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APPROPRIATE TECHNOLOGY IN WATER PURIFICATION AND SEWAGE TREATMENT

by

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SYNOPSIS

Industrialized world standards and technology on water supply and sanitation have been applied with mixed success to developing countries. In such countries the health aspects of water supplies and waste treatment are of prime importance. By recognizing the mode of spread it is possible to improve the health situation by applying simple but appropriate technologies, ranging from the provision at conveniently placed points of an abundant supply of untreated water to the purification of drinking water by simple modified slow sand filters.

While the conventional flush toilet and sewer system is generally accepted as the only realistic way of dealing with sanitation, non-conventional sanitation systems which could sequentially be upgraded from simple pit systems ultimately to the conventional flush toilet system could be more appropriate for conditions in Southern Africa.

WHAT IS THE PURPOSE OF WATER PURIFICATION AND SEWAGE TREATMENT?

We live in an ever changing world with different communities in different stages of development and with different needs for water supply and sanitation. Before one could determine what technologies would be appropriate, one would have to define the purpose of why it is indeed necessary to purify water and sewage.

It is generally accepted that water for domestic use is purified for three main reasons namely health, aesthetics and economics. The importance of satisfying part of, or all the abovementioned reasons would depend on the level of income and development of the community. In a developing community the question of health would be the all important while in a fully industrialized community all three reasons for purifying water would be equally important.

Similarly, the principal purpose of sewage treatment would be for health and environmental protection reasons. Only once the goals are clearly identified can a programme be designed for implementing the appropriate technology.

In this paper some factors are presented which could be of help in selecting the appropriate technology for water supply and sanitation.

WATER SUPPLY IN DEVELOPING COUNTRIES

In most industrialized countries adequate domestic water supplies of the highest quality are taken for granted. In most developing countries on the other hand most people are often too poor to pay for a supply of completely safe water through a multiple tap system in the home. This means that water has to be fetched from different sources and carried over varying distances, often under very poor hygienic conditions, which makes the health aspect of water quality the all important.

Although the ideal solution to the water related health problem would probably be the supply of an abundant quantity of a safe water, more often than not this is just not possible. Under such conditions a knowledge of the most common water related infections could be of value in deciding the appropriate steps to be taken to improve the health situation as simply and economically as possible.

Bradley (1978) recognized that between 20 and 30 different infective diseases may be affected by changes in the water supply. The disease causing agent could be identified as viral, bacterial, protozoal and helminthic. Bradley used their mode of spread as a basis for dividing the causative agents into four main categories, a knowledge of which could be used to great advantage to limit their effect. These categories are

- Infections spread through water supplies - water-borne diseases,
- diseases due to the lack of water for personal hygiene - water-washed diseases,
- infections transmitted through an aquatic invertebrate animal-water-based diseases, and
- infections spread by insects that depend on water - water related insect vectors.

A summary of the more important examples of each category and possible actions to be taken is given in Table 1.

TABLE 1: CLASSIFICATION OF EFFECTIVE DISEASES IN RELATION TO WATER SUPPLY (After Bradley, 1978)

Category	Examples	Relevant water improvements
1. Water-borne infections		
(a) Classical	Typhoid, cholera	Microbiological sterility
(b) Non-classical	Infective hepatitis	Microbiological improvement
2. Water-washed infections		
(a) Skin and eyes	Scabies, trachoma	Greater volume available
(b) Diarrhoeal diseases	Bacillary dysentery	Greater volume available
3. Water-based infections		
(a) Penetrating skin	Schistosomiasis	Protection of user
(b) Ingested	Guinea worm	Protection of source
4. Infections with water-related insect vectors		
(a) Biting near water	Sleeping sickness	Water piped from source
(b) Breeding in water	Yellow fever	Water piped to site of use

From the information given in Table 1 it is clear that depending on the particular circumstances the appropriate technology for improving the health situation would be as simple as to protect the water source and user or to make greater volumes of water available for the user at convenient places. Only once these options are proved to be inadequate should more sophisticated alternative technologies be considered.

APPROPRIATE TECHNOLOGY IN WATER TREATMENT AND THE LEVEL OF SOPHISTICATION

In developing countries in general the per capita income is low so that there just is no money available for sophisticated equipment and design of water treatment plants as used in most developed countries. The most appropriate technology to apply under these circumstances is one that has a low initial cost, is simple and economical to operate, contains a minimum of non-local equipment and emphasizes the use of cheap available labour.

In the design of the treatment plant itself certain simple engineering principles should be applied whenever possible. Wagner (1983) suggested the following:

- Use of gravity flow should be made as far as possible.
- Headloss should be conserved whenever and wherever possible.
- Allowance for future demand should be incorporated in the basic design.
- Simplifying innovations and sound advances in design should be considered.
- The design must be so that it will be able to treat the raw water available.

The well known slow sand filter is the simplest of a series of available treatment technologies and lends itself very well to incorporation of the above design suggestions and being appropriate as a first reliable and simple treatment system. A recent advancement in the slow sand filtration process is the incorporation of either a river bed or river bank graded media roughening filter before the familiar slow sand filter. This pre-filtration increases the filter cycle substantially. A slow sand filter with roughening filter is diagrammatically presented in Figure 1.

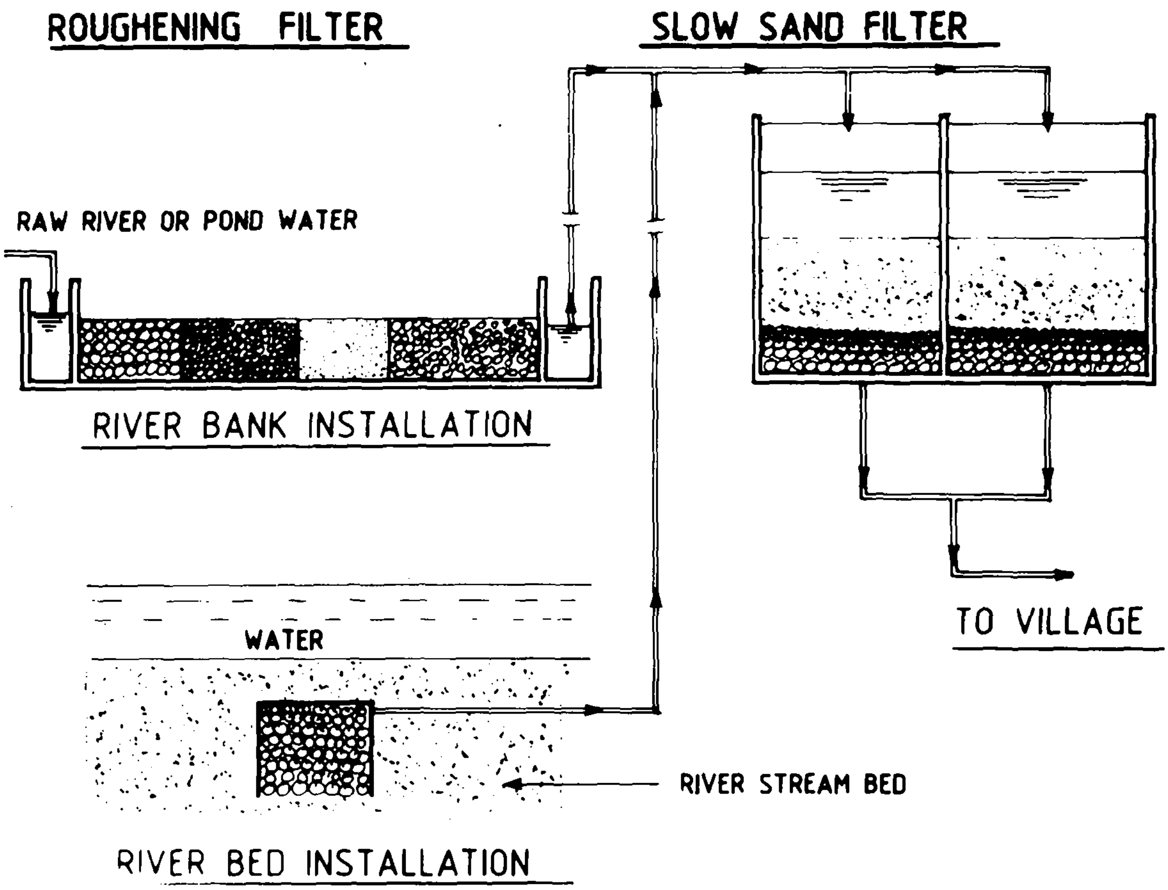


FIGURE 1: ROUGHENING FILTER PRIOR TO SLOW SAND FILTER

If more advanced technology is needed investigation into the use of direct filtration should be considered. Direct filtration is one of the most effective ways of reducing construction and operating costs since it only requires that the colloids be destabilized into small filterable flocs. This eliminates large settling basin structures and usually most of the flocculation units. Direct filtration should also be considered for upgrading and expanding existing plants.

Although the idea is not to give a comprehensive list of available technologies, it is clear from the above that the appropriate technologies are usually the simplest and cheapest available for a particular application.

SANITATION IN DEVELOPING COUNTRIES

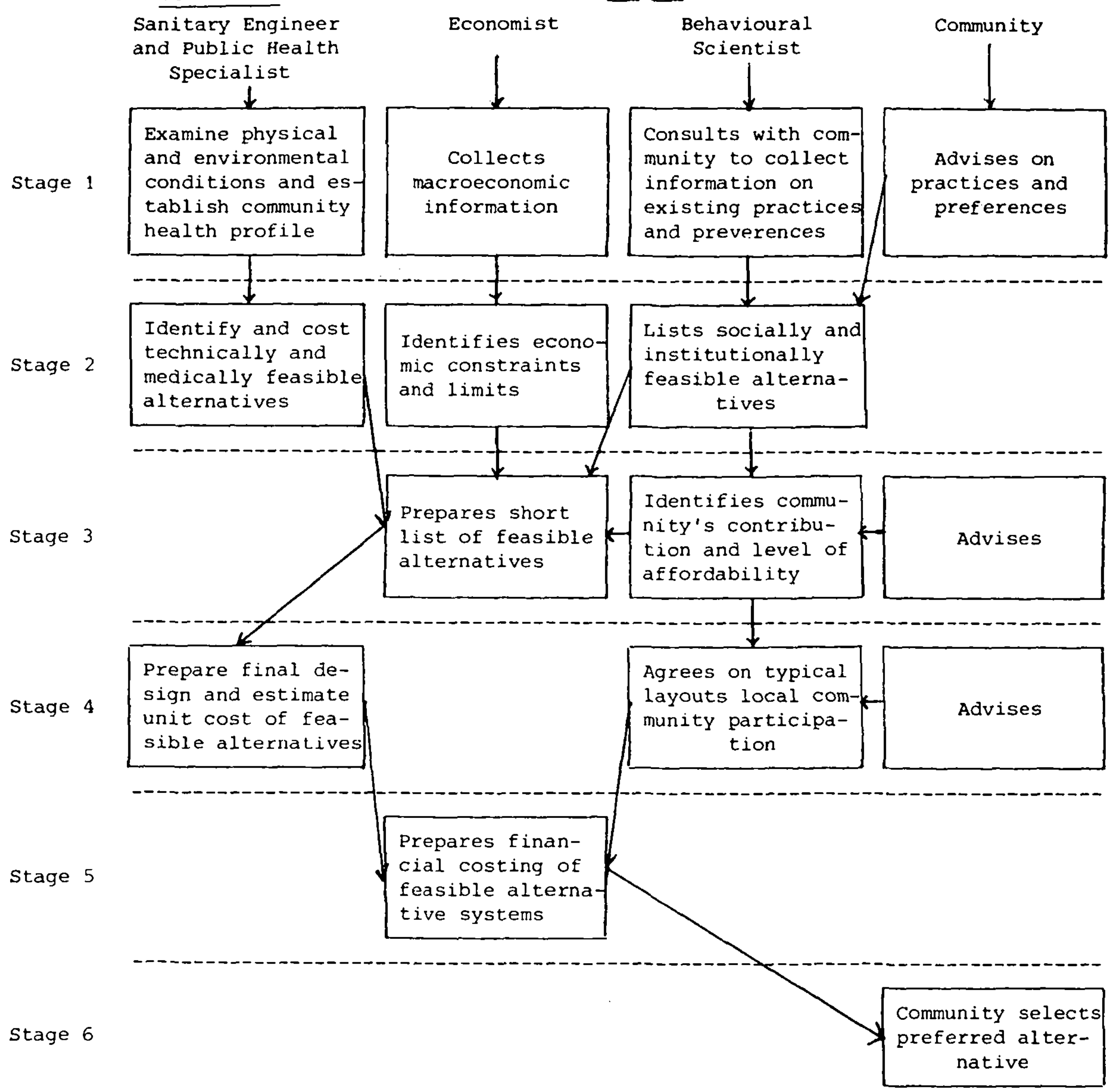
A convenient supply of safe water and sanitary disposal of human wastes are essential ingredients of a healthy and productive community. Inadequate facilities for disposal of excreta, reduce the potential benefits of a safe water supply by transmitting pathogens from infected to healthy persons. In industrialized countries, users and engineers have come to view the flush toilet as the essential part of an adequate solution to the problem of excreta disposal. This technology was designed to ensure user convenience rather than for reasons of health. To achieve the health goal it is therefore necessary to take a hard look at the general situation in developing countries.

The first priority of excreta disposal programmes must be human health, which means the reduction and eventual elimination of excreta-related diseases. This health objective can be fully achieved by non-conventional sanitation technologies that are cheaper than sewerage. It is therefore essential that a special effort should be made to identify and develop alternative technologies for sanitation that are appropriate to the conditions in developing countries and at a cost which the user can afford. Sequenced sanitation is likely to be more successful than the immediate installation of sewers as it allows the user to progress as he sees fit. This will depend on the user's preferences, financial resources and habits of personal hygiene.

The process of selecting appropriate technology begins by identifying all of the technological alternative methods of sanitation available. Of these possibilities there will usually be some technologies that can be readily excluded for technical, health or social reasons. From those technologies that are technically and socially acceptable and will provide the full health benefit, the least costly solutions are determined and the final choice has to be made on the grounds of what the community can afford. The stepwise selection of the appropriate technology has been given in a schematic form by Kalbermatten _et al_ (1980) and is presented in Table 2.

Table 2 suggests that for the choice of the appropriate technologies to be successful the combined action of the engineer, economist, behaviour scientist and the community is required.

TABLE 2: RECOMMENDED STRUCTURE OF FEASIBILITY FOR SANITATION PROGRAM PLANNING (after Kalbermatten *et al*. (1980)



WHAT ALTERNATIVE SANITATION TECHNOLOGIES ARE AVAILABLE?

From an in depth study on alternative sanitation systems around the world Kalbermatten *et al* (1980) identified 21 different sanitation systems - from simple on-site systems to community systems. A generic classification of these systems is given in Figure 2.

In a relatively dry and partly under-developed region like southern Africa, preference should be given to on-site and off-site dry sanitation systems as part of a sequentially intended upgrading sanitation programme. In this respect it has been found that up to 40 % of the water supplied

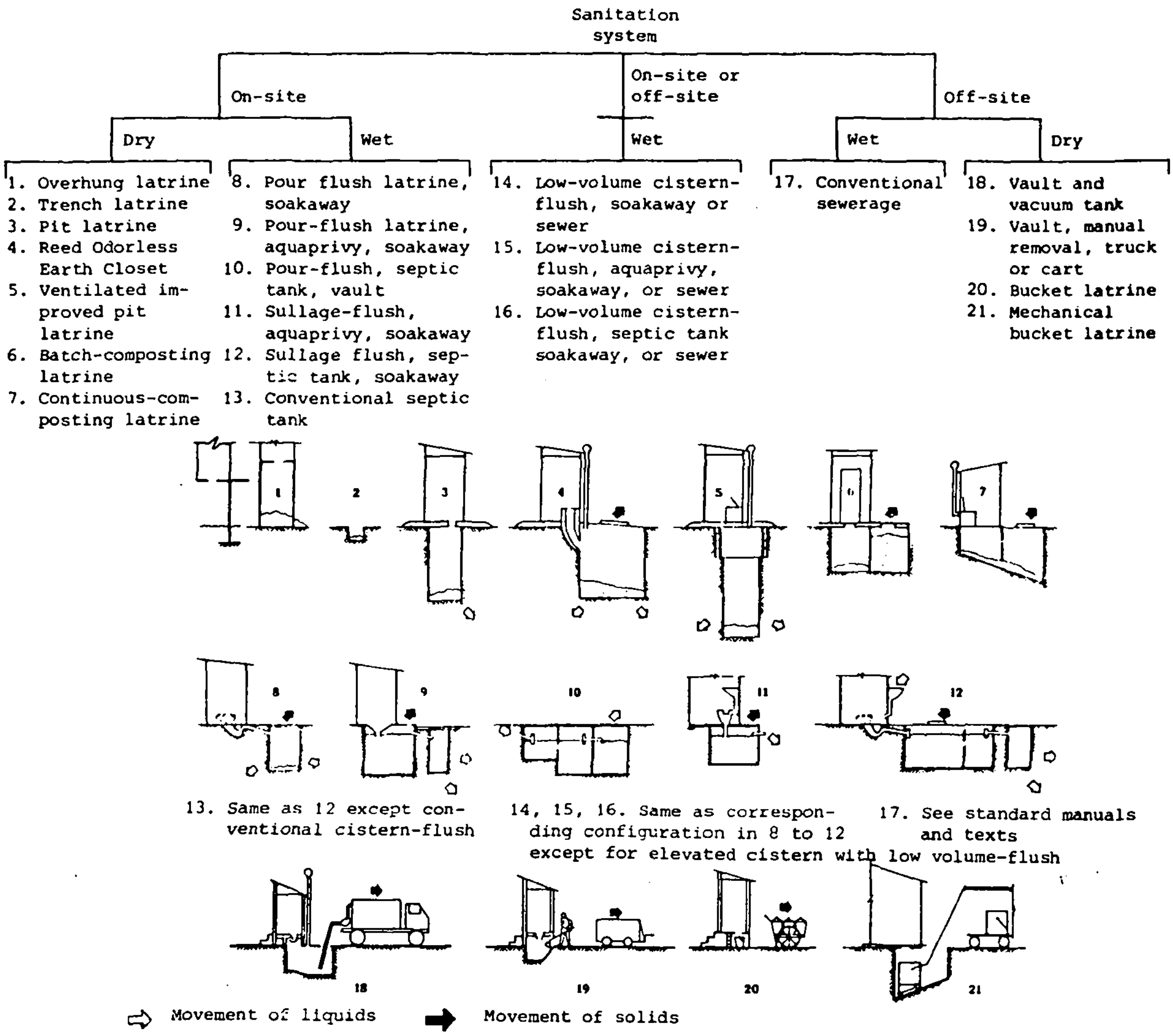


FIGURE 2: GENERIC CLASSIFICATION OF SANITATION SYSTEMS

to a household will be used only to flush away wastes. A dry sanitation system offers many advantages in this respect. The once smelly, fly breeding pit latrines have been improved to such a degree that a recent study showed that the so called Ventilated Improved Pit (VIP) latrines could be recommended for rural and urban areas of population densities of up to 300 persons per hectare (Morgan and Mara, 1982).

For the sequential upgrading of an existing sanitary system a comparison of costs of some of the available technologies could be of value. Such a cost comparison was made by Kalbermatten et al (1980) and is given in Table 3.

TABLE 3: AVERAGE ANNUAL INVESTMENT AND RECURRENT COST PER HOUSEHOLD FOR SANITATION TECHNOLOGIES (1978 US dollars)

Technology	Mean total annual cost	Investment cost	Recurrent cost
Pour-flush toilet	18.7	13.2	5.5
Pit toilet	28.5	28.4	0.1
Communal septic tank*	34.0	24.0	9.8
Vacuum-truck cartage	37.5	18.1	19.3
Low-cost septic tank	51.6	40.9	10.7
Composting toilet	55.0	50.9	4.8
Bucket cartage*	64.9	36.9	28.0
Medium-cost			
Sewered aquaprivy*	159.2	124.6	34.6
Aquaprivy	168.0	161.7	6.3
Japanese vacuum-truck cartage	187.7	127.7	60.0
High-cost			
Septic tank	369.2	227.3	141.9
Sewerage	400.3	269.9	130.4

*Per capita costs were used and scaled up by the cross-country average of six persons per household to account for large differences in the number of users.

The data in Table 3 show that of the comparable wet systems, the cost of vacuum-truck cartage is substantially lower than either septic tanks or sewerage. This is especially applicable in situations where upgrading is intended and money is scarce and labour plentiful.

CONCLUDING REMARKS

In the industrialized countries selection of the appropriate technology for a particular water supply or waste water disposal problem is rather simple when compared with most problems with water supply and waste disposal in developing countries. The reason for this is that a vast amount of technical information, covering virtually every aspect of off-site waste water treatment and enough money is generally available. Here the emphasis is more on aesthetics and environmental protection while the health and social values of the user play a minor role.

In general the conditions in most of the developing countries are completely different. Money, trained people and information on appropriate technology are scarce. The customs and social structure of the community play an important role which makes the selection of appropriate technology especially in the waste treatment field no longer the sole responsibility of the sanitary engineer.

There is no concise and universally correct definition of tehcnological appropriateness. The standards for determining the appropriateness of technology are related to the circumstances of the technology's application. No longer is it appropriate under all conditions to developing countries. Enough non-conventional alternative technologies are available. It is also no longer justified not to look at cheaper and simpler water treatment alternatives.

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OPERATOR TRAINING IN WATER PURIFICATION AND SEWAGE TREATMENT

by

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SYNOPSIS

A brief resumé is given of available formal training facilities in South Africa as well as in-service training programmes for water purification and sewage treatment operators in the national and independent southern African states and the involvement of the National Institute for Water Research (NIWR) of the Council for Scientific and Industrial Research (CSIR) in these in-service training programmes.

Shortcomings in the in-service training efforts for operators in these states are identified and recommendations are made for improving the system.

1. INTRODUCTION

Much has been said in the past about the necessity of adequate and meaningful training of water purification and sewage treatment operators. Employers or treatment plant owners seldom differ on the importance of this matter.

It is not the intention of this paper to motivate proper training of operators but to accept its necessity as an accomplished fact.

For the purpose of this seminar, the focus will fall mainly on the situation in developing areas, such as the national states and independent southern African states, with special reference to actual in-service training of the operators.

2. CLASSIFICATION AND REGISTRATION OF WATER CARE OPERATING PERSONNEL

In terms of Sections 37 and 38 of the Health Act (Act 63 of 1977) all potable water and wastewater treatment plants in South Africa, as well as the respective operating personnel, have to be classified and registered. Once the legislation has been finalized, implementation of the regulations will put the control of qualified operating personnel on a much more sound footing.

This legislation is, however, not applicable in some of the independent and national states and it will have to be accepted by the respective governments before it can be enforced. This, of course, would be very desireable because many of these states at present have to rely largely on educational and in-service training facilities outside their borders. They should, therefore, standardize and co-operate with neighbouring states on certification and control policies.

3. FORMAL THEORETICAL TRAINING FACILITIES

The Southern African Branch of the Institute of Water Pollution Control (IWPC) initiated formal training courses for sewage works operators in a few South African cities in 1960. These courses were usually arranged in collaboration with the respective City Engineer's Department and were held at one of the local treatment plants. By 1972 a total of 505 candidates had entered for these courses, which dealt with sewage treatment only. During 1973, Operators Certificate courses dealing with both drinking-water and sewage treatment were introduced at the Technical Colleges or Technikons of Pretoria, Witwatersrand, Durban and Cape Town for White; Athlone for Coloured; M.L. Sultan for Indian and Edendale and Shikoane Matlala (formerly Mmadikote) for Black candidates. More details of these centres appear in Table 1.

The entrance qualification for this course is standard eight plus six months practical experience of water or sewage treatment.

Both the Shikoane Matlala and Edendale Technical Colleges also offer a course at a lower level, called the Maintenance Workers Course, requiring only standard six plus six months practical experience, as entrance qualification. The term 'Maintenance Worker' is however, rather misleading. A more appropriate term for the qualification would have been 'Assistant Operators Certificate'.

TABLE 1: Technical training centres offering courses in water purification and sewage treatment

Name of centre	Postal address	Tel. No.	Contact person
Pretoria Technical College	P O Box 26193 Arcadia 0007	(012) 265241	Mr A J Minnaar
Witwatersrand Technikon	P O Box 3293 Johannesburg 2000	(011) 297136	Mr F J Jonker
Technical College Durban	Private Bag Congella 4013	(031) 251379	Mr L A Prins
Cape Town Technical College*	P O Box 726 Cape Town 8000	(021) 464555 461038	Mr I L Gibson
Shikoane Matlala Technical College	Private Bag X 4010 Seshego 0742	(01527) 5213	Mr J L Roux
Edendale Technical College	P O Sikoleni 4510	(0331) 81644/5	Mr E E Reid
M L Sultan Technikon	P O Box 1334 Durban 4000	(031) 316681	Mr E A Blair
Athlone Technical College	Private Bag Athlone 7760	(021) 679183	Mr J A Bester

*Due to lack of sufficient candidates, no courses were held so far.

4. IN-SERVICE TRAINING OF OPERATORS

4.1 Training within the organization

With bigger organizations such as water boards, local authorities, municipalities etc., there are usually sufficient knowledgeable and experienced staff on site to provide effective in-service training of learner-, as well as certified operators. In the rural areas the situation is drastically changed. It is very difficult to achieve good control and supervision if the various treatment plants are distant from the supervisor's office. To make matters worse, the learner operator at a small remote treatment plant is often the *only* operator at the plant.

4.2 Training of operators in the national and independent states

4.2.1 Contribution by the NIWR

Since 1965, the National Institute for Water Research (NIWR) of the Council for Scientific and Industrial Research (CSIR) has been involved in an advisory service to the South African Development Trust through the Department of Co-operation and Development, regarding water purification and sewage treatment in the national states and Trust areas. The in-service training of operational staff has always been an important component of this service but since 1978, according to the instructions of the Department of Co-operation and Development, this aspect has received higher priority than certain other tasks, such as plant monitoring services, etc. When Bophuthatswana, Venda and the Ciskei obtained independence in 1977, 1979 and 1981 respectively, their Governments entered into agreements with the NIWR, similar to that of the Department of Co-operation and Development, in order to ensure a continuation of the abovementioned advisory service.

Most of the governments or government services are still lacking a proper oganization to take care of the training programmes but some have already managed to build up a reasonable organization, such as the training facilities at Sundumbili provided by the KwaZulu Government Service.

4.2.2 Man-to-man training

While doing inspections at the various treatment plants, the NIWR officer spends time on the on-site training of the operators. This man-to-man training method is, of course, the most effective of all, but unfortunately it is also the most expensive and time consuming method. Due to the limited NIWR manpower available, this method is not quick enough by far to satisfy the demand for trained operators. The involvement of the employer or supervisory staff is therefore of the utmost importance.

4.2.3 Training courses in the various national and independent states

Various theoretical, but practically orientated, courses were presented by the NIWR (some with the assistance of one or two of the respective government/government service officials) in the national and independent states. The administrative arrangements were made by the local authorities. A summary of the numbers involved are given in Table 2.

TABLE 2: Summary of operator training courses presented in the national and independent states

Date	State (venue)	Number and category of candidates
Oct. 1979	Venda	10 Operators
May 1980	Lebowa	20 Operators
Nov. 1980	Lebowa	13 Leaner operators from Lebowa, KaNgwane, Gazankulu and Venda
Nov. 1981	Gazankulu	21 Leaner operators from Gazankulu and Lebowa
July 1982	Lebowa	6 Operators (Tuition : Laboratory Control methods)
Sept. 1982	Gazankulu	14 Learner operators
Nov. 1982	Ciskei	8 Sewage treatment operators
Totals : 44 Operators and 48 Learner Operators		

The numbers of candidates involved at these courses were reasonable to justify the costs but unfortunately the lecture rooms provided were often not suitable. In certain cases, the back-up administrative services also left a lot to be desired and in one case, problems with accommodation for the candidates were also experienced - all matters having an adverse effect on the course as a whole.

4.2.4 Courses at Soshanguve In-service Training Centre

In order to eliminate most of these problems, arrangements were made to present two courses per year at the Soshanguve In-service Training Centre (near Mabopane) with its excellent classrooms, workshops and accommodation facilities. The courses are each of two weeks duration. The first course, held during April, is a refresher course for certified operators and includes analytical process control methods and interpretation of results. The second course, held during August, is an introductory course for learner operators to familiarize them with the various treatment processes and the terminology before attending the formal course at the Technical Colleges. Thirty candidates can be accommodated per course.

There were 21 candidates at the April 1982 course and 25 (including 4 health inspectors) at the April 1983 course. In August 1982, 25 learner operators were trained and about 25 to 30 are expected for the August 1983 course. The NIWR is only responsible for providing the lectures and all administrative arrangements are made by the Training Division of the Department of Co-operation and Development. Candidates from all national or independent states can be sent on these courses by their employers.

As with courses offered in the respective states, no certificates are issued to the candidates. However, a comprehensive report on the performance of the candidates is sent to the respective employers.

4.2.5 Lecturing material/aids

(a) The lecturing material and text books presently available are not considered adequate for the training of the operators. As instructed by the Department of Co-operation and Development, lectures were compiled by the NIWR for operator training in both water and sewage treatment. Due to pressure of other tasks, these lectures have not been finalized as yet, but are being used at present in the draft form. The Department of Co-operation and Development indicated that once they have been finalized these documents could be made available to educational institutions.

(b) Audio-visual aids in the form of slides and tapes were purchased from the Water Pollution Control Federation (WPCF) in the United States of America, to be used with the section on sewage treatment. Once the lectures have been finalized, these aids will be modified to be more applicable to conditions in southern Africa.

(c) Various models of units such as pump sections etc., to be used in demonstrations during the course, were constructed or modified.

4.3 Training of supervisors

It stands to reason that when operators are trained while their supervisors are not included in the training programmes, a most undesirable situation will arise. The Department of Co-operation and Development was, at the time of preparing this paper, making arrangements for a course for these supervisors to be held at the NIWR, Pretoria, probably during September 1983. Supervisors from various national or independent states will be attending this course. The space available at the NIWR will limit the number of candidates to about 8, if analytical process control methods are to be included.

In the opinion of the NIWR personnel concerned, this type of in-service training course should be of much more value than the operators' courses discussed above, provided that these supervisors pass the knowledge gained, on to the operators under their control.

5. SHORTCOMINGS OF THE PRESENT SYSTEM

Because of its involvement in the in-service training of water purification and sewage treatment operators in the national and independent southern African states, the NIWR could identify the following shortcomings in these areas.

5.1 Lack of sufficient interest by the employer/supervisor

This shortcoming appeared to be applicable in most cases and there seemed to be a general complaint by the candidates to the effect that their supervisors showed little interest in the operator's progress. This is in agreement with the observations made by NIWR personnel working in these areas, which points to the lack of backing and technical guidance of the operating staff by their seniors. This, in the author's opinion, is in some cases due to the inadequate knowledge and process experience of the senior person. In other cases the supervisor is so overburdened by other tasks that it is impossible for him to pay any attention to the operation of the treatment plant - especially if the plant seems to be operated 'reasonably well'. His efforts may possibly be diverted in this direction only after a serious problem arises, instead of preventing such problems by better guidance.

It is a known fact that in certain areas, the supervisor may turn up at a plant with just sufficient time to sign the register and then to rush off to the next plant in order to get through his overloaded programme. This is a sure way of killing all the interest and incentive of the operator.

It is a pity that the statement must be made that the lack of interest in some cases appears to originate at the top or head of a department and works itself right down to the supervisory and operating personnel. This unfortunate condition has been reflected at some of these courses, where candidates arrived completely unprepared for the course; sometimes not only without the study material which was supposed to have been distributed to them well before the time, but also without the essential stationary.

5.2 Lack of promotion opportunities for the operators

This aspect is very closely related to the previous one. Many operators are quite outspoken about the fact that whether he does a fine job or whether he merely turns up at work every day, his chances of promotion remain just about the same. It is very important that a proper promotion structure be provided by the creation and filling of posts such as learner operator, operator, senior operator, chief operator, plant supervisor, superindendent and manager etc. The guidelines issued by the Department of Environment Affairs (RSA) should be consulted in this respect.

In addition to this, regional control superintendents and managers are required to form part of the very important pyramid structure which is necessary to ensure effective control in the remote areas. These regional control personnel should be very actively involved in the training programmes of the various authorities. One case is known where posts for senior operators have in fact been created by the Department of Works but due to unfortunate neglect, remained unfilled.

5.3 Lack of control test equipment

As performing certain control tests and the interpretation of the analytical results plays an integral and very important role in the operation of a treatment plant, it is for obvious reasons included in the training courses. Unfortunately the apparatus necessary for carrying out these tests is seldom provided for the smaller plants. This resultant complete lack of experience in using such equipment not only hinders the progress made by the operator at the training courses, but also places a question mark behind the long term significance of this part of the training efforts, as the operator cannot apply on his plant what he has been taught at the training courses. Fortunately at least one of the national states is at present making a determined effort to provide this essential equipment.

5.4 Non-uniformity of the formal theoretical training

The envisaged classification and registration of operating personnel is likely to be doomed to failure unless the tuition and examining of the operators can be done on a uniform basis for the whole of southern Africa. At present the numerous educational institutions and departments concerned examine the candidates in different ways; the candidates from Edendale and Shikoane Matlala are examined externally by the Department of Education and Training, requiring a 40 % pass mark, while the other institutions examine internally, requiring a 50 % pass mark.

A few months ago the Principal of the Shikoane Matlala Technical College, Mr H T O Muller, initiated discussions in an effort to introduce the so-called 'N-stream' system in the training of the water purification and sewage treatment operators. This, in the writer's opinion, will not only have the advantage of a built-in uniformity but will also open up opportunities for further studies and the obtaining of higher academic qualifications by those operators with potential.

At present, there is no further course that a qualified operator, holding only a standard eight school certificate, can take.

5.5 Lack of sufficient supervisory staff with adequate knowledge of the respective treatment processes

Although it is realised that the water treatment field is not the only one where this condition exists, it is felt that it is very undesirable for a sensitive industry such as this. Each and every supervisor should also be a training officer. The author has very strong feelings about the fact that the efforts and input by the NIWR in the in-service training programmes should be directed at the supervisor/training officer level rather than at the operator level.
As mentioned earlier, an effort is being made to arrange a course at the NIWR, Pretoria, for supervisory personnel from the national and independent states. Knowledge gained in this manner can then be passed on to the operators at their respective plants.

It should be clear, without any doubt, that the efforts by the NIWR to assist with the in-service training programmes are by no means sufficient for the training of all operators due to the great numbers involved.

6. RECOMMENDATIONS

The following recommendations are made in an effort to obtain maximum benefit from the in-service training programmes, which must at all costs be continued and expanded:

- Create sufficient posts for senior operating personnel and supervisors/training officers and fill the posts with personnel already identified as those showing potential and leadership abilities.

- These supervisors should have no other function than to manage and control operational matters. They should in no way be burdened by other tasks such as maintenance of pipelines etc., which should be the responsibility of a maintenance/repairs team.
- The supervisors should receive appropriate training at a more advanced level by making use of an external source of expertise such as the NIWR, Department of Environment Affairs, local authorities such as municipalities etc.
- The supervisors should be responsible for the training and guidance of operators under their supervision. If required, abovementioned external sources could be consulted on the *modus operandi* of such training programmes.
- Equip all treatment plants with the appropriate apparatus to enable the operator to perform the necessary process control tests. This should of course be coupled to proper record keeping.
- Take the necessary steps to bring to the notice of the respective governments, the advantages which could be gained by accepting legislation which will lead to a uniform classification and registration of water purification and sewage treatment operators.

As far as revision of the present formal theoretical training system is concerned, there is very little that the employer can do. This is a matter for the educational institutions and departments concerned.

7. CONCLUSION

Although a fairly dark picture has been painted by some of the facts in this paper, the author is convinced that if cognizance is taken of these recommendations, a vast improvement will soon be seen. The reason why this statement can be made quite confidently is because any person who has been closely involved with plant operation in the national and independent states will agree that in as short a time as one decade, we have already seen a great improvement in the quality of the operating personnel.

In closing, the author wishes to pay a tribute to all the personnel of the NIWR and the various local authorities who are involved in this very important training programme and who have, through their concerted and dedicated efforts, upgraded the quality of the operational staff.

8. ACKNOWLEDGEMENTS

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ALTERNATIVES FOR LOW TECHNOLOGY SANITATION

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SYNOPSIS

In developing countries funds and other resources available for housing and its associated services are limited and the demand for these facilities is ever increasing. The adoption of western housing standards by such countries invariably leads to the expectations of only a minority being satisfied. To prevent this, it is imperative that the principle of affordability should prevail and, consequently, that appropriate standards and technology should be employed. The provision of sanitation, which is the primary health service, should also conform to this principle. In the developing parts of this country, conventional waterborne sewerage and its associated level of water supply is usually too expensive. Appropriate alternatives for sanitation should therefore be considered. This paper deals with some of these and comments on the necessity for a carefully planned sanitation improvement programme.

SAMEVATTING

In ontwikkelende lande is beskikbare fondse en ander hulpbronne vir behuising en die verwante dienste beperk, en daar is 'n toenemende vraag na hierdie fasiliteite. Hierdie lande se aanvaarding van westerse behuisingstandaarde lei alleen tot bevrediging van die minderheid se verwagtings. Om dit te voorkom is dit noodsaaklik dat die beginsel van bekostigbaarheid moet geld, en dat toepaslike standaarde en tegnologie dus ingespan moet word. Voorsiening vir sanitasie, wat die belangrikste gesondheidsdiens is, moet aanpas by bogenoemde beginsel. In die ontwikkelende dele van hierdie land is konvensionele spoelriolering en die vlak van watervoorsiening wat daarmee gepaard gaan gewoonlik te duur. Toepaslike alternatiewe vir sanitasie moet dus oorweeg word. Sommige alternatiewe word in die referaat bespreek, en kommentaar word oor die noodsaaklikheid van 'n versigtig beplande program vir sanitasieverbetering gelewer.

INTRODUCTION

The provision of housing and its related services can be very expensive, and if the expectations of the population in this regard are above its means, this disparity can pose a major national problem. The imposition of housing standards that are too expensive for the individual, and the institution of a government subsidy to relieve this burden prevents a country from solving its housing problem. This approach invariably leads to a minority being satisfied, while the rest still live in unsatisfactory conditions.

The solution lies in finding a balance between housing needs on one hand, and available resources on the other. These resources include money, water and manpower which are usually limited and cannot be arbitrarily increased. Standards of housing can however be adapted to suit individual needs. In other words, standards and technology should be selected from within a range that a person can afford. Only in this way can a balance between needs and resources be attained.

A more affluent community will probably opt for a high level of technology which will provide it with a high level of convenience at a price which it can afford. A poorer community, on the other hand, will probably have to settle for a lower and less expensive technology which still satisfies its basic requirements for health and safety. A humanitarian approach to the poorer community which overlooks cost, will only postpone its development towards independence. The poor should rather be helped to help themselves. Their living standards should not be raised solely according to their expectations and at the expense of others. No economy can bear such a one-way traffic of funds, nor can any developing community be expected to rise above such paternalism and maintain its self-respect.

Most of the people in the independent and national states of South Africa are in a developing phase to which advanced western standards of housing and services are not appropriate. They are financially obliged to adopt low-technology solutions. This paper therefore deals with some low-technology alternatives for sanitation, which is the primary service required for safe and healthy living conditions.

SANITATION

Sanitation should be considered in the broad sense of water supply and sullage and excreta disposal. This is essential, because standards applicable to any one of these elements should also apply to the other two. Effective sanitation is required mainly to safeguard human health and should therefore be given priority in the provision of services; it should be followed by matters such as solid waste removal, shelter, energy, transport and community facilities. From a western viewpoint, effective sanitation implies waterborne sewerage and a fully reticulated water supply. These systems are expensive to construct and require high levels of skill to operate and maintain. Besides, waterborne sewerage pollutes large quantities of clean water to flush away excreta. It has not solved the problems of excreta disposal in the developed world, and should not even be considered in the developing parts of this country. Solutions other than the adoption of conventional practices should therefore be sought.

The main requirement of an effective sanitation system is to break the cycle of disease transmission from man to man. All of the options recommended in this paper fulfill this basic need. While conventional waterborne sewerage goes a step further and also provides optimum user convenience, this feature substantially increases the cost of the facility, and is not essential, particularly if the users cannot afford it. On the contrary, the proposed alternatives necessitate the on-site treatment of human waste and they depend to a larger degree on user care. Therefore, factors such as environmental, socio-cultural, institutional and political conditions, as well as the necessary education, should also be considered. Improvement in sanitation at low cost can only be achieved through an integrated approach using several disciplines and non-technical activities according to a well-defined implementation strategy.

The on-site treatment of human waste commonly causes health authorities and environmentalists concern over groundwater pollution. However, this should be seen in perspective. Groundwater pollution is only a problem if water is drawn for domestic use in the immediate vicinity of an on-site disposal unit. If clean water is supplied from a more remote source, pollution will not be a problem. In any event, the quantity of groundwater available might be insufficient to operate any other type of disposal system. If polluted groundwater is needed for domestic use, it can be purified as is done with most surface water. It may also be feasible to allow the short-term pollution of an extensive aquifer, and to upgrade the sanitation system to a non-polluting one when the aquifer is exploited.

RURAL SANITATION

In rural areas, where the settling of individual families or small groups is uncontrolled, a distant open stream or well usually serves as the water source, and excreta is disposed of by defaecation in the field or in conventional pit latrines. Household water has to be carried over long distances and the quantities that can be transported in this way are insufficient to ensure proper personal hygiene. In many cases the stream is heavily polluted because human and animal faeces have been washed into it by natural surface drainage. These conditions promote the spread of diseases such as cholera and even cause epidemics in rural areas, as has happened in recent years. One of the greatest difficulties in improving this situation is to convince the local community that the lack of sanitation is probably its main health hazard. They must first be led to understand the problem and then motivated to do something about it.

Technically, the solution is fairly simple, and can easily be demonstrated. A ventilated improved pit latrine (VIP latrine - see Figure 1) for each family is the solution to excreta disposal. This is basically a conventional pit latrine with a ventilation pipe which, together with other minor design improvements, provides a facility that is acceptable because of largely reduced odour and less insect nuisance. An alternative design that originated in Zimbabwe, is shown in Figure 2. A VIP latrine can be built at very low cost using local materials. For stability of the superstructure the upper part of the pit should be lined; an example of such a lining is shown in Figure 3. In loose sandy soil conditions, however, the entire pit should be lined

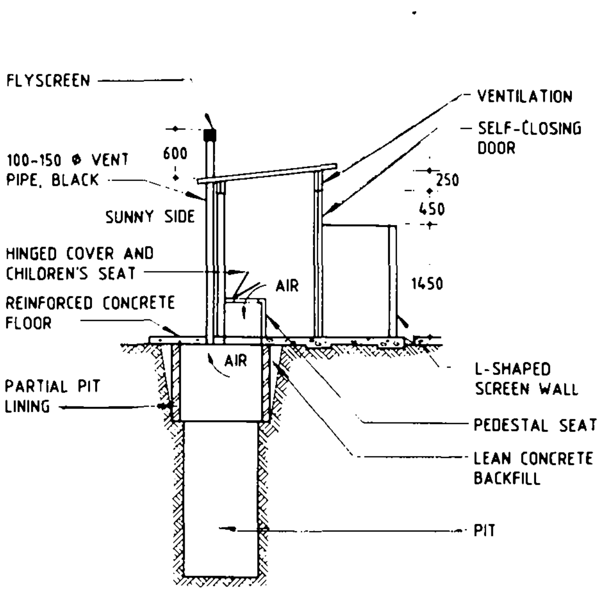

FIGURE 1: Ventilated improved pit (VIP) latrine (From a drawing by R A Boydell)

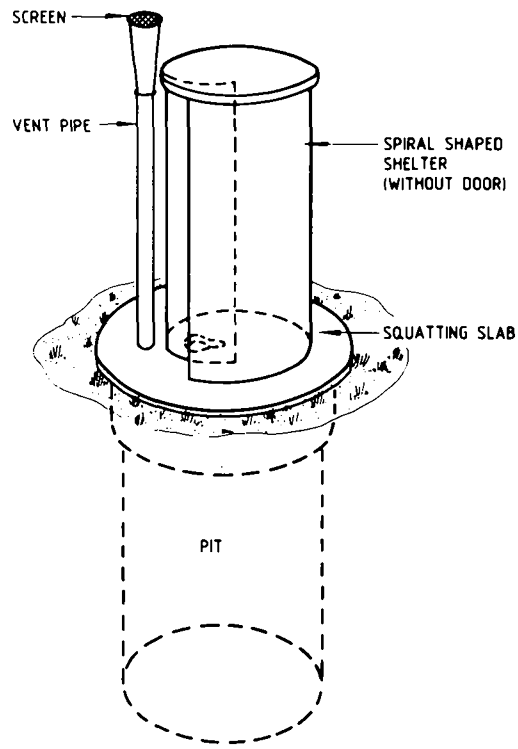

FIGURE 2: Zimbabwe design VIP latrine

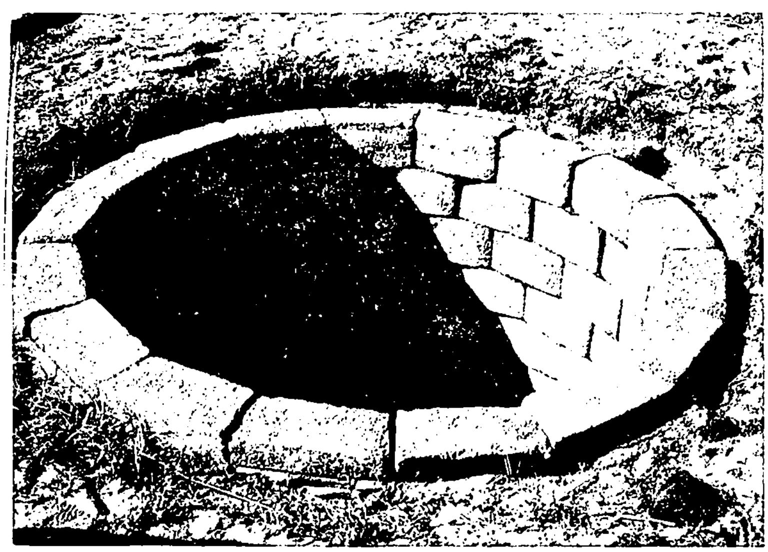

FIGURE 3: Pit lining of tapered sand/cement blocks in position in round pit

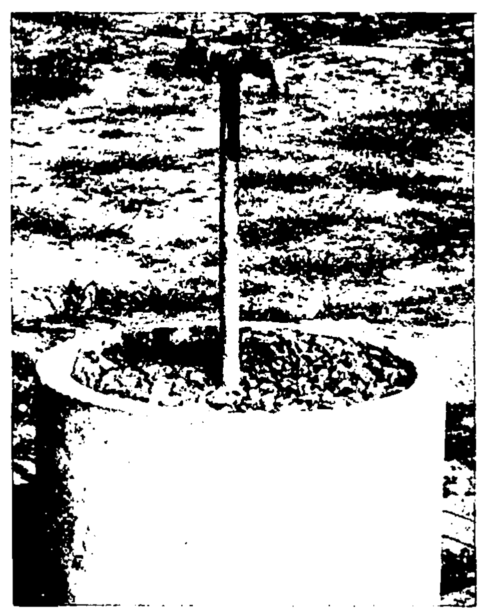

FIGURE 4: Public standpipe

to prevent the walls from caving in. Also, it is important that the latrine floor be above flood level. Existing conventional pit latrines could be upgraded to VIP standards.

Although the provision of proper latrines will reduce the pollution of water sources, the physical carrying of water still needs attention. An acceptable solution would be to provide at least one village water supply point, but preferably more, depending on the size of the community. This point could consist of a properly designed standpipe (Figure 4) which is fed by an adequately sized pipe from an upstream weir, or a borehole or well equipped with an easily maintained handpump. If the topography does not allow gravitational water feed, a handpump could be installed at the stream near the village, and water pumped to a tank in the village. As a general rule, no latrine should be located uphill or within 30 m of a water source if a safe water supply is to be ensured. Whichever alternative is selected, the cost will probably exceed the means of the recipients and some financial aid should be considered by the government. It is, however, advisable to use local labour wherever possible to keep the community's indebtedness as low as possible.

URBAN SANITATION

In the urban context sanitation improvement should be approached more systematically than in the rural situation. Various systems are available, the most appropriate of which should be selected for local conditions. No single alternative is suited to all possible circumstances. At the design stage possible upgrading sequences should be identified to ensure that most of the initial installation can be made use of in subsequent upgrades. Sanitation systems in general use are described below, with their advantages and disadvantages.

(a) Bucket system

This system consists of a temporary or permanent superstructure with a seat positioned over a bucket. A collecting, transport and disposal service empties the bucket frequently. No water is used for flushing. The volume of waste deposited in this system is kept to a minimum because of the need to empty the bucket manually, and other waste matter such as vegetable refuse and washing water, is disposed of elsewhere.

In this country, the bucket system has for many years been considered a suitable temporary alternative to waterborne sewerage. Although the capital outlay is small, the running costs are very high, efficient management is essential and it is difficult to recruit staff. In addition, there is a severe fly and odour problem both in the latrine and along the conveyance route and the obvious possibility of contact with raw excreta presents a health hazard. The most serious disadvantage of this system is that conventional waterborne sewerage is the only feasible method of upgrading, and this renders most of the initial capital investment redundant. Such upgrading places an immediate heavy financial burden on the community. For these reasons, the bucket system is not recommended in low-cost housing schemes.

(b) Conventional pit latrine

Pit latrines are the most common of the sanitary disposal facilities used in developing countries. In a conventional pit latrine a floor, seat (or squatting plate) and superstructure are situated directly over a pit in the ground. This pit receives and retains excreta, which are biologically converted into innocuous matter. The pit is usually about 1 m in diameter (or 1 m square) and 2 m deep. When the pit is filled to within 0,6 m of the ground surface the superstructure is moved to a new pit nearby and the old pit is filled up with soil and abandoned. Because odour and insects are a nuisance and because there is usually a danger of collapse or of children falling into the pit, these latrines are not popular. Also, little effort is made by the users to keep the seat or squatting area clean in what is often regarded as an unclean place. This aggravates the problems of hygiene. Existing conventional pit latrines should therefore be abolished or upgraded to VIP latrines.

(c) VIP latrine

As mentioned earlier, the VIP latrine has the additional feature of a vent pipe which ventilates the pit, and consequently the superstructure, to the open air, thereby rendering the latrine odourless. For this purpose a pipe of 100 mm in diameter is adequate, but 150 mm is preferred. The ventilating action is induced mainly by wind flow over the pipe outlet and is enhanced by solar energy absorbed by the pipe if it is located on the sunny side of the superstructure. An insect-proof screen fitted over the vent pipe outlet has proved effective to trap a large percentage of flies and mosquitos breeding in the pit, leaving the latrine virtually insect-free. Other necessary design improvements are listed below.

(i) Ensuring that the inside of the superstructure is sufficiently dark to discourage the entry of insects, either from the outside, or from the pit.

(ii) Partly or fully lining the pit (where soil conditions require it) to afford stability to the superstructure. An effective way of doing this is to dry-stack prefabricated tapered sand/cement blocks in a circular pit as illustrated in Figure 3.

(iii) Installing a prefabricated fibre-glass seat unit, fitted with a seat for adults, a children's seat and a seat cover. This should be smooth, easily kept clean, and preferably self-closing. (White has proved to be the most acceptable colour.)

(iv) Providing a smooth-rendered reinforced concrete floor that can easily be kept clean to inhibit infection by hookworm, whose larvae commonly penetrate the soles of bare feet.

Pits should be designed to last at least four years but preferably 10 years or more. To estimate the pit size one should generally allow 0.06 m^3/person/year. As in the case of conventional pit latrines, the superstructure should be moved to a new pit nearby when the pit has been filled to within 0,6 m of the ground surface. The old pit should be topped up with soil. The material in the old pit will be digested and after a year or more, it can be manually dug up and used as fertiliser; the emptied pit can then be used again. A VIP latrine is therefore a temporary structure; sufficient space is required on the plot to accomodate two pits or more over a prolonged period of time.

VIP latrines are cheap, easy for the unskilled to construct and maintain, and require little user care and municipal involvement. They lend themselves to the self-help ideal because their construction is labour-intensive. They need no running water. Separate arrangements for sullage disposal must be made but this is not a serious problem because the associated level of water supply is not likely to produce large quantities of sullage. A small soakpit will generally suffice.

The accompanying water supply system should consist of public standpipes in the street in a ratio of about one standpipe per ten sites. The basic design requirements for public standpipes are listed below.

(i) They must be simple and cheap, and easily installed and maintained by local labour; sophisticated apparatus is inappropriate.

(ii) The development of unhygienic conditions in the vicinity of the standpipe should be avoided.

(iii) They must allow for the filling of containers of various sizes with a minimum of waste. Taps discharging fixed quantities of water are not recommended.

(iv) They should be built of local materials as far as possible; imported prefabricated units are not appropriate.

(v) They should be reasonably resistant to abuse.

Figures 4 and 5 illustrate a standpipe that satisfies most of these requirements. Two outstanding features are the soakaway contained in a 1,2 m length of 600 mm diameter concrete pipe and the splash slab surrounding the standpipe. The possibility of connecting a garden hose to the tap should be prevented by fitting a specially moulded tap outlet. Water consumption should be measured.

Alternatively, there could be a kiosk with a metered water supply and three to five outlets that are controlled from within the kiosk. This system is usually operated by a private entrepeneur who hires the kiosk and buys water in bulk from the local authority for resale at a profit

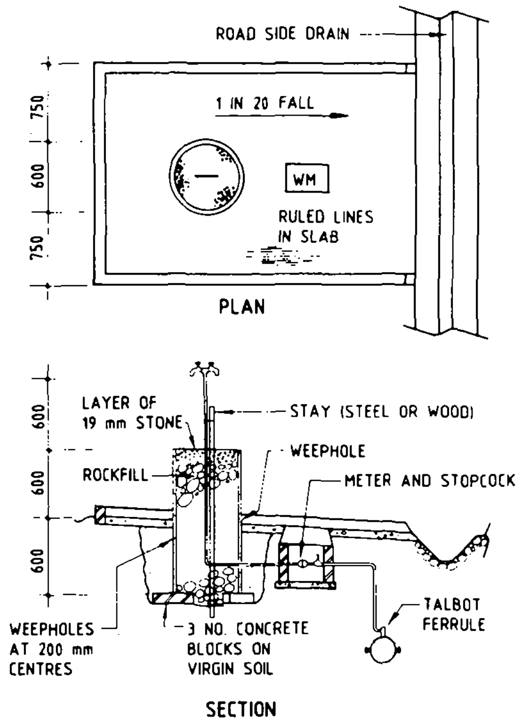

FIGURE 5: Design of public standpipe (From a drawing by B M Jackson)

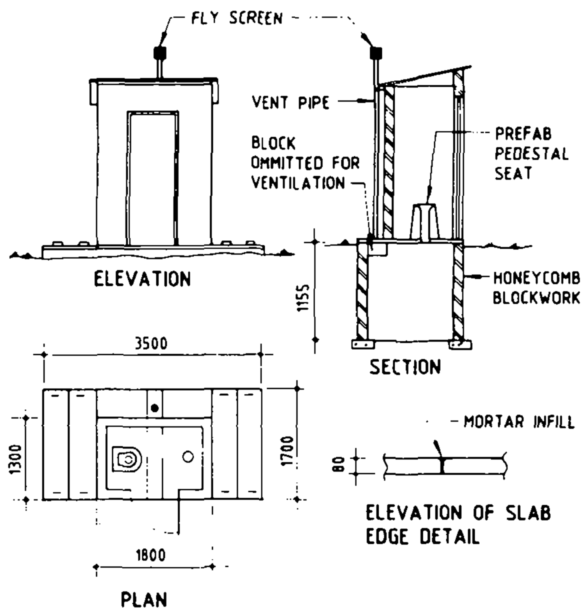

FIGURE 6: Design of VIDP latrine (From a drawing by B M Jackson)

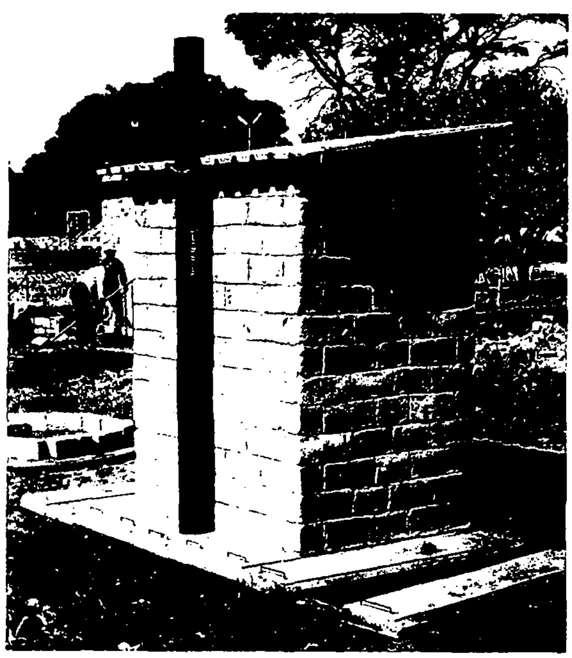

FIGURE 7: VIDP latrine built of sand/cement blocks

to consumers. Apart from the creation of job opportunities, this system encourages private enterprise and falls within the scope of the abovementioned requirements.

(d) Ventilated improved double pit latrine (VIDP latrine)

The VIDP latrine is an improved VIP latrine which is a permanent installation suitable for higher population densities, and which is designed to be emptied (see Figures 6 and 7). It consists of two pits, each of about 1,5 m^3 effective volume, to be used alternately on a two to three year emptying cycle. The pits are jointly ventilated by one pipe as in the case of the VIP latrine, and can be emptied either manually, if socially acceptable, or mechanically. For mechanical emptying specially developed suction appliances that will effectively remove pit contents in any condition are required. The development of such an appliance is being undertaken by the British Building Research Establishment. Because the pits are only about 1,1 m deep, they are much less likely to penetrate and pollute the groundwater than VIP latrines.

Although the basic VIP latrine design requirements also apply to VIDP latrines a few additional points should be noted.

(i) A full-depth pit lining should be built with the vertical joints in the masonry left unfilled to allow liquids to seep away.

(ii) Although the cover slabs may seem to be over-designed, they have to allow for limitations in the pre-casting operation, as well as for the heavy building materials that are often stored in and around latrines by householders.

(iii) The door should preferably open outwards to make storage space available for various household items. The VIDP latrine is frequently the only safe storage place available on a site.

(iv) Carefully machined, slightly conical moulds should be used to form the holes in the slabs to facilitate neat fitting of the seat and vent pipe.

VIDP latrines are more expensive than VIP latrines, but they can be more easily upgraded to small-bore sewered aqua-privies or septic tanks and are permanent facilities. The superstructure can be built by unskilled labour, but slightly higher skills are required to build a good substructure. The complementary water supply and sullage disposal systems will be similar to those of VIP latrines.

(e) Composting latrine

There are two basic types of composting latrine, one being a batch and the other a continuous processing unit. Both are generally expensive, sophisticated installations that require meticulous care for effective composting and are therefore not considered feasible options for low-technology sanitation.

(f) Pour-flush latrine

The pour-flush latrine consists of a shallow water seal pan integral with a squatting plate; it discharges through a short pipe to a seepage pit. Flushing is effected by pouring about 2 litres of waste water into the pan to remove excreta. Because of the discharge of unsettled solid matter into the seepage pit, the pit's life is limited by the gradual blocking of its walls. The corresponding water supply system is similar to that required for VIP latrines. A possible improvement to this system would be to use a pedestal pour-flush pan which discharges into a small septic tank and which can be upgraded to a cistern-fed unit ensuring effective controlled flushing. The effluent of the septic tank, together with sullage, could be either discharged into a soakpit, or carried away by small-bore sewers. For this purpose, a fully reticulated water supply would be required, and sullage should be reduced to a minimum by applying all the domestic water saving measures possible. Research towards developing such a low-flush pan is at present being done by the NBRI.

(g) Septic tank

The septic tank is part of an on-site waterborne disposal system and is suitable for either a single family or a whole community. It is an expensive system, but a permanent one, involving a fully reticulated water supply and it furnishes convenience and a high standard of hygiene. It requires little maintenance other than the emptying of sludge at regular intervals. Septic tanks are not considered to be a feasible permanent solution for a community but they can facilitate the differential development of sanitation facilities within a community until all members of the community have reached the same level of service. Septic tanks with soakaways are therefore viewed as an intermediate step in an upgrading sequence which culminates in a small-bore sewered septic tank system. This means that conventional waterborne sewerage should not always be the objective. An important advantage of this progressive approach is that the individual can upgrade his sanitation facility when he can afford it, without involving the whole community and, further, that such capital expenditure is immediately effective. In contrast, a conventional waterborne sewerage installation usually becomes fully utilised only after a number of years.

(h) Aqua-privy

An aqua-privy is essentially a small septic tank which receives only human waste and some water from a specially designed pedestal seat situated directly above the tank (see Figure 8). Excreta drops through a straight pipe and is discharged below the scum layer into the liquid, thus providing a water seal. Little water is required to clean the bowl

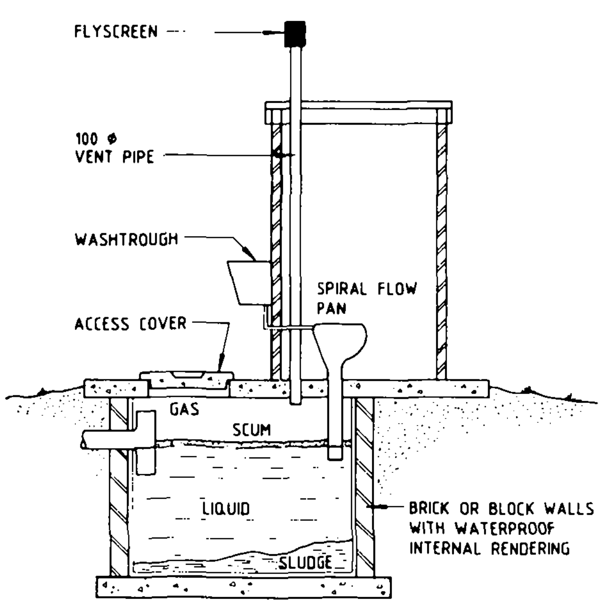

FIGURE 8: Aqua-privy (From a drawing by R F Carroll)

and maintain the level of liquid in the tank. A spiral-flow pan which receives discharge from a kitchen sink, a washbasin or a washtrough has proved effective in this system. On-site water should be supplied to the primary sanitary fixture. The effluent from the privy tank could be discharged to a soakaway or to a small-bore sewer system.

A modification of this concept is the anaerobic digestor, which incorporates a fully-enclosed prefabricated tank with a stirring mechanism to agitate the solid matter settled at the bottom and the scum at the top of the tank. Stirring is believed to improve the digesting process in the tank. This unit is relatively expensive. A plunger is needed to push the excreta through the drop pipe into the tank; this poses a problem of possible contact with raw excreta. Very little water is needed to clean the bowl but slightly more user care is required than for the conventional aqua-privy. Effluent is odourless and can be safely discharged into either a small soakpit or a small-bore sewer. A public standpipe water supply system is adequate for such a system. Although the water supply can be upgraded, further upgrading of the sanitary disposal system is not feasible.

IMPLEMENTATION STRATEGY

Low-technology sanitation schemes need careful planning, implemention and control for their satisfactory introduction and operation. One cannot create the mere physical facilities and expect the system to operate successfully without considering associated non-technical issues. Jackson summarised the essential requirements for a sanitation improvement programme as follows.

(i) Detailed site investigations (soil and groundwater conditions).

(ii) Assessment of available construction skills.

(iii) Design of appropriate hardware.

(iv) Options for procurement of materials and prefabrication.

(v) On-site technical advice and assistance.

(vi) Assessment of means, willingness to pay and financial assistance required.

(vii) Loan security and cost recovery systems.

(viii) Involvement of the private sector.

(ix) Motivation and training of clients.

(x) Awareness of local socio-cultural limitations.

(xi) User education.

(xii) Long-term follow-up and evaluation programmes.

In addition, a few points should be clarified. Firstly there is the issue of land tenure - no one is inclined to invest heavily in improving a site which is not his own. Then there is the question of who pays for what - in other words, the extent to which housing will be subsidised. Because government funds are limited and the intention is to assist all the country's inhabitants, subsidies should naturally be limited. Further, the role of consultants in low-cost services is changing significantly. Traditionally, the remuneration of consultants has been based on a tariff scale which was somehow tied to the contract value. For proposed low-technology schemes however, a modified tariff structure is required to enable the consultant's services to be used on a project which may have a minimum contract value.

When planning a sanitation improvement programme, much can be learned from experience gained in neighbouring Lesotho, Botswana and Zimbabwe. At this time, let it suffice to say that no sanitation project should be undertaken without a proper programme based on an integrated approach which takes into account all the needs and circumstances of that particular project.

CONCLUSION

While limited funds and other resources are available for the provision of housing and related services, appropriately low technology should be utilised as much as possible. All parties concerned will inevitably be forced to modify their attitudes to housing accordingly. For the provision of sanitation, which is the key service to safeguard public health, it is clear that waterborne sewerage with its associated level of water supply cannot be universally adopted. In most cases, it is not even an alternative to consider, either as an initial service, or as the ultimate aim. Several low-technology options, that are generally more appropriate and more affordable, are available to those who most need sanitation improvement and these should be taken advantage of. Technically these alternatives are fairly simple but the relevant environmental, socio-cultural, economical, educational and institutional factors should also be considered when a sanitation improvement programme is planned. More detailed information on these aspects is available from the NBRI.

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A INTRODUCTION

The Department of Co-operation and Development is, directly or indirectly through appointed agents or a relevant Department of Works, responsible for or involved in the provision of all services, including water supply and sanitation, in the national states and even in some of the Independent States. A national state can be defined as a self-governing territory within the Republic of South Africa which has been promulgated under Act 21 of 1971.

The Department's involvement in Independent States is normally limited to schemes which are constructed under an Independence Agreement or where technical assistance is requested by such a State.

The population of the national states is approximately 33% of the total population of South Africa and first-world standards of services cannot be provided for everybody with the present annual budget of R64,3 million. A large variety of schemes varying between highly sophisticated and very basic have as a result proliferated over the past few decades.

The Department depends on the technical input of a large panel of Consulting Engineers from the private sector for most of its projects. Contrary to popular belief, great minds do not think alike and the result has been a bewildering variety of purification (and other) projects.

To curb this tendency a set of Guidelines was formulated and is issued to prospective Consultants on assignment, indicating Departmental preferences based on experience of suitability insofar as maintenance, operation and performance are concerned. Although the document is generally well received concern has been expressed that it tends to limit innovative thinking, which is an unfounded fear as it is specifically stated that the Consulting Engineer is not relieved of any of his responsibilities nor is the scope of his professional freedom limited.

In this paper it is attempted to describe, in technical terms, some of the Department's water and sewerage schemes, to motivate preferences, and to give an overview of the present state of services in the states.

B GENERAL TECHNICAL INFORMATION AND DEPARTMENTAL PREFERENCES FOR SANITATION

B.1 BASIC SCHEMES

The most common type of basic sanitation is some form of pit-latrine. This can have venting systems, water-"locks" or any of a large number of modifications such as stirred anaerobic basins, etc. These systems are normally constructed departmentally.

Pit-latrines offer many advantages and where ground conditions and public acceptance are favourable this system is preferred. Where the former is unfavourable bucket systems are provided.

In the case of a fully-developed urban situation with small residential stands the provision of water-borne systems may be unavoidable and here the Department favours, through experience, certain systems.

B.2 OXIDATION PONDS

Oxidation ponds are used exclusively where health and effluent discharge standards can be met and have been found to operate satisfactorily without any maintenance or skilled operator-attention. The ponds must be designed to the IWPC's "A guide to the design of sewage purification works" and also allow for future upgrading. This is achieved by adding biological filters in parallel, by adding septic tanks in front of the anaerobic ponds and also by aeration using floating aerators. If, due to improvement of the works, the ponds are to be eliminated they should be incorporated into the new design as maturation ponds or waste sludge lagoons.

If oxidation ponds are proposed as the sewage purification unit irrigation of effluent could be a prerequisite for obtaining permits and the relevant irrigation system thus forms part of the design.

B.3 BIOLOGICAL FILTERS (CONVENTIONAL WORKS)

A strong preference is expressed for biological filter type plant in the Departmental Guidelines due to practical experience of reliability in spite of bad maintenance and operation.

A few factors tend to weigh against this preference namely:

(a) Construction costs are high.

(b) Effluent standards (nitrogen and phosphate removal) tend to favour activated sludge.

As far as cost is concerned, it has been found that by manipulating interest rates and related factors the total cost of conventional works may well be lower than that of an activated sludge works (electricity included) and yet with a limited capital budget may not necessarily be the optimum solution. As far as nutrient removal is concerned, the limitations of conventional works are well documented.

The favoured position of conventional works is thus somewhat in jeopardy but where a medium or small size works is required in an area not likely to be classified as "sensitive" in terms of the Water Act and where the electricity supply is suspect, biological filters remain a departmental preference.

B.4 ACTIVATED SLUDGE WORKS

Activated sludge works tend to be favoured due to their relatively low capital cost and high effluent standards. Although the Department has had many different types of activated sludge plants constructed during the past few decades, lack of operator-skill and mechanical maintenance has been problematical and resulted in a negative attitude to the system.

The incorrect selection of the process for particular applications has compounded the issue.

During the past few years the tendency has been to opt for activated sludge plants where these are fairly large and near industrial centres. The problem of lack of skilled operators has in some cases been solved by retaining the Consulting Engineer for the operation and maintenance of the plant.

The time to blindly propose a conventional works, just because the "Department prefers it" is past. The Consulting Engineer has a responsibility to fully consider more than one type of works before submitting a well motivated proposal. The cost difference can be illustrated in broad terms by comparing the conventional 4 Mℓ/d plant at Ulundi costing R3,5 x 10^6 and the 5 Mℓ/d actived sludge plant at Ngwelezana costing R1,3 x 10^6. A large premium is attached to the preference despite the fact that certain elements of the Ulundi plant have already been sized for the ultimate 12 Mℓ/d throughput.

C GENERAL TECHNICAL INFORMATION AND DEPARTMENTAL PREFERENCES FOR WATER SUPPLY

C.1 BASIC SCHEMES

Many of the Department's water schemes can unfortunately be defined as basic. Schemes could consist of a pumping station extracting raw water from a river and filling reservoirs, a normal borehole with a pump (electrically, hand, wind or diesel driven) or a dam to ensure that water is available for the surrounding rural population.

Where possible, an attempt is made to ensure that the water is safe by practising chlorination of some sort. This may be gas chlorination into a pumping main or even pill chlorination at the stand pipe supplying the water.

As the supply of adequate and safe drinking water is undeniably the highest health priority, it is quite clear where the Department's main concern is.

C.2 INTERMEDIATE SCHEMES

A few examples can be quoted where schemes other than full purification works have given an acceptable and cheap solution.

(a) Well points

A well point system, working very successfully, was installed in the sandy bed of the Buffels River not far from Nqutu. This system eliminates the need for purification and only chlorination is practised. It is acknowledged that there are only a few sites suitable for this type of scheme, but it illustrates the need for original thinking.

(b) Slow sand filters

Slow sand filters were once the most commonly used method of water purification in the world. The high construction cost, high labour cost and area required for the filters have contributed to a decline in popularity.

In the age of "appropriate technology" and "Third World technology" there is an increasing awareness of the potential of this type of treatment system especially so where space and labour requirements do not predominate in the national states and electrical power is unavailable. Construction costs can be greatly reduced by using plastic-lined earth "lagoons" filled with sand from local sources. As the sand for slow sand filters has a fairly strict grading requirement, sieve grading as well as the periodic hand cleaning of filters increases labour use.

The Department has a few successful small slow sand filtration works in operation. A so-called "standard works" has been developed in conjunction with the CSIR (NIWR) where a small reservoir, acting as sedimentation tank, is built inside a larger reservoir. The space between the two reservoirs is filled with sand to form a slow sand filter and water simply overflows from the inner reservoir to the filter. Pre-treatment with coagulants and post-chlorination can be incorporated. Quite a few of these plants erected departmentally operate successfully in KwaZulu.

The high turbidity of many of the surface waters exceeds acceptable limits for sand filters and this is overcome by the use of alum as a coagulant and flocculation/sedimentation tanks before the filters. The filters have been simplified by using Bidim as a separation medium below the sand and as an insurance chlorination is applied after filtration.

C.3 FULL CONVENTIONAL WATER PURIFICATION SCHEMES

Most of the Department's larger water purification plants are rapid sand filtration units preceded by chemical treatment and sedimentation. There are not many alternatives to this system and the basic preference expressed in the guidelines is for limited mechanical components. Desludging of sedimentation tanks can preferably be done by emptying the tanks and hand-cleaning rather than by a scraper mechanism. If possible flocculation must be done in channels and not by mechanical methods.

The prescribed sedimentation and filtration rates are low to allow for lower than optimal operation with particular reference to chemical dosing rates and the backwashing of filters. The new water treatment plant at Ulundi is a good example of sophisticated control equipment being kept to a minimum.

In conclusion it can be stated that the Department's water treatment plants, unlike the sewage treatment plants, tend to have fewer mechanical and operational problems and that units designed broadly to the preferences expressed in the guidelines with limited mechanical equipment perform satisfactorily.

D THE STATE OF SANITATION AND WATER SUPPLY IN THE VARIOUS NATIONAL STATES

The state of the subject services in the various national states is evaluated according to the following categories:

(a) No services : People depend on natural streams, dams or springs for their water supply. These are not protected against pollution and no post-treatment exists. Sanitation is uncontrolled or consists of pit-latrines provided by the users.

(b) Partial services : People have a source of safe (chlorinated) water and at least pit-latrines. The water could be available at stand pipes not further than 150 m away or from centrally situated reservoirs.

(c) Full services : Full services are defined as an individual water connection to each stand providing fairly unlimited quantities of safe and aesthetically good water and sanitation in the form of full water-borne sewerage or similar reasonably sophisticated system.

Cognisance must be taken of the fact that the collection of data of this nature is subjective and the figures stated serve only to illustrate present trends.

D.1 GAZANKULU

Gazankulu has an area of ± 12 000 km^2.

The total population is 506 000, 4% of which reside in towns and 96% in rural communities or smaller towns.

Three per cent (3%) enjoy full services and 30% have partial services. The 1983/84 capital budget for schemes is R17 million.

D.2 KANGWANE

Kangwane has an area of 3 800 km^2.

The total population is 350 000, of which 15% reside in towns and 85% in rural communities or smaller towns.

Nine per cent (9%) enjoy full services and 41% have partial services. The 1983/84 capital budget for schemes is R5,6 million.

D.3 KWANDEBELE

KwaNdebele has an area of 1 030 km^2. The total population is 275 000, 7,0% of which reside in towns and 93% in rural communities or smaller towns. Nine per cent (9,0%) enjoy full services and 63% have partial services. The 1983/84 capital budget for schemes is R5,9 million.

D.4 KWAZULU

KwaZulu has an area of 30 000 km^2 and covers most of the province of Natal.

The total population of KwaZulu is 4 million 17% of which reside in an urban situation and the rest in rural communities or smaller towns. Twenty per cent (20%) enjoy full services, 30% have partial services and the rest have no formal water supply or form of sanitation. The capital budget for the provision of new or improved water schemes and sanitation is R13 million for 1983/84.

D.5 LEBOWA

Lebowa has an area of 22 476 km^2.

The total population is 2,47 million, 10% of which reside in towns and 90% in rural communities or smaller towns.

Nine per cent (9%) enjoy full services and 50% have partial services. The 1983/84 capital budget for schemes is R17,3 million.

D.6 QWA-QWA

Qwa-Qwa has an area of 500 km^2. The total population is 300 000 of which 12% reside in towns and 88% in rural communities or smaller towns. Twelve per cent (12%) enjoy full services and 88% have partial services. The 1983/84 capital budget for schemes is R5,7 million.

D.7 GENERAL

Various inhibiting factors influence the provision of services of which a lack of sufficient assured funds is the most critical.

In some instances natural resources are limited. KwaNdebele has only one main river for its water supply and underground sources have a high fluoride content. Of sixty boreholes sunk in Kangwane recently only 20% were successful and use is thus made of sand well points.

People normally settle on ground of low agricultural potential, which increases the cost of services due to hard or rocky ground and greater pumping heights and distances.

The rapid influx of people in some areas complicates the provision of services. A town in KwaNdebele with 10 000 sites which will be two years old in January already has a population of 50 000 and is 40 kilometres from the Elands River.

High costs are incurred in transporting water in many areas as an interim measure and the lack of qualified staff negates the effectiveness of large schemes.

It has been estimated that some 133 000 sites in towns are required of which the provision of water will cost R344 million and sewage R206 million.

In rural areas some 253 000 sites must be developed and the provision of rudimentary services will cost some R250 million.

Estimates have in the past however always been found to be conservative.

E CONCLUSION

Despite achievements much remains to be done. The figures quoted for capital budgets certainly indicate that funds are limited and that original and appropriate thinking is required in the design of schemes. The decision makers in the national states must also temper their demands and not insist on grandious schemes serving a limited number of privileged people but rather aim to supply as many people as possible with basic sanitation and safe drinking water in adequate quantities.

CURRENT STATUS OF WATER SUPPLY IN VENDA

by

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SYNOPSIS

In the Republic of Venda considerable progress has been made towards providing the entire population with clean water. The professed goal of the water decade - to secure safe drinking water for all by 1990 - can easily be achieved in this rapidly developing country. Running purified water is being delivered to the houses of an ever growing percentage of the population.

Water supply schemes utilizing underground as well as surface water resources are being developed in Venda. These vary in size from single boreholes equipped with hand pumps to regional water projects. The largest project, the Vondo Regional Water Scheme, is designed to supply purified water to the central part of the country in which approximately 40% of the population is concentrated.

Introduction

More than 95% of the Venda population live in rural villages. Most of these villages are well planned residential units for the farming com= munities of the various agricultural areas. Some villages close to each other are often grouped together in large units and are referred to as "agricultural settlements". Less than 5% of the population live in pro= claimed rural and urban townships. In Thohoyandou which includes Sibasa, Makwarela and Shayandima approximately 2 350 families live in houses on properly serviced stands. In the rural towns of Vuwani and Makhado a total of approximately 140 houses have so far been erected on serviced stands.

Rural village stands are not individually provided with public services such as water, sanitation, electricity or roads and stormwater drainage, but all villages have access to either natural surface water or instal= led water outlets or standpipes.

Rainfall and Water Resources

The mean annual precipitation (MAP) varies in Venda from below 400 mm on the northern plains to as much as 2 000 mm high up in the mountains. The MAP in the Klein Letaba and Levubu catchments increases slightly from 800 mm in the south to 1 000 mm on the southern foot hills of the Soutpansberg. In the mountainous central part of Venda the rainfall generally increases with the height above sea level to a maximum of 2 000 mm. On the western slopes of the mountain and further down the Nzhelele valley the rainfall drops sharply from 1 600 mm to 500 mm over a distance of approximately 15 km.

The major rivers in Venda are the Levubu (main tributaries Dzindi and Mutshindudi) the Mutale (tributaries Tshirovha and Mbodi) and the Nzhelele (tributaries Mutshedzi and Mufongodi). Other important rivers are the Ngwedi which is a tributary of the Mutshindudi and the Nwanedzi river which crosses the northern boundary of Venda shortly after its confluence with the Luphephe river. (See Fig. 1)

The Mutale, Nzhelele and Mutshindudi rivers have their sources within a few kilometres of each other in the high rainfall Thathe Vondo region of the Soutpansberg mountains where 5% of the area of Venda contributes an estimated 33% of the total run-off of approximately 450 million kl/a.

The mean annual run-off (MAR) of the Mutale is 97 million kl from a 165 km^2 catchment area. The catchment area of the Mutshindudi at the Vondo Dam is 51 km^2 and the MAR 29 million kl.

Although many Venda communities depended on groundwater resources for many years, no extensive survey has yet been made to determine the potential yield. Some boreholes yielding 45 kl/h and more are being ex= ploited in the southern and central parts of Venda. Unfortunately groundwater of the dry regions of Venda often has a very high mineral content and is also extremely corrosive.

Responsibilities

At present two Government Departments are responsible for the supplying of water in Venda. The Department of Agriculture and Forestry undertakes the provision and maintenance of all basic services to rural villages. The Department of Transport and Works develops, operates and maintains regional water schemes and water supply systems to district service centres and the national service centre of Thohoyandou.

Both the Department of Transport and Works and the Department of Agri= culture and Forestry appoint consulting engineers to assist them in feasibility studies, planning and detailed design of water supply schemes. Consultants also prepare contract documents and undertake the supervision or project management of construction contracts. Both De= partments have their own departmental construction and maintenance teams who undertake limited construction works. For most contracts however tenders are invited from the private sector.

It is the policy of the Government to promote the establishment and support the effective functioning of a local authority for Thohoyandou which amongst other duties will also be responsible for the upgrading and maintenance of services. Likewise district authorities will under= take the same responsibilities for services in district centres. Local authorities of rural settlements are encouraged to participate in the installation and maintenance of basic services. The Government will assist local urban and rural authorities and guide them to attain the highest possible degree of self-reliance.

Design Standards for Water Supply Schemes in Venda

The capacity of a scheme is determined by the daily demand of all the consumers who are expected to be dependent on that scheme by the end of the design period. To function satisfactorily the capacities of the different elements of a scheme are not necessarily equal as fluctuations in the required rate of flow are much greater at the consumer outlets than at the point of intake.

No prescribed standards have yet been laid down for water supply schemes. The following are some of the guidelines which are normally followed in designing such schemes.

Average daily demand (ADD):	
Rural villages with standpipes	300 l /household
Urban serviced stands	1 200 l/stand
Mixed industries	25 kl/ha
Schools and offices	50 l/person
Boarding houses	200 l/person
Hospitals	450 l/bed
Losses in the system	10%
Reservoir capacities:	
Gravity fed	1,5 ADD
When pumped	3,0 ADD
Purification Works	1,75 ADD
Flow rates in Pipelines:	
Raw water pipelines	1,75 ADD
Main pipelines and reservoir feeders	1,5 ADD
Reticulation systems	4,5 ADD

Spacing of standpipes in villages:

Maximum distance between outlets and individual houses	200 m
Maximum number of households per outlet	25

For the development of sources no standard procedure can be laid down. For each individual scheme the Government required a detailed investi= gation by specialized consultants who have to study all aspects of hydrology, foundation conditions and construction materials and report their findings before a decision can be made to continue with further planning of the scheme.

Likewise general design standards can not be prescribed for water treatment plants, but the quality requirements of the purified water can be specified. The South African Bureau of Standards has a specification for the quality requirements of drinking water which compares favourably with the World Health Organisation standards. In Venda all major puri= fication plants are designed to yield what is generally referred to as SABS Class A water.

Types of Water Supply Schemes

Since time immemorial the calabash and clay pot have been used to trans= port water in Venda. Today the container may be modernised and water is brought close to man in a variety of ways but in many instances the woman carrying water home on her head is still the final link between the source and the consumer.

The smallest water supply schemes operating in Venda today are boreholes equipped with handpumps. There are at present hundreds of these instal= lations in the country and many families are totally dependent on such boreholes for their daily water supply.

More sophisticated borehole schemes consist of one or more boreholes equipped with diesel or electric pumps which deliver water directly into reservoirs from where it is distributed to standpipes or other outlets in rural villages. The oldest of these schemes are those at Masakona and Vyeboomsdrift. Other important borehole schemes are to be found at

Khubvi and Tshituni. At Khakhu a scheme has recently been developed where a single borehole (capacity 50 kl/h) supplies the average daily demand of 180 kl.

The wellpoint system is another variation of groundwater exploitation. A number of wellpoints are installed in sandy deposits and connected to a single pump. Examples of these systems are those in operation at Mashamba, Mashau and Nthabalala.

Perhaps the easiest way to develop a water scheme in the mountainous water-rich part of the country is simply to divert water from a foun= tain or stream into a gravity pipeline which can either feed outlets directly or discharge into a reservoir. Many rural villages and schools are provided with water in this way. Water obtained from springs or streams high up in the mountain usually is of a comparatively high quality, but in some cases chlorination has to be applied in the reser= voir feeder mains.

Water from the larger rivers is often badly polluted especially during low flow conditions. A number of pumping schemes along such rivers do exist. Water is merely disinfected which in itself is not ideal. Because of the high unit cost of small water treatment plants this type of scheme for individual communities is not desirable.

It is sometimes advisable to combine different water sources in a single scheme. The Tshifhire-Murunwa scheme which is at present being consider= ed will draw water from two streams and a number of boreholes for a present population of 3 500.

Under certain circumstances even regional water schemes which are indi= vidually discussed below can be combined with or supplemented by local schemes. In Tshakuma the supply from the Vondo Scheme will be augmented by existing boreholes. Where regional water projects are developed they usually replace local schemes which have become inadequate due to popu= lation increase. In most cases it is impractical to incorporate these small schemes in the new system because of maintenance and operating costs but in future some may be reconsidered when growing demands jus= tify their reinstatement.

Phiphidi Water Scheme

The Phiphidi scheme which was constructed in 1963/64 was the first of its kind in Venda. The source is a 15 m high concrete dam (capacity 300 000 kl) in the Mutshindudi river 10 km to the west of Thohoyandou. The scheme initially consisted of a 560 kVA hydro electric power plant, which is still the only one in Venda, a 1 750 kl/d purification plant, a pumping station, two reservoirs with a combined capacity of 2 200 kl and 11 km of pipelines. Water was supplied to all villages between Phiphidi and Sibasa, the towns of Sibasa, Makwarela and Shayandima and Tshilid=zini hospital.

By 1973 the total water demands exceeded the capacity of the scheme and the supply had to be augmented by a temporary system of well-points in the sandbanks along Phiphidi dam.

During the period 1973 to 1982 the Phiphidi Scheme was systematically replaced by the Vondo Regional Water Scheme. In future the Phiphidi scheme will consist only of the dam and the hydro-electric power plant.

Vondo Regional Water Scheme

In 1971 an investigation was conducted to find practical ways of impro=ving the domestic water supply to Sibasa and surroundings and to provide irrigation water for a proposed tea project at Thathe Vondo. The result of the study was a blue print for the Vondo Regional Water Scheme which was approved and initiated in 1972. (See Fig. 2)

When the founding of the new Venda capital Thohoyandou was announced in 1974 the original plan of the Vondo Project had to be adjusted to pro=vide for the future water demand of the city. Other modifications and extensions to the plan have been investigated and applied where practi=cal and economically justified. Eventually the region will be bordered by the southern watershed of the Mutale river in the north and the Klein Letaba river in the south and will extend from Tshakuma on the western border of Venda to Tshivhilwi 25 km north east of Thohoyandou - an area of 750 km^2 which is at present inhabited by approximately 160 000 people or 40% of the Venda population. Construction of the Vondo Scheme began in 1973. The initial phases were in fact improvements of the Phiphidi Scheme. Until the completion of Vondo Dam in 1982 the Phiphidi dam was the only source of water for the Vondo Scheme. Two reservoirs and seve= ral pipe lines of the original scheme are permanently incorporated into the Vondo Scheme.

The main feature of the scheme is the Vondo dam in the Mutshindudi river 14 km west of Thohoyandou. The 30 m high earth fill dam has a "morning glory" type spillway with a discharge capacity of 320 kl/s. The dam was so designed that the storage level can later be raised by 18 m whereby the storage capacity will be increased from the present 5 million kl to 30 million kl. The potential yield of the first phase is 11,5 million kl/a and that of the second 20,5 million kl/a. The Vondo dam was con= structed during the period from 1979 to 1982 at a total cost of R5,9 m.

A 4,5 km long 500 dia pipe line gravitates raw water from the dam to the water purification plant at Phiphidi. The first phase of the Phiphidi plant was constructed from 1975 to 1977 and had a capacity of 10 000 kl/day. During 1982/83 the plant was enlarged to a capacity of 40 000 kl/day which is approximately twice the present sustained summer peak demand of the whole region.

The catchment area of Vondo dam is virtually uninhabited and the runoff is normally of good quality. At the Phiphidi plant the purification process consists only of chemical dosing and rapid sand filtering.

From the purification works clean water is fed into three main distri= bution systems - the Thohoyandou system, the Donald Fraser system and the Vuwani system.

The Thohoyandou system is subdivided into three sub-systems. For the first water is pumped 50 m high over a distance of 6,5 km to a 13 000 kl reservoir from where it is distributed to Sibasa, Makwarela and other high-lying residential areas of Thohoyandou. The second sub-system gra= vitates water from the purification works to a 9 000 kl reservoir from where it serves the central part of the city. Eventually 4 such reser= voirs will be built to meet the increasing demands of this part of the capital. The third subsystem delivers water from Phiphidi via a 7 000 kl reservoir to Shayandima, Tshilidzini hospital and the industrial area of the city. Eventually the two lower systems will be linked to supplement each other automatically when necessary. About 8 rural villages around Thohoyandou also receive water from the Thohoyandou system.

The Donald Fraser system will eventually supply water to seventeen rural villages, the proposed town of Tshitereke and two hospitals, Donald Fraser and William Eadie. From Phiphidi water is pumped 60 m high to a 1 800 kl reservoir (a larger one will be required soon) from where a 28 km long gravity pipe line delivers water to the reservoirs of the various consumers along the way. Several pumping stations were required to supply high-lying villages.

The Vuwani system extends southwards over a distance of 30 km. Water is gravitated all the way but has to be pumped to Tshakuma and part of Lwamondo. About 20 settlements as well as the towns of Vuwani and Tshi= fulanani will be served by the system. The population of some of these settlements such as Lwamondo and Tshakuma already exceeds 10 000. Eleven reservoirs with storage capacities ranging from 300 kl to 1 200 kl have been constructed and at least another 10 will be required.

Both the Donald Fraser and Vuwani systems will be about 75% completed by 1984 after termination of all current contracts. The Thohoyandou system is extended from time to time as the need arises and in accordance with the approved plan for the city water supply system.

The total cost of the Vondo Regional Water Scheme until completion of the current contracts will be approximately R 19 m.

Nzhelele Water Scheme

The Nzhelele valley is inhabited by a rural population of approximately 20 000 which is concentrated in various agricultural settlements. The Siloam hospital is situated halfway down the valley and further to the west the town of Makhado (present population 8 000) is being developed.

Construction of the Nzhelele Scheme started in the mid seventies when water was diverted from the upper reaches of the river and piped to Siloam and the surrounding villages. During the past 8 years the scheme has been extended as far west as Makhado, 32 km from the diversion. The main pipe line gravitates water through three pressure zones down the valley. Water for Makhado then has to be pumped 130 m high over a dis= tance of 0,9 km. Distribution of water from the main pipe line to vil= lages either through gravitation or pumping is still under way.

Due to the unreliability of flow in the Nzhelele River a storage dam is required for proper functioning of the scheme. This dam is being planned in the Nzhelele River on a site near the diversion weir. At present only the water supply of Siloam is being purified but in the near future a purification plant for the treatment of the total domestic water supply will be constructed.

Mutale River Project

The feasibility of a development project in the Mutale valley was first studied in 1970. A second investigation was conducted in 1979. The main object of this proposed scheme was the irrigation of more than 10 000 ha in the Tshiombo valley and on the Malonga Plains. At least 2 dams and an extensive canal system were foreseen. The Mutale River Project would then also provide for a more reliable supply of potable water to the agricul= tural settlements in the Mutale valley and to the proposed town at Tengwe.

Future Planning

In a report titled "Human Settlement Policy and Strategy for Venda" the Bureau for Economic Research, Co-operation and Development recommended that a national settlement plan should be drawn up in terms of the Go= vernment's national development policy. In view of the fact that water resources will play an important role in such an agriculture-orientated country, planning of the water resources of Venda will have to receive special attention in the drafting of a national development plan.

The financing of water supply schemes will always be problematical be= cause they can never be highly economical from an investor's point of view. Financing institutions like the new Development Bank for Southern Africa will nevertheless always be entitled to demand that the economi= cal aspects of alternative schemes be carefully analysed. It is also generally acknowledged that water cannot be regarded as a free commo= dity for ever and that the cost of water supply schemes must be re= covered as far as possible. When a reasonable price has to be paid for water it will reduce the possibility of misuse and contribute to the overall economy of the scheme.

In the long run the availability of an adequate supply of clean water for every citizen of Venda will undoubtedly enhance the standard of living and health conditions in this country. To any nation these are invaluable assets.

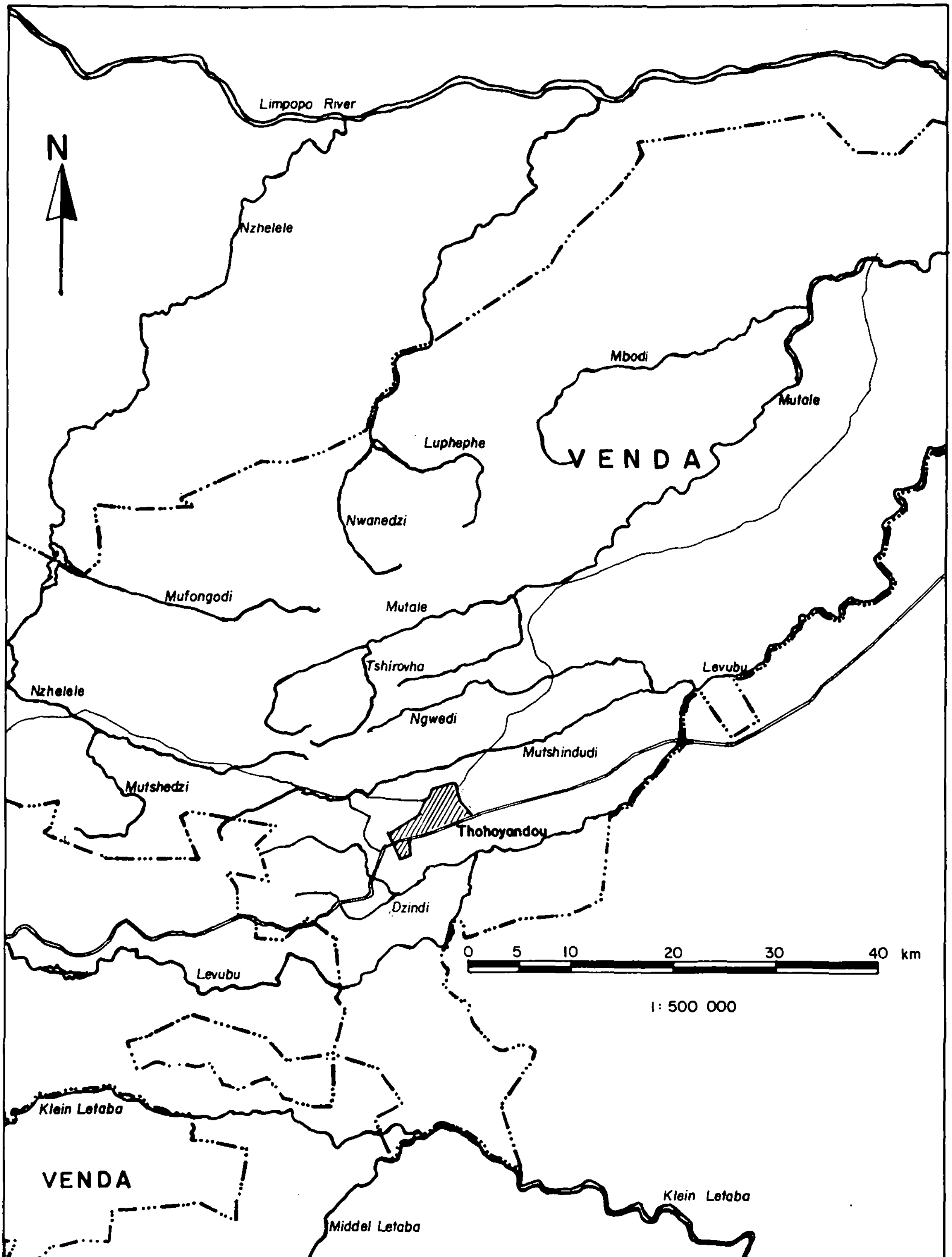

FIGURE 1 – Venda River Systems

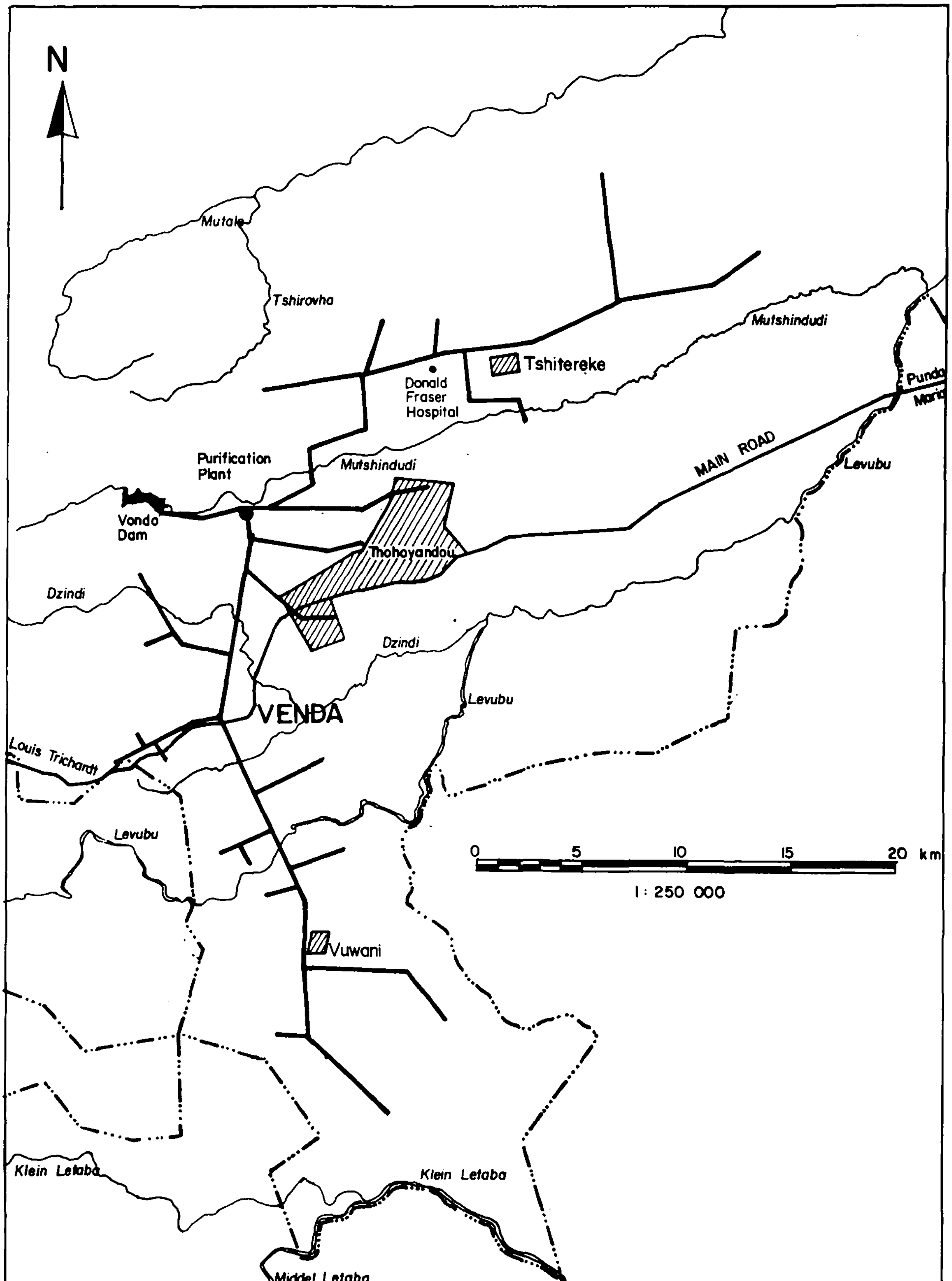

FIGURE 2 - Vondo Regional Water Scheme

PERFORMANCE OF STABILIZATION PONDS

by

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SYNOPSIS

Operational data from 14 Stabilization pond systems for the treatment of wastewater in various regions of South Africa, collected over a period of nine years were studied to establish the performance of these systems.

Temperature variation seemed to have only a slight effect on effluent quality. In both summer and winter, the removal of chemical oxygen demand (COD) and Ammonia Nitrogen was much better than formerly assumed in this country. Some of the Ammonia N seems to be removed by simultaneous nitrification and denitrification in the ponds. After a maturation period of a year or more phosphate levels in the final effluent may decrease to below 1 mg/ℓ P.

OPSOMMING

Nege jaar se bedryfsdata van 14 stabilisasiedamstelsels vir die behandeling van afvalwater in verskeie dele van Suid-Afrika is bestudeer om die werkverrigting van hierdie aanlêe te bepaal. Temperatuurverskille het uitvloeiselkwaliteit baie min beïnvloed. Vir beide somer- en wintertoe-

stande was die verwydering van chemiese suurstofbehoefte (CSB) en ammoniakstikstof baie beter as wat daar voorheen in Suid-Afrika veronderstel is. 'n Gedeelte van die ammoniak-N word waarskynlik deur gelyktydige nitrifikasie en denitrifikasie in die damme verwyder. Na 'n verouderingstydperk van 'n jaar of langer in die damme mag fosfaatkonsentrasies tot minder as 1 mg/ℓ daal.

INTRODUCTION

Stabilization pond systems came into general use in South Africa in the 1960's following development work in the USA, the impetus given by the SA Water Act No 54 of 1956 and further research work conducted by the National Institute for Water Research and others. Pond systems for the treatment of domestic waste water were constructed mainly for smaller communities that could not afford sophisticated sewage purification works. It is not surprising, therefore, that, because of low cost, this method of sewage treatment received wide application in the National States, for smaller local authorities, hospitals and other rural institutions. The NIWR's research work led to the publication of *A Guide to the Use of Pond Systems in South Africa* by Meiring *et al.* (1968). Since then, many more stabilization pond systems have been constructed, to a large extent according to the design criteria given in the *Guide*.

The contract between the NIWR and the Department of Co-operation and Development (C&D) to provide Water Supply and sanitation services to the National States led to the monitoring and collection over many years of data on the effluents produced by a number of the Pond systems in these areas. These data were collated and interpreted in an attempt to obtain further information on the performance in practice of stabilization pond systems, and were subsequently used in the publication of a revised *Guide* entitled *Pond Systems for the Purification and Disposal of Domestic Wastewater from Small Communities: Use, Design, Operation and Maintenance* (Drews, 1983).

LITERATURE

In the past two decades, much advanced work has been done on the facultative aerobic pond system especially with respect to design methods, and many different approaches to model construction were published. A list of such publications is given (Drews 1983). Other authors, notably Marais (1970) (a & b) have mentioned the following important facts about the behaviour of pond systems in South Africa:

- The sludge layer in the primary pond stores BOD in winter and releases it to the supernatant in the summer.

- The pond liquid is mixed under windy conditions and stratified under quiescent conditions, particularly in summer.

- Mixing and stratification determine the types and concentrations of algae present.

- Generally with stratification the algae are reduced in concentration, hence reducing the reoxygenation capacity of the pond.

- Reduced oxygenation capacity coupled with high sludge BOD feedback into the supernatant during summer can cause anaerobic pond conditions with odour development.

- Radiation does not appear to be a limiting factor for abundant algal growth in South Africa.

- For the same total volume a series of ponds is superior to a single pond in reducing pollution concentration.

- Series operation can achieve the same reduction of Faecal Coliforms as that obtained from a chlorinated conventional works effluent.

- Oxygen is only generated to the depth the radiation can penetrate.

- The Facultative ponds - usually the primary pond of a system - are by far the most common type of stabilization pond in the world, often also referred to as oxidation ponds.

- Experimental observation on full-scale ponds indicates that the effluent BOD_5 shows surprisingly little seasonal variation.

These findings emphasize the complex processes taking place in a pond or pond system to be kept in mind when these systems are monitored and evaluated.

SCOPE AND MODUS OPERANDI

Controlling the performance of pond systems in terms of the Department of C & D contract entails the collection of grab samples for chemical analyses, usually of all the effluent from the various ponds, but sometimes of effluent from the final pond only. However, no concurrent temperature measurements, flow-measurements or estimates or population equivalent load estimates on the systems were provided. Temperature effects were therefore classified into cold or warm seasons according to date of sampling, and the other factors were subsequently estimated, mainly from population figures.

The approximate hydraulic and organic loadings were established and from the estimated flows and the capacities of the ponds the theoretical retention times were calculated. Analytical results were available for a total of 14 systems treating domestic sewage. The effluent quality parameters loading rates and retention times obtained thus were used to study the behaviour over the years of these stabilization pond systems.

SAMPLING AND ANALYTICAL METHODS

The sampling of the effluents of pond systems was done at irregular times depending on expediency, sometimes only once or twice a year. Grab samples were probably permissible as a considerable amount of mixing and quality uniformity could be assumed for each pond, but grab samples of incoming raw sewage had no meaning. Samples were normally preserved with mercuric chloride, especially when collected long distances away from the laboratory.

The following methods of analysis were employed:

pH	-	by glass electrode pH meter.
COD	-	as described in APHA Standard Methods, 14th Edition
OA (4 h)	-	British Ministry of Housing and Local Government Method. H.M. Stationary office.

Ammonia N - The distillation method as described in APHA Standard Methods, 14th edition

Nitrate N - The Salicilate method, described by Müller and Widemann (1955)

Ortho-phosphate as P - Method of Murphy and Riley (1962) as improved by Harwood *et al* (1969).

EXTRAPOLATION OF THE DATA AND RESULTS

Of the 14 pond systems selected for evaluation, five were in KwaZulu, five in Lebowa and four in the Ciskei, Figures 1 to 6 show the layouts of some of the pond systems evaluated. The requirement of a large primary pond followed by smaller secondary ponds was largely implemented in the design, but the ratio of the sizes of the secondary ponds to the primary pond by no means concurred with the ratio of 1,25 suggested by Meiring *et al.* (1968). There was considerable size variation and the area of the secondary ponds was usually too small.

Nevertheless, the results were graphed and arranged in Tables to obtain a classification of the different systems. The final significant, extrapolated data on these 14 systems are given in Table 1.

Two of these pond systems were very much underloaded compared with the usual load criterian of 135 kg BOD/ha.d on the primary pond. Some seemed more or less normally loaded, while others were highly overloaded.

COD AND OA

The analyses of the final effluent samples were interesting in that the COD and OA (unfiltered) values, complied with the S.A. General Standard limits at times i.e. COD <75 mg/ℓ and OA (SABS) <10 mg/ℓ), notably for the systems with a lower loading. The frequency of compliance within certain ranges of COD and OA values (unfiltered) are shown in Table 2.

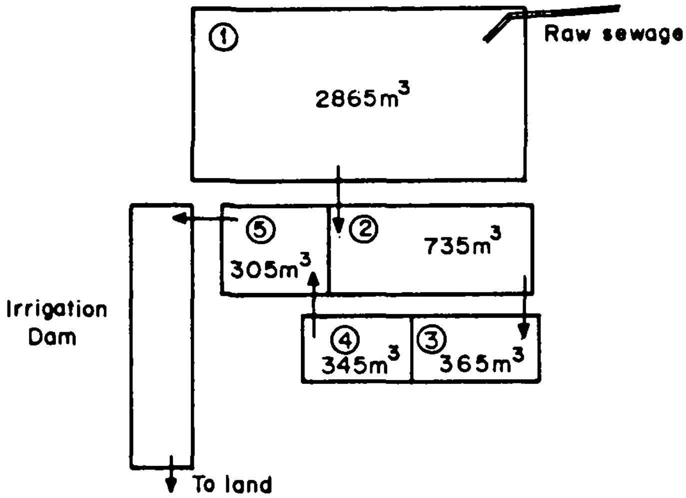

FIG. 1 FORT COX AGRICULTURAL COLLEGE PONDS

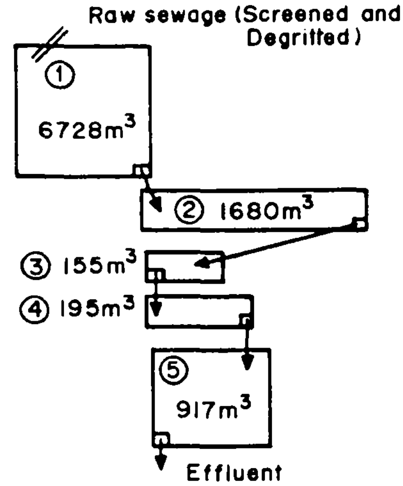

FIG. 2 NOMPUMELELO HOSPITAL PONDS

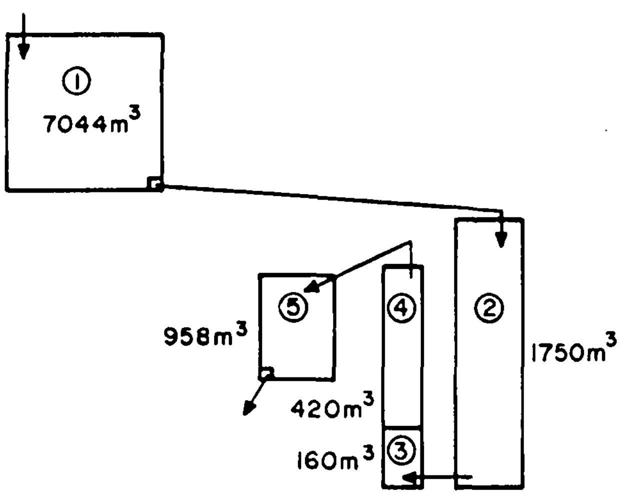

FIG. 3 EKUPHUMLENI OLD AGE HOME PONDS

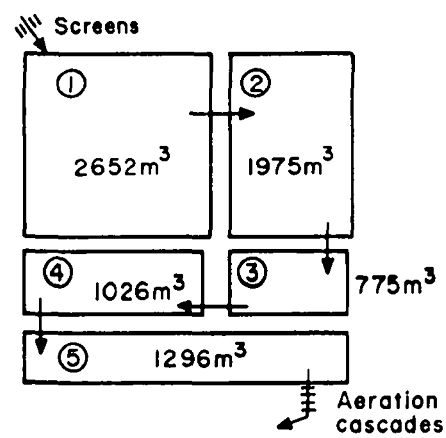

FIG. 4 H.C. BOSHOFF HOSPITAL PONDS

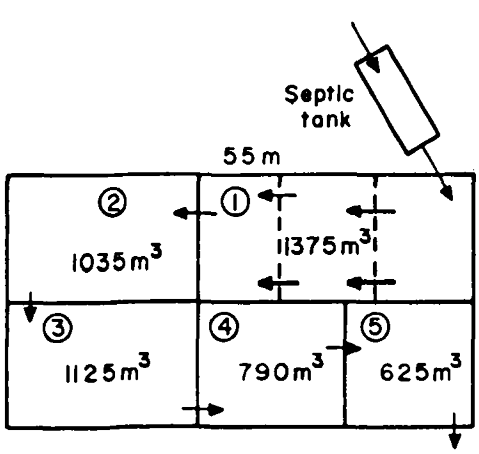

FIG.5 GEORGE MASEBE HOSPITAL PONDS

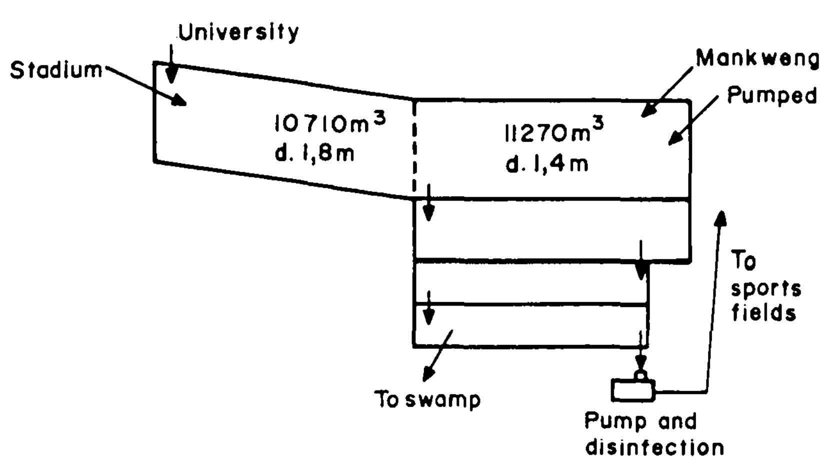

FIG. 6 TURFLOOP UNIVERSITY PONDS

TABLE 1

Average performance of pond systems as extrapolated from existing data (Limits of primary pond BOD loading : 162,5 kg/ha.d (Shaw *et al.*, 1962), 135 kg/ha.d (Meiring *et al.*, 1968)

NAME OF SYSTEM	Number of Ponds	Total System retention time (days)	Primary Pond Loading rate (kg/ha.d.)	Ratio: Area of Secondary to Primary Ponds	COD (mg/ℓ)	OA (4 hours) (mg/ℓ)	Ammonia N (mg/ℓ)	o-Phosphate as P (mg/ℓ)
Primary ponds underloaded at less than 50 kg/ha.d. - Results as below								
Nompumelelo Hospital	5	149	44	0,44	<110	<8	<5,5	2-8
Ekuhphumleni Hospital	5	152	49	0,47	38-56	3,0-6,0	0,5-1,8	down to ∿1,0
Primary ponds loaded at around 135 kg/ha.d. - Results below.								
Fort Cox Agric. College	5	68	131	0,82	40-70	3-6	0,5-3	3 down to <1,5
Magabeni	4	64	132	0,77	40-100	9-11	<1,0	-
Makuta	5	42	139	0,50	95-210	13-25	20-32	-
H.C. Boshoff Hospital	5	48	110	1,91	50-231	14	0,5-1,1	2 to 0,1
Primary ponds loaded at around 162,5 kg/ha.d. - Results as below.								
Ngwelezana Township	4	51	158	1,00	60-110	4-14	<1,1	down to <1,0
Ngwelezana - old ponds	4	68	178	1,53	40-90	6-14	down to <1,0	down to <1,5
George Masebe Hospital	5	44	168	2,6	145&200	12 and 17	<3	2 and 6
Primary ponds <u>overloaded</u> at more than 200 kg/ha.d - Results as below.								
St. Matthews Hospital	4	43	221	0,98	300-500	22-38	<7,5	8 down to 3
Turfloop University	4	34	228	0,71	60-250	6-20	0,4-16	down to 0,5-2,8
Ngwelezana Hospital	4	30	300	1,00	60-250	7-20	<2,0	down to <1,0
Mokopane Township	4	22	341	0,70	85-91	7	2-7,2	1,5-4,5
GaKgapane	9	26	-	0,68	82-260	8-20	1,5-31	0,5-8

Note: Values shown as ranges <u>or</u> as less than a certain figure were those achieved most of the time. There were occasional figures outside the range.

AMMONIA N

Similarly, Table 3 shows the frequencies with which Ammonia Nitrogen figures fall within selected value ranges for the pond system effluents. Those that exceeded the General Standard limit of 10 mg/ℓ were all systems with theoretically overloaded primary ponds i.e. >135 kg BOD/ha.d. Many systems, even some heavily loaded ones, gave Ammonia N concentrations below 1 mg/ℓ in 31 % of instances while 81 % complied with the Ammonia N limit of 10 mg/ℓ, in many instances even in winter.

TABLE 2

Frequency of compliance of final pond effluent COD and OA values (not filtered) with the value ranges as shown.

Pond System	COD mg/ℓ				OA (4 h) mg/ℓ			
	0-40	40-75	75-150	>150	0-5	5-10	10-20	>20
Nompumelelo Hospital	-	5	2	-	2	5	-	-
Ekuphumleni Hospital	3	4	-	-	5	2	-	-
Fort Cox Agric. College	-	9	-	-	8	1	-	-
Magabeni	1	3	1	-	-	4	1	-
Kwa Makuta	-	-	9	4	-	-	10	3
H.C. Boshoff Hospital	-	2	2	1	-	-	-	-
Ngwelezana Township	-	3	4	-	1	4	2	-
Ngwelezana-old ponds	1	3	3	-	-	5	2	-
George Masebe Hospital	-	-	5	3	-	1	5	1
St. Matthews Hospital	-	-	-	6	-	-	4	2
Turfloop University	-	-	2	7	-	5	6	-
Ngwelezana Hospital	-	1	4	3	1	2	4	2
Mokopane Township	-	1	3	1	-	1	2	-
Ga Kgapane	-	-	5	9	-	3	10	-
TOTALS	5	31	40	34	16	33	46	8

TABLE 3

Frequency of compliance of final pond effluent Ammonia N values with value ranges as shown.

Pond System	Ammonia N mg/ℓ			
	below 1,0	1,0-5,0	5,0-10,0	>10,0
Nompumelelo Hospital	-	4	3	-
Ekuphumleni Hospital	2	5	-	-
Fort Cox Agric. College	3	6	-	-
Magabeni	4	-	1	-
Kwa Makuta	2	-	2	8
H.C. Boshoff Hospital	3	2	-	-
Ngwelezana Township	5	2	-	-
Ngwelezana - old ponds	2	1	-	4
George Masebe Hospital	3	5	1	-
St. Matthews Hospital	0	1	5	-
Turfloop University	4	2	5	-
Ngwelezana Hospital	7	1	-	-
Mokopane Township	-	2	2	1
Ga Kgapane	-	3	3	8
TOTAL	35	34	22	21
% of Total Samples:	31,2	30,4	19,6	18,8

PHOSPHATES

The orthophosphate concentrations in the final effluent were revealing in that, in most cases, as the pond systems aged the o-phosphate P, which was initially at normal levels as for raw sewage, decreased, after filling of the ponds, to considerably lower effluent values within a year or more as shown in Figure 7. In five pond systems the final values were less than 1 mg/ℓ as P after a few years. In some pond systems, however, this trend of decreasing phosphates was not so obvious. The reason for such discrepancies from one system to another cannot be explained at this stage.

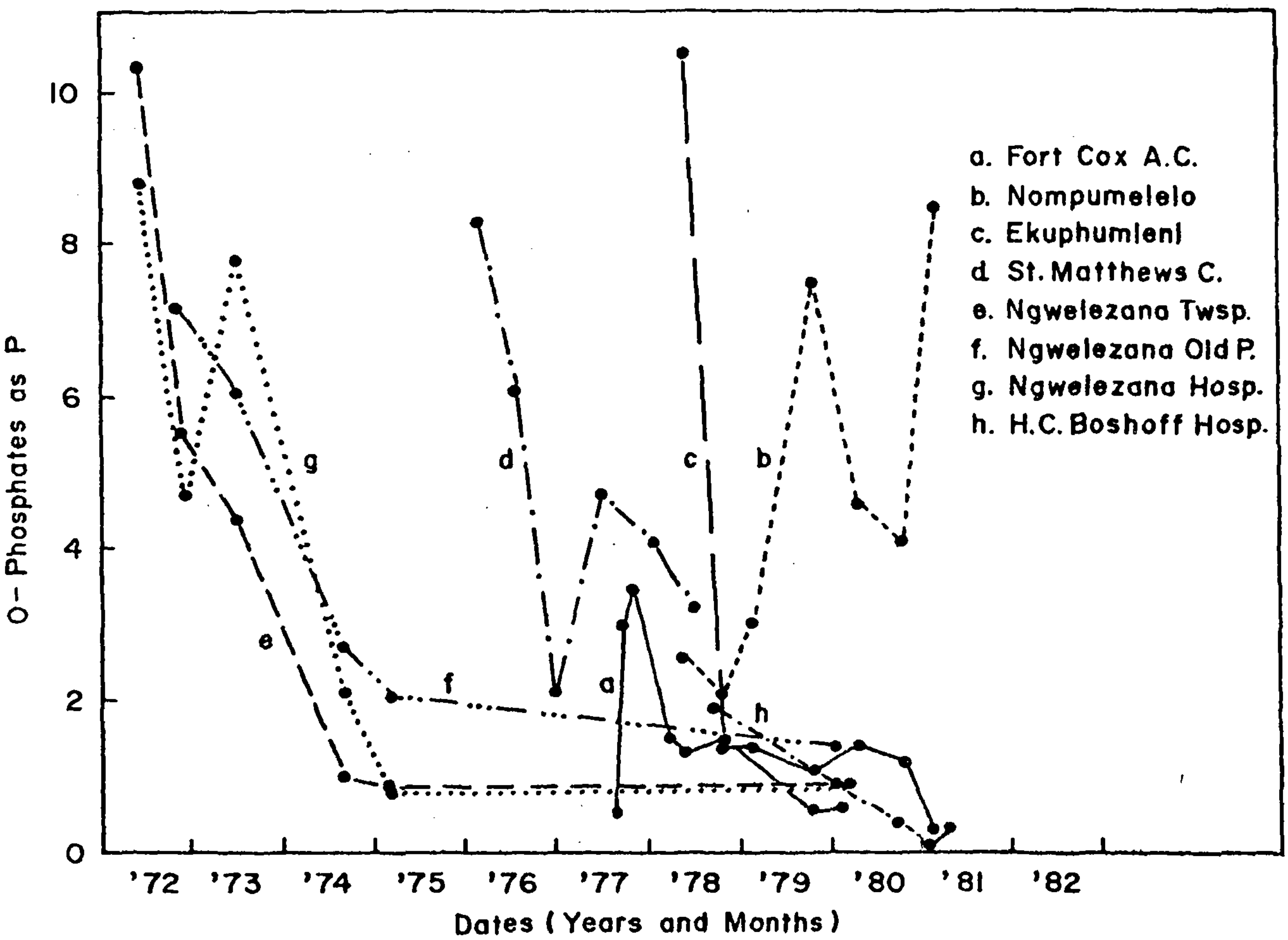

FIG. 7 O- Phosphates in final pond effluents

NITRIFICATION AND DENITRIFICATION

Although nitrates were determined for only a few systems there is a strong indication that nitrification and denitrification take place within the system as seen from Figure 8, where a nitrate increase is shown through the first few ponds and a decrease in the subsequent final ponds. This does seem odd though since nitrification and denitrification would be expected to take place in the top oxygenated layer and the bottom anaerobic layers of each pond respectively. However, the complex liquid interchanges caused by inflows and climatic variations make an explanation of the mechanism difficult.

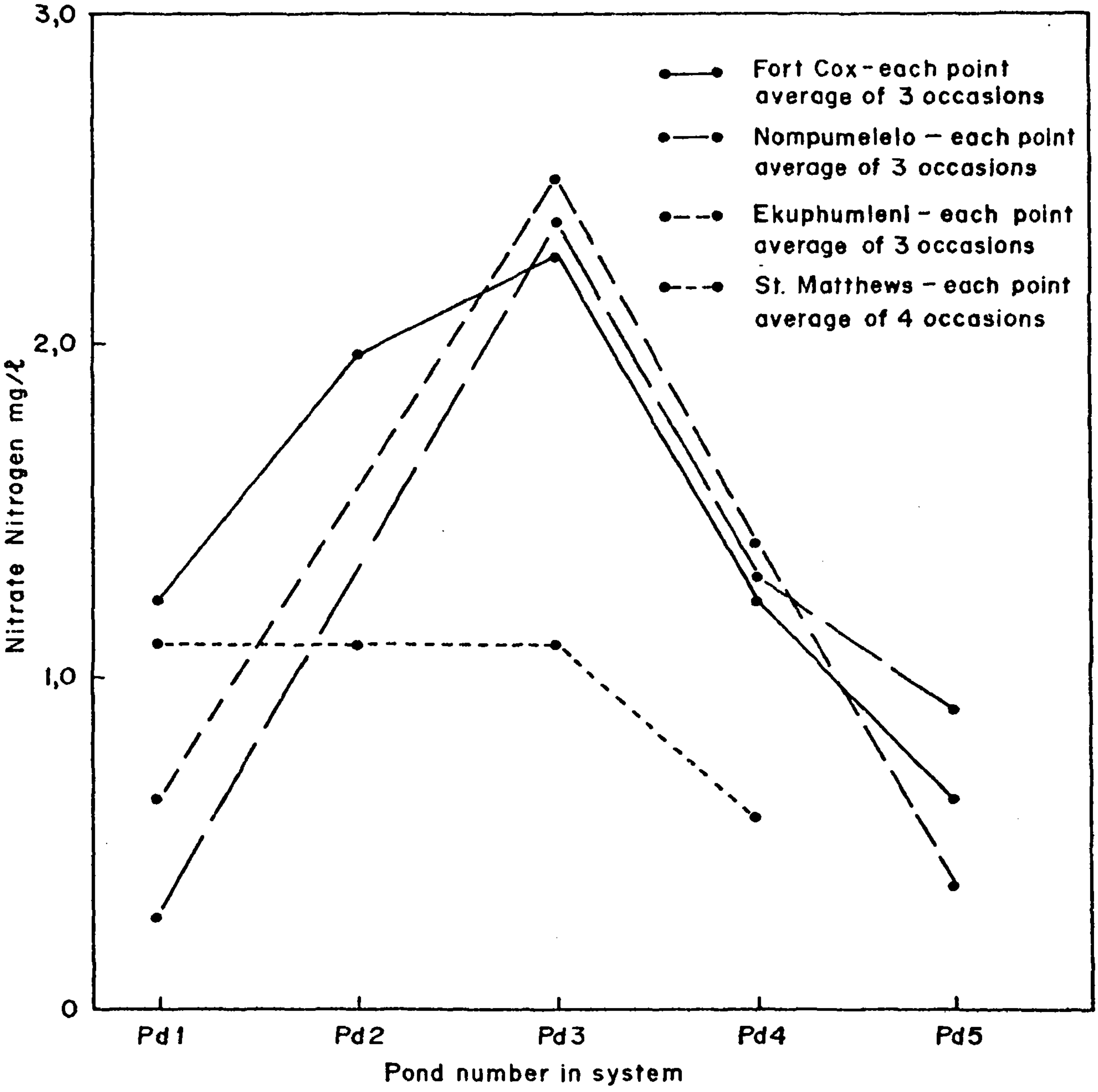

FIG. 8 Nitrification and Denitrification through pond system

DISCUSSION AND CONCLUSIONS

In conclusion, the results, of evaluation of the 14 pond systems as given in the previous section are summarized in the following conclusions :

- In only five of the 14 systems the COD and OA of the effluent complied with the General Standard limits most of the time. Failure of the other systems to comply was attributed to either overloading or the presence of algae in the effluent. Pond systems that had effluent COD values greater than 150 mg/ℓ or OA values greater than 20 mg/ℓ were all overloaded in the primary ponds i.e. at more than 135 kg BOD/ha.d., except apparently the H.C. Boshoff Hospital Ponds. It was therefore considered that the previous figure for expected effluent quality of 250 mg/ℓ COD (Meiring *et al.* 1968), which a correctly designed and loaded stabilization pond was expected to achieve under most South African conditions, could fairly safely be reduced to 150 mg/ℓ for unfiltered samples and to 120 mg/ℓ for filtered samples. Similarly the figure for OA (4 h) for unfiltered samples should remain at 20 mg/ℓ and for filtered samples it should be increased to 15 mg/ℓ .

- The Ammonia nitrogen removal rate through the systems was, in general, found to be vastly superior to what had been previously accepted. Often this was possibly due to the excessively long retention times, but even in some overloaded systems Ammonia reductions to below the General Standard limit occurred. In 12 of the 14 systems the Ammonia Nitrogen in the effluent was less than 10 mg/ℓ and for 8 of these, it was consistently below 3 mg/ℓ even in winter. For this reason it was thought expedient to reduce the expected Ammonia-N figure for stabilization pond effluent quality from 35 mg/ℓ (Meiring *et al.* 1968) to 10 mg/ℓ .

- Winter and summer temperatures did not seem to affect the performance of ponds very much with respect to COD, OA and Ammonia N removal. No correllation was evident that could be attributed to the seasonal temperature changes. This was definitely the case with 11 out of the 14 systems. Ponds often seemed to have clearer and better effluents in winter than in summer.

- Good o-Phosphate removal, in many instances to less than 1 mg/ℓ, was indicated by 7 out of 11 systems after an initial running in or adaptation period.

- Nitrification and denitrification apparently takes place simultaneously in pond systems, which was established in four of the systems, for which nitrates were measured in every pond.

- From these results it was rather difficult to establish whether the general criterian of 135 kg/ha.d. BOD load on the primary pond was still acceptable or whether it should be increased or decreased. From Table 1 Pond systems with primary pond BOD loading rates of 44, 49 and 131 kg/ha.d complied with the S.A. General Standard. Those with 132, 158 and 178 kg/ha.d. complied partially. Two systems with 110 and 139 kg/ha.d. loadings did not comply, although the loading rates were within or nearly within the limit. Yet other systems with a loading rate of 300 and 228 kg/ha.d. did comply partially in spite of the high loading.

  There is therefore no regular pattern for these loading rates in relation to the results produced. The same was true when effluent quality was compared with loading rates over the whole pond system.

  It was therefore felt that the design loading of 135 kg BOD/ha.d. <u>or</u> 2500 P.E./ha.d. should be considered valid until more definite information becomes available.

ACKNOWLEDGEMENTS

Thanks are due to Mr. J.S. Wium for permission to extract a large amount of information from his 'Services to the Department of Co-operation and Development' files, as well as to Mr. R.C. Monsear Wilson and Mr. A. Rheeder for supplying information on certain pond systems and to the Chief Director of the NIWR, Dr G.G. Cillié, for permission to present this paper.

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CURRENT STATUS OF SANITATION IN VENDA

by

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SYNOPSIS

Venda has a rural population. Approximately 95% of its estimated 400 000 people live in sparsely populated agricultural settlements, where individual households can provide their own sanitation.

The Department of Transport and Works is responsible for sanitation in urban areas and other points of concentration, e.g. hospitals. Adequate provision has been made for sanitation in these areas.

It is government policy not to allow over-population of the agricultural settlements. This will require greater urbanisation and associated centralised sanitation in future.

1. INTRODUCTION

Venda has an estimated present (1983) de facto population of 400 000 people. Over the years less than 5% of the population have become urbanised. The large majority of people still live in the more than 300 agricultural villages spread throughout Venda. Population densities in the villages are low with plot sizes ranging between ¼ and ½ hectares.

The size of agricultural villages varies considerably depending on the district and chieftaincy in which they are situated. In the sparsely populated Mutale district for instance, village populations vary from less than 100 inhabitants to a maximum of 1 500 people. In the Tshivhase chieftaincy in the more densely populated district of Sibasa on the other hand, there are villages with populations of more than 10 000 people. These large villages are not rare occurrences - there are in fact more than ten villages in this chieftaincy with more than 4 000 inhabitants.

In these villages the individual households provide their own sanitation, usually by way of pit latrines. Washwater is invariably drawn from one of the numerous streams of Venda. This rudimentary system has provided ade= quate sanitation for the people of Venda through the ages.

With the development of the country and an increase in the population it was however inevitable that points of concentration would occur. The first points of concentration were around the town of Sibasa where an urban population started to settle and at the three major hospitals of Venda. Providing adequate sanitation at these points became the responsi= bility of the Department of Transport and Works.

2. THE SEWERAGE SCHEMES OF VENDA

Waterborne sewerage systems with purification works were provided and are operated by the Department of Transport and Works for the capital complex of Thohoyandou, for Makhado town and for the three hospitals Thilidzini, Donald Fraser and Siloam.

2.1 Thohoyandou Sewerage Works

By far the biggest outfall system in Venda is the unit that serves the capital, Thohoyandou, with its three suburbs Makwarela, Sibasa and Sha= yandima. With a total length of 55 km of collector sewers and 18 km of sewer mains this system can serve approximately 60% of the area of Tho= hoyandou now being developed and its suburbs. The average dry weather flow through the system ranges from 1 200 to 1 500 kl/day.

Until recently purification of the sewage has been effected through a system of maturation ponds. These ponds were replaced by a conventional purification works complete with primary sedimentation, biological fil= ters, secondary sedimentation, a maturation river, digestors and dry beds. The new works was completed and commissioned in the beginning of 1983 and has a first stage rated capacity of 3 000 kl/day and an allowan= ce for 3 further extensions of 3 000 kl each. The design was based on an estimated flow of 100 litres of sewage/person/day and a B.O.D. (biochemical oxygen demand) of 45 g/person/day.

This system is functioning highly satisfactorily and is being monitored by the National Institute for Water Research of the CSIR.

At the request of the Department of Agriculture and Forestry the pipe layout at the purification works was changed to allow conveyance of the purified effluent to the old maturation ponds. The intention is to use it for irrigation or fish culture.

2.2 Tshilidzini Hospital Outfall Works

Tshilidzini hospital was founded in 1956 and has a total of 355 beds. This hospital serves the southern regions of Venda with a population of approximately 150 000 people.

The hospital's sewage is treated through a 4 channel activated sludge orbal system with a rated capacity of 150 kl/day. Polishing of the effluent is through a maturation river. Although this plant is running at at least 1½ times design capacity the effluent from the maturation river is still acceptable. After chlorination the effluent is used to irrigate the vegetable gardens of the hospital.

A major extention to this hospital is proposed in the near future. To cater for this higher demand, all the sewage will be gravitated via Shayandima to the Thohoyandou works.

2.3 Donald Fraser Hospital Outfall Works

The Donald Fraser Hospital with its 412 beds serves a community of approximately 170 000 people in the central and north eastern parts of Venda.

The effluent from this hospital is also treated in an activated sludge orbal system. The system has only three channels and a rated capacity of 136 kl/day. The hospital generates approximately 235 kl of effluent per day. Most of the flow is generated in the hospital's laundry. Al= though this plant is completely overloaded (especially hydraulically) it is still functioning surprisingly well. To alleviate the pressure on this plant, future planning is to separate the laundry effluent and treat that in maturation ponds. Treated effluent is again used for irri= gation after chlorination.

2.4 Siloam Hospital Maturation Ponds

With its 496 beds, Siloam Hospital is the largest in Venda. It serves mainly the Dzanani district in the north western part of Venda. The population served is approximately 80 000 people.

The outflow from the hospital is treated through a system of maturation ponds consisting of 2 primary ponds with a total area of 10 000 m^2 and 5 secondary ponds with an area of 13 000 m^2.

The quality of the effluent is excellent and it is used for irrigation of crops used in the hospital.

2.5 Makhado Township Maturation Ponds

Makhado is a township of 80 houses being developed as a service centre for the Dzanani district. The town is water and sewer reticulated. The sewage is treated in a system of 4 maturation ponds with a total area of 1 500 m^2. Provision has been made to double the pond area to meet expected future demand.

3. PROBLEM POINTS IN THE PRESENT SYSTEM

The previous short account shows that sanitation throughout the country is at present functioning reasonably well. There are however points of stress in the present system that will have to be attended to in the near future. Three of the main points are:

3.1 The larger agricultural settlements

It has been mentioned that some of the agricultural villages have 10 000 and more inhabitants. That so many people can be grouped together without providing some aid in their sanitation is quite unrealistic. Some of the inhabitants are in fact providing only the most rudimentary latrines, a state of affairs that leads to unsavoury conditions in certain areas.

This problem can be alleviated by helping the inhabitants to construct proper latrines, preferably with some system of sludge draw-off. These can be designed in such a way that they can later be converted to aqau privies when these settlements become water-reticulated.

3.2 Pollution of Streams

The sparkling streams of Venda are of its finest assets and must be guarded jealously. Most of the population are at present, and will be for many years to come, dependent on these streams for their potable water.

Unfortunately these people are also obliged to use these streams for their washing. The recent drought has accentuated the fact that these streams can no longer fulfill this dual function during the dry seasons. Serious cases of pollution have occurred, especially in the streams run= ning through the more densely populated areas, e.g. the Dzindi, Dzondo, Mvudi, Mutshindudi and the lower regions of the Levubu rivers.

To relieve the burden on these streams, serious consideration must be given to the provision of washing facilities in conjunction with the reticulation systems at present being constructed in several of the agricultural settlements.

3.3 Schools as Points of Concentration

Venda has an estimated 160 000 school children in 350 schools. This is an average of more than 400 pupils per school. Several of these schools are without any form of sanitation or have at best the most rudimentary systems.

Reticulated water at each of these schools is a goal that is being strived at. Once this is achieved, aqua privies or even complete water-borne sewerage systems with septic tanks could be a permanent solution.

4. FUTURE DEVELOPMENTS

It is government policy not to allow the agricultural villages to become over-populated. People not directly dependent for a livelihood on agri= culture will no longer be allowed to settle in these villages.

Provision for the settlement of non-farmers and their families will be made in rural and urban service centres. Two of these towns have been approved and development will start in the near future. The towns are Tshifulanani and Tshitereke.

4.1 Tshifulanani

The proposed Tshifulanani township is in the Lwamondo chieftaincy in the Vuwani district, adjacent to the Louis Trichardt-Punda Maria tar road and approximately 13 km from Thohoyandou. Provision is made for 1 150 erven ranging in size from 900 m^2 to 2 500 m^2. It is ensivaged that water and sewerage will be provided for in a site and service type scheme where self-built houses will initially be erected.

Water will be supplied to Tshifulanani under the Vondo Scheme. Sewerage will initially be pit latrines. As the township expands the sewage of Tshifulanani will be treated at the Thohoyandou main outfall works, this will require a low lift pump station.

4.2 Tshitereke

Tshitereke township is planned in the Tshivase chieftaincy in the dis= trict of Sibasa. The existing settlement of Tshitereke houses approxi= mately 2 500 people in a traditional settlement pattern. The future town= ship will have approximately 600 erven with an average size of 1 500 m^2.

Water will be supplied to the town through the Donald Fraser branch of the Vondo Scheme. Sewerage will be handled through pit latrines for many years to come but it is foreseen that a proper system will have to be provided for to meet future requirements.

5. CONCLUSION

The traditional settlement pattern in Venda gave rise to low population densities throughout the country. This has enabled individual households to manage their own sanitation.

Over the past 20 to 30 years points of concentration have developed and it became necessary to provide sanitation at these points. Except for the larger agricultural villages and the schools, a problem that we still have to address ourselves to, the Department of Transport and Works has coped adequately in providing and running sanitation services at these points.

It is government policy not to allow over-population of the agricultural settlements. Non-farmers at present residing in these villages will eventually be moved to urban areas. Maintaining sanitary conditions in these new urban areas is one of the challenges of our future.

6. ACKNOWLEDGEMENT

The opportunity afforded me by the Minister and Director General of Transport and Works to publish this article is gratefully acknowledged.

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SOME DISEASES IN SOUTHERN AFRICA RELATED TO INADEQUATE WATER SUPPLY AND SANITATION

BY

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SYNOPSIS

An adequate water supply and a sanitary excreta disposal system are considered as basic subsistance needs to maintain the minimum level of health in any community. The inadequacy of these facilities, often prevalent in rural areas, are associated with many water- and food-borne diseases. The modes of transmission of some of these diseases are briefly discussed and the importance of excreta disposal as part of environmental hygiene is described. The necessity of a sufficient quantity of good quality water for the purpose of drinking and food preparation and to maintain personal and domestic hygiene is high-lighted.

INTRODUCTION

Many health authorities consider the provision of the four basic subsistance needs viz. adequate water supply, sufficient food, hygienic sewage and waste disposal and suitable housing as essential elements to maintain the minimum basic level of health. Without ignoring the significance of the other two elements, this paper deals exclusively with the health implications associated with water supply and sewage disposal in rural areas.

The health and aesthetical problems associated with inadequate water supply and improper disposal of human excreta have been recognised decades or even centuries ago. For this reason the provision of community sewage collection, treatment and disposal systems as well as public water supply systems are standard practice today in highly developed areas and in industrialised countries. Unfortunately these services have been neglected and not been made available to the majority of small and deep-rural communities in non-industrialised and developing countries throughout the world. There are many reasons for this unhealthy state of affairs such as: a lack of funds, infrastructure and expertise; scattered occupation of land and unplanned settlement; low educational levels and insufficient knowledge; high population growth; community habits, customs and cultural preferences; etc.

In an effort to improve health and general living conditions in rural areas and because water is essential to support life, the main aim in the past had been to improve the utilisation of water resources and to develop water supply systems. Limited attention has been given to the development of human excreta disposal systems, prevention of water pollution and the protection of water sources in these areas.

It is ironical that despite all the knowledge about the presence and dangers of pathogens in human excreta, the efficient disposal thereof is so often grossly neglected. These problems raised so much international concern that the "Drinking Water Supply and Sanitation Decade 1981 to 1990" has been declared by the United Nations Organisation.

THE HEALTH RELATIONSHIP OF WATER SUPPLY AND EXCRETA DISPOSAL

Unhygienic disposal of human excreta is often associated with the lack of adequate water supplies and other sanitation facilities, insufficient personal hygiene and with a low economic status. As all of these and other related components may have an effect on health, it is difficult to assess the role played by each in the transmission of communicable diseases. However, good examples are described in literature where the death rate attributable to a disease such as typhoid was cut by a considerable percentage after the introduction of a privy construction programme. Similarly, studies have been reported showing the significance of water availability in the control of shigellosis and the mortality from diarrhoeal diseases among infants. Not ignoring the value of a good quality water source, many health officials believe the availability of sufficient quantities of water within close reach may be even more important to improve the health status of the community concerned. The abundant use of water usually results in better personal and general domestic cleanliness.

HOW IS DISEASE TRANSMITTED BY EXCRETA?

The causitive organisms of enteric diseases may be parasites, bacteria or viruses. The sick person (or carrier) serves as a reservoir for these micro-organisms. They are therefore discharged in the excreta (faeces and/or urine) and infect healthy persons when ingested. These micro-organisms may reach the mouth of a healthy person either through contamination of the hands with infected excreta or through the consumption of contaminated water, milk or food. Domestic flies and even animals may also play a part in this contamination. For the transmission of some parasitic diseases, specific intermediate hosts are necessary in which part of the life cycle of the parasite is completed.

In order to transmit disease the following factors are necessary:

° a causitive or etiological agent (viruses, bacteria, parasites)

° a reservoir or source of infection of the causitive agent (sick or infected person)

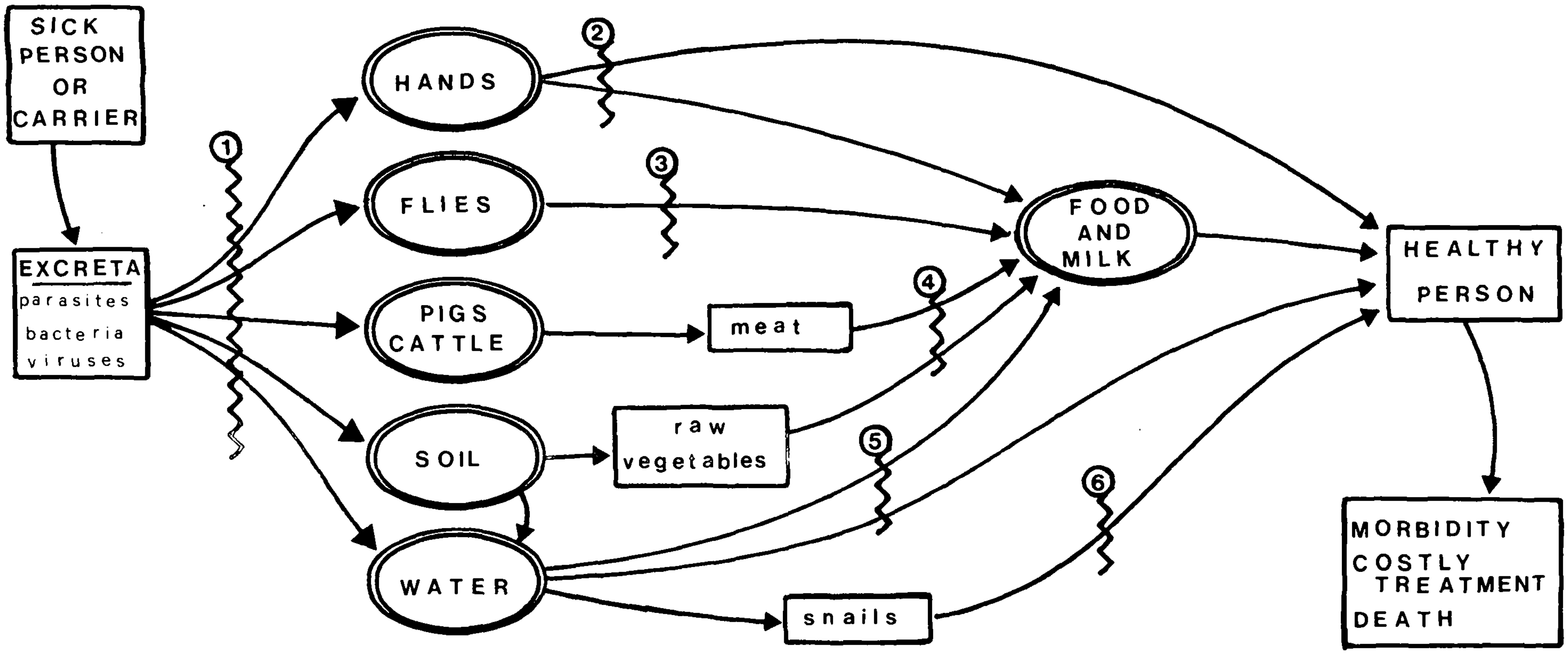
- a reservoir or source of infection of the causitive agent (sick or infected person)
- a mode of escape from the reservoir (faeces and urine)
- a mode of transmission from the reservoir to the potential new host (hands, food, milk, water, soil, flies, intermediate hosts)
- a mode of entry into the new host (oral, inhalation, dermal)
- a susceptable host (a healthy or undernourished person)

All six these conditions must be present to make the spread of disease possible. If any one of these conditions is absent or the timeous sequence is interrupted, the spread of disease will be stopped.

The diagram in Figure 1 illustrates the basic routes in which the causitive agents of excreta-borne diseases are transmitted from sick or infected persons to healthy or susceptable persons. Also shown in the diagram are a number of precautionary measures which can be taken to prevent the transmission of causitive agents to healthy persons. These actions serve as barriers to prevent the spread of water- and food-borne diseases.

From an environmental health point of view the various modes of transmission of the pathogenic micro-organisms must be identified, investigated, evaluated and eliminated wherever possible. In different parts of Southern Africa and in different communities, the modes of transmission may vary in the degree of importance. Although some may be of greater significance, all likely modes of transmission should be guarded against.

The diagram in Figure 1 shows that the introduction of sanitary collection, handling, treatment and disposal of human excreta in such a manner that the infectious agents cannot enter the intermediate routes of transmission to reach a new host, is the most important barrier. By introducing this sanitary barrier and by practising sound personal and domestic hygiene, the spread of excreta-borne diseases can be prevented or limited to the minimum.



Barriers to prevent spread of disease

1. Sanitary handling, treatment and disposal of excreta - prevent soil and water pollution.
2. Wash hands after defecation and before handling food.
3. Prevent fly breeding and practise sound pest control.
4. Wash and cook food properly.
5. Treat and disinfect water if contaminated.
6. Avoid contact with bilharzia infested water.

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FIGURE 1 TRANSMISSION OF EXCRETA-BORNE DISEASE

FIG 1

WATER SOURCES AND SUPPLY

Two major water sources viz. surface water and groundwater, are utilised for drinking and domestic purposes. As a result of a growing population, increased human activities and the careless disposal of wastes, all surface waters must be considered as polluted and contaminated with micro-organisms which may cause diseases, unless proved safe. Contamiated surface water must always be treated to prevent the transmission of water-borne diseases.

Underground water is usually considered to be free from pathogenic organisms. However, night-soil disposal and other systems such as pitlatrines and septic tank/French drains nearby, may contaminate underground water. If underground water sources become polluted, disinfection must be introduced and the cause be removed.

There is a general tendency to immediately blame the quality of the water sources wherever high incidences of water-borne diseases are found. However, limited or no attention is being given to hygiene aspects of the collection, transport and storage of drinking water. Furthermore, when water for domestic purposes is not freely available and has to be transported or carried over long distances, the use of water is often restricted to such small quantities that personal and domestic hygiene is seriously being affected. The lack of water may then become a more important contributory cause for the spread of disease than the original quality of the source water. Vibrio cholerae can multiply sufficiently on cooked foods and some raw foods to produce levels constituting an infectious dose. In endemic areas this could be a mode of transmission within homes and small communities where hygienic food practices are difficult to adopt and follow (Kolvin and Roberts, 1982).

EXCRETA-, WATER- AND FOOD-BORNE DISEASES

As described previously, the pathogens present in human excreta may follow various routes of transmission to infect healthy people. For this reason it is not possible to classify these diseases as either water- or food-borne only. In Table 1 the more common diseases are listed and the generally accepted modes of transmission indicated.

TABLE 1 WATER- AND FOOD-BORNE DISEASES CAUSED BY PATHOGENS PRESENT IN HUMAN EXCRETA

DISEASE	COMMON MODE OF TRANSMISSION
Typhoid and paratyphoid fever	food and water
Cholera	food and water
Bacillary dysentery	food (and water)
Amoebic dysentery	food (and water)
Diarrhoeal diseases	food and water
Infectious hepatitis	food (and water)
Ascariasis	soil, (food and water)
Tape worm	meat of intermediate host
Bilharzia	contact with infested water

Brief details of the tabled diseases are given in Appendix 1.

COMMUNITY INVOLVEMENT

When a country or any area is being developed, community involvement and development should be integrated in such programme. The provision of water supply systems and sanitation facilities must therefore also be included in any development plan. The ultimate test of success of any water supply and sanitation project is whether or not people use the facilities. Community involvement and participation should begin when new facilities are being planned and selected. The simultaneous need for health education cannot be over-emphasised. The best indication of a strong interest in the provision of these facilities is the willingness of the community to contribute to the construction cost with either money or free labour, to pay a reasonable fee for the services once the systems are operational and to actively participate in the maintenance thereof.

CONCLUSION

1. Many water- and food-borne diseases such as typhoid, cholera, dysentery, etc. are caused by the lack of adequate sanitation facilities or the proper use thereof. This situation is aggravated by the use of contaminated water sources and the lack of sufficient water to maintain personal and domestic hygiene.

2. When developing any country or area the simultaneous provision of adequate sanitation and water supply systems is essential.

3. To obtain the biggest benefit from any sanitation and water supply programme, it is necessary for the community concerned to be involved and to participate from the early planning stages. These programmes should also include health education as integral part of a general community development strategy.

4. The improvement and upgrading of sanitation and water supply facilities will not only improve the health status of the community concerned, but will also have a positive impact on the socio-economic development.

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APPENDIX 1

SOME DISEASES OF MAN IN WHICH EXCRETA SERVES AS A SOURCE OF INFECTION

1. TYPHOID AND PARATYPHOID FEVER - An acute, infectious, communicable, notifiable disease, usually characterised by abdominal tenderness, pyrexia (feverishness) and diarrhoea

    ° Causitive organism: Salmonella typhi and paratyphi A, B, C excreted in the faeces and urine of infected persons or carriers.

    ° Transmission mode: Man - faeces, urine - food, water, vegetables grown in contaminated soil - man. Flies may play a role.

    ° Prognosis: Good, if treated early and if complications have been prevented.

2. CHOLERA. An acute infectious, formidable, notifiable disease, usually characterised by severe diarrhoea and dehydration. However, up to 75% of cases can be asymptomatic or inapparent and become pseudo-carriers for approximately 2 weeks.

    ° Causitive organism: Vibrio cholerae. In Southern Africa biotype El Tor, serotype ENABA. Organisms are secreted in faeces and vomitus for 2 to 3 weeks in untreated or inapparent cases.

    ° Transmission mode: Man - faeces, vomitus - water, food (flies, soil) - man.

    ° Prognosis: The mortality rate in untreated acute cases is very high. In promptly treated acute cases it is low - approximately 5%.

3. BACILLARY DYSENTERY (SHIGELLOSIS). A mildly acute infectious communicable disease, characterised by inflammation of the colon and rectum with blood and mucus in the stool.

° Causitive organism: A number of different shigellae excreted in the faeces of infected persons. A carrier state may develop.

° Transmission mode: Man - faeces - food, water, (soil) - man. Flies may be an important mode of spread of the disease.

° Prognosis: Depends on age, resistance and treatment, but is good under favourable conditions. Mortality of children under the age of 5 years is high.

4. AMOEBIC DYSENTERY (AMOEBIASIS). An acute or chronic protozoal disease characterised by inflammation and ulceration of the mucous membrane of the colon.

° Causitive organism: A pathogenic protozoan, <u>Entamoeba histolytica</u> excreted in human faeces as cysts or in vegetative form.

° Transmission mode: Man - faeces - food, (water) and vegetables eaten raw - man. Flies may contribute to spread of disease.

° Prognosis: Mortality rate in children under age of 3 years may be as high as 40%. In adults prognosis is good if treated and no complications have occurred.

5. OTHER DIARRHOEAL DISEASES. An acute or chronic disease characterised by mild or severe diarrhoea.

° Causitive organism: Shigellae, salmonellae, <u>Escherichia coli</u>, parasites and viruses excreted in human faeces.

° Transmission mode: Man - faeces - food, (water) - man. Flies may contribute to spread of disease. Animals and birds harbour same salmonellae.

° Prognosis: Various diarrhoeal diseases are considered to be the main cause of death among children in economically underdeveloped areas.

6. VIRAL HEPATITIS. An infectious, notifiable disease characterised by inflammation of the liver and development of jaundice.

° Causitive organism: Hepatitis A virus is excreted in urine and faeces of infected person several days before onset of illness until a week after the onset of jaundice.

° Transmission mode: Man - faeces, urine - food, water - man.

° Prognosis: This is influenced by the virulence of the virus, age and general health of host, but complete recovery although slow, occurs in most cases.

7. ASCARIASES. A worm infestation caused by ingestion of parasite ova. The symptoms are not characteristic.

° Causitive organism: <u>Ascaris lumbricoides</u>, a round worm, established in the intestine, produces eggs which are excreted in the faeces. Ascaris eggs can withstand adverse conditions and remain viable for months.

° Transmission mode: Man - faeces - food, soil and vegetables grown in contaminated soil - man. Development of worm proceeds without intermediate host.

° Prognosis: In severe cases intestinal obstruction may occur. Treatment is safe.

8. TAPE WORM. A worm infestation caused by eating undercooked infected beef or pork. Loss of weight, digestive disorders and loss of appatite may occur.

° Causitive organism: Taenia solium (pork tape worm) and Taenia Saginata (beef tape worm) living in the small intestine of man produce eggs which are excreted in the faeces.

° Transmission mode: Man - faeces - intermediate host (cattle, pig) - meat (cyst) - man. Intermediate host is essential.

° Prognosis: Complications are rare. Safe treatment is available. Man can get self-infection with resultant cysticercosis of the brain, etc.

9. BILHARZIA (SCHISTOSOMIASES). A disease caused by a parasitic worm which completes its life cycle partly in humans and partly in the snail as intermediate host. The disease is characterised by haematuria and lesions of the bladder, urethra, ureters and colon. Fever occurs about 2 weeks after infestation.

° Causitive organism:
Schistosoma haematobium causes urinary bilharzia - intermediate host is Bulinus (Physopis) africanus.
Schistosoma mansoni causes intestinal bilharzia - intermediate host is Biomphalaria pfeifferi.

° Transmission mode: Man - urine and faeces (egg) - water (miracidiums) - snail (cercariae) - water - man (through skin or by ingestion)

° Prognosis: Good if treated early. The worm may survive for 30 years in the body.

10. Man can also contract diseases by making contact with excreta of infected animals - Leptospirosis, Tetanus, Toxoplasmosis, etc.

CHLORINATION OF SMALL-SCALE WATER SUPPLIES

by

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SYNOPSIS

Many diseases, including cholera, typhoid and stomach upsets, can be transmitted by polluted water This paper describes the use of chlorine to disinfect small-scale drinking water supplies (up to 100 000 ℓ/d), particularly with respect to rural areas and developing countries.

The paper explains how diseases can be transmitted into water from the faeces of infected persons, some of the steps that can be taken to minimise the pollution of water sources and the need for a health education programme to be carried out in conjunction with the supply of safe drinking water to a community.

Chlorination is the most commonly used method of disinfecting water supplies in southern Africa. However, there are several important factors concerning the water quality and method of chlorination which affect the disinfection process, and these are discussed.

Chlorine is available in various forms, as a pure gas or in liquid or solid compounds. The important advantages and disadvantages of each form are explained. Some chlorination equipment has been specifically designed for use with small-scale water supplies, and five representative types of equipment are described.

A water supply which is suspected of being polluted should be regularly sampled by a health officer trained in the correct sampling procedure, and tested to determine whether it contains *Escherichia coli* (E coli). This is a type of micro-organism which, although relatively harmless itself, indicates whether the water has recently been polluted by faeces, and therefore could also contain pathogenic micro-organisms. The S.A. Bureau of Standards: 'Specification for water for domestic supplies'[(1)] states that drinking water should contain no E. coli in a 100 mℓ sample.

Prevention of pollution

It is preferable to use water sources which are not polluted, if this is practicable. There are three basic categories of water sources: rainwater, groundwater and surface water (streams, rivers and lakes).

Rainwater is collected from the roofs of buildings and stored in covered tanks. This water is generally safe to drink, but it can become polluted if the roofs or storage tanks are not clean.

Groundwater from deep boreholes is generally not polluted because pathogenic micro-organisms are removed as the water filters through the soil down to the water table. However, if the soil is porous, enabling the water to drain rapidly through it, then there is a likelihood that the groundwater could become polluted if there is a source of pollution nearby, such as pit latrines. Water from shallow boreholes and wells is more likely to become polluted, and open wells can also be polluted by dirty buckets being dropped into the water.

The likelihood of groundwater pollution can be reduced by:

- siting pit latrines as far away from boreholes and wells as practical.

- designing the pit latrine so that there is at least 1 m of unsaturated soil between the bottom of the hole and the water table.

- covering open wells and installing a hand pump. The Blair pump, which was developed in Zimbabwe for this purpose, costs less than R100.

Surface waters become polluted by people washing and bathing in the water and by rainwater running over polluted ground into the stream or lake. This is generally not practical to control, but, if possible, drinking-water should be taken from a point upstream of the sources of pollution.

If the water is collected in buckets or other containers and carried to the home, then it can become polluted during transport or within the home. This must be prevented by teaching the people good hygiene practices as part of the health education programme.

FACTORS AFFECTING CHLORINATION

General

If it is necessary to use a polluted water source for obtaining drinking-water, then the water should be made safe to drink by being effectively and continuously disinfected before use. Unreliable disinfection is not acceptable as it gives the consumer a false sense of security.

Chlorine is commonly used to disinfect water supplies because it is effective, readily available at an acceptable cost and the chlorine residual which remains in the water provides some measure of continued protection if the water is polluted again after it has been disinfected. However, chlorine is a dangerous chemical if it is not used correctly and, if an excessive dosage is used, it imparts an objectionable taste to the water.

Also, there are several important factors concerning the characteristics of the water and the method of chlorination which must be taken into account to ensure effective disinfection. These factors are discussed below.

Pretreatment

The presence of suspended material in water interferes with the disinfection process. This suspended material gives the water a turbid or cloudy appearance and the water must be clarified, so that it looks clear, before chlorination. Clarification can be achieved by the addition of chemicals, settling and filtration. This is discussed in the NIWR information sheet: 'The purification of drinking-water'.[2]

Neither the common treatment processes nor chlorination will remove chemical substances in the water. These chemicals can only be removed by sophisticated treatment processes.

Chlorine demand and pH of water

The minimum chlorine dosage necessary to ensure effective disinfection depends on the characteristics of the particular water. A sample of water from each source should be laboratory tested to determine these characteristics.

Each water has a specific chlorine demand, which is the amount of chlorine required to react with substances in the water to form chlorine compounds. These compounds are either weak or non-disinfectants, and it is only when the demand is satisfied that the remaining chlorine, known as the free residual chlorine, is available for disinfection. The chlorine demand is primarily affected by the presence of ammonia and organic substances in the water. Some of the organic compounds formed can give the water an objectionable taste.

The pH of the water (a measure of its acidity or alkalinity) is another important factor as it governs the forms in which the free residual chlorine occurs. Chlorination is most effective at a pH value of less than 6,5 (slightly acid water) and becomes less effective as the pH increases (i.e. as the water becomes more alkaline) owing to the change in the form of the free residual chlorine from the form HOCl, a strong disinfectant, to the form OCl^-, a relatively weak disinfectant.

The minimum chlorine dosage necessary for disinfection of a particular water is the chlorine demand plus the required free residual chlorine.

Chlorine mixing and contact period

The chlorine must be rapidly mixed with the water, followed by a period of time for the chlorine to react before the water is used by the consumer. This period, known as the contact period, should be at least 30 minutes, preferably longer. It is generally provided by a tank between the chlorine injection point and the point of supply. Short-circuiting between the inlet and outlet of the tank should be prevented by installing a baffle wall inside the tank. A design of a contact tank for use with a hand pump is shown in Figure 1.

Required chlorine dosage

To ensure effective disinfection with a pH of up to 7,7 the water must be clear and the free residual chlorine after 30 minutes contact period should be not less than 0,5 mg/ℓ . For water with a pH greater than 7,7 the free residual chlorine should be 1,0 mg/ℓ [3].

The free residual chlorine can be measured in the field by the DPD method, using DPD No. 1 tablets and a Lovibond, Hach or similar comparator. The equipment commonly marketed for testing the chlorine in private swimming pools measures the total chlorine dosage (i.e. the chlorine demand plus the free residual chlorine). Therefore, this equipment should only be used if the chlorine demand of the water has previously been determined and if the equipment gives a chlorine reading in mg/ℓ .

FORMS OF CHLORINE

General

Chlorine is available as a pure gas or as chemical compounds in liquid or solid form. The commonly used compounds which are accepted by the S.A. Department of Health and Welfare as safe for use with drinking water are sodium hypochlorite liquid and calcium hypochlorite granules and tablets.

Chlorine reacts chemically with many substances, which is why it is very corrosive. The reaction can be violent, causing an explosion, if chlorine gas or compounds come into contact with organic products, such as oils, particularly at high temperatures. Therefore all forms of chlorine should be stored in a well ventilated area away from organic products (i.e. not stored in workshops or pumphouses) and where the temperature is less than 25 °C . The safety precautions recommended by the manufacturers of the chlorine and chlorine compounds should always be followed.

Chlorine gas

Pure chlorine is supplied as a liquid in high pressure steel containers, but is released from the container as a gas. There are two sizes of containers available in southern Africa, a 100 kg cylinder (containing 68 kg of chlorine) and a 1 650 kg drum (containing 925 kg of chlorine). As well as being corrosive, the gas is also poisonous to breathe and is heavier than air.

Gas is the most commonly used method of chlorination at water treatment plants because it is the cheapest form of chlorine and it can be accurately dosed. The equipment is safe to use by properly trained personnel, but special safety features should be incorporated into the design of the chlorination building and the installation of the equipment. Recommended safety equipment should be provided. The chlorine manufacturer can advise on these requirements.

Gas chlorination is generally not recommended for small-scale water supplies because there is usually only limited supervision by trained personnel.

Sodium hypochlorite liquid

Sodium hypochlorite is supplied as a liquid in 20 ℓ or 200 ℓ drums, and it contains 15 % chlorine concentration (gm/mℓ) when it leaves the factory. However, the chlorine solution is not stable, but gradually reduces to less than 10 % during three to four months storage. This problem can be overcome by diluting the solution to 5 % chlorine concentration (i.e. by adding two parts of water to one part of the original hypochlorite solution) immediately it is received. The diluted solution will remain relatively stable over several months if stored at a temperature of less than 25 °C .

Sodium hypochlorite is commonly used with small-scale water supplies because it is safer than chlorine gas in circumstances where there is limited supervision by trained personnel. Nevertheless, the safety precautions recommended by the manufacturer should always be followed.

The active ingredient of commercially available bleaches, such as Jik and Javel, is also sodium hypochlorite diluted to 3,5 % chlorine. These bleaches can be used for batch disinfection of individual buckets or drums of water. Disinfectants sold by pharmacies, such as Milton, only contain 1 % chlorine.

Calcium hypochlorite

Calcium hypochlorite is marketed commercially under the trade name HTH. It is supplied as white granules or as tablets, and contains 70 % chlorine. This chlorine concentration remains relatively stable provided the calcium hypochlorite is stored in sealed plastic or glass containers.

Calcium hypochlorite is readily available in the granular form in 5 kg or 10 kg containers from supermarkets, as it is commonly used for chlorinating private swimming pools.

Calcium hypochlorite tablets are available in 80 mm and 55 mm diameter sizes, designed for use with private swimming pools. They are also available in 46 mm diameter size, known as 'HTH tablets for use in the Flowrite chlorinator' which is a chlorinator that was developed by the National Institute for Water Research (NIWR).

It should be noted that 'stabilized' chlorine tablets are also marketed for swimming pool use. These tablets are the same size (80 and 55 mm diameter) and look identical to calcium hypochlorite tablets. However, the 'stabilized' chlorine tablets contain a cyanurate compound. Cyanurates have not been approved by the S A Department of Health and Welfare for the disinfection of drinking water, except on a short-term, emergency basis, as it is suspected that these compounds could possibly cause cancer with long term use.

Calcium hypochlorite is used for the disinfection of small-scale water supplies, either directly in the solid form or by dissolving the granules in water to form a chlorine solution. However, this compound does contain a small percentage of insoluble material. This material is not harmful to drink, but the chlorination equipment must be properly designed so that the insoluble material will not cause an operational problem. For instance, in chlorinators using solid calcium hypochlorite the insoluble material can gradually build up a blanket on the surface of the granules or tablets, thus reducing the rate at which chlorine is dissolved from the remainder of the calcium hypochlorite. With chlorinators using a calcium hypochlorite solution the insoluble material can cause blockages in small diameter pipework.

Tablets for disinfecting individual water containers

There are several makes of tablets that are commercially available and which are designed for disinfecting an individual container of water, such as a one litre water bottle. In some cases the disinfectant is chlorine, whilst in other cases it is halozone or iodine.

The effectiveness of these tablets has not been tested by the NIWR. Therefore, if a health authority intends to promote the use of this type of tablet, then it should carry out tests to ensure that the brands of tablets which are available in its area are effective disinfectants.

METHODS OF CHLORINATING SMALL-SCALE WATER SUPPLIES

Batch chlorination

Batch chlorination means the chlorination of individual containers of water, such as 20 ℓ buckets and 200 ℓ drums. In these cases the chlorination is an individual rather than a community responsibility.

The S.A. Department of Health and Welfare advises that a commercially available bleach, such as Jik or Javel, can be used for this purpose. For a 20 ℓ container the dosage should be 5 mℓ (1 teaspoonful) of bleach. The dosage should be increased proportionately for larger capacity containers. The bleach should be thoroughly mixed with the water and then allowed to stand for at least two hours, preferably longer, before drinking the water.

Requirements of chlorination equipment

The most appropriate method of chlorination of a community water supply depends on the particular circumstances. However, the following points should be taken into consideration when choosing chlorination equipment:

- the form of chlorine used must be suitable for the particular circumstances. The persons handling it must be trained in its use and in the safety precautions recommended by the manufacturer. They should also be provided with recommended safety equipment. In addition, the form of chlorine must be readily available at an acceptable cost

- the chlorination equipment must be suitable for the intended use, taking account of the pump rate, quantity of water used per day, whether the equipment is required to dose chlorine continuously during the day or intermittently, whether the chlorine is dosed into a pressurized pipeline and other relevant factors. The equipment should also be robust, easy to operate and require minimum maintenance. Any spare parts that may be necessary should be readily available locally

- the chlorination equipment must consistently dose chlorine within specified limits, provided it is operated correctly, i.e. it must always dose at least the minimum chlorine necessary for disinfection of the particular water, but the maximum dosage should not make the taste of the water objectionable

- the water supply should not be accessible to the consumers until after it has been chlorinated and had 30 minutes contact period. This is to prevent people from drinking water that has not been properly disinfected.

Chlorination equipment

Chlorination equipment is commercially available that has been specifically designed for use with small-scale water supplies. These chlorinators use sodium hypochlorite or calcium hypochlorite as the chlorine source. Some of these chlorinators have been tested by the NIWR to determine whether the accuracy and reliability of chlorine dosage is satisfactory for use with drinking water supplies. However, the tests did not include data on how well the equipment can stand up to long term usage in the field. A selection of representative equipment, which gave satisfactory chlorine dosages is described below (b to e). These chlorinators are not necessarily the best or the cheapest equipment available and are listed by way of illustration only. However, some of the other equipment tested did not give such satisfactory results.

a. Constant flow chlorinator - A typical design of this type of equipment is shown in Figure 2.[4] It is not manufactured commercially, but can be easily made. It has not been tested by the NIWR.

The chlorinator provides a continuous dosage of hypochlorite solution, and the dosage rate remains constant as the hypochlorite storage container gradually empties. The chlorine dosage is regulated by either adjusting the height of the inlet and outlet tubes or by varying the chlorine concentration of the hypochlorite solution in the container.

The equipment is inexpensive, but the principal disadvantage is that the chlorine dosage is continuous unless it is manually stopped by removing the floating bowl from the container. Also, some arrangement must be made to ensure good mixing of the hypochlorite solution with the water, such as by dosing the solution as the water flows over a weir in a channel. The equipment is not suitable for injecting chlorine into a pressurized pipeline.

b. Flowrite chlorinator - this equipment was developed by the NIWR. It is designed for flow rates between 20 and 40 ℓ/min (1 200 to 2 400 ℓ/h) and is suitable for use with hand pumps and small mechanically operated pumps. The chlorinator itself does not require electricity or other power source for operation. The chlorine source is 46 mm diameter calcium hypochlorite tablets, and the equipment can accept up to three tablets at a time, which is sufficient to chlorinate 10 000 ℓ of water. However, the tablets must be replenished each day and therefore, if a lesser quantity of water is used, only the number of tablets which are required for one day's use should be inserted in the chlorinator each day. Chlorine dosing ceases when the pump is not operated.

The results of the NIWR tests of this equipment are reported in a paper 'Development of a borehole chlorinator' by P. Williams.[5] The chlorinator is now manufactured commercially and it costs approximately R70. A simple pipework arrangement is necessary for the installation of the chlorinator.

c. Self-powered chemical doser - This equipment consists of a 150 ℓ capacity tank plus a 10 ℓ storage tank for sodium or calcium hypochlorite solution. The raw water is pumped into the 150 ℓ tank and, each time this tank fills, a preset quantity of chlorine solution is dosed into the water. An automatic syphon then empties the 150 ℓ tank and the cycle starts again. The chlorine dosage ceases when the water flow stops.

The equipment has few moving parts and does not require electricity or other power source for operation. The equipment is generally installed at the inlet into a storage tank. It is not suitable for injecting the chlorine solution into a pressurized pipeline.

The equipment has the capacity to chlorinate up to 100 000 litres of water per day. The hypochlorite solution tank would need to be replenished every few days, the actual period depending on the water flow and the chlorine dosage. The cost of the equipment is approximately R1 000 which does not include a stand to support it.

c. Chemical dosing unit, - this equipment operates by water pressure. It consists of a water meter which is connected to a simple piston type of dosing pump. The dosing pump draws sodium or calcium hypochlorite solution out of a tank and injects it into the water flowing through a pipeline. The tank holding the hypochlorite solution can be any capacity and therefore, if it is large enough, it may only need to be refilled every few weeks. The dosing of the chlorine solution adjusts automatically to variations in flow rate through the pipeline, and the dosage ceases when the water flow stops. The equipment can be installed at any convenient location in a pressurized pipeline.

There are several sizes of units available. The smallest size is installed on a 25 mm diameter pipeline and can be used to dose up to 60 ℓ/min (3 600 ℓ/h) of water, although the pressure loss through the unit at this flow rate is approximately 50 kPa

(5 metres water pressure). The chlorine solution is well mixed with the water flow when it is injected into the pipeline. However, there is no adjustment on the equipment and therefore the only method of regulating the chlorine dosage is by varying the strength of the hypochlorite solution. The cost of the smallest size of unit is approximately R400 and it is available in South Africa from several suppliers of water treatment equipment.

e. Electrical chemical dosing unit - This equipment is similar to the previous, except that the dosing pump is electrically operated. Therefore there is little pressure loss through the unit. However, the dosing pump operates in pulses, with up to several seconds between each pulse during which no chlorine is injected. Therefore the unit should be installed very close to the contact tank so that the turbulence at the inlet into this tank can provide the necessary mixing effect. This unit costs approximately R450.

CONCLUSION

The purpose of disinfecting a water supply is to prevent the spread of waterborne diseases in a community. This purpose can only be achieved if the chlorination system that is installed operates effectively and reliably, and if the people drink only water that has been disinfected.

The design of each chlorination system must take into consideration the water quality factors which affect chlorination, the most suitable form of chlorine compound and the most appropriate chlorination equipment for the particular circumstances. The chlorination project must also have the cooperation of the people who use the water.

The four types of commercially available equipment described in this paper have been tested by the NIWR as representative of the satisfactory types available on the South African market. Names of suppliers can be obtained from the NIWR.

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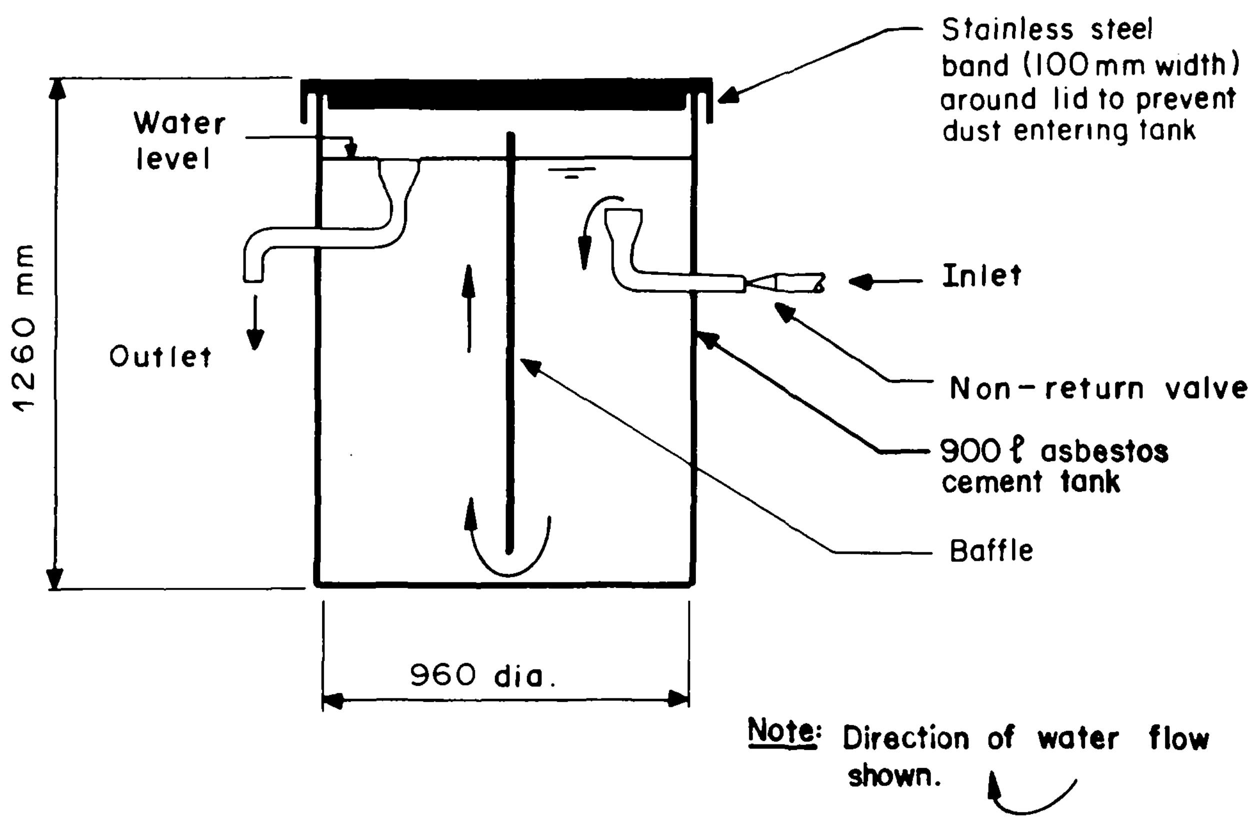
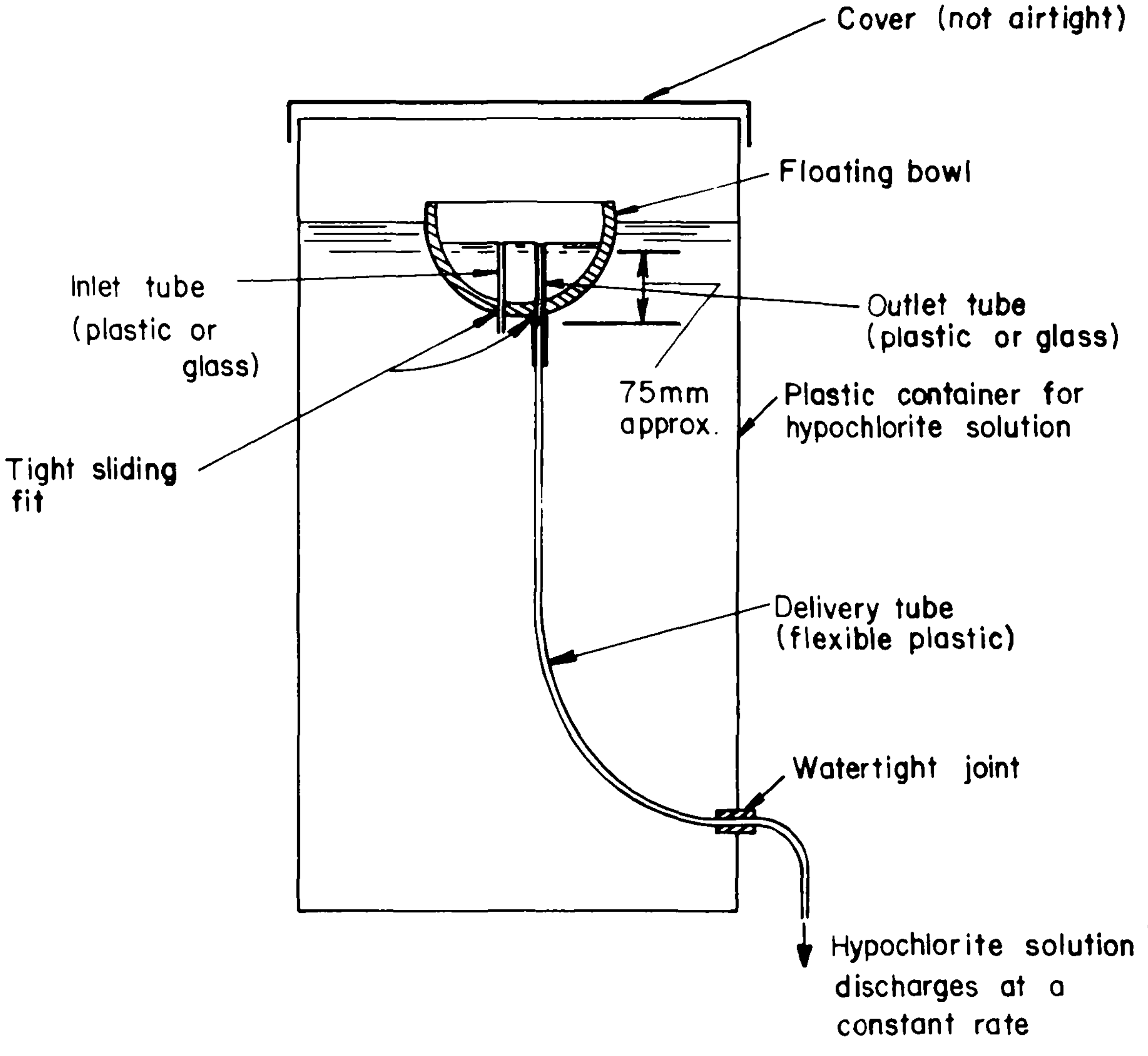


FIGURE I. <u>CHLORINE CONTACT TANK FOR HAND PUMP</u>



Note: The dosage rate of hypochlorite solution can be regulated by adjusting the heights of the inlet and outlet tubes in the floating bowl.

FIGURE 2. CONSTANT FLOW CHLORINATOR

FISH PRODUCTION USING ANIMAL WASTES AS A NUTRIENT SOURCE

by

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SYNOPSIS

Results obtained on the use of pig, cattle and chicken manure as nutrients to supplement feed in fish polyculture, using a combination of three varieties of the European common carp, the Chinese bighead, silver, grass and black carps as well as the cichlid *Oreochromis mossambicus*, are discussed. The effects of decline in water temperatures below 20 °C on growth of the different species are compared. Reference is also made to heated, treated domestic sewage effluent used as cooling water by a power station for the production of fish.

OPSOMMING

Resultate verkry tydens die gebruik van vark, bees en hoendermis as 'n aanvulling tot viskos in vispolikultuur waartydens o.m. gebruik gemaak is van 'n kombinasie van drie variëteite van die gewone Europese karp, die Sjinese dikkop, gras, silwer en swart karpe asook die bloukurper *Oreochromis mossambicus*, word bespreek. Die invloed van dalende watertemperature laer as 20 °C op die indiwiduele groeitendese van die verskillende vissoorte word vergelyk. Daar word ook verwys na die moontlike benutting vir visproduksie van verhitte, behandelde huishoudelike riooluitvloeisel wat vir afkoeldoeleindes deur 'n kragsentrale gebruik word.

PAPER NOT AVAILABLE AT TIME OF GOING TO PRINT.

POSSIBLE HEALTH HAZARDS IN FISH FARMING USING SEWAGE

by

E M Nupen

1. INTRODUCTION

The inherent value of combining a waste treatment system with a food production system, resulting in the improved quality of the treated wastewater, is fully acknowledged; simulated research has undoubtedly proved the feasibility of economic fish yields and the efficiency of such waste treatment processes [1,2,3,4]. Although much research has been done on aquaculture systems to evaluate the effects of pollutants, whether they be chemical or microbiological, on the growth rate or health of the fish themselves[5,6], very little is known about the effects on the health of terrestrial users of the fish protein products obtained from such aquatic systems. The premise that certain aquatic species, such as the Northern Quahang, can accumulate a given bacterium to the equilibrium concentration of that bacterium in a water[7], may possibly not apply to the edible part of fishes, as the accumulation in the Northern Quahang takes place mainly in the digestive gland and to a lesser extent in the siphon of this shell fish. Again coliform and faecal coliform analyses on paua meat (muscular foot), harvested from sewage-polluted sea water, indicated that, although high numbers of these bacteria were isolated from the viscera, the meat contained <10 bacteria per gram[8].

Current literature indicates negative findings on human bacterial diseases being transmitted through fish[2], but the possibility of the accumulation of heavy metals and pesticides which could be deleterious to human health, is still being investigated[9,10]. As the use of low cost waste treatment stabilization ponds are ideal in rural developing areas in Southern Africa, the health risk of the inevitable concomitant cultivation of fish in such systems needs to be evaluated. This paper discusses these risks in relation to findings from various analyses of fish cultivated in a series of ponds receiving different types of sewage-polluted waters.

EXPERIMENTAL DESIGN

1. During the summer of 1981-1982 the microbiological and chemical quality of fish were investigated in conjunction with a study on the health aspects of algae culture in wastewater[11]. Two sets of ponds receiving sewage contaminated water were stocked with carp, silver carp and *Oreochromis mossambicus*. One set received an additional feed of Epol pellets, and the other algae pellets produced from the algae wastewater system[11].

2. Seven ponds, situated adjacent to a treatment plant in Pretoria, receiving mainly domestic sewage were stocked with *O. mossambicus* fingerlings in November 1983. A control pond (no. 1) received tap water only, ponds no. 2 and 3 received settled sewage, ponds no. 4 and 5 received algae stabilization pond effluent after algae flotation and ponds no. 6 and 7 received the algae stabilization pond effluent[11]. Pond design was not ideal, being restricted by space and financial considerations. Fish from each pond were harvested in May 1983 for microbiological and chemical analyses. Weekly microbiological analyses were done on all pond waters and periodic checks were carried out on the chemical quality of these waters.

SAMPLE PREPARATION AND ANALYTICAL METHODS

1. Microbiological

During the algae feeding experiments, various techniques were tested for the aseptic processing of fish samples. Direct dissection of fish, even using sterile instruments and gloves, yielded bacterial counts in raw fish fillets. A method whereby the whole fish was immersed in a commercial chloramine solution before disinfection, resulted in the recovery of low numbers of indicator bacteria. However, this method interfered with the organic chemical analyses, causing the recording of high numbers of peaks during gas chromatography determinations as a result of the many chlorinated hydrocarbons formed. Ultimately, fish prepared for bacteriological analyses were scaled, washed in tap water and dried between sterile paper towels. The skin was painted with a 0,5 % gentian violet solution and, always using sterile instruments, a skin incision was made along the base of the tail and up along the dorsal fin. Gently lifting the corner, the skin could be ripped off the flesh, and a fillet dissected so that no contamination from the sewage polluted exterior of the fish was possible. Weighed fillet samples were mascerated with 1:10 w/v sterile distilled water in a Sanyo Solid State SM 1000 E blender at speed 8 for 2 min . Standard plate counts (SPC) were done directly on the prepared suspensions(12). Faecal coliform counts (FCC) and salmonella determinations were carried out according to methods given in the Standards Act(13), except that selenite Brilliant Green Broth (Difco) was used as being more selective than lactose broth for salmonella isolations(14).

Ten fish from ponds 2 and 3 were chloroformed in a 1:10 000 solution for 2 min and blood samples were aseptically taken in a 2 mℓ syringe directly from the heart. Blood samples were tested for faecal coliforms and salmonellas as above. To act as a control, known concentrations of *E coli* I organisms were simultaneously suspended to a 1:10 000 solution of chloroform for 2 min. The suspension was then evaluated by the membrane filtration technique in order to determine if the chloroform could have inactivated micro-organisms in the fish blood during the 2 min anaesthesia period.

2. Chemical

Fish were scaled and dissected to obtain 2 fillets and the liver from each fish. Fillets were thoroughly washed in distilled water and chemically analyzed by methods previously described[15,16,17]. Raw and cooked fillets (boiled) and the livers were analyzed for metal content. Organic chemical analyses were done on the raw and cooked fillets and sanitary analyses were carried out on the cooking waters. Extracts from raw and cooked fillets from both a male and a female fish from the control pond (1) and the settled sewage polluted pond were tested by the Ames/*Salmonella* test for mutagenic activity[18]. Extracts for the mutagenic assays were prepared by the addition of 3 g sodium sulphate (anh.) and 20 mℓ distilled water to one gram of chopped fish flesh, followed by treatment for 2 min with an Ultra-Tunase homogenizer. The resulting suspension was twice filtered through the same sintered glass funnel (Por 2). The filter residue was re-extracted as previously with fresh acetone. The composite extracts were evaporated to dryness in a rotary vacuum evaporatot at 60 °C and the residues dissolved in 1/5 of the volume of acetone originally used for the extraction. The mutagenic activity of volatile materials and materials insoluble in acetone cannot be detected activity by this method.[19]

RESULTS

1. Fish from algae ponds

The fillets of fish harvested from sewage ponds (with supplementary algae pellet feed) contained an average of 17 ± 10-26 faecal coliforms per 100 g sample. There was one *Clostridium perfringens* per 100 g in one of the ten carp fillets tested. No salmonellas were isolated from the 23 fish samples analyzed. Fish from the Epol supplemented ponds had on average 26 ± 18-37 faecal coliforms per 100 g, but no salmonellas were isolated from the 23 fish tested. No faecal coliforms or salmonellas were isolated from the 23 fish tested. No faecal coliforms or salmonellas could be isolated from cooked specimens from either pond.

Levels of Hg, Pb, Cd and Cu were all below those recommended in Water Quality Criteria 1972. (EPA.R3.633 March 1973).

2. Fish from sewage pond experiments

No faecal coliforms or salmonellas were ever isolated from the sterily prepared 50 g fillets of fish reared in the control or the six sewage contaminated ponds; nor from the blood samples taken from fish reared in the sewage ponds 2 and 3. No die-off of *E. coli* occurred during the 2 min exposure to chloroform in the control test.

The average concentrations of mercury, lead, copper, cadmium, zinc, chromium, cobalt, nickel and manganese found in the fish cultivated in ponds 2 and 3, ponds 4 and 5 and ponds 6 and 7 did not differ appreciably from the average concentrations found in the control pond 1 (Table 1). The levels of these metals did not differ from those found in cattle muscle and liver[24], or those recorded in an intensive study on fresh water fish done in the USA[10], or in South African shark meat[15] or Thailand estuarine fish[26] (Tables 2 and 3). Copper, lead, zinc, were all well within the limits for fish products laid down in the South African food, Drug and Disinfectants Act[20].

Amounts of PCB, DDE, TDE, DDT, lindane or dieldrin were below the limits of detection in both raw and cooked fish fillets grown in the control pond. PCB, DDE, TDE and DDT were also not detectable (within the limits of detection) in the raw and cooked fillets of fish from all the other ponds (Table 4).

Although lindane and dieldrin were not detectable in the raw and cooked fish from the control pond, nor the raw fish from ponds receiving algae pellets, traces of both pesticides were found in the raw fish cultivated in the sewage polluted pond, and measurable amounts of lindane (3,49 μg/kg) and dieldrin (9,15 μg/kg) were found in the cooked flesh samples of fish from these ponds (Table 4). Measurable quantities of both lindane (4,06 μg/kg) and dieldrin (2,17 μg/kg) were also found in cooked fillets from fish cultivated in the ponds receiving unflotated algal pond effluent, but only dieldrin (3,93 μg/kg) was present in the cooked flesh of fish cultivated in the ponds receiving flotated algal pond effluent after flotation (Table 4).

No mutagenic activity was detectable in any of the extracts tested by the Ames/*Salmonella* mutagenicity tests. Only boron exceeded the levels laid down for drinking-water in all the cooking-waters tested, after the boiling of the cultivated fish (Table 5).

DISCUSSION

When sterile precautions were taken neither salmonellas nor faecal coliforms could be isolated from the flesh of fish grown in sewage contaminated waters. Contamination of fish flesh from the sewage polluted waters can obviously occur during handling or processing of the fish. In a survey of catfish processing, 48,6 % of the finished fish flesh products were positive for *Salmonellae*, improvement of the processing technique reduced the frequency of *Salmonellae* isolations to 0 %. Baker and co-workers[23] were also unable to isolate *Salmonellae* from fish flesh and concluded that, since the *Tilapia* flesh was not invaded by *Salmonellae*, proper processing should yield an unadulterated product. As proper processing is not always possible it is advised that fish grown in sewage polluted waters should always be eaten cooked. Care should also be taken to clean preparation areas adequately in order not to contaminate other foods.

The presence of mutagens was not evident, nor was there any evidence of a build-up of trace metals in the fish flesh, even though the domestic sewage effluent used did, to some extent, contain industrial discharges. Most organic pollutants were below detectable limits, the highest concentration of an organic pollutant recovered was dieldrin (9,15 μg/kg) in the cooked flesh of fish cultivated in the sewage polluted ponds. The advised human intake limit for dieldrin is 2 ng/day [21]; 9,15 μg/kg constitutes an intake of 3 ng/day, assuming a minimal constant daily intake of 300 g of fish. Although this intake is only just above the limit and a daily intake of 300 g cooked fish is unlikely, the presence of dieldrin and even low levels of lindane must be considered a potential health risk while these two pesticides remain in use.

From the above findings, fish grown in waste treatment stabilization ponds should not present a health hazard, provided that simple precautions are maintained in food handling and that the ponds are restricted to domestic wastes.

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Average concentrations of heavy metals in *Oreochromis* after growth in various types of sewage polluted waters, Pretoria.

(mg/kg wet weight)

TABLE 1

Type of pond feed	Hg	Cu	Cd	Pb	Zn	Cr	Ni	Mn
Raw sewage								
muscle	0,06	0,27	0,03	0,02	14,3	7,8	0,32	0,75
cooked muscle	0,10	0,48	0,03	0,02	22,5	11,9	0,46	0,37
liver	0,11	17,65	0,10	0,03	19,1	46,8	0,82	3,39
Algae pond eff. after flotation								
muscle	0,03	0,63	0,02	0,02	16,2	4,35	3,95	0,34
cooked muscle	0,04	0,58	0,16	0,02	21,5	5,25	0,75	0,07
liver	0,02	3,55	0,08	0,03	18,4	27,2	1,41	1,22
Algae pond eff.								
muscle	0,01	0,63	0,07	0,01	10,5	11,1	1,38	0,07
cooked muscle	0,03	0,36	0,13	0,03	16,9	18,1	0,64	2,48
liver	0,04	2,78	0,08	0,02	24,9	12,9	1,84	6,50
Control								
muscle	0,02	0,59	0,02	0,02	13,5	9,2	0,07	0,06
cooked muscle	0,19	0,48	0,03	0,03	31,9	8,4	0,10	4,89
liver	0,05	11,8	0,04	0,01	36,4	5,7	0,17	8,40

Concentration of heavy metals in foods after growth in natural environments

(mg/kg wet weight)

TABLE 2

Species	Hg	Pb	Cd	Cu	Cr	Zn	Reference
Bovine							
muscle	<0,02	<0,06	<0,04	1-9	<0,1	16-107	24
liver	<0,03	<0,5	<0,6	<135	<0,9	<126	
Fresh water fish - USA (whole fish)	0,11	0,32	0,07	-	-	-	10
Shark meat (South Africa)	2,3	0,8	0,03	0,6	0,55	5,8	15

Comparison of average heavy metal concentrations in estuarine ash and fish cultivated in sewage polluted waters

(μg/g dry weight)

TABLE 3

Species	Hg	Pb	Cd	Cu	Cr	Zn	Ref.
Estuarine fish (Thailand)	0,1	11,6	0,91	1,58	9,6	123	26
Oreochromis (Daspoort)							
(a) Control	0,08	0,09	0,09	2,81	45,0	66,0	
(b) Sewage	0,2	0,05	0,1	1,17	17,2	64	
(c) Algae flotated	0,01	0,08	0,09	2,81	19,6	72	
(d) Algae effluent	0,04	0,02	0,29	2,88	46,8	46	

Pesticide analyses on raw and cooked fish harvested from sewage polluted ponds, Daspoort (µg/kg)

TABLE 4

Pond Feed 1	PCB	DDE	TDE	DDT	Lindane	Dieldrin
Control						
raw	ND	ND	ND	ND	ND	ND
cooked	ND	ND	ND	ND	ND	ND
Sewage						
raw	ND	ND	ND	ND	+	+
cooked	ND	ND	ND	ND	3,49	9,15
Algae pond after float						
raw	ND	ND	ND	ND	ND	ND
cooked	ND	ND	ND	ND	ND	3,93
Algae pond effluent						
raw	ND	ND	ND	ND	ND	ND
cooked	ND	ND	ND	ND	4,06	2,17

ND = not detectable : detection limits are 0,05 µg/kg with the exception of PCB where the limit is 0,5 µg/kg.

\+ = detectable not quantifiable.

TABEL 5 RESULTATE VAN CHEMIESE ANALISES on waters after cooking of fish fillets

	Datum		Grense: Aanbeveel/ Risiko	83-06-01						
	Monsterpunt			A	B	C	D			
	Hardness		20-300							
	Troebelheid	(NTU)	1/5							
	Kleur	(Pt-Co)	10/20							
	pH		7-8,5/6-9,5							
	Elektriese geleiding, 25 °C	(mS/m)	70-300							
mg/ℓ	Natrium	(Na)	100-400	100	119	106	83			
	Kalium	(K)	200/400	645	580	450	443			
	Kalsium	(Ca)	150/200	4	3	3	2			
	Magnesium	(Mg)	70-150	29	27	23	22			
	Chloried	(Cl)	250/600	170	217	190	170			
	Sulfaat	(SO_4)	200/600	370	383	235	225			
	Totale alkaliniteit	($CaCo_3$)	-							
	Silika	(Si)	-							
	Kjeldahl-stikstof	(N)	-	255,0	257	225	203			
	Ammoniak-stikstof	(N)	1/2	110,0	121	66	60			
	Nitraat + Nitriet-stikstof	(N)	6/10	<0,2	<0,2	<0,2	<0,2			
	Nitriet-stikstof	(N)	-							
	Totale fosfaat	(P)	-	295	282	213	193			
	Orto-fosfaat	(P)	-	240	239	156	143			
	Chemiese suurstofbehoefte	(CSB)	-	7100	4600	5050	3900			
	Organiese-koolstof	(C)	5/10							
µg/ℓ	Metileenblou aktiewe stowwe	(LAS)	500/1000							
	Fenole	(Fenol)	10-20							
	Sianied	(CN)	200/300							
	Bromied	(Br)	1000/3000							
	Fluoried	(F)	1000/1500							
	Aluminium	(Al)	150/500	1350	820	1335	1650			
	Boor	(B)	500/2000	1800	880	765	870			
	Kadmium	(Cd)	10/20	<5	<5	<5	<5			
	Chroom	(Cr)	100/200	<25	<25	<25	<25			
	Koper	(Cu)	500/1000	40	48,3	<25	30			
	Yster	(Fe)	100/1000	105	107	108	103			
	Mangaan	(Mn)	30/1000	<25	<25	<25	<25			
	Nikkel	(Ni)	250/500	<25	<25	<25	<25			
	Lood	(Pb)	50/100	<25	<25	<25	<25			
	Sink	(Zn)	1000/5000	190	155	55	60			
	Kwik	(Hg)	5/10							
	Arseen (Anorganiese)	(As)	100/300							
	Selenium (Anorganiese)	(Se)	20/50							

OPMERKINGS: A = fish from control pond
B = fish from pond receiving sewage
C = fish from pond receiving flotated algae pond effluent
D = fish from pond receiving non-flotated algae pond effluent

ALGAE HARVESTING

by

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SYNOPSIS

This paper deals with a new method for harvesting microalgae from high-rate ponds treating wastewater. A description is given of the technical solutions used in previous works for harvesting algae. The most promising is based on the flocculation of the microalgae with flocculants and the separation of the flocs from the liquid phase by means of a dissolved air flotation unit (DAF). Although the basic principles used in the proposed method are similar to the flocculation - DAF, it relies on the production of photosynthetically produced oxygen for the *in situ* flotation of the flocs also formed *in situ*. The method is called *in situ* dissolved oxygen flotation (ISDOF) and its main characteristic is that the equipment for flotation has been greatly simplified. A description is given on how ISDOF operates and how it was developed into an appropriate technology that can be applied in developing areas for the combined upgrading of pond effluent quality, algae harvesting for animal feeding and also for obtaining water for irrigation. An example of the quality of the clarified effluent

produced in a pilot plant using the *in situ* dissolved oxygen flotation is presented, together with the characteristics of the algal slurry separated.

1. INTRODUCTION

High-rate and stabilization ponds have proven to be a simple and economical means of treating waste water[1 2]. The development of freshwater microalgae in a high-rate pond is enhanced by dissolved nutrients and by exposure to sun. Two positive effects are obtained in the pond; namely the removal of part of the nutrients, and the production of photosynthetic oxygen. The oxygen which is essential for the aerobic decomposition of organic matter by bacteria, would otherwise have to be introduced into the waste water by costly mechanical or chemical methods. In times when the need for energy conservation is repeatedly stressed, the use of a process based on solar energy is well warranted.

The main problem presented by the use of stabilization and high-rate ponds is that if their algae-laden effluents are discharged to a water body or stored in inrrigation dams, the decay of the suspended algae may exert a high oxygen demand[3]. Therefore, carry-over of algae in the effluent has to be avoided. Further motivation for the removal of microalgae from stabilization ponds before reuse, is that -

(a) microalgae may produce some undesirable chlorine compounds when the effluent is chlorinated before use. Microalgae may also reduce the residual chlorine level.
(b) Microalgae deposits may clog the spray nozzles or drippers of irrigation equipment when the effluents are used for irrigation.

As a result of the separation of microalgae, a rich biomass is obtained, which has considerable potential as animal feed. The production of algae on a continuous basis, at high yields per unit area, has been demonstrated when treating waste water[4 5 6]. The main problem encountered with the application of algae production is the high cost of separating the algae from the effluent.[7] Several authors [7 8 9] reviewed the techniques for microalgae harvesting. These include : centrifugation, microscreening, flocculation followed by dissolved air flotation or by sedimentation, and vacuum filtration. The use of one-step centrifugation was reported as being uneconomical[10]. Preconcentration by sedimentation followed by centrifugation has been proposed as a means of reducing costs[7], but it would seem to be impractical to couple stabilization ponds, which are relatively inexpensive to operate with centrifuges which are expensive to operate[8].

Microscreening seems to be an economical and effective technique for removing colony forming and filamentous algae.[11] By developing screens with 1 to 6 µm pore size, it is possible to remove suspended algae successfully without having to add chemicals.[12] Two main disadvantages of microscreening are, however -

(a) The possible variation of algal species in the ponds throughout the year affecting the reliability of the separation. When filamentous or colony forming algae appear for instance, large pore screens could be used; however, when microalgae develop these units may be inadequate.

(b) The low concentration of solids obtained in the back wash of the screens : 1-1,5 %[13], affecting the cost of further processing (i.e. thickening and drying).

Among the methods used nowadays, flocculation followed by flotation[9 14] seems to be the most accepted and reliable method for algae removal from pond effluents containing a high concentration of algae. However, the combination of chemicals with dissolved air flotation is still too costly. As with microscreens, the capital outlay for equipment is too high for the application of these methods in small communities and developing areas.

Algae Harvesting

This paper presents the evolution of algae harvesting from the conventional dissolved air flotation (DAF) and introduces a simplified procedure for harvesting microalgae, called *in situ* autoflotation.

2. DAF AND ITS MODIFICATIONS

The principles of DAF and the criteria for designing DAF flotation equipment are summarized by Vrablik[15]. This process is used in the paper industry[15] and for thickening sludge[16]. The tendency of microalgae flocs to float, was used to harness flotation for removing from pond effluents[17]. A diagram of a conventional DAF unit for harvesting algae is shown in Figure 1. This type of equipment was used when DAF was first applied for removal of algae[18 19 20].

It was found that the coagulation vessel for flash mixing was unnecessary, consequently flocculants were injected in-line, the retention time being sufficient to allow adequate floc formation[20]. The preparation of the pressurized water-air mixture was simplified by omitting the compressor, and air was drawn into the inlet of the pressurization pump through a Venturi[21] (Figure 2).. A further simplification was achieved through the use of polyelectrolytes which are effective within a pH range between 7 and 9, unlike alum or ferric chloride which has an optimum pH at a lower value than the pH normally observed in pond effluents. Thus the pH meter, the pH control unit and the acid dosing pump could be spared[22]. Another change based on previous experiences [17 21] entailed using the oxygen produced photosynthetically, which under conditions of supersaturation releases very small bubbles. The use of these bubbles replaced the use of the following equipment : a pressurization tank, pressurization pump, compressor and 30 % of the flotation unit volume, saved by not performing the recirculation of 30 % of the clarified effluent[20] (Figure 3). A more recent modification, performed at the Daspoort pilot plant of the National Institute for Water Research, is the use of photosynthetic oxygen to produce autoflotation *in situ* either in part of the high-rate pond or in a separate channel. This saves the flotation unit tank construction, the pump to feed it and the scrapper device.

3. *IN SITU* AUTOFLOTATION

The effluent of a high-rate pond operated at a retention time of 5 days was pumped into a 17 m^3 channel. This channel was used as the flotation unit. Harvesting was performed as a batch basis operation.

The separation started when the channel was full and when the dissolved oxygen level was above supersaturation (usually above 12 mg/ℓ . At this stage the inflow was discontinued. The flocculation of the algae and the flotation was performed *in situ.* A paddle wheel kept the channel mixed and the algae in suspension. Flocculation was performed either by adding a freshly prepared solution of 0,4 to 0,8 % alum at a dose of 20 to 120 mg/ℓ or by using the polyelectrolyte Zetag 57 in a 0,1 to 0,2 % solution, at doses varying from 3 to 10 mg/ℓ . A combination of both chemicals at a dose of 60 mg/ℓ alum and 2 mg/ℓ polyelectrolyte was also applied. Different ways of distributing and mixing the chemicals were tested, namely -

(a) by adding to the inflow of a submerged pump which was pumping the water of the channel before the paddle wheel,

(b) adding near a flash-mixer placed before the paddle wheel, and

(c) adding through a diffuser submerged in the channel. The diffuser consisted of three perforated pipes, as wide as the section of the channel, connected to a manifold and submerged at different depths, thus ensuring a good distribution of the flocculant. The flocs form after the slow mixing action of the paddle wheel and float downstream, where they are intercepted by an inclined plate placed immediately before the diffuser.

At the beginning of the experiments the floating algal blanket was pushed into an outlet channel, perpendicular to the flow. Later, when the polyelectrolyte was used and larger flocs with a firm consistency were obtained, the float was removed by means of a net. Samples of clarified water were taken by immersing stoppered bottles and opening them at about 25 cm depth. From these samples total suspended solids and chlorophyll a were determined. Occasionally NH_4 and NO_3-N, PO_4 and COD were determined on filtered samples by means of an automatic analyser. The same determinations were performed on the channel water before flotation.

4. RESULTS

The results of several runs comparing different ways of adding the polyelectrolyte to the channel are shown in Figure **5**. The use of the diffuser showed the best results, being also the simplest alternative. Therefore, it was used in the follow-up experiments.

The effect that an increase of the dose of polyelectrolyte at 2,5 mg/ℓ intervals had on the total suspended solids (TSS) removal by *in situ* autoflotation, is seen in Figure 6. A dose of 8 mg/ℓ was used for chemical cost calculations.

Table 1 shows some of the results obtained by different combinations of dissolved oxygen (DO) levels and polyelectrolyte doses. When the DO was high and the polyelectrolyte (10 mg/ℓ dose) was not well dispersed in the channel, the percentage of removal was low (52,9 %). When the same dose of polyelectrolyte was added through a nozzle or through a diffuser, the removal efficiency increased (70 % and 91 % respectively). When autoflocculation of the algae was observed, the dose of polymer could be reduced (3 mg/ℓ) and removal was still 78,3 %. This indicates that substantial chemical savings could be attained if autoflocculation could be optimized and produced at will.

Aluminium sulphate produced flocs too fragile for manual harvesting. Aluminium sulphate and polyelectrolyte (60 mg/ℓ and 2 mg/ℓ respectively) did not attain a good removal (65,7 %) in spite of being accompanied by a DO of 13,8 mg/ℓ.

Algae Harvesting

The most successful results obtained by *in situ* autoflotation are comparable to the average of 15 runs using a dissolved air flotation unit. However, more runs have to be performed with *in situ* autoflotation to check its reliability. It should also be noted that the percentage of solids in the float of the dissolved air flotation is higher than that obtained by *in situ* autoflotation, but when thickening on a screen is allowed, this difference diminishes.

5. DISCUSSION

Autoflotation has been described and used in South Africa for the removal of algae from maturation and facultative ponds, using alum as a flocculant[11 21]. It was shown that the dissolved oxygen concentration had to be above 14 mg/ℓ and that alum dosage could be reduced by adjusting the pH [23]. Dissolved air flotation was generally applied for algae separation using alum as a flocculant[8 9 18]. The autoflotation process was aided by air through a Venturi installed in the delivery line to the flotation unit, achieving a unit without recirculation[20]. Further simplification was achieved by replacing alum with a polyelectrolyte, which is not pH sensitive[22]. Recently, autoflotation was used for harvesting microalgae from high-rate ponds treating animal wastes [24]. The autoflotation was performed on a circular tank and the ratio of flocculant to air-dried solids was 1,09 for alum and 0,37 for the polymer Purifloc C31[24].

In situ autoflotation as presented in this paper has been shown to be effective in removing microalgae from pond effluent treating municipal waste water. The ratio of polymer Zetag 57 to algae removed is 0,04 to 0,05. The DO concentration was reduced during a 60 m flotation by 1 to 2 mg/ℓ, thus at 200 mg/ℓ the oxygen/solids ratio was between 0,005 and 0,01. This ratio is lower than the 0,02 A/s ratio usually used for DAF designing purposes. This lower ratio can be attributed to the small size of nascent O_2 bubbles and their quick entrapment by the floc formed in seconds by the polymer.

Algae Harvesting

It is not clear if the supersaturated oxygen is bound to the flocculant-solid phase by electrical charge phenomena or if it is entrapped in the floc structure which is rapidly formed (seconds) when using Zetag 57. Since the flocs formed with the polymer are relatively large, the probability of floc-bubble contact is greater than with the small flocs formed with alum[15].

To remove 88 to 90 % of the chlorophyll a using Zetag 57 at a dose of 8 mg/ℓ and at a cost of R5,70/kg results in a cost of chemicals of R0,05/m^3 of effluent treated. Expressed in other terms, the cost of the chemical required to upgrade the quality of 5 000 m^3 effluent containing 200 to 250 mg/ℓ TSS, and obtaining as a by-product 1 t of algae (dry weight basis), is R228.

It was shown that the dose of polyelectrolyte could be reduced when small flocs produced by autoflocculation were present in the effluent. When the autoflocculation process is better understood and when it is possible to obtain autoflocculation at will, the dose of polyelectrolyte may be considerably reduced. One can also envisage the possibility of manipulating autoflocculation and autoflotation in order to further reduce costs.

The collection of the algal float in *in situ* autoflotation is performed manually, in order to reduce equipment costs and maintenance. If required, a mechanical collecting device can easily be installed. The algal flocs produced with the polyelectrolyte, contained from 4 to 6 % solids and dewatered easily on a screen to 8 to 10 % solids.

The level of oxygen required for *in situ* autoflotation should be related to the temperature of the water, and should be 2 to 3 mg/ℓ above the saturation value.

The possibility that a certain part of the flocs may be precipitating to the bottom of the channel has still to be investigated.

Algae Harvesting

The disadvantage of *in situ* autoflotation is that its operation is limited to a couple of hours per day. Considering the amount of equipment saved together with the lower amortization and maintenance costs, this drawback is amply compensated for since *in situ* autoflotation satisfies the requirement of simplicity and ease of operation which is necessary for small communities, and which is not satisfied by DAF[8].

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TABLE 1

EFFECT OF DIFFERENT COMBINATIONS OF DISSOLVED OXYGEN LEVEL AND POLYELECTROLYTE DOSE ON THE *IN SITU* REMOVAL OF MICROALGAE FROM POND EFFLUENT

DOSE	DOSE POLYELECTROLYTE	TSS INFLOW	TSS OUTFLOW	% REMOVAL	% REMOVAL CHLOROPHYLL a	NH_4-N	NO_3-N	PO_4-P	COD	% SOLIDS IN FLOAT	
14	10	208	98	52,9		2,5	3,9	2,6	68	4,7	
8	10 spray	254	76	70,0	75,7					-	
nm	10 diffuser	370	86	76,7						5,5 (after decant)	
12,5	10 diffuser	120	<10	91,0							
12	3 diffuser	240 auto-flocculation	52	78,3						-	
13,8	2 diffuser + 60 alum	216	74	65,7		14,6	3,6	6,0/3,0	122/62	1,8	
12,4	8 diffuser	208	40	80,7	87,7	13,2	4,8	5,0	134/70		
6,1	8 diffuser			almost no flocs recovered due to low DO						6,6 (net collection)	+ 10 % by decantation
DAF + running unit		284	44,6	83,5	90,5	3,4	3,2	4,4	43	7-8	10-12 %
DAF + filtration unit		284	12,8	95,5	99,8						

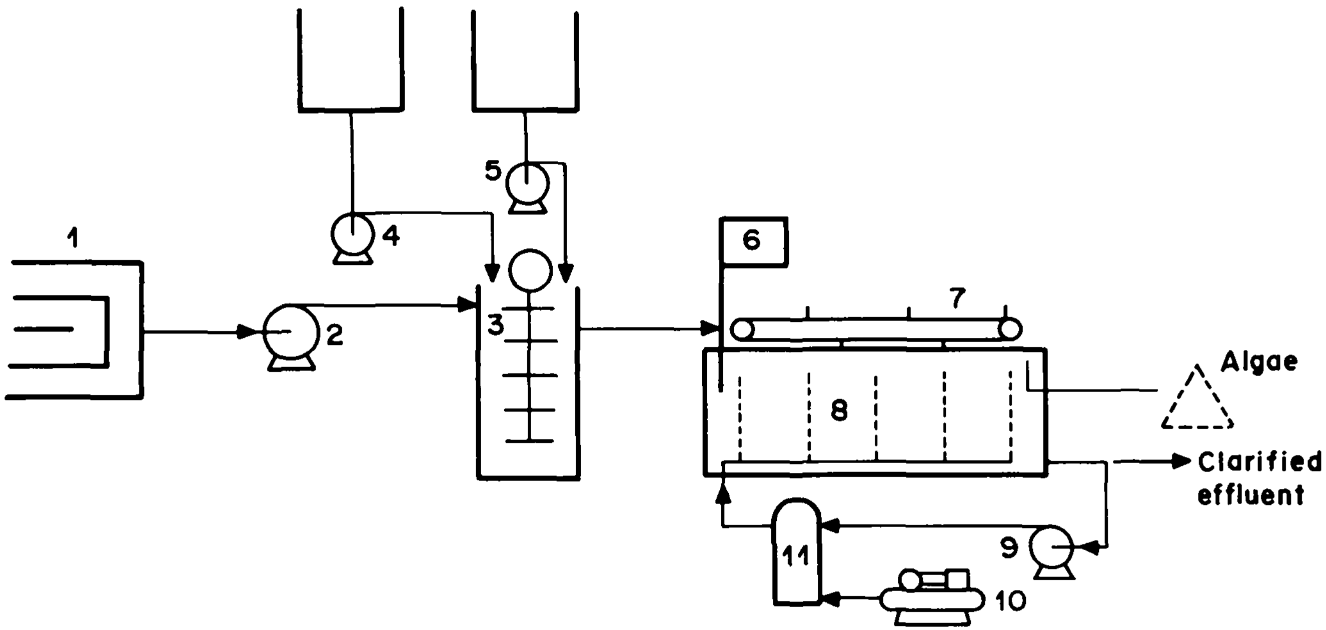

FIG. 1 Dissolved air flotation diagram.

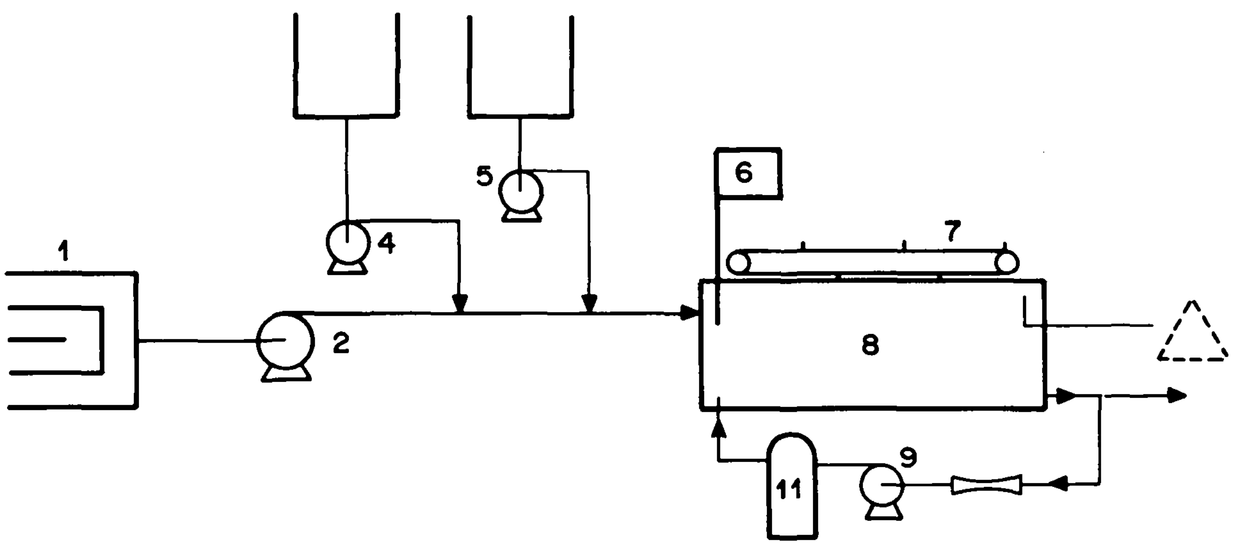

FIG. 2 Modified D.A.F. (without flash mixing and compressor).

1. H.R. Pond
2. Pump
3. Rapid mixing
4. Dosing pump flocculant
5. Dosing pump acid
6. pH meter & Controller
7. Scrapper
8. Flotation unit
9. Pressurization pump
10. Air compressor
11. Pressurization tank
12. Flotation channel

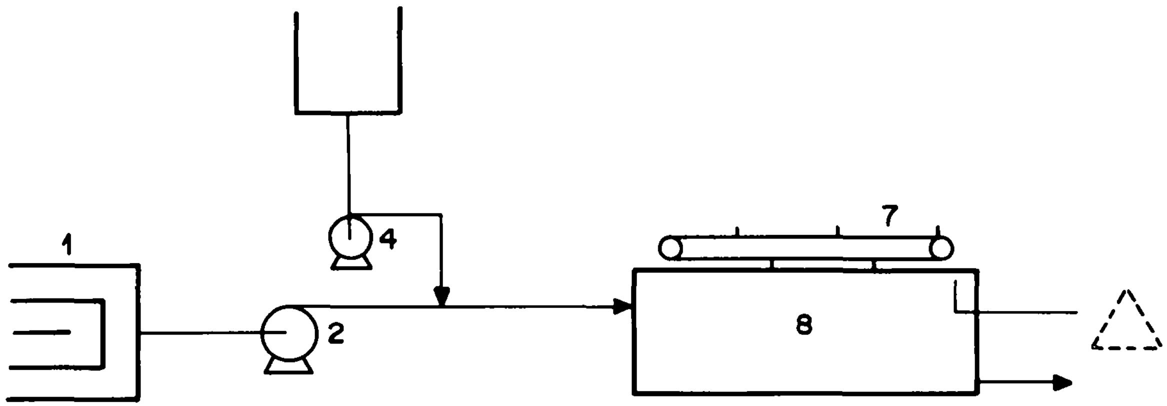

FIG. 3 Autoflotation unit or "Dissolved oxygen flotation"
(Without recirculation pump, pH meter, pH control, pressure vessel and Venturi)

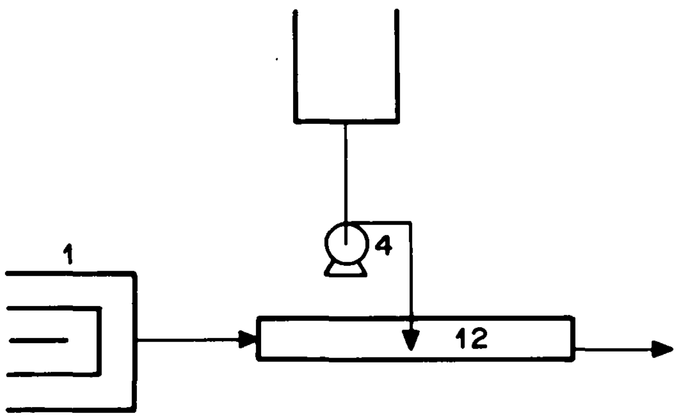

FIG. 4 In-situ autoflotation.

1. H.R. Pond
2. Pump
3. Rapid mixing
4. Dosing pump flocculant
5. Dosing pump acid
6. pH meter & Controller
7. Scrapper
8. Flotation unit
9. Pressurization pump
10. Air compressor
11. Pressurization tank
12. Flotation channel

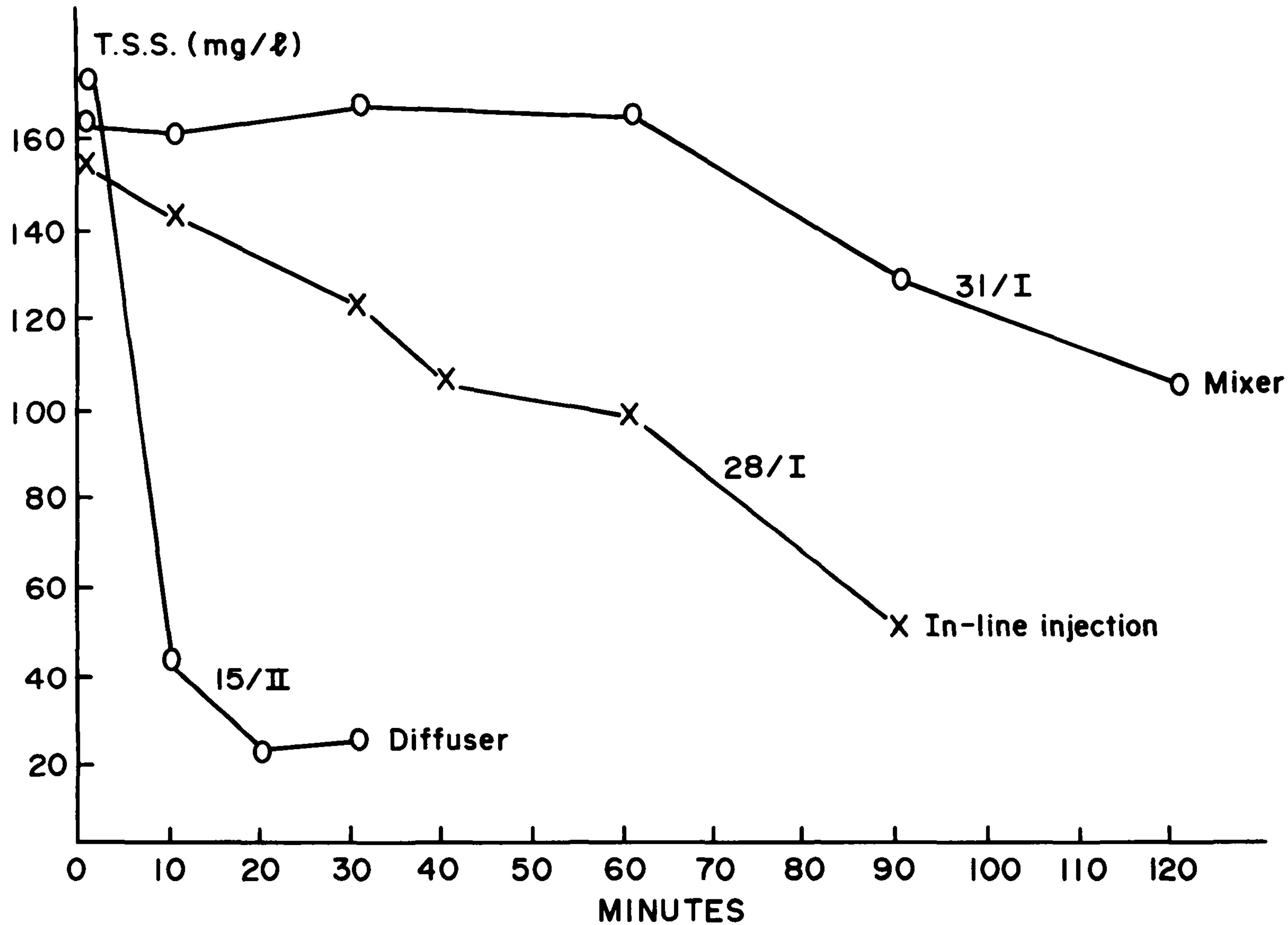

FIG. 5 In-situ autoflotation of microalgae. Effect of 5mg/ℓ polyelectrolyte on TSS removal. Daspoort 1983.

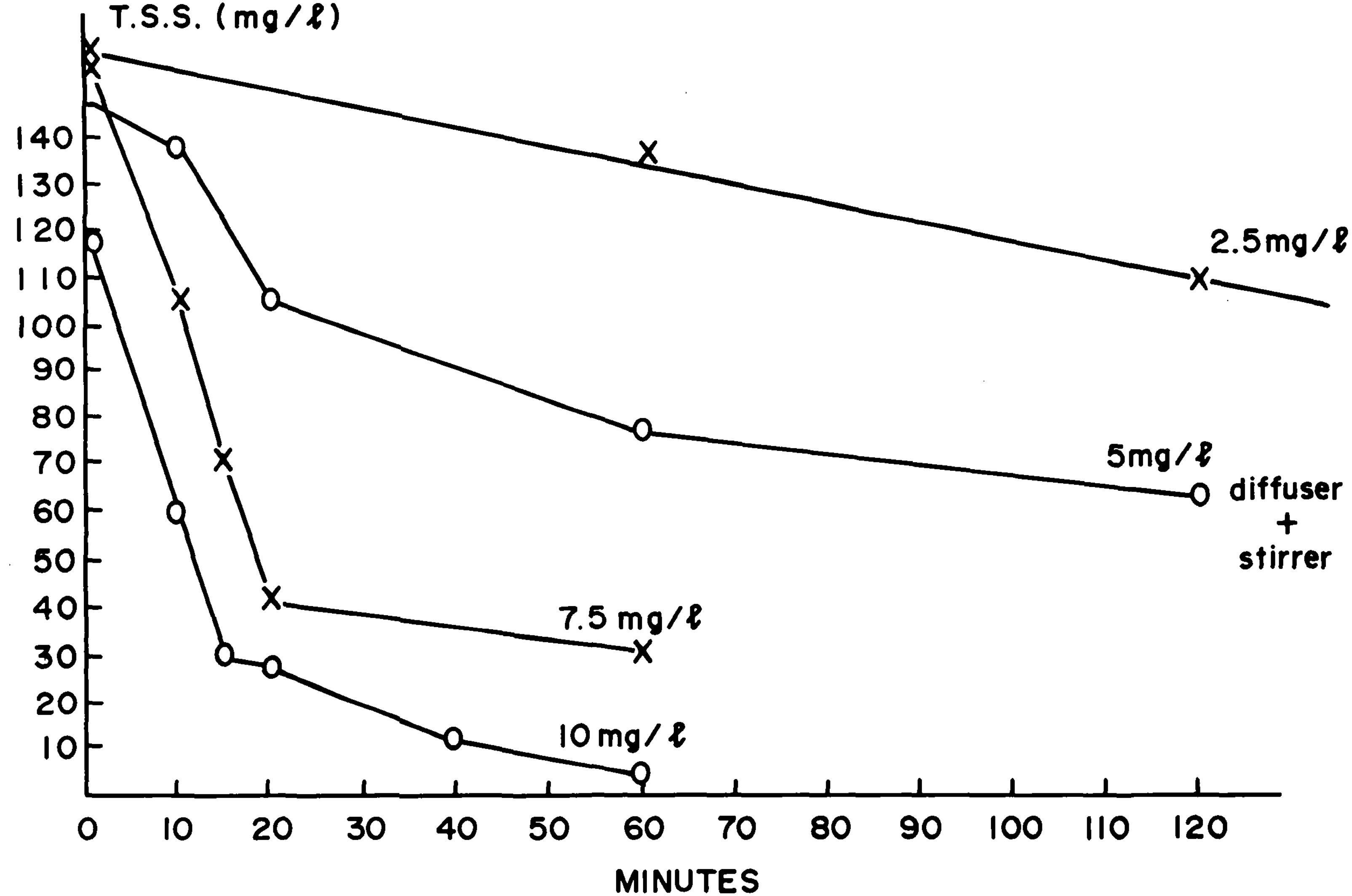

FIG. 6 In-situ autoflotation of algae. Effect of polyelectrolyte (Zetag 57) dose on the removal of TSS. Daspoort 1983.