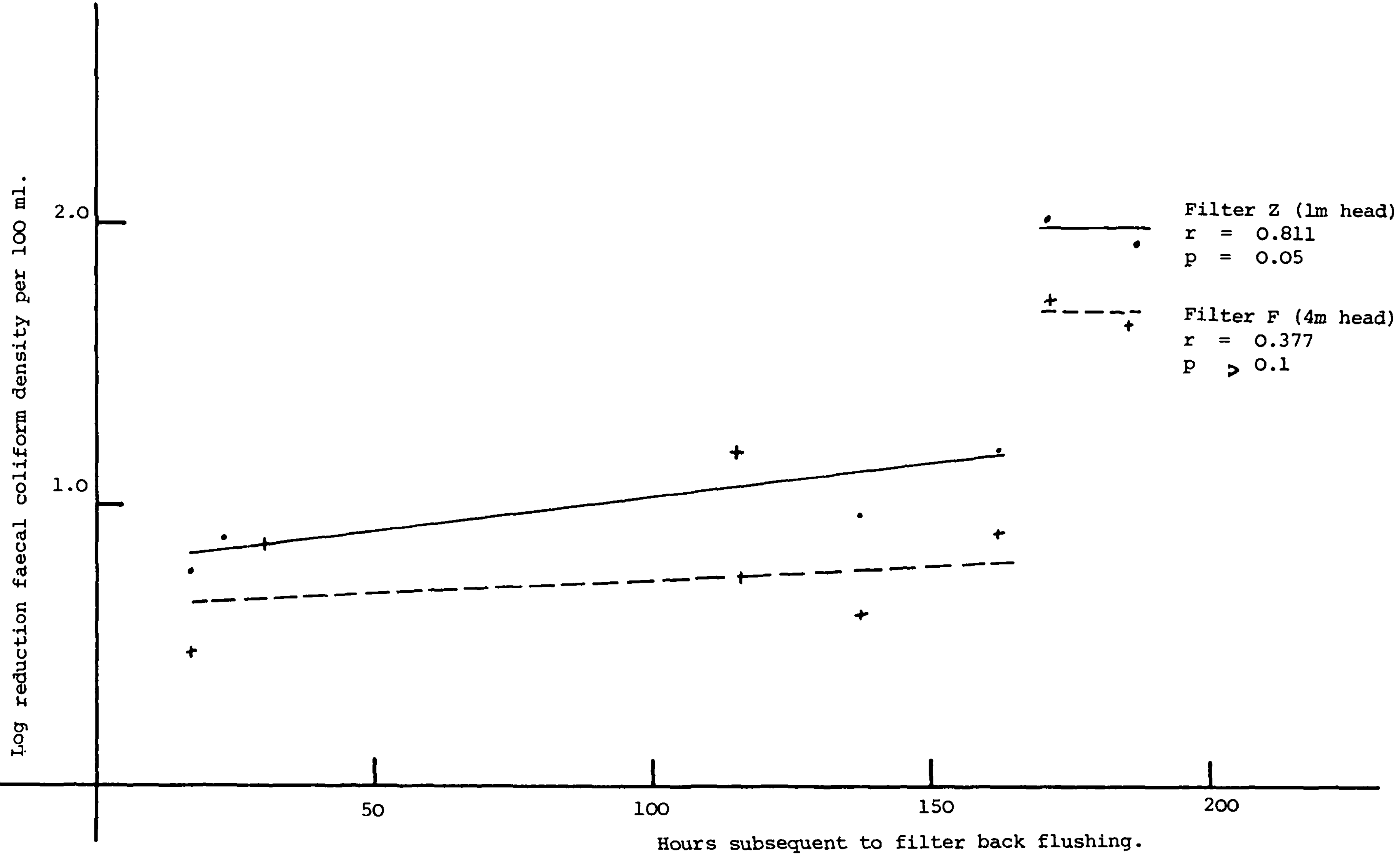


FIGURE 32. RECOVERY OF SLOW SAND FILTER EFFICIENCY SUBSEQUENT TO BACK FLUSHING WITH MODERATELY CONTAMINATED WATER.

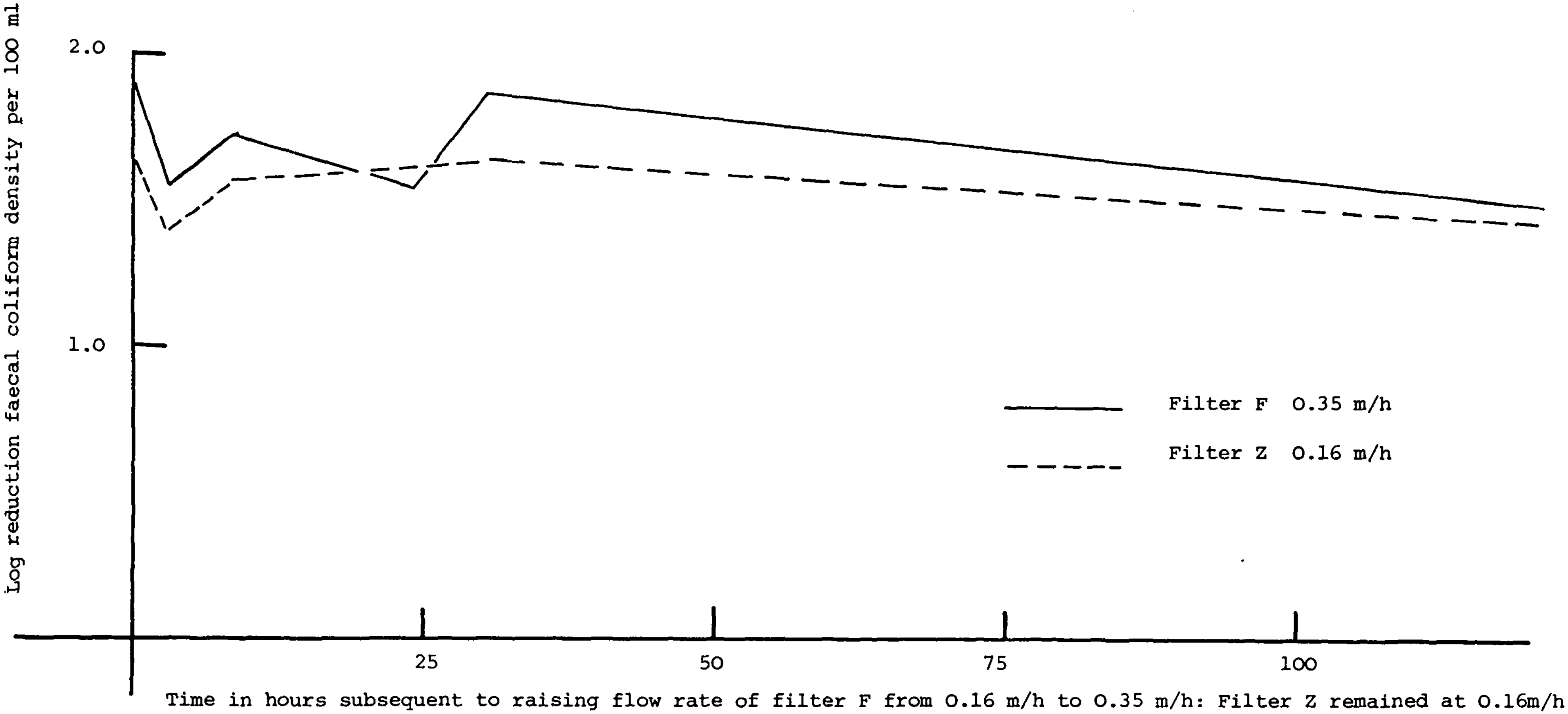


FIGURE 33 EFFECT ON SLOW SAND FILTRATION EFFICIENCY OF RAISING FLOW RATE: FAECAL COLIFORM DENSITIES.

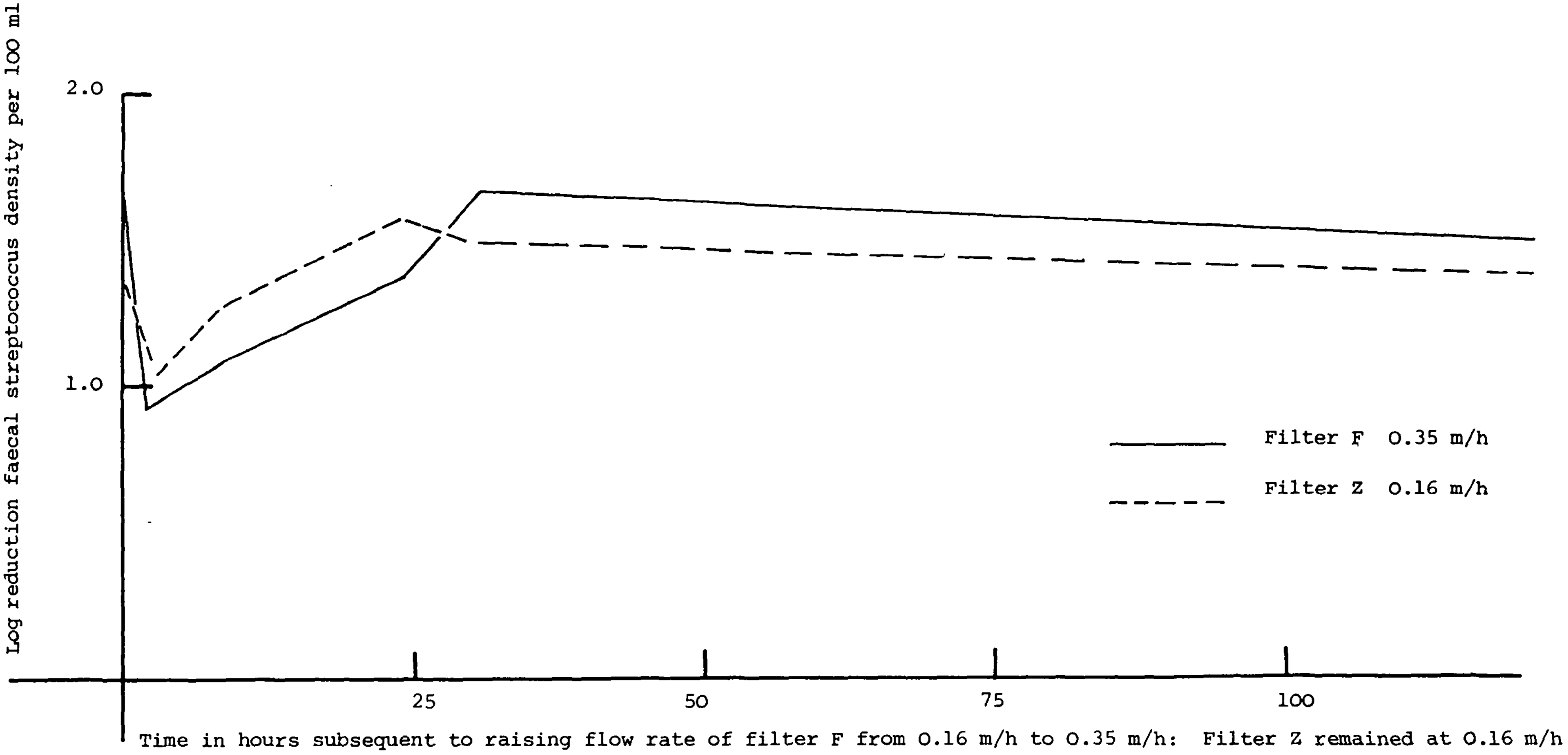


FIGURE 34 EFFECT ON SLOW SAND FILTRATION EFFICIENCY OF RAISING FLOW RATE: FAECAL STREPTOCOCCUS DENSITIES

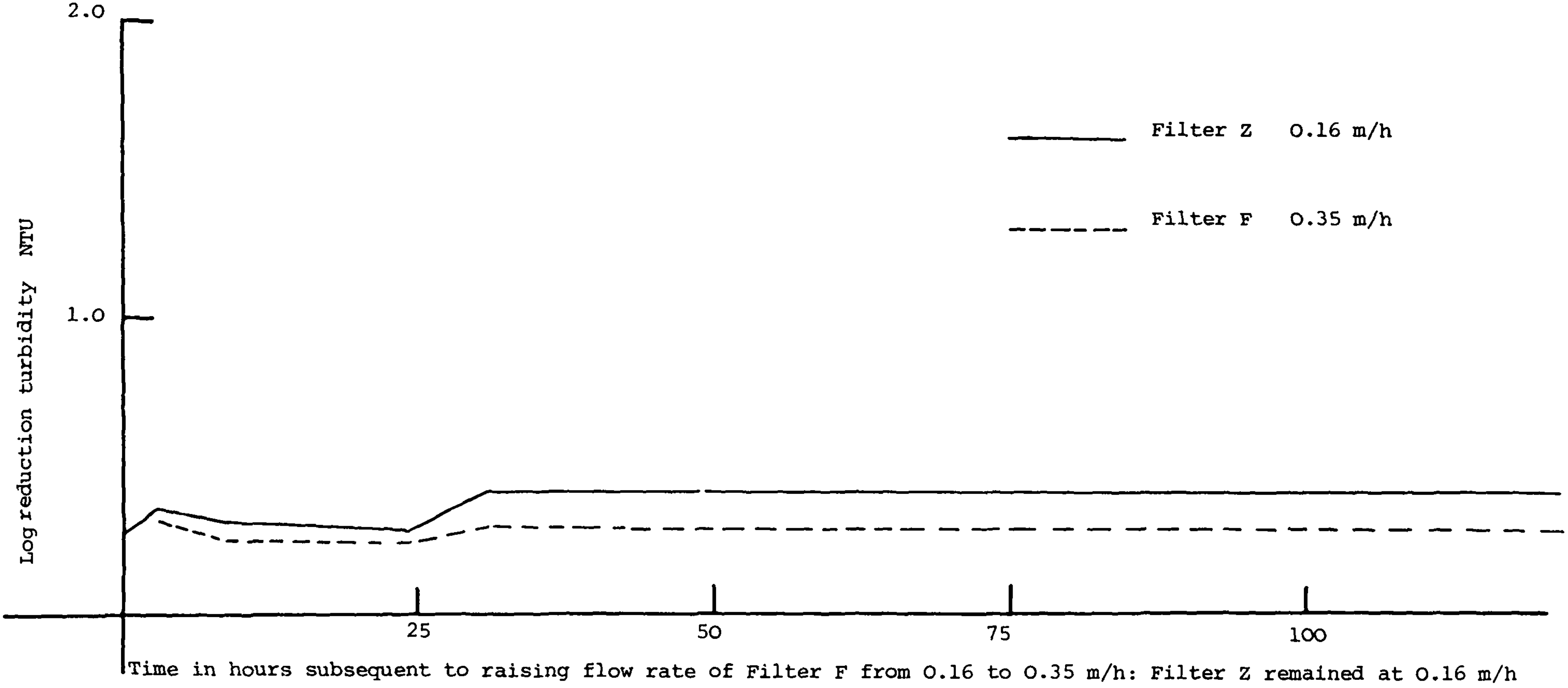


FIGURE 35 EFFECT ON SLOW SAND FILTRATION EFFICIENCY OF RAISING FLOW RATE: TURBIDITY

Overall Performance

The performance of the dual sand filtration system in summer operating conditions i.e raw water temperatures in excess of 10°C, may be assessed with reference to figures 36-44.

Figures 36 and 37 describe the dissolved oxygen levels in raw, prefiltered and slow sand filtered water in parallel dual sand filtration systems F and Z over a five week period. Oxygen levels in the raw water occasionally exceeded 200% saturation, presumably due to the photosynthetic activity of the algal soup which was the pond at that time, and in those cases no extrapolation to oxygen concentration in mg/L could be made. In consequence, the graph of raw water dissolved oxygen is interrupted at three points; however, it is clear that the concentrations were broadly in the range 12-16 mg/L.

Oxygen depletion due to prefiltration by sub-sand abstraction was significant, and this is reflected in the dissolved oxygen concentrations in the supernatant water of the slow sand filters. The supernatants had some access to atmospheric oxygen and thus the apparent oxygen depletion may not represent the real initial depletion in the sub-sand filtrate prior to delivery to the slow sand filter modules. However, for the purposes of assessing the biological activity of both slow sand filters, it may be noted that the available dissolved oxygen throughout the 5 week period was in the range 6-10 mg/L. Depletion of oxygen in these secondary filters was substantial in the early part of the filter runs; in both cases oxygen levels in the filter outlets were reduced by more than 4 mg/L for 10 days. Thereafter, oxygen depletion dimished until by the end of the 5 week experiment it was minimal i.e less than 1mg/L

The apparent decrease in biological activity in the slow sand filters during the filter run is due to a combination of factors. Firstly, the water temperatures during this period declined from a peak of approximately 22°C to less than 15°C between days 20 and 35 (figure 38). On the premise that a

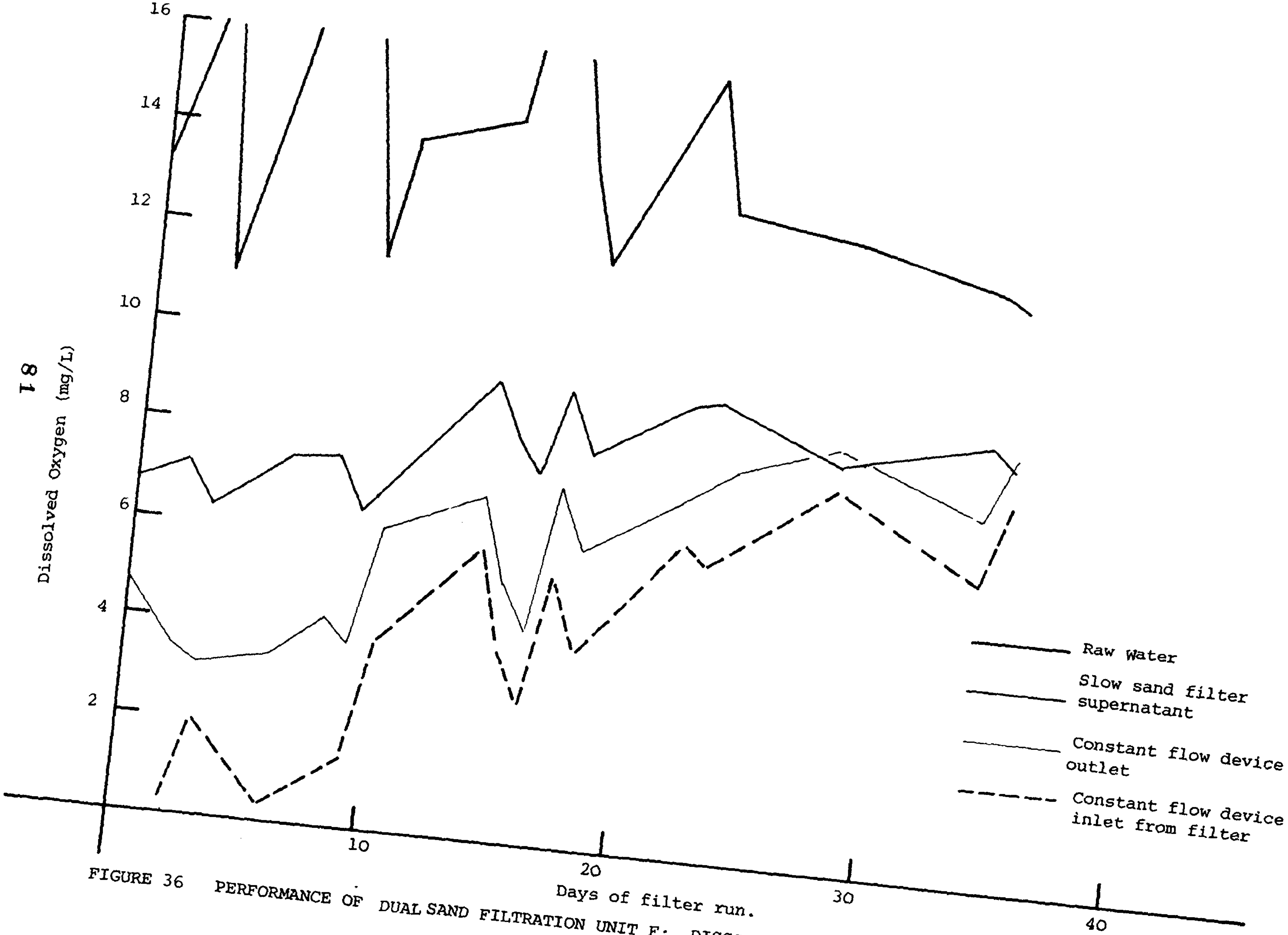


FIGURE 36 PERFORMANCE OF DUAL SAND FILTRATION UNIT F: DISSOLVED OXYGEN

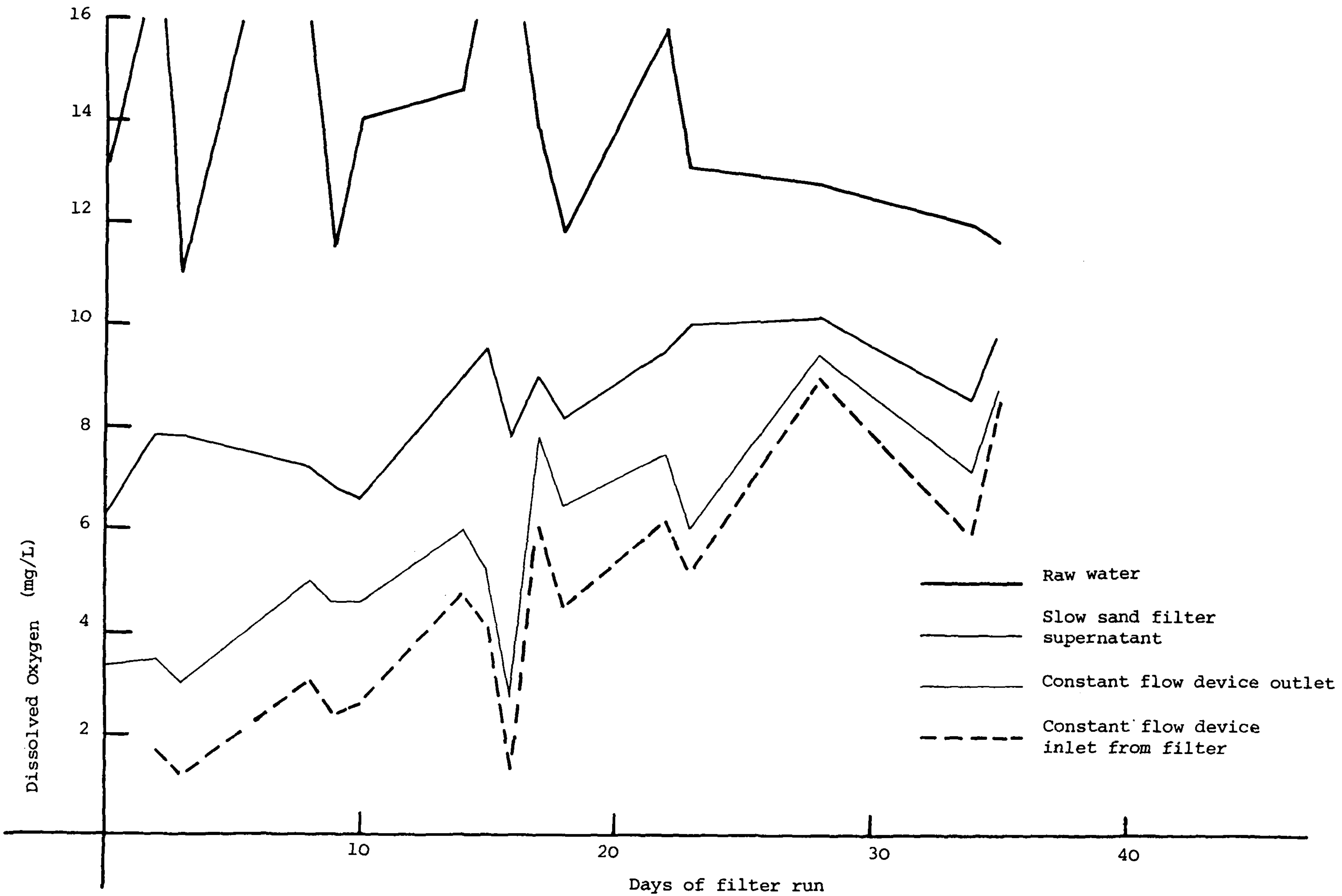


FIGURE 37 PERFORMANCE OF DUAL SAND FILTRATION UNIT Z: DISSOLVED OXYGEN

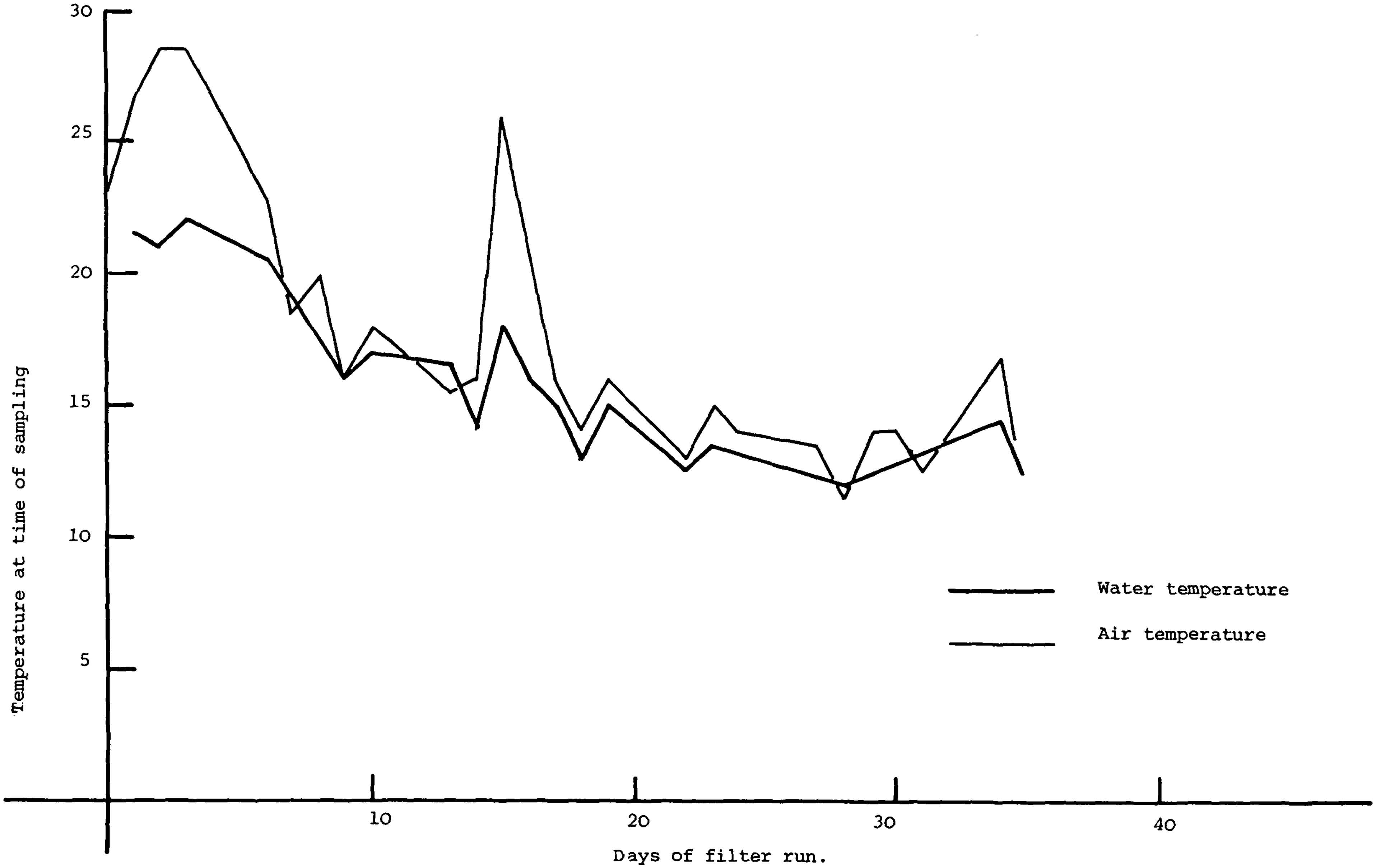


FIGURE 38 VARIATIONS IN TEMPERATURE DURING SLOW SAND FILTRATION RUN.

10°C drop in temperature is associated with a halving of the rates of most biochemical reactions, the fall in water temperatures could feasibly account for almost a halving of oxygen depletion. Secondly, the period of maximum respiratory activity is certain to coincide with the period of maximum growth of the biological populations i.e. at the commencement of filter runs. Data will be presented at a later stage which describes how quickly the microflora and fauna become established in the sand and filter fabrics in the early stages of filter runs.

The re-oxygenation effect of the constant flow device is apparent in both systems throughout the filter runs. The re-introduction of oxygen into the filtrate occurs as water cascades down the telescopic delivery tube in the centre of the device. Meanwhile, fresh air is automatically drawn down through holes in the ball float. The increase in dissolved oxygen was normally in the range 1-3 mg/L - a valuable contribution from the point of view of acceptability of taste of the treated water.

Figures 39 to 41 represent the overall percentage efficiencies of the dual sand filtration system with respect to faecal coliform, faecal streptococcus and turbidity reductions. It is encouraging to note that within one day of the commencement of filter runs, 90% (1 log) reductions in faecal coliform densities were obtained, and within 6 days reliable 99-99.9%+ (2-3+ log) reductions were established. This implies that with a raw water density of faecal coliforms of 1,000 per 100 ml, the filtrate would ordinarily contain levels below 10 per 100 ml. This level of efficiency was obtained despite the fact that the prefilters were backwashed every week. Reductions in faecal streptococcus densities were not quite as high as those for faecal coliforms. This may be attributable to the generally greater resistance of faecal streptococci to treatment processes and to environmental stress. Reductions in turbidity remained relatively constant around 90% (1 log). This probably represents the minimum expected efficiency for the dual

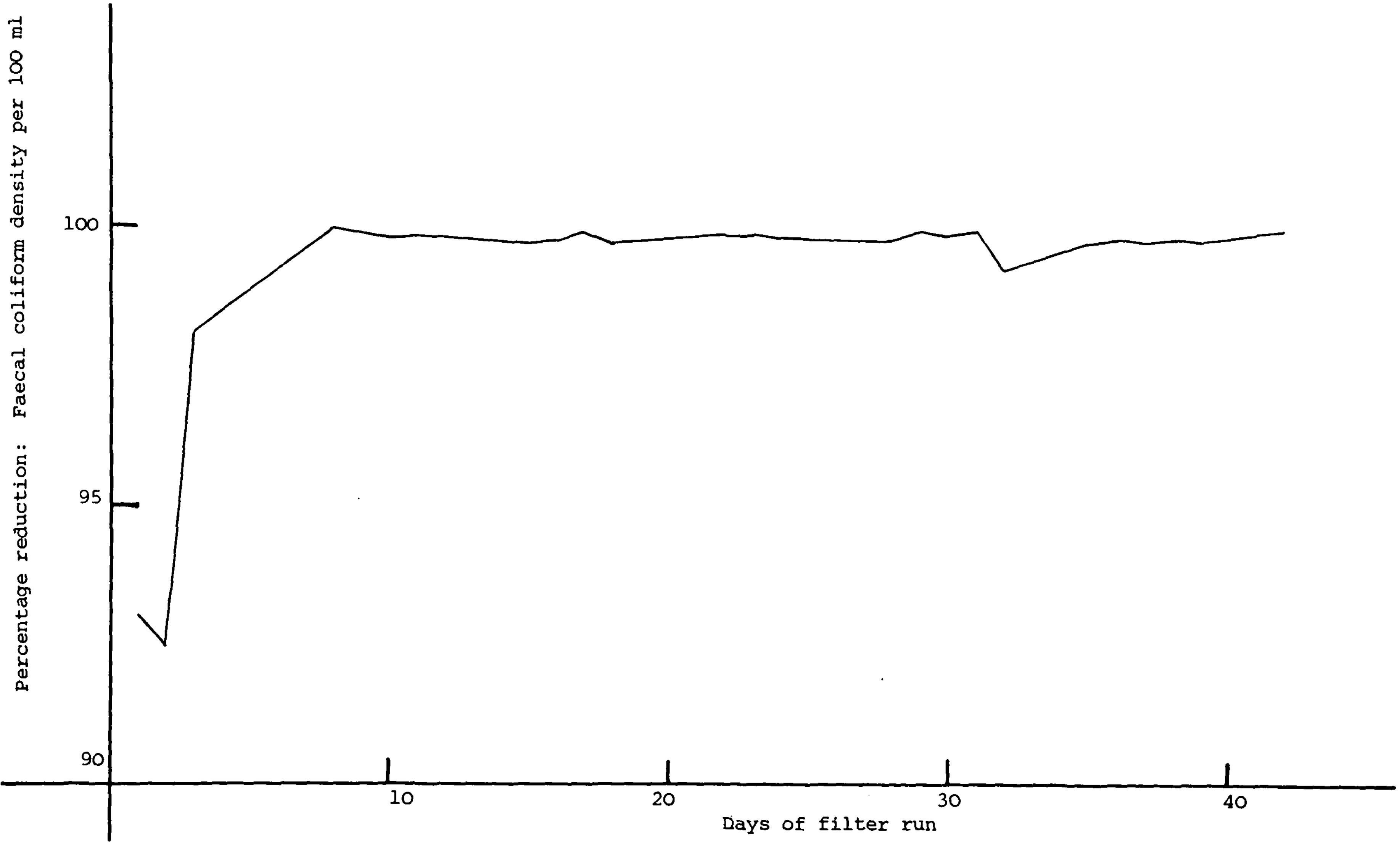


FIGURE 39 DUAL SAND FILTRATION EFFICIENCY: FAECAL COLIFORM REDUCTIONS
(Data based on means of duplicate samples from two parallel filters)

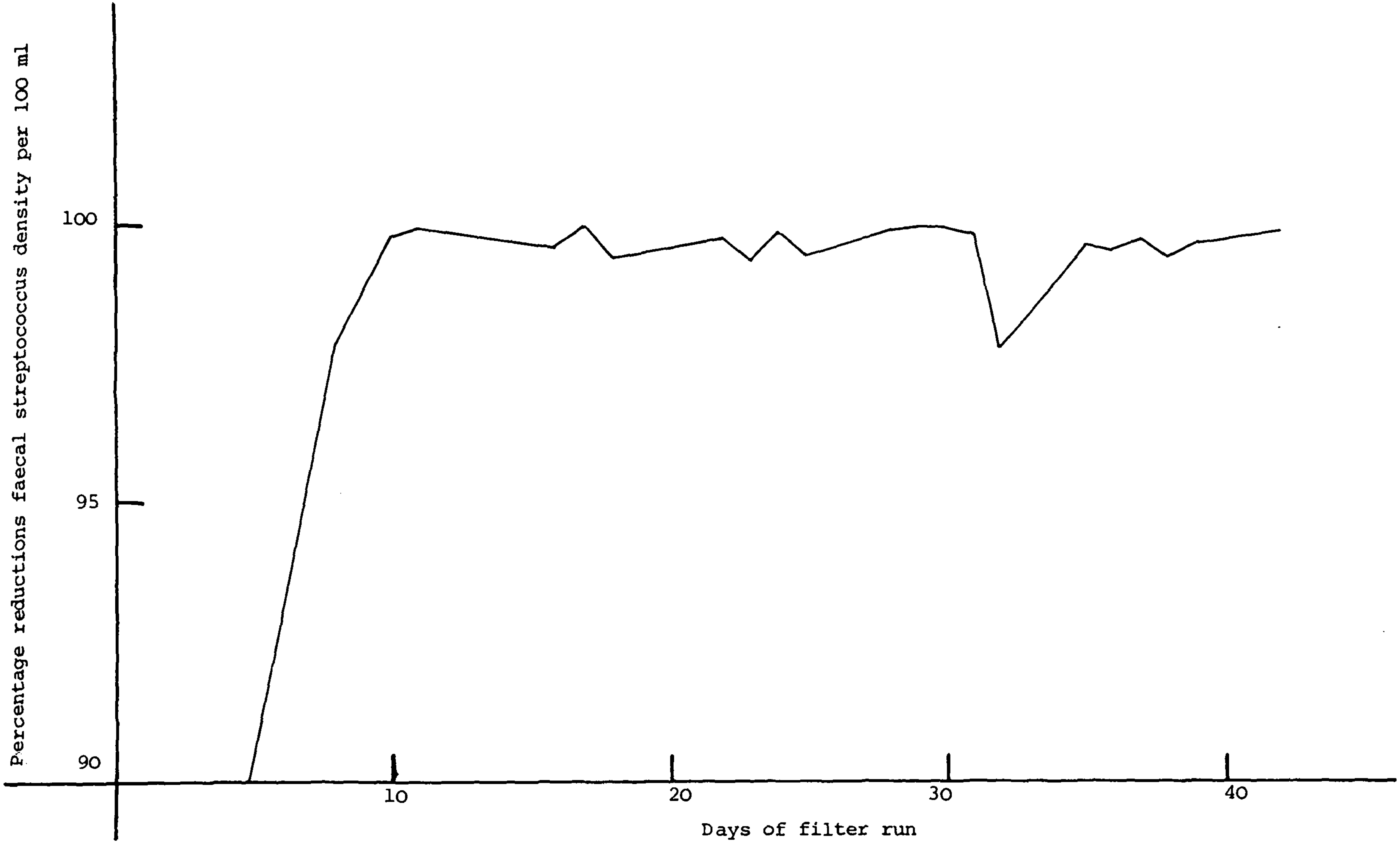


FIGURE 40 DUAL SAND FILTRATION EFFICIENCY: FAECAL STREPTOCOCCUS REDUCTIONS
(Data based on means of duplicate samples from two parallel filters)

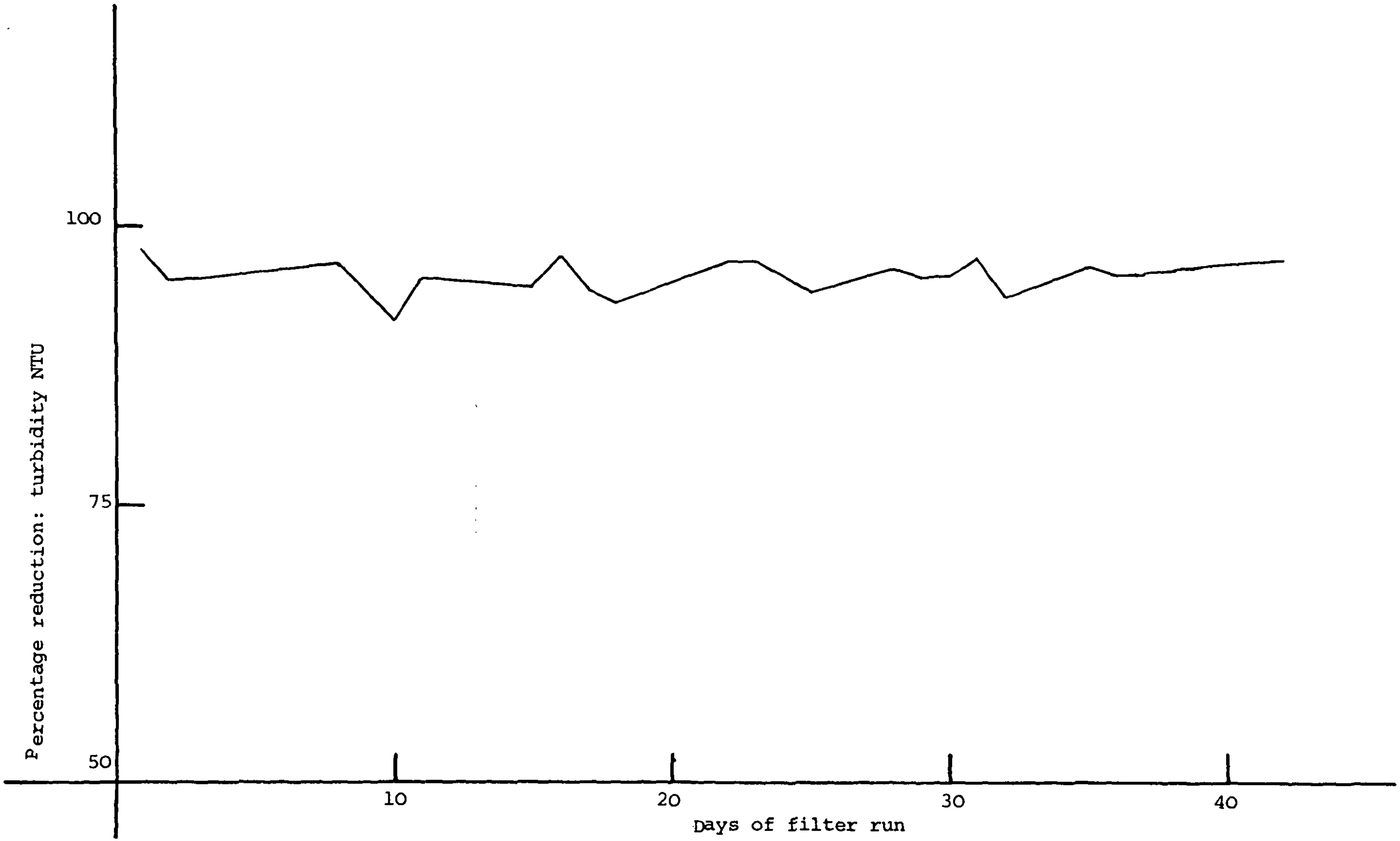


FIGURE 41 DUAL SAND FILTRATION EFFICIENCY: TURBIDITY REDUCTIONS
(Data based on means of duplicate samples from two parallel filters)

sand filtration system, since it was obtained during a period of low suspended solids loading and a raw water turbidity of only 5-15 NTU. Thus, there was very little scope for greater efficiency than that observed.

The effects of cleaning of both prefilters and slow sand filters on the overall efficiency of the system may be judged from figures 42, 43 and 44. The results for raw water and final treated water are expressed for two parallel systems (F and Z) in terms of log counts for each parameter. This is not a particularly satisfactory method of plotting the data - where results of 0 faecal coliforms per 100 ml were obtained they could not be assigned a log value - however, the expansion of scale in the range 1-10 (0-1 log) faecal coliform density is necessary to illustrate the effect of cleaning. It is clear from figure 42 that whenever sub-sand filters were backwashed (labelled on the horizontal axis with a number 3) there immediately followed an elevation in bacterial densities in the final filtrates. This normally caused an increase to around 1 log i.e. 10 faecal coliforms per 100 ml. The effect of cleaning the slow sand filters by skimming or backflushing can be assessed from the occasion when this maintenance procedure coincided with backwashing of the primary filters (labelled 2 on the axis). In this case an unacceptable elevation to 1.5-1.8 log i.e. 32-63 faecal coliforms per 100 ml occurred.

The implications of these observations for operation and maintenance procedures are plain. At no time should simultaneous cleaning of both filtration systems occur unless i) a down-time equivalent to that allowed after commissioning can be tolerated; or ii) disinfection is practised.

The deleterious effect of cleaning on faecal streptococcus densities in the slow sand filter effluents in more marked (figure 43), but again, even with raw water levels in excess of 1,000 per 100 ml, provided that good maintenance practice is followed, the filtrate densities can usually be kept below 10 per 100 ml. As previously noted, turbidity fluctuations in the treated waters are much less apparent during and just after cleaning

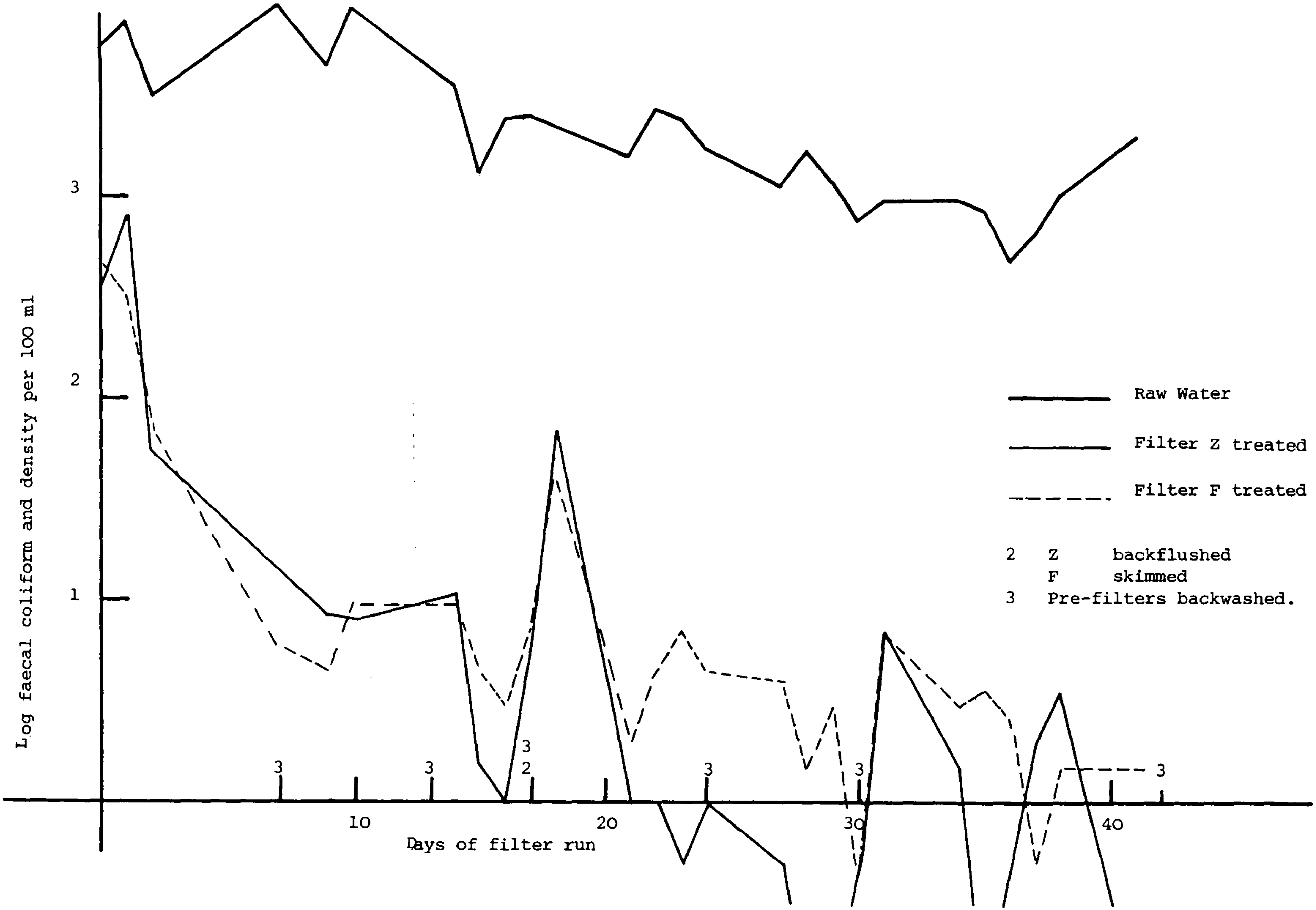


FIGURE 42 PERFORMANCE OF DUAL SAND FILTRATION SYSTEM: FAECAL COLIFORM DENSITIES

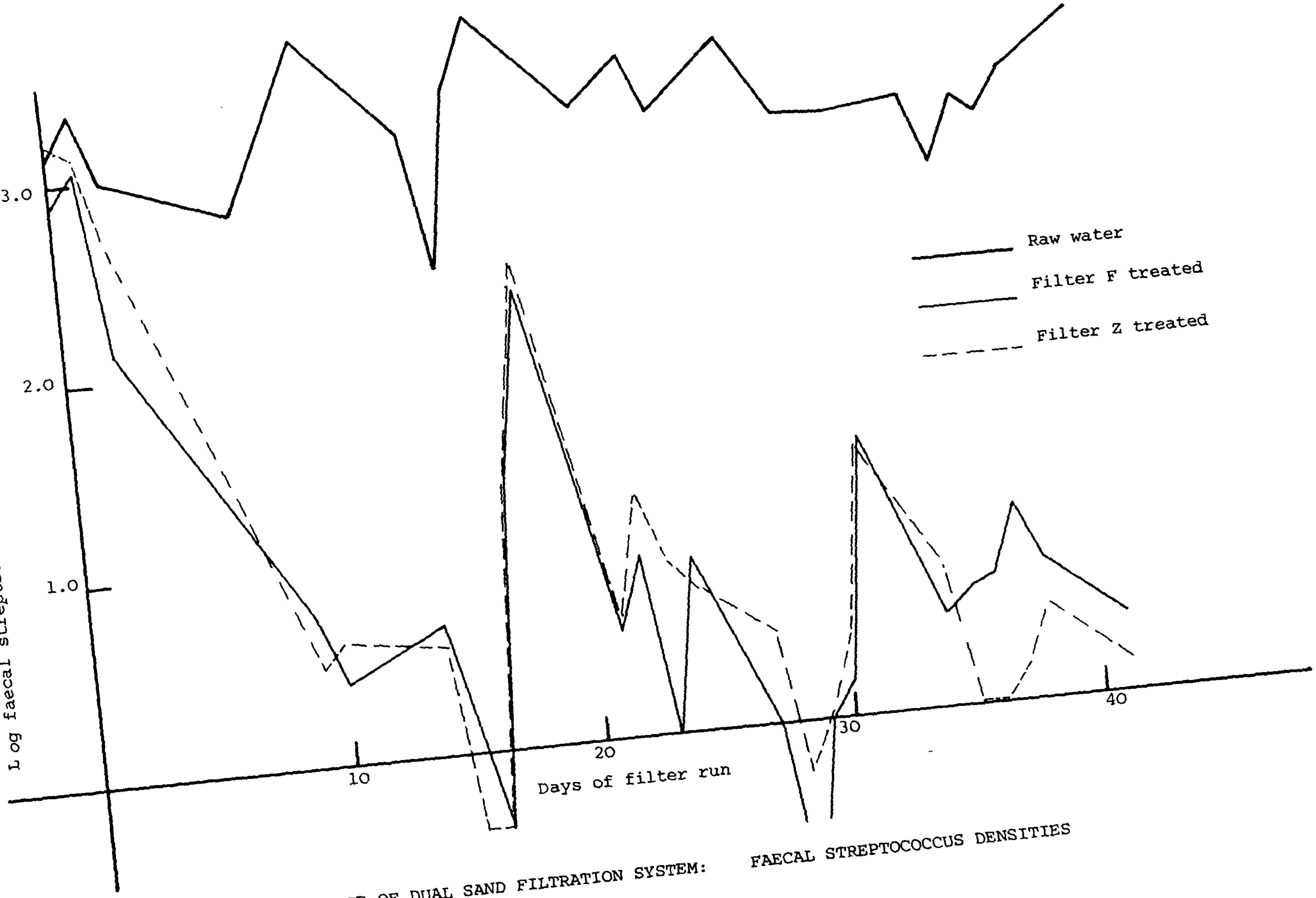


FIGURE 43: PERFORMANCE OF DUAL SAND FILTRATION SYSTEM: FAECAL STREPTOCOCCUS DENSITIES

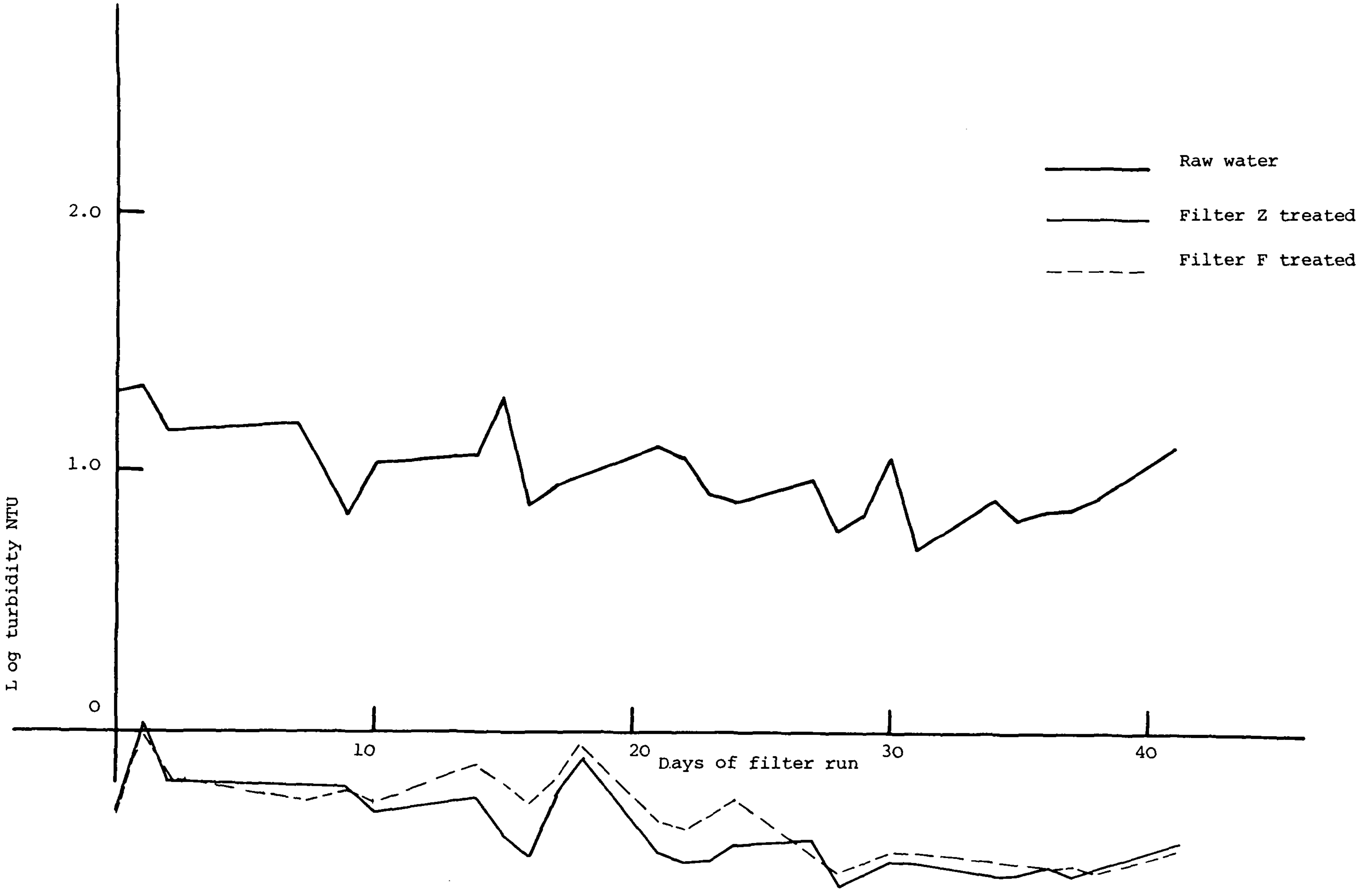


FIGURE 44: PERFORMANCE OF DUAL SAND FILTRATION SYSTEM: TURBIDITY

operations. In consequence, although turbidity levels increased sharply when both filtration stages were cleaned together, the quality of the filtrate did not deteriorate to unacceptable levels, and remained well below 1 NTU for most of the filter run.

Fabric Efficiency

Having identified what appeared to be the most promising fabrics in the first phase of experimentation, there was a requirement for identifying the optimum number of fabric layers and their orientation for efficiency of treatment, ease of maintenance and cost-effectiveness. The main fabric - a coarse material (code 305) was tested alone at two different filtration rates in multiple layers. The amount of silt retained in each layer is expressed as a volume per square metre of material (table 1).

TABLE 1: PENETRATION OF SILT IN MULTIPLE LAYERS OF A SINGLE FABRIC (CODE 305) IN FILTERS OPERATED AT 0.23 m/h (FILTER X) AND 0.34 m/h (FILTER Y).

	SLOW SAND FILTER X		SLOW SAND FILTER Y	
Layer	Silt Content		Silt Content	
	L/m^2	% age	L/m^2	% age
1	5.49	87.8	9.89	95.1
2	0.72	11.5	0.41	4.0
3	0.05	0.8	0.03	0.3
4	0	0	0.04	0.3
5	0	0	0.03	0.3
6	0	0	0	0
Total	6.26	100	10.40	100

It is apparent that whether the flow rate is 0.23 m/h or 0.34m/h, the vast majority of silt (greater than 99%) is retained within the top two layers of a simple fabric multi-layer. Very little silt is retained in lower layers. This has very practical implications for the incorporation of fabrics in the protection of slow sand filters. As far as silt exclusion is concerned, there is clearly no advantage in having more than two layers of an individual fabric type. However, it has been shown (Skilton, 1983) that as the top layer of a multi-layer becomes silted-up, the protozoal and small metazoal populations migrate downwards away from this layer. Thus to maintain the in situ biological populations after filter cleaning, it is probably necessary to have two and ideally three layers of a single fabric to ensure that at least one layer remains a hospitable environment for these organisms. Then if the silt-laden top layer is washed out and replaced as the bottom layer, a rotating pattern of fabric replacement can be adopted.

It has been postulated in the first project report (Wheeler et al, 1983) that an alternating series of coarse and denser fabrics might improve efficiency of silt deposition due to the alternation in water velocities and increased local turbulence which should occur as a result. This factor was investigated, and on purely empirical grounds appears to have been proven (table 2). The same amount of fabric was placed in two identical filters but in different configurations. Filter Y contained a series of three double layers each comprising one coarse and one dense fabric layer. The coarse layer was the previously selected main fabric (code 305). The dense layer was another synthetic fabric (code T3) of significantly different texture and finer fibres than fabric 305. Filter X contained three layers of coarse fabric above three layers of dense fabric. It is evident that the alternation of density yielded substantially higher efficiency of silt retention and reduced penetration of silt into the top 5 cms of the sand bed by a factor of nearly 2.5. Since the great majority of silt which enters the sand bed is retained within the top 5cms, the silt volumes in each fabric layer and the sand are also expressed as a percentage of the total. From these figures it is apparent that whereas the simple configuration of three

TABLE 2: PENETRATION OF SILT IN MULTIPLE LAYERS OF TWO FABRICS (CODE 305 - COARSE AND CODE T3-DENSE) AND UNDERLYING SAND BED IN TWO FILTERS WITH ALTERNATING FABRIC DENSITIES (FILTER Y) AND SIMPLE ARRANGEMENT (FILTER X).

SLOW SAND FILTER Y					SLOW SAND FILTER X				
Layer	Layer type	Material	Silt content L/m^2	% age	Layer	Layer type	Material	Silt content L/m^2	% age
1	Top Double Layer	Coarse	19.4	49.4	1	Top Triple Layer	Coarse	17.6	40.5
2		Dense	8.9	22.7	2		Coarse	2.9	6.6
					3		Coarse	1.5	3.5
3	Middle Double Layer	Coarse	1.7	4.4	4	Bottom Triple Layer	Dense	1.1	2.0
					5		Dense	0.01	0.2
4		Dense	0.9	2.3	6		Dense	0.01	0.2
5	Bottom Double Layer	Coarse	0.01	0.02					
6		Dense	0.03	0.07					
Sand	Top 5cm		8.33	21.11	Sand	Top 5 cm		20.4	46.9
Total			39.27	100%				43.52	100%

coarse plus three dense fabrics excluded 53% of the silt loading from the bed, the alternating configuration excluded nearly 79%.

These unequivocal results led to the acceptance of the principle of alternating density in the specification of fabrics for the UOS-ODA small scale slow sand filters. It is apparent that three double layers provide the optimal cost-effective arrangement for effecting high silt exclusion and encouraging the maintenance of biological populations between filter runs.

Upflow Gravel and Sand Prefiltration

Two pilot upflow filters were installed in order to give a general impression of the potential value of incorporating such a stage in the UOS-ODA package. Filters were constructed in 50 gallon circular polyethylene tanks with underdrainage inlets of holed pipework plus approximately 10 cms of coarse gravel. Filter medium depth was restricted to 30 cms of pea gravel (10-12 mm shingle) or builder grade sand. The gravel and sand prefilters were run in parallel at flow rates of 0.5-0.9 m/h and given weekly gravity backwashes, effected by rapid drain down (figure 45).

Although the filtration rate of the sand filter was usually lower than that of the gravel filter, the results obtained from both are comparable (table 3). It is particularly interesting to note that faecal bacterial reductions were quite high and certainly well worth having. In contrast, reductions in turbidity were relatively low which implies that either the retention time was insufficient (flow rate too high or bed depth too low), or that the filters had not fully matured. The main purpose of upflow roughing filtration is the removal of suspended solids prior to slow sand filtration and so these effects will be further investigated in the programme of research concerned with horizontal filtration.

It is well worth restating the value of gravel prefiltration in terms of its low maintenance requirements and high efficiency. Whether upflow or horizontal roughing filtration is employed will largely depend on local geographical factors. Nevertheless, the evidence from other studies quoted in Section 3 and the brief experimentation conducted at Surrey to date confirm the advantages of gravel filtration and suggest that perhaps contrary to expectations, the efficiency of bacterial and turbidity reductions are comparable to those in sand, even at relatively high flow rates.

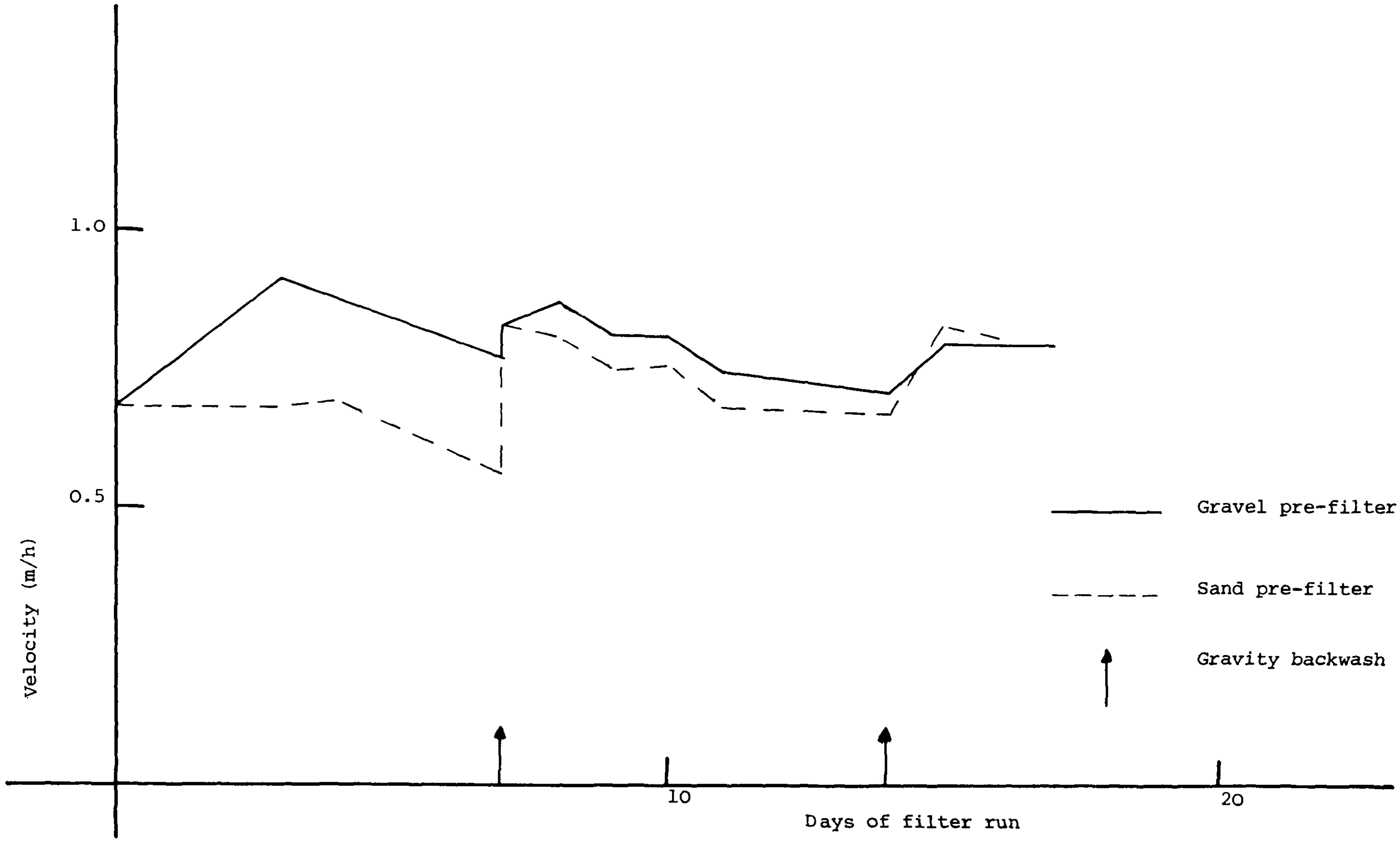


FIGURE 45 OPERATIONAL PERFORMANCE OF UP-FLOW PRE-FILTERS: FLOW RATES

TABLE 3: PERFORMANCE OF GRAVEL AND SAND UPFLOW PREFILTERS OPERATED AT 0.5-0.9 m/h

	GRAVEL PREFILTER Log reductions			SAND PREFILTER Log reductions		
	Faecal coliforms per 100 ml	Faecal streptococci per 100 ml	Turbidity NTU	Faecal coliforms per 100 ml	Faecal streptococci per 100 ml	Turbidity NTU
MEAN	0.587	0.609	0.142	0.769	0.636	0.179
SAMPLE STANDARD DEVIATION	0.149	0.364	0.071	0.250	0.209	0.099
POPULATION STANDARD DEVIATION	0.138	0.340	0.066	0.232	0.195	0.092
N	7	8	7	7	8	7

Observations on the Pollution Incident

As previously mentioned, the experimental period was shortened by the occurrence of a fairly severe pollution incident which affected the raw water source in early summer. Whilst the incident was in itself a cause of frustration, the effects and observations are worth recording since several lessons were learned in the course of overcoming the problem.

Following heavy rainfall in the period 28-30 May, it was noted on June 1 that the sub-sand abstraction units and slow sand filters were returning neglibible efficiencies of bacterial removal. Two days later, turbidity readings in the slow sand filtrate actually exceeded those in the raw water, and dissolved oxygen levels in both raw and treated waters were zero. Clearly there had been a total breakdown in the biological processes of filtration. By June 6, no improvement had occurred and all units were decommissioned. At this point, the activity of sulphate reducing bacteria had caused substantial blackening of all sand media and fabrics (plates 7, 8 and 9), growth of iron bacteria on surfaces in contact with running water had caused red-brown staining of pipes and tanks, and all life in the raw water from fish to filamentous algae had died (plate 10).

The direct cause of the above effects was discovered to be a very large ingression of farm silage liquor into the pond which had been washed into the water during the period of heavy rainfall.

Two attempts to re-oxidise filter media by backwashing with oxygenated water proved unsuccessful, and eventually all media were replaced. This necessitated the excavation and relaying of the sub-sand abstraction units in fresh sand, digging out the slow sand filters and recommissioning with new sand and fabrics. On August 4 all units were set running but three days later the characteristic ammoniacal smell, surface scale and iron oxide deposits associated with growth of the iron bacteria were detected in slow sand filters F and Z. By this stage, the raw water was again fully oxygenated and as it was suspected that residual organic leachates from two

Plate 7. Blackened medium removed from polluted sub-sand abstraction bed.

Plate 8. Blackened medium in polluted upflow sand module revealed by scraping.

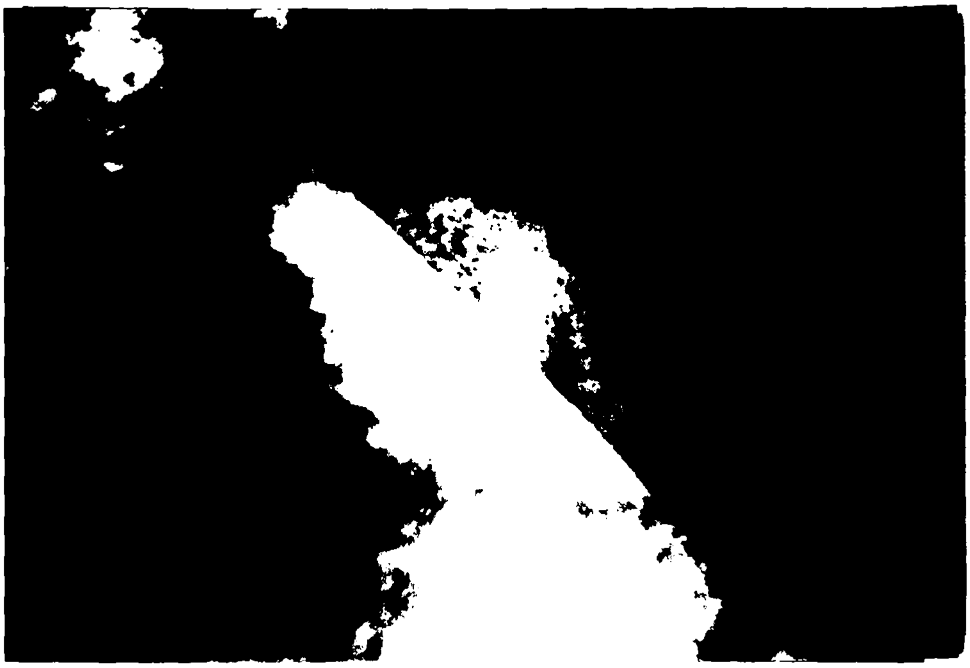


Plate 9. Blackening of filter fabrics due to activity of sulphate reducing bacteria in the slow sand filter module.

Plate 10. Raw water source after pollution incident showing decay of filamentous algae.

of the sub-sand abstraction beds were responsible for the iron bacterial growth, the slow sand filters were converted to direct raw water feed. Within 24 hours the symptoms of iron bacterial growth had disapppeared.

The sand in one of the abstraction beds (A) had been replaced very effectively since it was installed in a separate concreted area of the pond. However, it was impossible to totally clean the two abstractions beds in the body of the pond (B and C) since this area could not be drained as efficiently as the concreted area. Thus beds B and C retained a small portion of the material which had been affected by the pollution incident and those beds were subsequently associated with residual side-effects.

Slow sand filters fed from bed A functioned normally, but those downstream of beds B and C exhibited iron bacterial growth in the supernatant water and rapid blockage of the filters resulted. This effect was eventually ameliorated by the inclusion of an upflow gravel prefilter between sub-sand abstraction and slow sand filtration. This stage allowed the luxuriant brick-red growth of iron bacteria within and above the gravel bed thereby permitting the slow sand filters to behave in a relatively normal fashion again. The gravel filter was backwashed weekly to prevent the excessive build-up of the iron-bacterial growth, and backwashings were spectacular in their loading with red-brown biomass.

A more negative residual side-effect of the pollution incident vis-a-vis the sub-sand abstraction units was the establishment within the beds of atypical microbiological populations which liberated large amounts of gas - presumably a by-product of fermentative reactions stimulated by the high organic nutrient loadings which remained in the pond bed. This feature had not been observed previously. The direct effect of the activity of these populations was a reduction in the amount of water which could be withdrawn from the bed, since the pump now delivered a mixture of water and gas. A reflection of this is depicted in the figures describing the build-up of head loss (vacuum pressure) in the sub-sand units with respect to time (figures 46 and 47).

Figure 46 shows the approximately linear relationship between vacuum pressure and days of filter run for a normal, unpolluted abstraction bed. In comparison, the increase in vacuum pressure for the residually polluted abstraction beds B and C is not linear with time (figure 47). Following backwashing there was a short period of increasing head loss, but as the gas producing microbiological populations became re-established, the water filtration rate declined, bed blockage ceased, and the vacuum pressure readings remained relatively static.

The problems associated with the pollution of the sub-sand abstraction units by a raw water containing high levels of organic waste have been enlightening. Months after the raw water quality had been restored, and despite the resanding of abstraction beds, residual deleterious effects were still being observed. The main effects, reduction of available pretreated water volume and stimulation of iron bacterial growth in downstream filters, combined to render the secondary, slow sand filtration process difficult to operate. The growth of iron bacteria in conventional slow sand filters is a rare phenomemon, normally associated with acidic water of high organic content and low dissolved oxygen. For this reason it is often associated with summer weather conditions. The summer conditions prevailing during the period of this study may have been contributory to the observed malfunction of the dual sand system incorporating residually polluted sub-sand abstraction. However, the fact that the system operating with a totally resanded (i.e. non-polluted) sub-sand unit did not exhibit any side-effects confirms that it was the pollution which was mainly responsible.

This observation corresponds with the findings of an earlier investigation of sub-sand abstraction where a simulated microbiological contamination of sand beds resulted in relatively long term residual contamination of filtrates (Wheeler and Lloyd, 1978).

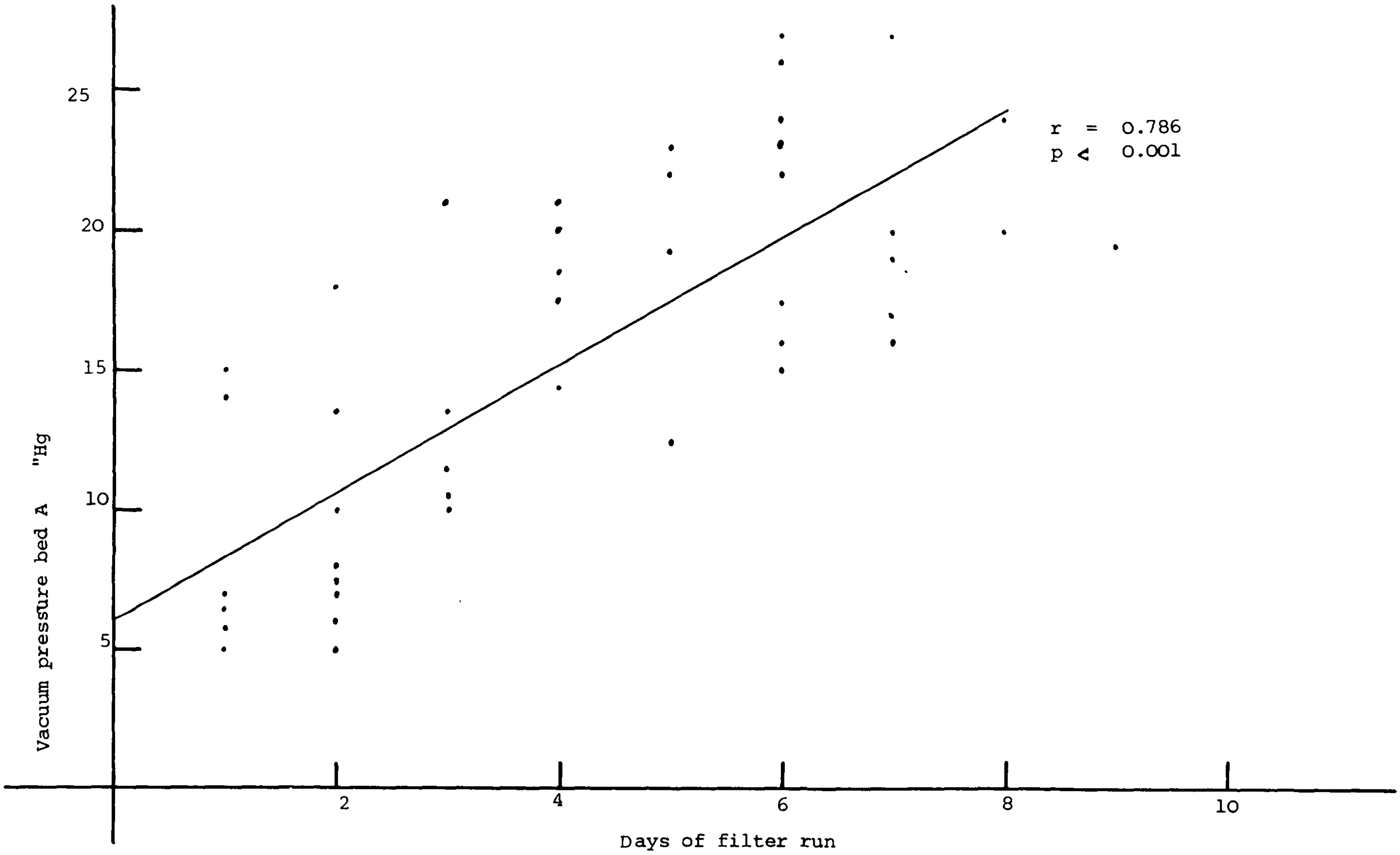


FIGURE 46 POLLUTION INCIDENT: INCREASE IN HEAD LOSS IN ABSTRACTION BED

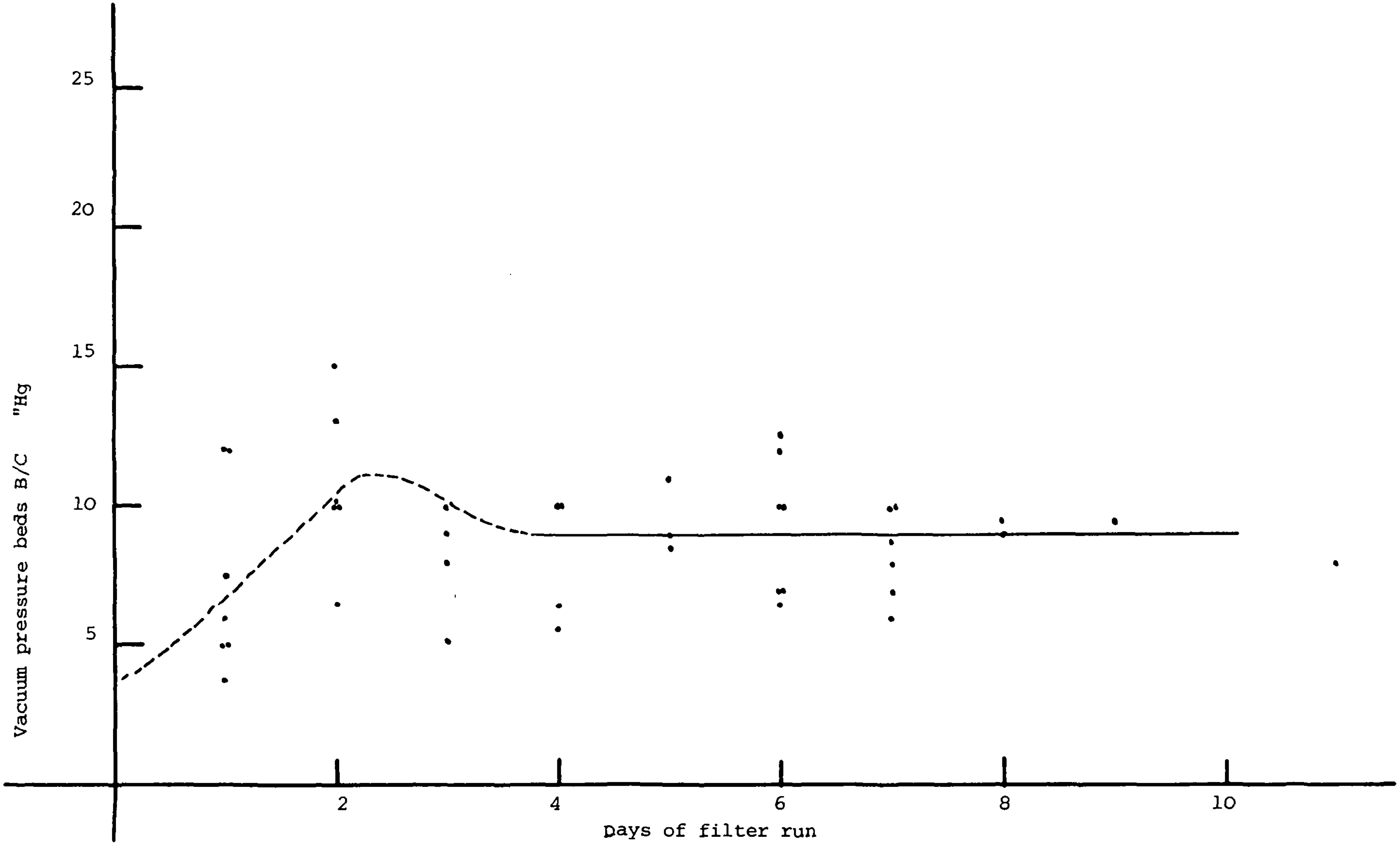


FIGURE 47 POLLUTION INCIDENT: FAILURE OF HEAD LOSS BUILD-UP DUE TO GAS PRODUCTION IN ABSTRACTION BED.

The overall conclusion of the incident must therefore be that in areas subject to chronic organic pollution or occasional high levels of such pollution, sub-sand abstraction may not be the ideal form of pretreatment prior to slow sand filtration. In such cases a more appropriate form of pretreatment would be one where the filter medium may be totally replaced, relatively simply and cheaply at short notice in the event of pollution. If the pretreatment selected is some form of catchment or storage facility, the basin or tank which has been polluted should be capable of total drainage and cleaning, again at short notice. In either case it may be prudent to plan in terms of alternative or reserve pretreatment modules which may rapidly be brought into service to maintain continuity of supply to the slow sand filtration modules immediately the pollutant loading has passed.

Sand Grading

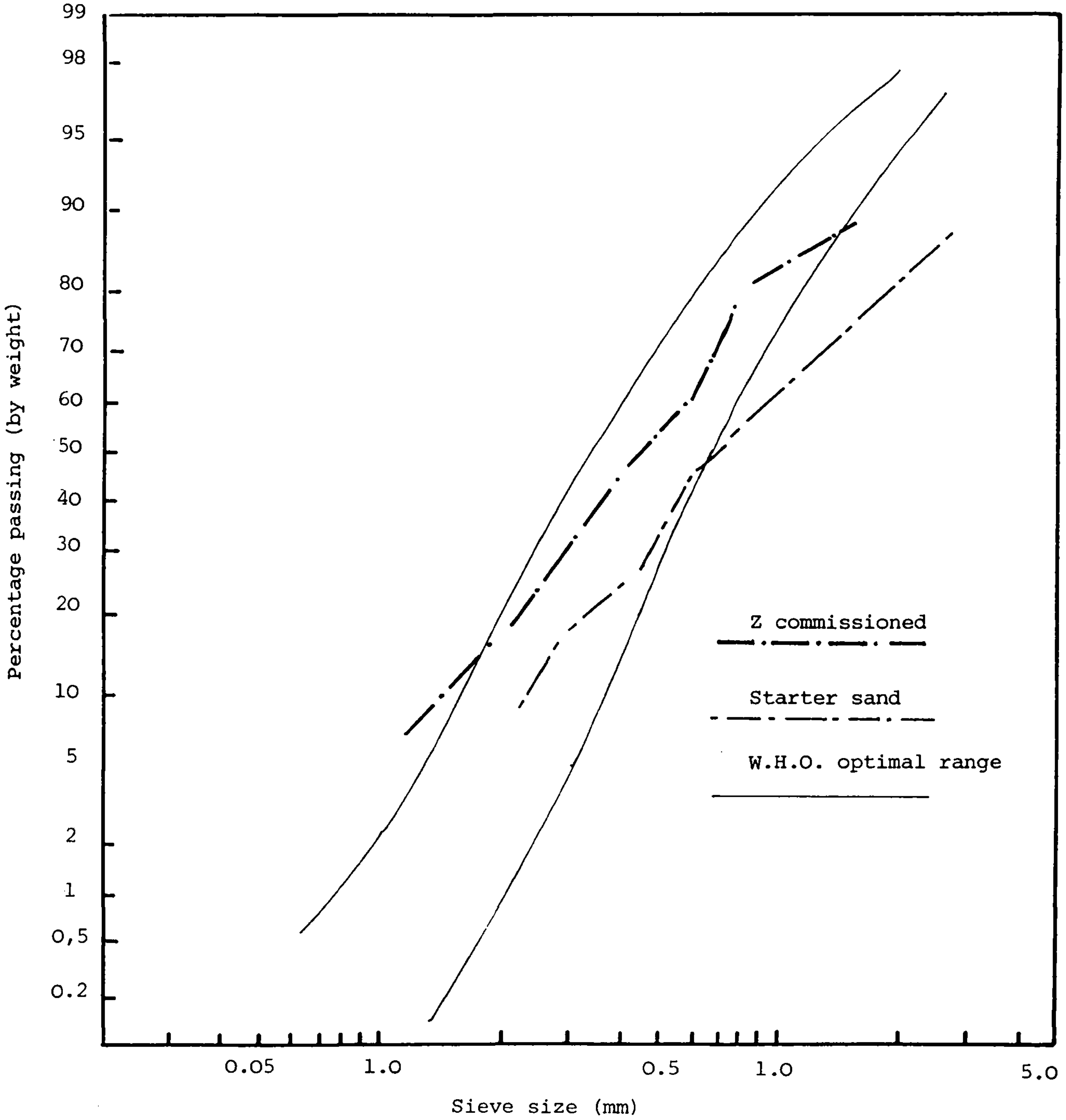
The potential for in situ cleaning and regrading of the available sand medium by a simple backwashing process has already been described (Wheeler *et al*., 1983). In the first phase of experiments, filters of 0.8 m^2 containing coarse, builder grade starter sand were backwashed with a head of water of only 2m and the resulting filter medium was substantially closer to the WHO/IRC recommended grading. In the second phase this procedure has been successfully applied with filters of 1.5 m^2 - the design size of the demonstration slow sand filter modules for use in Peru.

Figure 48 illustrates how the coarse nature of the sand may be overcome in 1.5 m^2 filters by allowing the larger particles to sediment downwards towards the under drainage during fluidisation or backwashing. This increases the proportion of essential finer particles in the upper horizons of the sand bed. However, care should be taken, since it is possible to obtain a medium which is too fine by the excessive application of backwashing - especially if this is combined with the accumulation of silt following filter runs. This is demonstrated by figure 49.

Figure 51 demonstrates the effect of silt penetration alone on size grading, co-efficient of uniformity and silt volume of the sand bed. Whilst the effect was not too great, the accumulation of fines derived from suspended solids gives the profile a general shift to the left, rendering it less suitable for sand filtration. However, the silt accumulation responsible for this shift, namely 21% by volume, was quite substantial and much more would render the sand bed virtually impermeable in any case.

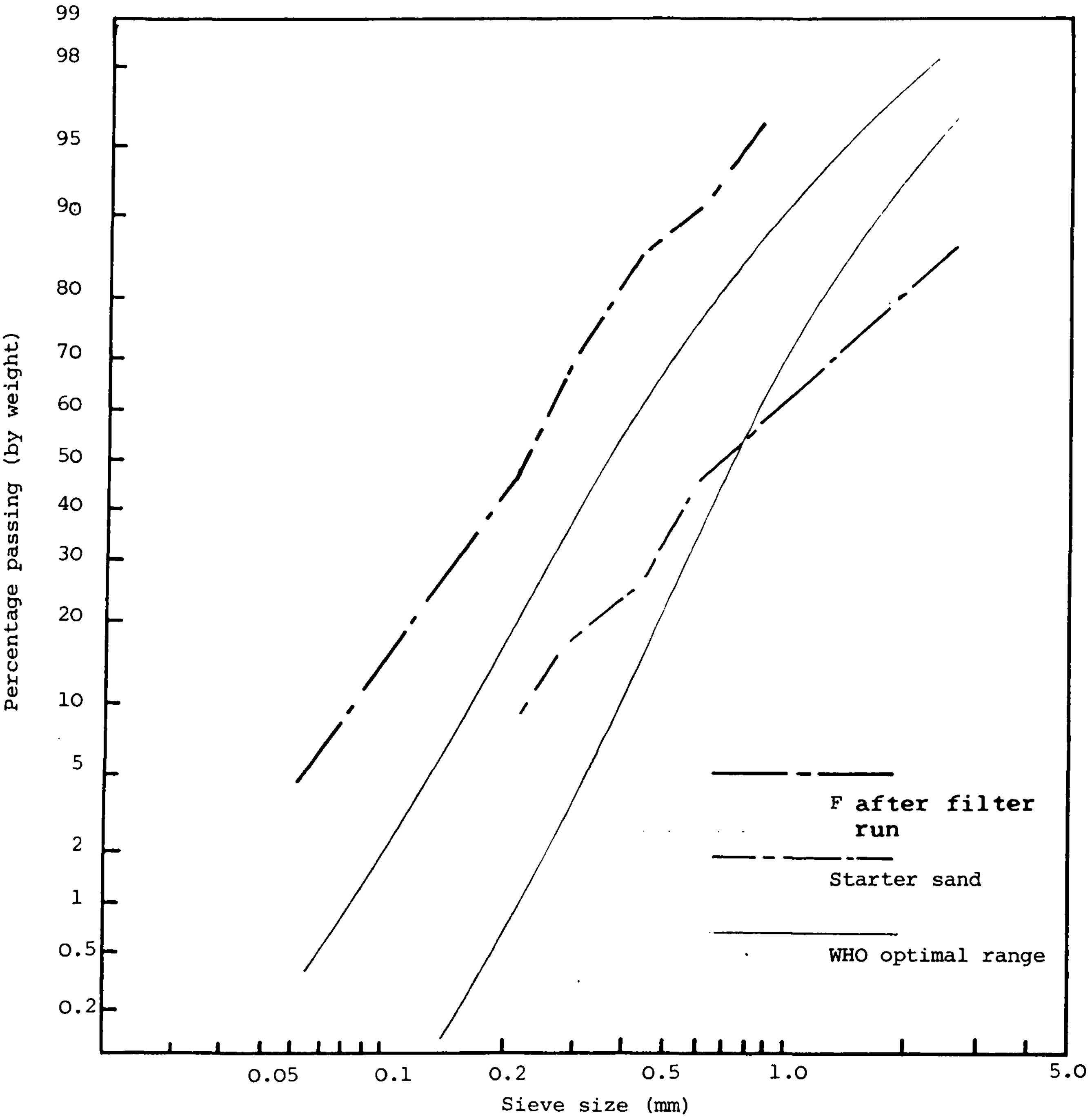
The result of compounding silt penetration and backwashing on the grading of the sand bed is shown in figure 50. Starting with a sand (on commissioning) which was entirely within the WHO/IRC recommended range, it may be observed how the combined effects of backwashing (3.8.83) and silt accumulation during the second filter run (16.9.83) may increase the

FIGURE 48   PARTICLE ANALYSIS FOR TOP 5cm OF SLOW SAND FILTER Z BEFORE AND AFTER BACKWASHING



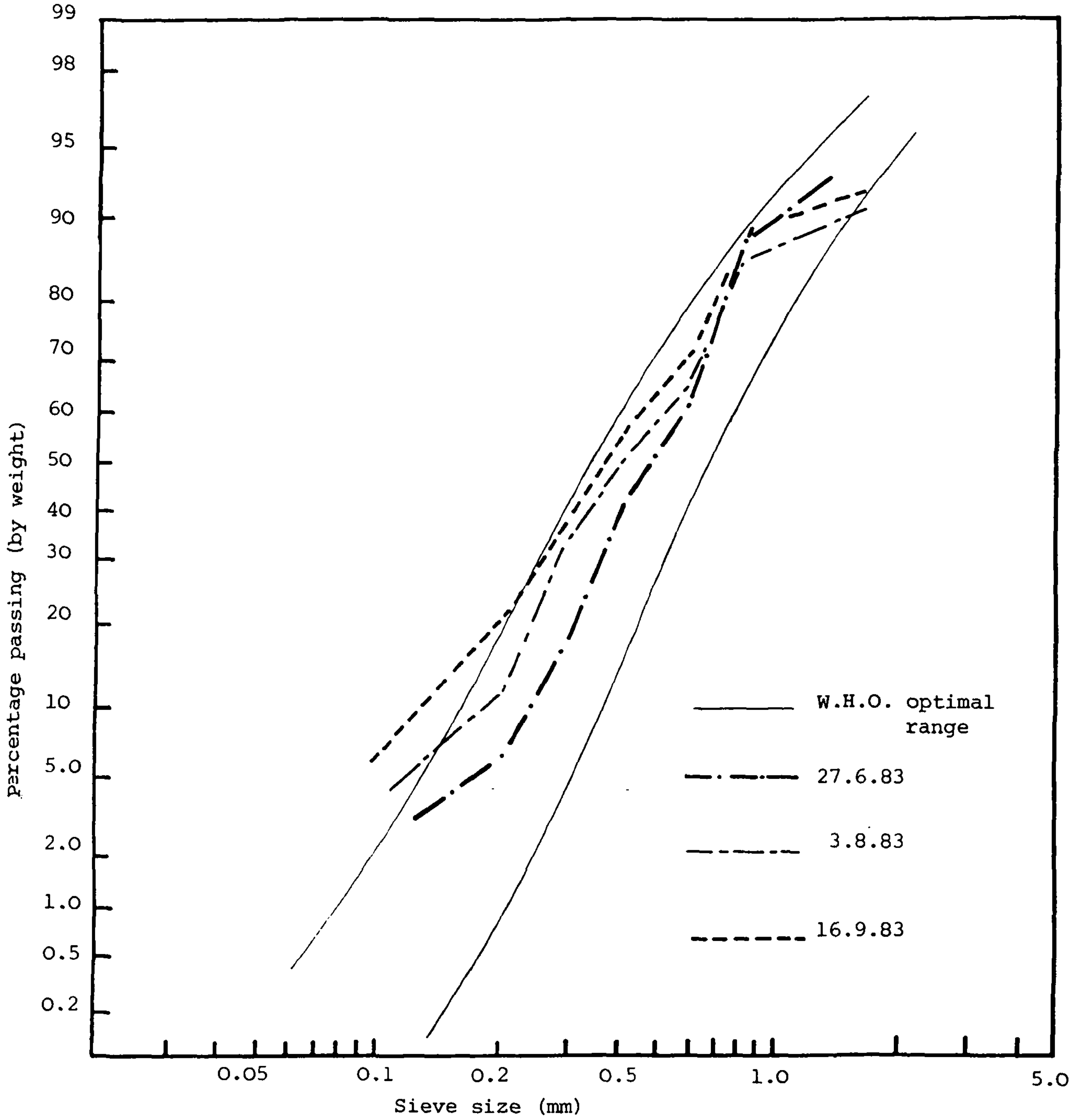
	Z commissioned
Effective size	0.145 mm
Coefficient of uniformity	4.7
Silt volume	0.3 %

FIGURE 49 PARTICLE ANALYSIS FOR TOP 5cm OF SLOW SAND FILTER F BEFORE AND AFTER REPEATED BACKWASHING SHOWING THE EXTENT OF POSSIBLE REGRADING.



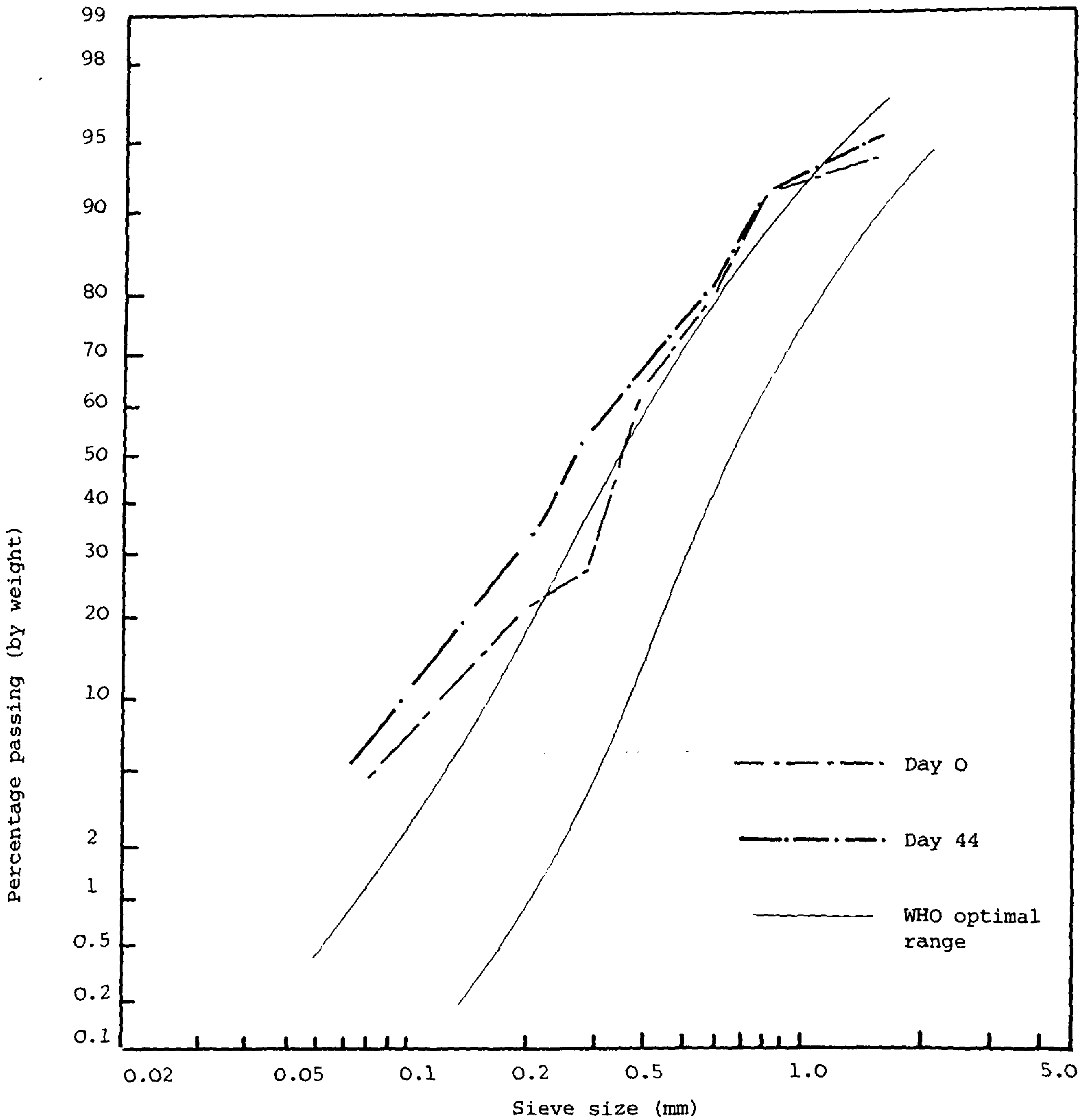
	F after run
Effective size	0.076 mm
Coefficient of uniformity	3.16
Silt volume	8.69%

FIGURE 50 PARTICLE ANALYSIS FOR TOP 5cm OF SLOW SAND FILTER Y SHOWING EFFECT OF FILTER RUN AND IN-SITU BACKWASHING AND BACKFLUSHING.



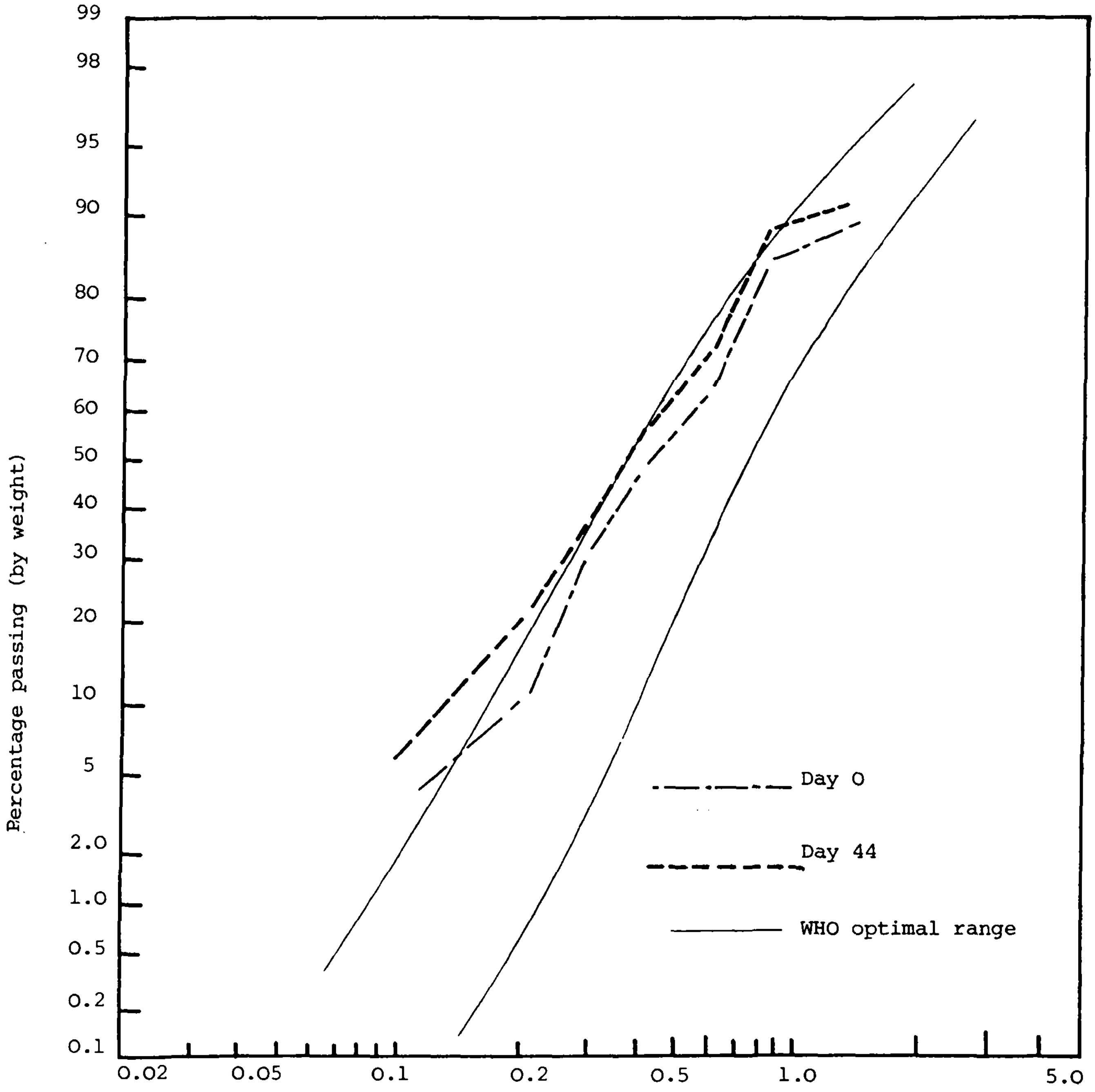
	27. 6. 83.	3. 8. 83	16.9.83.
Effective size	0.25 mm	0.19 mm	0.13 mm
Co-efficient of uniformity	2.7	2.8	3.54
Silt volume	2.3 %	0.95 %	8.33 %

FIGURE 51 PARTICLE ANALYSIS FOR TOP 5cm OF SLOW SAND FILTER X BEFORE AND AFTER FILTER RUN.



	Day 0	Day 44
Effective size	0.13mm	0.1mm
Coefficient of uniformity	3.0	3.5
Silt volume	0.46%	21%

FIGURE 52 PARTICLE ANALYSIS FOR TOP 5 cm OF SLOW SAND FILTER Y BEFORE AND AFTER FILTER RUN



	Day 0	Day 44
Effective Size	0.19 mm	0.13 mm
Coefficient of uniformity	2.8	3.54
Silt volume	0.95 %	8.33 %

fraction of fine particles to beyond the recommended portion.

These observations endorse the earlier conclusions (this report) that following commissioning and production of the desired filter medium grading, backwashing by fluidisation of the sand bed should not be re-employed as a means of cleaning. The routine regeneration of bed permeability may properly be effected by gentle backflushing involving no fluidisation. However, when more thorough cleaning is eventually necessitated by the excessive penetration of silt into the sand bed, this is best achieved by skimming. The skimmed sand may then be cleaned externally and replaced on the next skimming occasion - a process which will not substantially effect the sand grade since only a very small amount of the medium will be involved (approximately 0.03 m^3).

SECTION 7

Summary and Conclusions

This section will be confined to a simple restatement of some of the more important findings of the experimental programme to date.

It was indicated earlier that major importance would be attached to the selection of those design and construction features which would be most likely to ensure maximum process efficiency on a purely technological level. Coupled with this however, is the essential requirement for the development of operation and maintenance procedures which are most likely to be actually applied. This involves consideration of technological, social and economic constraints. Whilst the results of both first and second phases of experimentation have allowed most of the technological questions to be answered satisfactorily, there remain several areas of social and economic uncertainty which can only be assessed in the light of experience in Peru. For this reason it is considered prudent to await feed-back from the Peruvian demonstration programme before provisional operation and maintenance schedules are prepared. Nevertheless sufficient progress has already been made with the simplification and streamlining of routine operation and maintenance duties to warrant the assertion that if these duties are neglected it will not be due to technological complexity or unreliability.

It is worth re-emphasing the main conclusions of the technical development programme to date since they have considerable significance for the successful prosecution of this project and indeed others which follow a similar model.

1: The application of sub-sand abstraction as a prefiltration stage to slow sand filtration may have disadvantages when compared with other pretreatment options such as longitudinal gravel filtration and reservoir storage, but in favourable circumstances it does offer excellent improvement in both physical and bacteriological water quality. The principle drawbacks of sub-sand abstraction are:

a: the requirement for a relatively powerful pump if villages of several hundred persons are to be adequately provided for on a continuous basis;

b: the vulnerability to pollution and subsequent difficulties in recommissioning which may occur if site selection is not careful or if an ideal site is not available;

c: the feature of oxygen depletion which may deleteriously affect downstream biological filters in certain circumstances; and

d: the requirement for fairly frequent maintenance by backwashing, even in only moderately turbid waters, which results in greater labour commitments as well as slight reductions in process efficiency whenever cleaning is undertaken.

2: The inclusion of synthetic, robust filter fabric layers in alternating density configuration provides substantial protection to the slow sand filtration process, both operationally by excluding the majority of suspended silt particles and in efficiency terms by helping to maintain the beneficial microorganisms intact during maintenance procedures.

3: The commissioning of small-scale slow sand filters is greatly assisted by vigorous in situ backwashing i.e. fluidisation of the sand medium.

4: The maintenance and cleaning of small-scale slow sand filters may be confined to two simple procedures;

a: regular backflushing (gentle upflow - **NOT** fluidisation) with treated water, accompanied by external cleaning of top fabric layers, and subsequent replacement of filter fabric multi-layer with cleaned fabrics down-most; and

b: occasional skimming of sand beds accompanied by routine fabric maintenance (as above), external washing of skimmed sand, and its replacement by previously washed skimmings.

5: Slow sand filtration can be successfully scaled down to units of 1.5 m^2

without noticeable effect on quality; short-circuiting does not occur even at relatively high flow rates and with minimum bed depth.

b: A packaged, modular system of prefilters and protected slow sand filters may be installed simply and inexpensively in small rural villages of up to 1,000 inhabitants whilst retaining its flexibility and ease of operation.

7: Daily flow rate adjustments may be obviated by the incorporation of a constant flow device at the outlet of the slow sand filter.

8: A dual filtration system based on prefiltration and protected slow sand filtration may yield water of consistently potable quality from faecally contaminated surface waters without recourse to terminal disinfection.

SECTION 8

Further Work and Researches in 1984

The UK experimental programme for the forthcoming year will concentrate on two main areas;

1: the determination of the dispersion and mechanisms of removal of pathogenic viruses and bacteria of faecal origin in the slow sand filtration process (this work may well be pursued in collaboration with a UK water authority and discussions are currently under way with the Thames Water Authority - see Appendix III); and

2: the development, optimisation and application of alternative forms of pretreatment, notably horizontal gravel filtration, and the application of filter fabric protection to larger scale slow sand filter works in the UK (this work has been made possible by the interest and financial support of the Water Research Centre, Stevenage, UK).

Concurrently, field trials will be progressed in Peru, and a more detailed discussion of the work will be provided from Lima in the near future.

Whilst all the funding of personnel and the great majority of funding for the hardware for the Peruvian demonstration programme has been supplied by the UK Overseas Development Administration, to whom we are indebted, the generous supplementary assistance of OXFAM and Pendär Environmental (UK) Ltd. is gratefully acknowledged. We should also like to recognise the support of the UK Water Research Centre in the funding of important areas of allied research.

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Process aids for slow sand filtration

by Mauricio Pardon, Dave Wheeler and Barry Lloyd*

A progress report on the Surrey University (UK) project to simplify water treatment by slow sand filtration for use in developing countries.

	Number	%
Sedimentation problems	108	36
Filtration problems	99	33
Disinfection problems	267	89

Table 1. Proportion of Peruvian water works experiencing technical problems with treatment processes.

VIRTUAL *unanimity exists on at least one subject of water resources development in the Third World:* that the most appropriate process for improving the hygienic quality of surface water is slow sand filtration (SSF). However, an essential requirement in the successful application of slow sand filters is the provision of adequate supervision and maintenance. The most important function of any maintenance schedule is to ensure the continuity of the process. Due to the fact that the process relies on the action of bacteria, only where water flow can be guaranteed continuous will the performance of slow sand filters be optimized, and the safety of the water supply maintained.

Unfortunately guidelines for operation and maintenance have not been followed in a number of developing countries and it is therefore highly questionable whether technologically more advanced systems can be successfully operated in those areas.

In Peru, for example, over 1,000 water supply systems have been installed over the last 20 years. Four hundred and twenty of these give poor service or are paralyzed. Seven hundred supply untreated water and only 300 supply treated water. In the latter category, a significant proportion have technical operational problems and it is poignant to note that 89 per cent experience difficulties with disinfection (Table 1).

Similarly, evidence from well-supervised conventionally operated slow sand filters under unfavourable circumstances with high levels of suspended solids in the inflowing water leading to rapid blockage, or daytime-only flows[2], demonstrate that the absence of continuity may prevent the process working properly.

As part of a programme to develop and test a small scale rural water treatment system, a research team at the University of Surrey's Department of Microbiology funded by the UK Overseas Development Administration has produced four ways of helping to preserve continuity by simplifying the installation, maintenance and control of slow sand filters. These process aids are not new in themselves but they represent novel applications, both on the scale proposed and in their individual function.

Historically, the water industry has been fairly precise in specifying the characteristics of the sand chosen for its slow sand filters. Of principal concern are the silt content (the 'effective size' defined as the sieve size through which 10 per cent of the sand, by weight, will pass) and the 'coefficient of uniformity' (the ratio of the sieve size through which 60 per cent of the sand will pass, to the effective size).

Too high a level of silt (i.e. greater than 5 per cent) in the sand selected will cause premature blockage of the filter due to the accumulation of more silt and suspended matter from the water above it. The uniformity coefficient (ideally in the range 1.5 to 3) and effective size (ideally in the range of 0.15 to 0.35) ensure that the grade of sand is neither too coarse for effective absorption and sedimentation of particles, nor so fine that it suffers rapid blockage or hinders the movement and proliferation of beneficial micro-organisms. Too coarse a grain would lead to the water travelling too short a distance within the

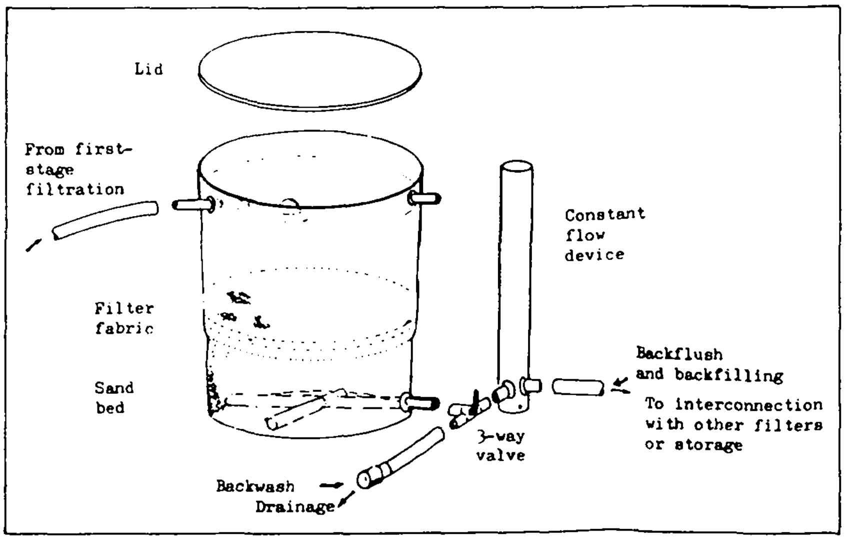

Figure 1. Arrangement of the prototype small-scale slow sand filtration system

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sand bed and consequent inefficiency in filtration.

The water industry in Europe operates on a large scale which encourages careful selection of filter media. However, in many rural circumstances in developing countries carefully graded sand may not be readily available. It is particularly unlikely that a 'clean' sand (one with a low silt content) will be found locally.

Backwashing slow sand filters is probably considered unconventional if not heretical by many present-day engineers, but it was first successfully applied by Thom at Greenock in 1827 and later by the Gorbals Sanitation and Water Company in 1846.[3]

It has been demonstrated at Surrey that by applying a moderate head of water (less than 3m) to the underdrainage of a small scale sand filter (1.2m in diameter) the sand may be backwashed and silt content quickly and efficiently reduced from 17 per cent to less than 1 per cent. Also this process inevitably leads to coarser material sedimenting downwards, so that the bed grades itself. Thus, although the bed as a whole may not be uniform, individual layers—most notably the crucial top 5cm—have substantially increased uniformity and are therefore much more suitable for slow sand filtration (Figure 2).

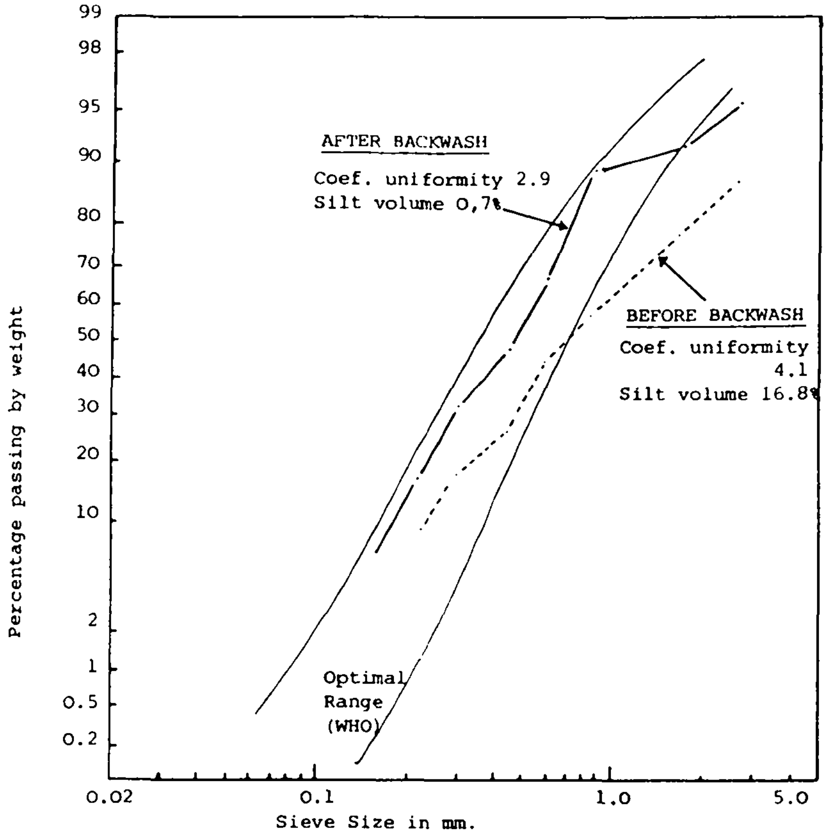

Figure 2. Improvement in the uniformity and reduction in silt content of the top 5cm of a slow sand filter bed by backwashing in situ

Although backwashing may not be feasible on a full scale sand filter—the necessary upward velocity would not be attainable through conventional underdrainage—it can

Experimental slow sand filter, with constant flow device in the foreground

be easily applied to small scale rural treatment plants of 1-4m diameter.

Maintenance

Vigorous backwashing as described above is neither desirable or necessary even for small scale slow sand filters as part of regular maintenance. It has been demonstrated that a momentary gentle 'back-flush' is sufficient to make a blocked sand bed permeable again. A filter run of 46 days was achieved in very unfavourable circumstances with backflushes roughly twice weekly (applied when head loss of outflowing water exceeded 50cm). During this period the silt content in the top 5cm of the bed rose successively from 0 to 10, 20, 37 and finally 43 per cent (by volume) before full backwashing as described above was necessary.

Since no silt is actually removed during backflushing, merely dislodged and redistributed, head-loss cannot be attributed simply to rising silt content. The bed also appears to pack itself more closely during each filter run and it is this packing which is interrupted by the backflush mechanism. The technique is demonstrably less traumatic than the conventional cleaning process: skimming the top layer off the filter. Even at water temperatures of less than 5 degrees C, when growth of micro-organisms might be expected to be almost at a standstill, process efficiency was fully recovered within 80 hours.

Protecting the sand filter

Most authorities accept the necessity for protecting slow sand filters from sudden deteriorations in water quality since the biological processes are best served by a uniform loading.

It is particularly important to minimize the amount of suspended solids deposited. The amount of solids flowing into the filter is reflected by the turbidity (cloudiness) of the water. For this reason the International Reference Centre[4] recognises that in circumstances where raw water turbidity regularly exceeds 10TU (turbidity units) some kind of pretreatment is vital if the length of the filter run is not to be unreasonably short. The UK Thames Water Authority relies on sedimentation by reservoir storage and attains reductions in turbidity of up to 94 per cent. This gives water flowing into its slow sand filters a turbidity of only 2TU—ideal for slow sand filtration[5].

The direct protection of the filter by fabrics laid on the surface of the sand bed has not been adopted on a wide scale, although it is not a new idea. In the 18th and 19th centuries both sponge and wool were tried in France but their eventual decomposition led to complaints about the taste of the water. Hemp, tow, hair and cotton were employed in UK filter designs in the last century[6].

Fibrous filters

Naturally fibrous materials e.g. coconut fibre, have been suggested recently as appropriate for developing countries, but there have only been limited attempts to apply robust non-bio-degradable synthetic fibres in slow sand filters. One example where this is being tried is the OXFAM water treatment package developed for disaster situations, which employs a single layer of air filter fabric[7].

Trials at the University of Surrey have demonstrated that under controlled conditions the application of a combination of synthetic fibres—available from Universal Filters—can at least treble the average length of slow sand filter runs and under optimal circumstances may exclude 85 per cent of the silt load from the top of the sand bed[8]. The most efficient configuration tested to date consisted of a 'sandwich' of coarse and denser fabrics.

The mechanism by which silt was removed by these fabrics was not sieving. The vast majority of the particles removed were around 5µm in diameter—far smaller than the holes in the fabric. Sedimentation and adsorption due to the tortuous path which water has to follow through the fabric, plus the change in its velocity as it passes through coarse, then fine layers of fabric are thought to be the principal reasons for the fabrics' efficiency.

Two significant observations have been made in the experiments at Surrey. Firstly, even heavily silt-laden fabrics do *not* contribute to the total head loss of the sand filter. Thus simply removing the fabrics at the end of a filter run does not regenerate the permeability of the bed on its own. Backflushing is necessary for that. Secondly, the fabrics are rapidly colonised by a large population of organisms which scavenge on faecal bacteria and viruses. The fabrics effectively become home to a stable colony of the beneficial microfauna.

Extension

We conclude from these two observations that the fabrics actually operate as an extension of the familiar *schmutzdecke*, or biologically active layer of the slow *sand filter*. Not only is the silt load deposited over a substantially greater depth, extending filter run lengths significantly, but by simply rotating the fabrics (cleaning the upper of the two double-layer 'sand-

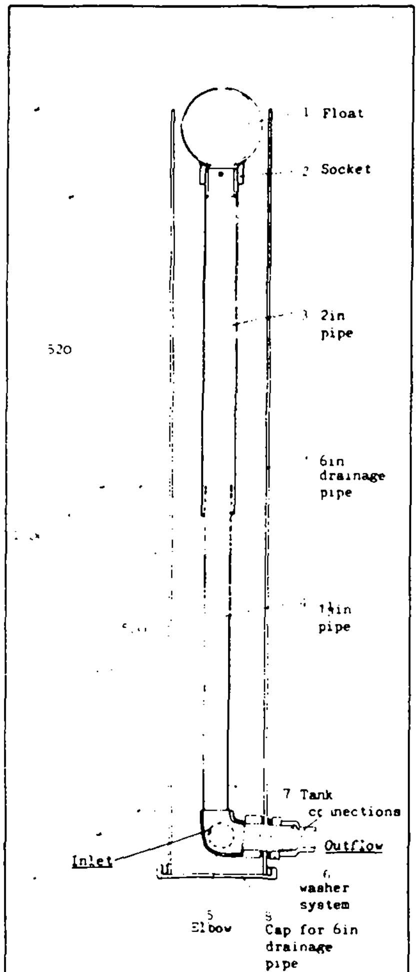

Figure 4. Section through the 'Sureflo' constant flow device. All dimensions in millimetres, numbering refers to Table 2.

wiches' every few weeks and replacing it on the bottom), a continuous population of helpful and voracious protozoa and metazoa is maintained.

Constant flow device

A feature of the slow sand filtration system is that the progressive blockings of the sand bed throughout the filter run implies the need for some sort of daily manipulation of flow. To achieve this, a number of conventional inlet and outlet flow control devices are in existence[4,9]. But, small scale filtration involves other factors which can only be fulfilled by a simple device operating at the filter unit outlets.

The option adopted at the University of Surrey was a floating 'weir' which can work at constant precalibrated flows. Similar systems have been already proposed and applied in slow sand filtration[4,10,11]. In developing the constant flow device, the following considerations were taken into account. The device should:

1. Act as an adjustable valve to control flow and provide a constant filtration velocity throughout the entire filter run. The flow rate should be adjustable in order to give flexibility to the system, for instance, during maintenance.
2. Substitute for a flow rate measurement device.
3. Avoid daily manipulation of valves to compensate for the blocking of the bed as the filter run progresses.
4. Provide a pressure head-loss monitor in order to allow planning for maintenance.
5. Indicate an end point to drainage to avoid accidentally draining the filter bed or to resist occasional negative pressures during operation.
6. Allow for the interconnection of filter units to backfill or backflush by gravity when a unit is recommissioned after maintenance.
7. Act as an aeration device for the filtered water.

As stated above, the device is an adaptation of a floating weir outlet. Its location in relation to the filter unit is shown in Figures 1 and 3. The device is made exclusively from standard plumbing parts, fittings and pipes so that it can be constructed in developing countries. The components involved are summarized in Table 2. The assembly of the device as well as the dimensions developed to fit the Surrey slow

Item No.	Description	Amount
1	5in diam. plastic float	1
2	Threaded socket diam. 2in	1
3	Pipe class C diam. 2in	0.6m
4	Pipe class C diam. 1½in	0.6m
5	Elbow diam. 1½in	1
6	Washer system	2
7	Tank connectors with appropriate size nipples 1½in	2
8	Cap for diam. 6in	1
9	Drainage pipe diam. 6in	1.2m

Table 2. List of components for the 'Sureflo' constant flow device.

(The device is currently available in kit form from Pendar Environmental Ltd, Bridgwater UK.)

sand filtration system are shown in Figure 4 (page 26).

Recent monitoring has shown that this device can substantially raise the low oxygen levels of the water flowing out from the filtration unit. This is likely to improve the filtered water's acceptability to consumers.

At present the device is serving a filter working at flow values ranging from 0.30 to 0.55cu m/hour.

Future assessment

During the next two years the device will be tested in Peru as part of the Surrey University water treatment system. ITDG hopes to collaborate at this stage. Three questions must be asked of the device itself:

1. Whether wear has any effect on its performance as a result of sliding and rocking.
2. What is the most appropriate means of keeping the device vertical in field installations during operation and maintenance.
3. How easily it can be used by rural community water workers.

Operation

The constant flow device consists of a 5in *pvc* ball float which provides for a constant head of water over two openings drilled through a 2in threaded socket. This is in turn mounted on a telescopic discharge pipe. By adjusting the area of the opening with the threaded socket, the discharge rate can be regulated. The level of water in the 6in pipe provides hydraulic resistance to the flow through the filter bed. The bed will then discharge at the calibrated rate (see Figure 5). At the same time, this level reflects the increasing head loss caused by blockage of the filter bed. In effect, the device acts as an automatic throttle valve.

An important feature to note is that the 1½in upright pipe of the telescopic arrangement remains 5cm above the same level to avoid accidental drainage of the filter bed due to an interruption of the inflow of water. This would damage the established population of bacteria.

To backfill or backflush a filter unit for maintenance or commissioning, the sliding 2in pipe is removed and the inlet to the storage tank for filtered water is closed. The flow from other units operating in parallel is thus directed into the drained filter through the modified device. This provides a gentle backflushing.

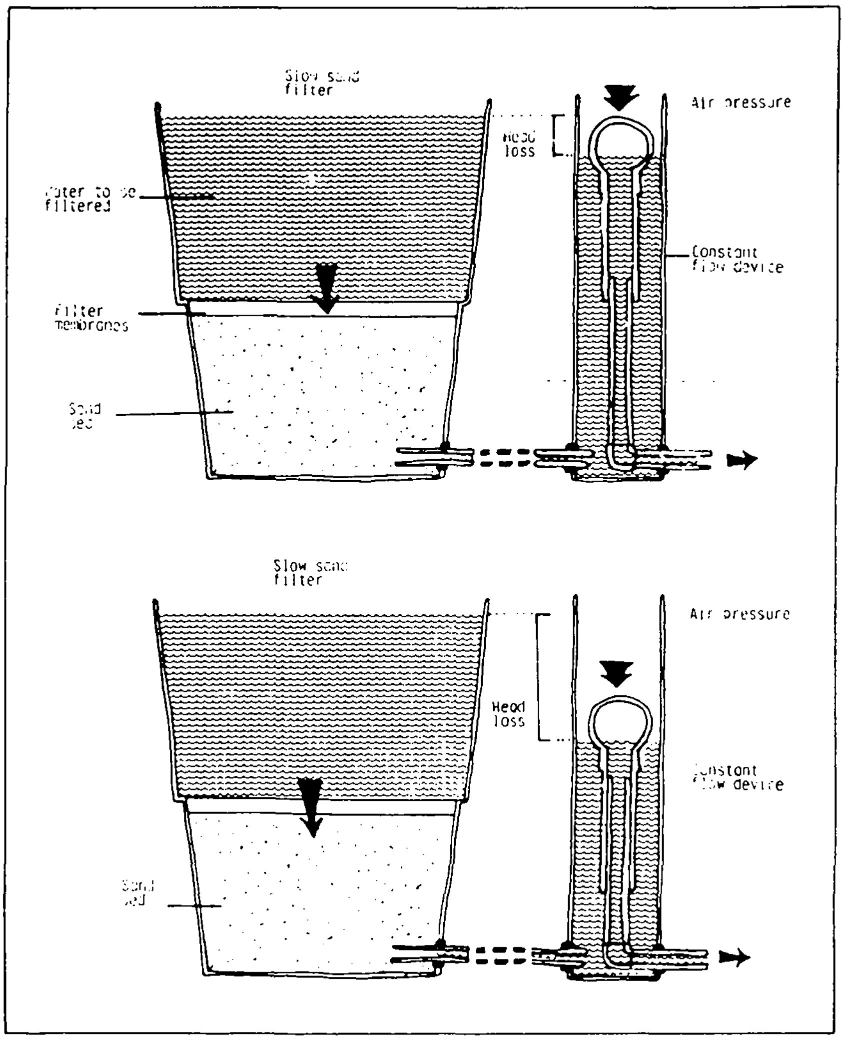

Figure 5. Diagram to illustrate the operation of the constant flow device.

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FILTERABILITY INDEX

TITLE	METHOD	COMMENTS
"Treating of Water'	Based on $F = \frac{HC}{VCot}$ i.e. ratio of the output of the filter (head loss, filtrate concentrations) to the input (quantity of suspension per unit face area) Purely theoretical equation.	Not intended as a 'design tool' for engineers Requires 1 litre of sample and takes 20 min. to perform
Manual of British Water Engineering Practise	1) Houston:- Determining vol. of water under a constant head which will pass through a linen/lint pad in unit time compared with a standard water (distilled or tap) Filterability Index $= \frac{\text{Vol. of unit water per unit time}}{\text{Vol. of test water per unit time}} \times 100$	Similar to method under scrutiny, although a known vol. to pass through as opposed to time: Warns of variations in pads Quick and simple test
	2) Metropolitan Water Board Boucher and Crean shields check head losses and plug into equation. $I = \frac{0.389}{V_1} \cdot \log_e \frac{(H_o)}{(H_o)} \quad (F = {}^1/_I)$	Impractical to use, too complicated

FILTERABILITY INDEX

TITLE	METHOD	COMMENTS
Water Treatment and Examination	McNabb:- Membrane Filter Water filtered, filter transferred onto a microscope plate, left to dry at 55°C for 24 hrs	Useful method to quantify particles present.
	No. organisms present counted using McNabb equation 'most probable no.' of organisms present predicted	More appropriate linked with Houstons Method.

FILTERABILITY METHOD

METHOD

Using a Buchner flask, with a 7.0cm diameter funnel the time taken for a known volumn of 'test' water to percolate through a Whatman GF/A filter is recorded.

Similarly for the same volume of distilled water; the time taken to percolate througn a whatman GF/A filter is recorded The filterability Index is expressed as:-

$$\frac{\text{Time taken for distilled water}}{\text{Time taken for 'test' water}} \times 100$$

To accurately evaluate the filterability index a set procedure is required to time the passage of the water through the filter. This is established by timing how quickly a water sample passes between two lines on the Buchner Funnel. The distance between the two lines represents a volume of 100 ml.

This has been found to be the most accurate way of timing the passage of water through the filter. Using a vacuum pump (25" H_g) to suck the water through the filter was tried but the samples of distilled and 'test' water passed very quickly through the filter leading to a wide spread in results due to different interpretations of when the water sample had finally passed through:-

The percolation method has also been chosen as it is more appropriate to the action of a slow sand filter. Suspended solids, and turbidity data can be linked to the filterability index, the suspended solids being analysed using the same Whatman GF/A filters.

Filterability Index

Following a further test on the reliability of the Whatman GE/A Filters it was found that there was an unacceptably high variation in times for a known volume of water to percolate through a filter.

Time (secs) 84.1 , 96.4, 85.7, 41, 64.4, 54.3

Average Value = 70.27 secs

Standard deviation = 19.3

This is in comparison with an earlier test

Time (secs) 56.4, 56.6, 56.8, 56.5, 57, 59.

Average value = 57.0 secs

Standard deviation = 0.893

Such a large variation in filter performance is unsatisfactory and as a result a new method has been devised.

Using a vacuum pump, with a head of 27mm Mg, a 150 ml sample is sucked through a sartorious membrane, the time taken being noted.

The filterability Index is still expressed as :-

$$\frac{\text{Time taken for distilled water}}{\text{Time taken for test water}} \times 100$$

The variation in time for 150 ml of distilled water passing through a sartorious membrane has been tested

Time (secs) 19.0, 18.0, 17.5, 18.1, 19.8, 17.1, 21.6, 19.7, 19.0

Average value = 18.86 secs

Standard deviation = 1.31

Aothough there is some variation the new method to assess filterability is accurate to ± 10%

APPENDIX III

Proposal for Collaboration on Aspects of Slow Sand Filtration Efficiency between University of Surrey (Department of Microbiology) and the Thames Water Authority.

Introduction

The University of Surrey is currently working on a project concerned with the application of small-scale slow sand filtration in village water supplies in developing countries. The project is funded by the UK Overseas Development Administration (O.D.A.) and includes funding for

1: the development, installation and evaluation of small-scale packaged water treatment plant in six rural villages in Peru;

2: fundamental research into the mechanisms of removal of pathogenic microorganisms in the slow sand filtration process.

The developmental phase is now complete and plant installation is presently underway in Peru. A recent publication which described some of the developmental features is attached. Crucial in the successful operation of slow-sand filtration in the absence of skilled labour is the simplification of operation and maintenance procedures. This has been achieved by a combination of filter protection and automatic flow control.

Filter protection is achieved by the application of pre-filtration (roughing filters) and filter fabrics which are overlaid onto the slow sand filter bed. It has been demonstrated that filter fabrics can significantly extend filter run lengths where high levels of inorganic suspended matter are present in the primary filtered water. Also the fabrics provide a substrate for the growth and multiplication of beneficial microflora and fauna thus extending the effective depth of the schmutzdecke. By rotation of fabric layers, this population can be maintained intact even during cleaning operations, thus significantly improving the continuity of efficient biological treatment.

Proposal

The above phenomena have been demonstrated using water of highly variable microbiological and physical quality. However, it is recognised that to investigate the mechanisms at a more fundamental level, influent water of a much more stable quality is essential. Clearly, reservoir stored water comes closest to meeting the optimal requirements for efficient slow sand filtration and such a source is available at several of the larger Thames Water Authority works.

Following discussions with Peter Toms and Dr. Jennifer Colbourne of T.W.A., it seems that there would be mutual advantage in running the U.O.S.-O.D.A. package plant in parallel with conventional water treatment processes either at Hampton or at Ashford Common.

The plant occupies very little space, basically comprising three circular tanks 1.5 m^2 in area and 1.2 m high with associated pipework. There are four installation options

Option	Works	Location	Supply	Site Works
1	Ashford Common	Behind pump-house	Microstrainer feed	None-gravity flow
2	Ashford Common	By Ash pit	Filter supernatant	Mole-drilled abstraction point in filter, 20 m underground pipe laid
3	Ashford Common	Inside basement of pump house	Microstrainer treated	Possibly tapping of pipework
4	Hampton	Inside rapid sand filtrate collection house (fish monitor section)	RSF feed	None - gravity flow

Of these options, number 4 is presently favoured by Surrey, but this is subject to microbiological quality considerations i.e. the influent quality should not be too good to start with, and naturally to the advice of the T.W.A. Divisional Engineer.

The project would have three main aims.

1: To further investigate the efficiency of filter fabric protection of slow sand filtration.

2: To quantify the phenomenon of enhanced biological treatment afforded by the application of filter fabrics.

3: To determine the fate of microorganisms including faecal bacteria and human enteric viruses, in the slow sand filtration process.

It is intended to use the natural microbiological flora of the influent water in these investigations. Where elements of that flora are absent the addition of supplementary organisms may be considered in discussions between Surrey and T.W.A. In this case it will be assured that at no time will the filtrate of the Surrey plant contain organisms whose presence would not be considered normal in their type or numbers for reservoir stored water. Furthermore, automatic disinfection will be constantly available to ensure that the filtrate meets WHO standards for drinking water before returning the filtrate to waste.

Time-scale

It is hoped that trials may commence as soon as convenient, Spring 1984 appearing to be the most likely time. Experimentation would be conducted for an initial period of twelve months.