INTERNATIONAL RESEARCH AND DEVELOPMENT PROJECT ON SLOW SAND FILTRATION

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TECHNOLOGY TRANSFER IN THE SSF PROJECT

Report of an International Evaluation Workshop

The Hague 2-4 September 1991

IRC International Water and Sanitation Centre, The Hague, The Netherlands
NEERI National Environmental Engineering Research Institute, Nagpur, India
CINARA Centro Inter-regional de Abastecimiento y Remoción de Agua, Universidad del Valle, Cali, Colombia
PWA Provincial Waterworks Authority, Bangkok, Thailand

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The centre aims to ensure the availability and use of appropriate knowledge and information in the water, sanitation and environment sector in developing countries.

Activities include capacity development for information management, exchange of available knowledge and information, and development and transfer of new knowledge on priority issues. All activities take place in partnership with organizations in developing countries, United Nations organizations, bilateral donors, development banks, and non-governmental organizations.

Emphasis in programme activities is on community-based approaches including rural and low-income urban water supply and sanitation systems, community participation and hygiene education, the roles of women, maintenance systems, rehabilitation and environmental management.

The multi-disciplinary staff provides support through development and demonstration projects, training and education, publications, documentation services, general information dissemination as well as through advisory services and evaluation.

For further information about IRC and the SSF project:

IRC
P.O. Box 93190
2509 AD The Hague
The Netherlands

Telephone : +31 - (0)70-33 141 33
Telefax : +31 - (0)70-38 140 34
Telex : 33296 irc nl
Cable : Worldwater, The Hague

For further information on the country projects:

NEERI - National Environmental Engineering Research Institute
Nehru Marg, Nagpur 440-020
India

Telephone : 09-91-712-53 66 56
Telefax : 09-91-712-52 38 93

PWA - Provincial Waterworks Authority
72 Chaengwattana 1, Laksi
Bangkhen, Bangkok
Thailand 10210

Telephone : 09-66-2-55 11 020
Telefax : 09-66-2-55 21 547

CINARA - Centro Inter-Regional de Abastecimiento y Remoción de Agua
Universidad del Valle-Facultad de Ingeniería
A.A. 25157
Cali, Colombia

Telephone : 09-57-23-39 23 45
Telefax : 09-57-23-39 32 89

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LIBRARY, INTERNATIONAL REFERENCE
CENTRE FOR COMMUNITY WATER SUPPLY
AND SANITATION (IRC)
P.O. Box 93190, 2509 AD The Hague
Tel. (070) 814911 ext. 141/142
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Preface

The International Research and Demonstration Project on Slow Sand Filtration (SSF) has been under way since 1976. Sponsored by the Department of Research and Development of the Netherlands Ministry of Foreign Affairs, it was initiated by institutions in Colombia, India, Jamaica, Kenya, Sudan and Thailand, and coordinated by the IRC International Water and Sanitation Centre. The resulting activities in Colombia, India and Thailand have provided extensive experience of SSF in tropical conditions, and have led to new insights into the design, operation and management of the technology.

A fundamental feature of the project has been the capacity-building element. In each country, a national organization has been responsible for operation of the SSF research and management of the demonstration projects. IRC has provided advice and technical support where requested, and has facilitated the gathering of technical information from international sources and the exchange of ideas and experiences among the participating countries. The learning process has thus helped to develop expertise within the project countries, which is now available to advise and support more widespread application of SSF.

Consistent with this concept of encouraging the sharing of information among the developing country experts, the Ministry of Foreign Affairs adopted a similar approach in its 1991 evaluation of the SSF Project. Rather than employing independent evaluators to examine the SSF programmes in each participating country, IRC was asked to convene a Workshop for the project leaders, to enable them to undertake a self-evaluation and critical appraisal of the whole programme. The evaluation would, at the same time, provide a valuable opportunity for exchange of ideas and combined analysis of problems and prospects.

The Workshop was held at the IRC offices in The Hague on 2-4 September 1991. Participants were:

Ms S. Buaseemuang	Provincial Waterworks Authority (PWA), Thailand;
Mr G. Galvis	CINARA (Centro Inter-Regional de Abastecimiento y Remoción de Agua), Universidad del Valle, Colombia;
Dr R. Paramasivam	NEERI (National Environmental Engineering Research Institute), India;
Mr T.K. Tjiook	IRC International Water and Sanitation Centre;
Mr J.T. Visscher	IRC International Water and Sanitation Centre;
Mr P. de Lange (part of meeting)	Ministry of Foreign Affairs;
Mr K. de Wilde (moderator)	Consultant;
Mr B. Appleton (Rapporteur)	Consultant.

This report presents the principal findings of the meeting, together with a brief summary of the experiences on the SSF Project in Colombia, India and Thailand.

PRINCIPAL CONCLUSIONS

1. NEW STATE-OF-THE-ART IN SLOW SAND FILTRATION

The slow sand filtration (SSF) demonstration projects and subsequent operational plants provide extensive and well-validated data on the performance of SSF schemes over a wide range of conditions not previously considered within the scope of SSF. With simple and economic pretreatment, SSF plants can be used to treat river water with high levels of contamination _ even very "flashy" tropical rivers. This makes the technique economic and appropriate for a high percentage of the rural population and small urban centres which depend on river water as their source. Water supply planners and designers thus have a new and attractive option, which is not a panacea for all water quality problems, but nevertheless has great potential.

2. SCOPE FOR COMMUNITY-BASED MANAGEMENT

Simplifications to the design and operation and new equipment and techniques for monitoring plant performance have made it possible for the upkeep of SSF plants to be under the control of the beneficiaries. With the right motivation, training and support, local communities have proved well able to manage SSF plants, and willing to pay for the dependable service provided as a result.

3. MULTIPLE BARRIER AGAINST HEALTH RISKS

Conventional treatment of surface water supplies (chemicals, rapid filtration, chlorination) depends heavily on the final chlorination stage to remove disease-carrying organisms. If chlorination fails, the water is unsafe. Remarkable results from Colombia show that the successive stages of pretreatment, slow sand filtration and chlorination each contribute significantly to the removal of bacteria and other disease threats. If chlorination fails, the level of contamination will not pose a serious threat to human health.

4. FLEXIBLE IMPLEMENTATION METHODOLOGIES

With the experience from the SSF project, it is possible to apply an integrated approach to treatment plant design, operation and maintenance. This includes maximum community involvement, full prior pilot testing of proposed pretreatment and SSF designs on a representative range of waters, training and support of local operators/caretakers, and development of monitoring, surveillance and plant maintenance guidelines. The technology is flexible enough to permit adjustment if necessary later. Although SSF design appears simple, to ensure successful implementation and avoid failures, designers and implementors need sufficient experience with the technology or good advice.

5. CONTINUING COST SAVINGS

Innovative pretreatment systems like the dynamic roughing filters, and improved drainage arrangements with consequent reductions in the design thickness of the sand-bed, have already led to significant savings in the capital and running costs of SSF plants. Pretreatment has also made possible the recuperation of earlier slow sand filters, which had been taken out of service because of frequent clogging. Continuing research and development is indicating that further savings are possible with improved pretreatment technologies.

6. CAPACITY BUILDING

The SSF project itself has contributed to the development of national expertise in SSF technology in the participating countries. This aspect is especially important as, in any transfer of technology, problems arise in adapting to local conditions and these are best solved through local expertise. The development of CINARA into a flourishing centre for sector research, development and support is an outstanding example of what can be achieved through commitment and a rigorous focused approach. A massive momentum has been developed in Colombia, to implement SSF on a wide scale, and there are demands for spread of the technology into neighbouring countries. Capacity building is an important element at the community level too. Each SSF project includes enhancement of the community's own capabilities to manage its water supply, with spreading benefit into other development activities.

7. LEARNING THROUGH EXPERIENCE

The project showed that it is much more effective to learn from the experience of others when the transferred technology or approaches can be readily tried out in local conditions. By combining the information and advisory support provided through IRC with applied research in the laboratory and in development and demonstration plants, the SSF project established a good setting for technology transfer which can also be applied to other issues (see paragraph 7.3).

WORKSHOP REPORT

1. TECHNICAL FINDINGS

1.1 The viability of slow sand filtration (SSF) as a water treatment process in tropical conditions has been demonstrated conclusively. Laboratory and field tests in India, Colombia and Thailand have provided evidence of the effectiveness of SSF for treating a variety of surface and ground waters. Combined project and international experience has shown SSF to be particularly efficient in removing a wide range of substances, including organics, suspended solids, viruses, protozoa, faecal coliforms, true colour, iron and manganese. The project has verified that SSF has advantages over alternative treatment processes such as chemical water treatment, particularly in rural areas and small to medium-sized towns. Further information on SSF technology is presented in Annex 1.

1.2 In a number of areas, the SSF project has advanced current thinking on the design of slow sand filtration systems. The simpler designs established in the project save on costs without diminishing performance.

- The size and grading of sand has been shown to be less critical than indicated in current text books, and considerably less critical than for alternative filter systems. The project research has enabled clear criteria to be set for sand size and grading. These generally mean that local river sands can be combined to provide suitable filter media, rather than having to transport sand from further afield to meet the previous tight specifications. Use of local sand can have a significant impact on both capital and running costs.
- Improved technical knowledge of the SSF process has led to design adaptations which permit the use of a shallower sand bed and drainage system to achieve the same filter performance. Initially, it was shown that a minimum bed depth of 0.6m was sufficient to achieve adequate performance. That implied an initial bed depth of 0.9-1.0m. Application of innovative drainage systems has helped to achieve a further filter height reduction of some 0.3m. Again, the effect on costs is considerable.
- Slow sand filters can cope with higher levels of contamination in the inlet water than was previously thought possible. On the basis of evidence already available, SSF can cope with COD levels in the raw water up to 20mg/l. Pretreatment trials currently under way suggest that it will be possible to increase this limit even further if slow sand filters are combined with pretreatment units.

1.3 Controlling the rate of filtration is the key to adequate functioning of slow sand filters. The conventional method of outlet control can be impractical in some village water supplies. A simple method of inlet control has been developed and shown to work just as effectively as outlet control. It makes SSF even more suitable for community-based management.

A flow rate of 0.1-0.2m/h is the norm for treating surface water, to give a reasonable time (several weeks, or months) between cleaning operations. The project trials have shown that increasing this rate to 0.3m/h is quite acceptable for one or two days, for example while another filter is out of service for cleaning (in Europe, filters are sometimes run at rates as high as 0.6m/h, but these are the final stage of a series of treatment processes, and they receive water with a very low suspended solids level). In India, the possibility of increasing the filtration rate temporarily has meant that there is no longer a tendency to design SSF plants with a "standby" provision, resulting in considerable cost savings.

1.4 As with other biological water treatment processes, intermittent operation of slow sand filters does not produce a good filtrate. If dependable power and/or fuel supplies are not available provision of a raw water balancing tank may be considered, providing that site conditions permit a continuous gravity feed from the tank to the filters. Alternatively, the filters may be operated at a declining rate until the inlet flow is restored.

1.5 In some countries, filters have been covered as a way of combating the effects of algal blooms. Tests in India suggest that the shading may not always be effective in terms of enhanced filter performance. Careful pilot testing is recommended before any decision is taken to cover filters.

2. PRETREATMENT DEVELOPMENTS

2.1 The initial phase of the SSF Project made it clear that slow sand filters were effective in tropical conditions for treating surface waters with turbidities up to 20NTU. However, increasing contamination and seasonal fluctuations mean that many surface water resources in developing countries have much higher turbidities for at least part of the year.

2.2 In India, a number of SSF plants benefit from upstream storage of the raw water in bankside reservoirs, which produce raw water with low turbidities. Others are preceded by river bed filtration. A rapid appraisal of two of these showed that this system can be effective in reducing turbidity, COD and faecal coliforms, though the data are limited, as at the time of the tests the river had a naturally low turbidity due to failing monsoon rains.

2.3 To extend the application potential of SSF to more turbid waters, the project initiated tests on various pretreatment methods. The tests have demonstrated that simple and cost-effective pretreatment systems can be designed, and that these have the potential to remove turbidity, bacteria, and colour. Fears that desludging might prove a problem turned out to be unfounded; the dynamic roughing filters and upflow filters under development in Colombia have simple and effective desludging systems which can be readily operated by local scheme caretakers.

Addition of pretreatment stages gives SSF an additional important advantage over other treatment options - a multiple barrier against gross pollution or health-threatening bacteria. A typical Colombian plant involves an intake unit with a dynamic roughing filter, an upflow pretreatment filter, a slow sand filter and, where feasible, chlorination. The combination is highly effective in removing contaminants, but even if one process fails, the others ensure that serious bacterial contamination will not get through into the public water supplies. This contrasts with the heavy dependence on disinfection to protect supplies treated in plants involving, for instance, rapid gravity sand filters.

It was the Colombia trials which demonstrated for the first time the highly effective removal of bacteria and colour in pretreatment processes. Work is continuing, to provide comparisons of different pretreatment techniques and match them with slow sand filter designs to optimise costs and establish a multiple barrier against disease-causing organisms. Adequate pretreatment may, for example, allow a higher rate of filtration to be used in the slow sand filters.

3. DESIGN GUIDELINES AND DEMONSTRATION PLANTS

3.1 Following the initial research in India, NEERI, in collaboration with IRC, developed design guidelines and standard component designs and drawings for SSF plants suitable for village-level operation in developing countries. The concept of standby units was eliminated, and a standard formula enabled designers to estimate the most suitable number of filter beds for any given area.

3.2 The findings formed the basis of demonstration projects, intended to confirm the application of SSF in full-scale plants. The four demonstration projects in India were monitored over 1-2 years. They validated the guidelines and led to improved procedures, for example for dealing with the problems of intermittent operation. They also provided valuable cost information, demonstrating the competitiveness of SSF over other water treatment options. The demonstration projects provided a very good opportunity for designers, implementors and O&M staff jointly to learn from experience and yielded valuable feedback for further development/adaptation.

3.3 Updated standard SSF component designs and drawings are now included in the Manual on Water Supply and Treatment of the Central Public Health and Environmental Engineering Organization (CPHEEO Manual), which is the key document for design engineers in India. The design guidelines are now also included in the official Indian Standards.

3.4 In recent years, more than 250 SSF plants have been constructed in India, mostly to the new design principles, which means a saving in construction cost of 10-20% per plant. NEERI is receiving regular requests for detailed information on the design and operation of SSF plants.

3.5 The evolution of the SSF project in Colombia differed from that in India, in that there was no initial research phase. Two demonstration plants were constructed by the Instituto Nacional de Salud, but their remote location meant that regular monitoring and fault-finding was difficult and that they could not easily be used for receiving visitors or for training purposes. To overcome the lack of research data and operational experience, CINARA, with advisory support from IRC, initiated a research programme and constructed several pilot scale SSF plants, benefiting from project experiences in India and other project countries. Subsequently, new demonstration projects were constructed close to the CINARA base. These offered additional learning experiences, alongside the pilot plant research and an extensive literature review.

3.6 Pretreatment was a priority, as Colombian rivers have high seasonal fluctuations in water quality. Successful demonstration of SSF with pretreatment led to pressure for rapid replication. Through an open discussion of both achievements and mistakes, CINARA has been able to convince implementing agencies to control the pace of development to match implementation with proven technological development and motivation and training of local communities.

3.7 The two initial remote demonstration plants are still working, but they cannot be monitored frequently. A further 20 plants have been built with CINARA advice, of which 7 are being regularly monitored. About 30 more are planned.

3.8 In Thailand, two demonstration plants were built, one including a pretreatment system. Though these plants are performing well, only three more have been built since, out of a total of more than 40 new plants. Because it takes up a large part of their engineering education, Thai engineers still favour rapid sand filtration and chemical treatment.

4. COST ADVANTAGES AND SCOPE FOR SSF APPLICATIONS

4.1 Comprehensive data from India, Colombia and Thailand demonstrate that SSF is the most economic option for treating surface water over a range of community sizes, and will usually be the right option for rural communities. There is also evidence that SSF running costs are within the affordability range of most low-income communities, and that potential users are willing to pay for the technology, when properly motivated. The two plants in Thailand, for example, have been operating for some eight years, completely run and financed by local communities. Similar data, though over a shorter period, are available from Colombia. There is clearly widespread scope for implementation of appropriately designed SSF plants in many countries. In India, for example, some 20% of rural settlements have to depend on surface water as the only reliable source. In Colombia, more than 90% of human settlements have populations below 30,000.

4.2 The design changes referred to in Section 1 mean that SSF plants based on project-generated design criteria are some 20-30% less costly than conventional SSF designs.

4.3 In Colombia, locally manufactured components are used for all the plants, resulting in appreciable cost savings without reducing performance.

4.4 Further cost reductions are expected, as pretreatment processes are better understood and costed. Conservative assumptions about pretreatment systems have been made in the current estimates, and these are already being shown to be capable of reduction.

5. DISSEMINATION OF FINDINGS

5.1 As the results of the demonstration projects have progressively confirmed the important role that SSF could play in future water supplies, promotional activities have been undertaken to spread that message to implementing agencies within the project countries and further afield.

5.2 The impact of dissemination efforts has been quite successful in India, where promotional activities included seminars/conferences and orientation-cum-training programmes, lectures to participants of training courses for waterworks operators and supervisors, and the incorporation of a revised chapter on SSF in the Government of India Manual on Water Supply and Treatment. A major breakthrough came with the organization of a two-day conference of Chief Engineers in charge of implementation of activities for the Technology Mission on Drinking Water. Feedback to NEERI showed that this led to active investigation of SSF applications in several Indian States. Subsequent orientation programmes for practising engineers from interested states kept up the momentum.

5.3 In Colombia, the activities of CINARA and the impressive performance of the demonstration projects have built up a demand for SSF implementation backed by national government co-financing support for community water projects. CINARA's promotion of controlled progress, with detailed analysis of local conditions and community willingness to participate ahead of any project implementation, has been accepted by implementing agencies. This ensures that SSF implementation will grow at a measured pace, matching the rigorous technical development of the process for varying local conditions. Meanwhile, publication of the demonstration plant results and dissemination of information through international meetings has sparked interest in other Andean countries. CINARA and IRC are presently considering requests for cooperation with interested agencies in Peru, Ecuador, Bolivia and Venezuela, and anticipates early initiation of SSF research and demonstration programmes in at least some of these countries in the near future.

6. HYGIENE EDUCATION AND COMMUNITY PARTICIPATION

6.1 The SSF projects in India, Thailand and Colombia have involved varying degrees of community participation and hygiene education.

6.2 In India, where it is well established that government agencies have the responsibility for providing water supplies according to national guidelines, the community contribution to projects generally involves only the provision of land for the necessary structures and some financial contribution. The SSF demonstration programmes specifically included a hygiene education component, and the project management committee included health department staff experienced in the application of KAP (knowledge, attitudes and practice) studies.

6.3 In Thailand, community participation and hygiene education are integrated into water supply programmes. PWA is moving away from community involvement in project construction, favouring financial contributions to allow more control over construction standards. Hygiene education has been shown to be successful in convincing participating communities to change from convenient free canal water, and to pay for treated water from the SSF plants.

6.4 Community participation in planning and building SSF plants and community management of installed schemes are fundamental parts of the Colombian approach. Communities are involved in the determination of all project activities, have to commit themselves to paying at least full operation and maintenance costs, and, in an innovative and highly effective initiative, are trained and motivated to monitor the performance of their SSF plants. This last aspect of the Colombian SSF project demonstrates the essential distinction between SSF and alternative water treatment processes for community water supplies: the inherent simplicity of SSF, enhanced by design changes produced during the project, make it well suited for community management. Not only does this have considerable impact on the sustainability and costs of community water supplies; it also contributes enormously to building the capacity and the confidence of communities to look after other aspects of their community affairs.

7. TRAINING AND CAPACITY BUILDING

7.1 Sustainability is a critical issue in community water supplies. There has been a high rate of failure in the past on all types of water systems, particularly those which depend on regular supplies of chemicals, or on highly skilled operators to keep the system functioning.

7.2 A major focus of the SSF project has been on the operation and maintenance needs of the plants and the consequent need for training and capacity building to ensure their sustainability.

Appropriately designed slow sand filtration is highly suited to community-based management, with considerable savings in cost when compared with other treatment technologies. SSF project experience confirms the need to ensure that communities, and particularly scheme caretakers understand the SSF process. The simplifications in flow control and in the design of individual components facilitate this process.

In collaboration with the partners in the different project countries, IRC has developed a manual for SSF caretakers and comprehensive guidelines for the operation and maintenance of SSF plants.

Communities can also be productively involved in the surveillance process, monitoring plant performance, collecting samples, etc, and this has a marked impact on the sustainability of the installed facilities. The Colombian SSF plants have shown how the capacity to monitor plant performance raises the confidence and status of plant caretakers and has a highly motivating effect throughout the community.

Simplified testing equipment, including kits for community use, has been designed and tested in Colombia.

Analysis of the operation and maintenance needs of SSF plants has highlighted the scarcity of O&M data on existing water supply schemes. In many cases, there is little or no record of plant performance or maintenance needs.

7.3 The SSF project approach enabled participating organizations to learn from experience and to become experts themselves in applying the technology in the widest sense, adopting fully integrated approaches. The hands-on experience gained on the demonstration projects means that they can now help others to get to grips with community-based approaches to SSF application. The development character of the project also meant that mistakes were made _and allowed to be made. The project team then developed their own solutions, with outside help provided only where necessary. This led to some innovative ideas, like the gooseneck valve introduced in Colombia.

7.4 The demonstration plants are also playing an important part in the training of plant caretakers and the building up of knowledge among implementing agency staff. Participants in NEERI training courses for waterworks operators and supervisors visit nearby demonstration plants for hands-on experience of SSF technology. CINARA uses the seven regularly monitored demonstration plants as focal points for structured training in all aspects of SSF for members of its regional working groups, which include implementing agency staff. This ensures that future implementors have a solid grounding in the technical principles of SSF technology and in its operation and maintenance needs.

7.5 As a direct result of the SSF project, CPHEEO training courses for waterworks supervisors and operators have a core component on slow sand filtration. SSF now features prominently in the curriculum of courses at the University of Cali in Colombia. With support from IRC, IHE, Delft, has added a strong element on SSF in its training courses for water and environmental engineers.

8. ORGANIZATIONAL/INSTITUTIONAL FINDINGS

8.1 While the choice of institutional arrangements in any particular country will clearly be linked to the way that the water and sanitation sector is organized, some general lessons can be learned from the SSF project experiences. In particular, the management of the project has to be such that information generated is made widely available within the country concerned. That means taking account of the national sector decision-making and information dissemination processes.

8.2 Even a technology as old as SSF requires adaptation to suit conditions in a particular country or region. Just as the technological adjustments have evolved from project experience, so too have the institutional lessons. Initial activities in Colombia were coordinated by the Instituto Nacional de Salud, a sector agency, but staff's involvement with their "own" programmes limited the access of other agencies to the information generated. Since the project coordination was taken over by CINARA, there has been a considerable improvement in accessibility to information and advice. Work is now being undertaken in collaboration with some 100 different organizations.

8.3 To a large extent, the comparatively successful dissemination of SSF messages in India and Colombia can be attributed to the linkages between the lead research agencies (NEERI and CINARA, neither of them involved in implementation of water projects) and the sector implementing agencies. The highly structured system of design standards in India provided an opportunity for NEERI to use its mandate (support for all state water programmes) to bring SSF principles to the attention of all state water and public health engineers through the operational manual and the national standards. CINARA, which was born as a direct result of the SSF project, has been careful to involve implementing agencies in all its working groups and its governing council, while preserving its own research mandate. The importance of this last point is that CINARA has been able to influence the implementing agencies in regard to the pace of development, ensuring that there is not a rapid rush to implement projects until the SSF process has been properly tailored to local conditions, and the community has been prepared.

8.4 There is a continuing need for the experience and expertise of the project participants to be made available to new users. Operational problems can then be remedied promptly, rather than leading to an abandonment of the technology through misconceptions about its sustainability. In Colombia, for example, when some full-scale plants produced poor quality filtrate, CINARA staff were able to trace the problem to inadequately washed sand which had been placed in the lower part of the bed.

9. THE ROLE OF IRC

9.1 IRC's role as Coordinator of the SSF project was widely appreciated by the national lead agencies. Aspects of the project coordination which were particularly commended included:

- Each agency benefited from access to wider international experience made available through the sharing of written reports, which were critically reviewed by IRC as part of the information exchange process.

- From the very beginning _ the 1973 meeting of representatives from a wide range of institutions in developing countries, at which the need for a project was identified _ national agencies and national professionals remained in the driving seat of each project, but had access to technical support/advice on request.

- Through IRC, the Dutch Government support was provided in a flexible way, responsive to emerging issues in the demonstration and development projects. This helped considerably to tune the projects to the local setting and needs.

- Promotion of SSF through press articles and technical papers gave the project prominence with governments and donors. This in turn helped to raise the standing of the lead agencies and the national programmes. Preparation of technical papers also helped to consolidate information generated by the project, and to undertake critical reviews of the findings.

- IRC's strong promotion of the multidisciplinary approach helped in getting this approach adopted by sector implementing agencies.

- Specifically in the Colombia project, IRC's support is seen as having had a major influence on the establishment of CINARA, which has now become an undoubted success as a sector research, development and support centre.

9.2 On the negative side, there is a feeling that the initial attempt to set up SSF projects involved too many countries. This stretched IRC's resources and limited the attention that could be given to each project in the critical start-up phase. On the other hand it was recognized that critical review of the early stages prevented unnecessary mistakes and led to the halting of projects which had demonstrated little chance of successful technology transfer. As a result, the three programmes which continued through three phases were those with the greatest scope for successful SSF development.

10. TECHNOLOGY TRANSFER

10.1 The SSF project has enabled some conclusions to be drawn about the approaches most likely to contribute to successful transfer of technologies and methodologies from one country or region to another. Most of these conclusions have general application, though all can be traced back to experiences (good and bad) with the SSF project.

10.2 Research and Development (R&D) is a key issue in technology transfer, yet it commonly receives only a low priority in developing country programmes and in donor support. Unless there is an early emphasis on solving the problems likely to arise during implementation, operation and maintenance, technological innovation cannot be expected to succeed. R&D is an important capacity building activity; experience with operational problems can enrich university curricula at the same time as stimulating the updating of operating manuals and training programmes of implementing agencies.

10.3 Technologies and methodologies need to be adapted to local conditions, not simply imported and implemented unaltered. As well as the technology, implementation procedures and community participation approaches need to be developed to suit individual circumstances. It is therefore important that technology to be transferred is backed by a comprehensive information package, including performance data and design criteria. Too often, developing countries find themselves struggling to introduce recommended technologies with inadequate information and little guidance on how to interpret what information is available.

10.4 Organizations in recipient countries or regions must be able to experiment with new technologies in a systematic way. For this, they need financial support and access to technical advice.

10.5 Introduction of new technology will only be accepted if it meets a perceived need, or has the potential to lead to significant cost savings.

10.6 During the introduction of transferred technology, agencies should take the opportunity to build up experience and technical capacity to guide the subsequent implementation, operation and maintenance.

10.7 Demonstration projects are essential when a new technology is being introduced. Among the advantages they provide are the validation of performance data and operational instructions, the development of local management capacity, and the establishment of promotional data and facilities. The best demonstration projects cover a variety of situations likely to occur during implementation. They should be managed by a multidisciplinary team which includes representatives of implementing agencies, but there is advantage in the lead agency not being under pressure to implement too rapidly, so that sufficient testing can be carried out in a flexible environment.

10.8 Local capacity building is of the utmost importance. The R&D effort should be led by national agency staff, with any external advisers concentrating on support. The timetable for demonstration projects should ensure that performance data will withstand critical scrutiny, and can be applied widely to varying circumstances. Dissemination of information from demonstration projects should be focused and timely, to provide prompt guidance to implementing agencies and prevent repetition of errors. It follows that results must be discussed openly, recognizing that analysis of mistakes can be more important than broadcasting of successes. Involvement of implementing agencies in the monitoring and management of demonstration projects provides an important communication channel.

10.9 National and international workshops can be an important way of disseminating knowledge and promoting new approaches. They must be designed with a clear purpose and include representatives able to analyse information critically and in a multidisciplinary way. There is also a need to involve all levels of responsibility, including political leaders, in the information chain. In the SSF project, replication was strongly stimulated in both India and Colombia, through involvement of sector specialists and political decision makers in the same fora.

11. FUTURE PRIORITIES

11.1 The SSF project has provided convincing evidence that SSF, with appropriate pretreatment, is a viable and cost-effective option for many rural and periurban communities. This message needs to be communicated widely, so that governments and donors see the technology as a natural choice when surface water is the principal source.

11.2 Pretreatment designs have advanced rapidly recently, and it is clear that further research and development will lead to further economies in the design of SSF and pretreatment plants. This requires more collection and collation of data, and the preparation of guidelines for designers on the way to select and test appropriate pretreatment in particular circumstances.

11.3 Continued data collection and collation is important on all SSF plants. Regular monitoring of plant performance is a prerequisite for satisfactory long-term success, and the data thus collected provide important comparisons with alternative techniques.

11.4 One basic requirement of any treatment technology is that it should operate satisfactorily over a range of flows and inlet water qualities. SSF compares favourably with other options in this respect, and this message needs to be reinforced through the preparation of detailed cost comparisons with technologies such as package treatment plants. The advantages of SSF will be especially apparent at low flows.

11.5 Exchange of information on SSF among developing countries has so far been inadequate. Further external funding is needed to ensure that the positive experiences in the few informed countries can be communicated to others where SSF could yield benefits.

11.6 The suitability of SSF for community management is another strong selling point for the technology. To augment this benefit, further collaborative work is needed on the ways of ensuring effective community management of SSF installations. Studies should focus on the role of water committees, the type of tariff structures, and techniques for mobilizing community monitoring and maintenance.

11.7 There is already a considerable demand for the successful Colombian experience with SSF to be transferred to other Andean countries. CINARA has received requests for assistance from agencies in Peru, Ecuador, Bolivia and Venezuela. Managing the necessary technology transfer will be challenging, and will require external advice and support to raise national capacities to develop and implement SSF programmes.

Country Report - Colombia

The SSF project in Colombia has produced some outstanding results. The performances of pilot and prototype SSF plants initiated as a direct result of the project have established new standards for plant design. Innovative pretreatment techniques have been developed to extend the range of SSF application and substantially improve the overall economics of the process. The Colombian experience has produced a comprehensive and authoritative data base from which SSF plants can now be designed with confidence. It has also created a launch pad for further research into pretreatment techniques and community management approaches which will make the SSF process even more cost effective.

Most of the accomplishments of the programme have been achieved since 1985. The initial stages of the SSF project were markedly less successful. That transformation holds many lessons for future research and development/technology transfer projects.

Background

The first two demonstration SSF plants were built in Colombia in 1980. There was no preliminary R&D phase; the plant design was based on early data from the research in India and on text books which primarily relate to developed country experiences. The sites chosen for the plants were not easily accessible for regular monitoring. They were selected by the initial national lead agency, Instituto Nacional de Salud to serve specific water demands, rather than for their R&D potential. Though the plants performed satisfactorily, monitoring was spasmodic and so the demonstration potential was limited.

Following a National Workshop in 1982, researchers in the University of Cali recognized the scope for wider application of SSF in Colombia. A committed group, already seeking ways to improve national water and sanitation technologies, adopted SSF as a research project. A global data gathering exercise was initiated, to provide the technological background for further development of the process in tropical conditions. It was this research group which later evolved into CINARA (Centro Inter-Regional de Abastecimiento y Remocion de Agua), the non-governmental agency which has become a leading authority on SSF and associated pretreatment technology.

Project achievements

Initial data gathering and adaptation of SSF designs to local conditions lasted until early 1985. It was combined with awareness raising among municipal water agencies in Colombia and establishment of information networks to ensure that data would be shared among all those who might have a future interest. The move into full-scale SSF applications was strictly controlled. The group began with small pilot plants, stepped up the monitoring of full-scale plants, and established a rigorous data base on performance linked to water quality, flow rates, etc, before sanctioning more prototypes. Workshops in 1985, 1986 and 1987 promoted SSF as a developing technology. Mistakes were openly discussed (the University base was an advantage here, as public accountability was not an inhibiting factor), and all agencies were encouraged to contribute to the search for solutions. The advantages of SSF over other treatment technologies were already becoming apparent, and creating a growing demand for rapid replication. The group has resisted this pressure to move ahead quickly, insisting on meticulous preparatory studies and proven performance in pilot plants before each full-scale plant has been built.

Important new elements were added to the programme in 1987, resulting in innovations such as the inlet control system for flow regulation and alternative underdrain systems. Following review of SSF experiences in Colombia, India, Europe, the USA and Brazil, carried out with support from IRC, pretreatment was identified as an essential need for Colombian surface waters. At the same time, a socio-economic dimension was added. Earlier attempts to involve communities in project preparation and eventually operation and maintenance had limited success, principally because of the lack of sociologists with sufficient appreciation of the scientific/technical issues involved. Training and dialogue between sociologists and technical staff overcame these communication problems.

Results from both new initiatives have been highly encouraging. CINARA's R&D on pretreatment has led to designs of SSF-based treatment trains able to cope with surface waters which are considerably more turbid and contain more polluting load than was thought feasible in the past. Plants can thus be designed to cope with the flashy rivers which are typical of tropical regions, and which can play havoc with physical-chemical treatment processes. It is fair to say that the Colombian SSF project is establishing new rules on the scope and design of SSF plants. The project also set out to ensure that any SSF plants built under its auspices would be sustainable. Design modifications and community mobilization components in all project schemes have ensured that benefiting communities can pay for and manage the installed facilities, with a minimum of technical backup from the implementing agencies. CINARA reports a remarkable degree of self-motivation in the communities which have benefited from the SSF project. Not only do community members carry out their own monitoring and surveillance, they have in some instances themselves called for increased water tariffs, to ensure that the resources were available for operation and maintenance.

CINARA's insistence on a measured pace of project implementation has meant that there is a pent-up demand for as many as 300 SSF plants requested by a wide range of communities. Up to August 1991, some 20 plants had been built in Colombia, of which 7 are being closely monitored. CINARA itself has grown into an internationally recognized research institute with a purpose-built research facility capable of housing some 80 staff, and equipped with extensive testing facilities and computerised data handling systems. To strengthen the transfer process further, Working Groups have been formed in eight different regions of Colombia. Each has prepared two development and demonstration schemes, and so developed the capacity to provide expert advice and information exchange among sector agencies.

Lessons

The success of the SSF project in Colombia can be attributed to a number of propitious elements:

- The project was led by an enthusiastic and proficient team which recognized and promoted the demonstrable economic and social benefits of SSF technology in Colombia
- Because CINARA is not an implementing agency, it was able to control the pace of implementation to match development and proving of the technology. This advantage was fortified by an openness in discussing development successes and failures, and by a positive objective to ensure widespread dissemination of findings
- Every aspect of the R&D has been fully documented and evaluated against experiences in other countries. CINARA's recommendations therefore have a high credibility and authority
- The project has adopted a multidisciplinary approach, ensuring full community participation and commitment
- The support provided by IRC has been available whenever needed, but has taken the form of advice and information, not interference. All decisions have been taken in a partnership approach between CINARA and IRC staff.

Country Report - India

The SSF project in India has had a major impact on the efficiency and economics of slow sand filtration plants throughout the country. Substantially modified design principles, developed in the project, are now incorporated both in the Government of India Manual on Water Supply and Treatment and in two specific standards on SSF issued by the Bureau of Indian Standards. An estimated 250 plants have been constructed to these new guidelines, saving about 10-20% of the capital and running costs when compared with previous designs. The new designs are also simpler to construct and operate. NEERI (National Environmental Engineering Research Institute), the lead agency for the SSF project in India, is receiving regular requests from State implementing agencies for information and advice on installation of new SSF plants.

Background

The first phase of the SSF project was applied research, aimed at verifying the suitability of slow sand filtration in tropical conditions. NEERI experimented with different operating conditions, basing initial designs on a questionnaire survey and literature review. Previous experience of slow sand filtration was primarily confined to Europe and the USA. The researchers tested higher rates of filtration, investigated measures to combat algal growth, evaluated the performance of filters with higher organic pollution in the raw water and the effects of intermittent operation, and compared filters with differing grades of sand, including the cheaper builder grade sand. Encouraging results showed conclusively that SSF was appropriate for tropical conditions, and that design modifications could bring cost and performance benefits.

The next, demonstration, phase saw four plants constructed using the guidelines developed from the applied research. The aim was to convince policy planners and professional engineers of the viability of the process, to identify operation and maintenance needs in village conditions, and to assess the training needs for local operators. This phase also included a community education and participation programme. The demonstration projects were monitored by a Project Management Committee which included engineers from the four participating States' Departments of Public Health Engineering (DPHE). New areas of research emerged from the monitoring, as a result of which NEERI developed a new method of flow control (outlet control) and new operational tools (e.g. turbidity meters), and initiated investigation of pretreatment methods for high turbidity waters. The demonstration phase resulted in improved procedures for design, operation and maintenance of SSF plants, which were incorporated in modified guidelines.

The third phase was dissemination of the project findings to as wide an audience as possible. National and International Workshops were used to promote the technology and compare experiences, and NEERI developed special training course on SSF for engineers and waterworks supervisors. This phase also saw the incorporation of SSF guidelines in the design manual and national standards, and the validation of cost benefit comparisons demonstrating the advantages of SSF over alternative treatment technologies for a range of flow rates.

Project achievements

The NEERI research was of fundamental importance in broadening the field of application of slow sand filtration. By demonstrating that satisfactory filter performance could be achieved with flow rates up to 0.3m/h, compared with text book recommendations of 0.1m/h, the research provided designers with new approaches to filter operation and maintenance which offer considerable financial savings.

Data collected from the demonstration projects and contributed by agencies participating in the project workshops have provided authoritative comparisons of the costs and performance of alternative treatment methods, helping to demonstrate the wide potential of SSF in areas where groundwater resources are not readily available.

The continued involvement of State DPHE engineers in the monitoring of demonstration projects and the dissemination of project findings has been an important promotion tool. SSF featured prominently in a conference of Chief Public Health Engineers from all states in India early in the project, and this was a key factor in raising awareness of the potential for more widespread applications.

NEERI's status as a research institute accessible to all state implementing agencies means that technical advice and amplification of guidelines is available, and there is growing evidence that SSF is being seen as a prime option whenever surface water sources are being used for new community water supplies.

Lessons

- Lead agency NEERI is a highly capable and well-respected institution with considerable influence on design, construction and operation and maintenance standards in the water sector throughout India. It is also a non-implementing agency, and therefore is able to pursue research projects without undue pressure for premature implementation of unproven technologies. This combination of technical competence and political independence is a big advantage in applied research programmes.
- Dissemination and promotion of project findings is a crucial part of technology transfer. Professional staff and policy makers need to be kept aware of emerging recommendations on a regular basis. Workshops can be valuable, but must have a clear focus and participants with a direct interest in the outcome.
- Together, the SSF projects in India and Colombia have demonstrated that text books based on European and US experiences cannot be applied to developing country conditions without substantial testing and modification. They have also shown that focused applied research can produce cost savings far surpassing the costs of the research.

Country Report - Thailand

The SSF project in Thailand has had less impact than those in Colombia and India. Though the two original demonstration plants have performed satisfactorily in comparison with plants using rapid gravity sand filters (RGSF), there has been little replication, and the Provincial Waterworks Agency (PWA) tends to favour RGSF in new plants. This is principally attributed to the fact that Thai engineering training gives more emphasis to RGSF.

Background

When the SSF project began in Thailand, responsibility for rural water supplies rested mainly with the Department of Health, and the project began under the auspices of that agency. As well as the applied research and demonstration elements, the project included a community participation and hygiene education component. PWA was established in 1979 and took over responsibility for new rural water supplies. Existing plants, including the two SSF demonstration projects, could be taken over by PWA, provided they met certain criteria. Urban projects outside the metropolitan area of Bangkok are also now part of PWA's responsibilities.

The demonstration projects have continued to function satisfactorily, but since 1979 PWA has constructed only another three SSF plants. None has any form of pretreatment. A number of other SSF plants are operating in Thailand, and some have been transferred to PWA, with mixed results. Pressure to serve as many people as possible in a short timescale leads PWA engineers to use the standard designs for RGSF plants, rather than experiment with SSF.

Project achievements

Operators working on the SSF demonstration plants recognize the advantages of the system over RGSF _ principally the simpler operation and the fact that no chemicals are needed. However, the operation of other plants is rudimentary, with inadequate operator training leading to neglect of proper sand replacement and other maintenance needs. Generally the plants are overloaded, though in these circumstances they are producing better quality water than some of PWA's RGSF plants, where the treatment process is frequently by-passed and untreated water is being supplied.

A National Workshop on SSF produced positive reactions from the 70-80 participants, but there was little follow-up.

Lessons

- The Thai project has come under the umbrella of an implementing agency subject to political pressure to implement new projects quickly. In these circumstances, there is little opportunity to experiment with alternatives to the standard designs. This reinforces the key message from Colombia and India, that R&D projects are best led by an agency which has influence with implementing agencies, but is not itself directly involved in implementation.
- Promotion and replication of new technology requires dedicated data collection, rigorous analysis of design parameters and performance data, and demonstration of economic and other benefits. Unless this can be achieved, replication may be disappointing
- Transfer of experiences from India and Colombia, particularly in relation to pretreatment needs and overall plant design, may make it possible to revive interest in SSF in Thailand.

Annex I. Description of Slow sand filtration technology

I.1 INTRODUCTION

Slow sand filtration is a very appropriate method for making water safe to drink. In many cases it has proven to be the simplest, most economical and reliable water treatment method. Slow sand filters are particularly efficient in removing harmful organisms such as bacteria and viruses, organic material but also have a good record in removal of iron, manganese, true colour, and suspended solids.

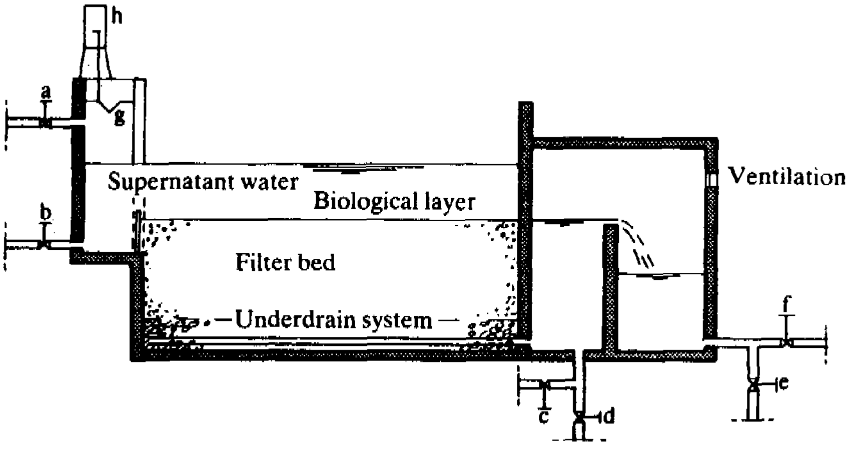
Slow sand filters are an essential element of water treatment works in various European cities, e. g. London and Amsterdam, as well as in many developing countries. The majority of these systems are giving satisfactory results. However, experience also shows that slow sand filtration is not a panacea. Careful analysis of the raw water quality is required to asses whether slow sand filtration is the best choice and what type of pre-treatment process is needed. This analysis also will provide the basis for designing the systems and establishing the essential maintenance requirements, which are crucial to the successful application of this technology. The summary information presented in this annex is largely based on the IRC publication "Slow Sand Filtration for Community Water Supply; Planning, design, construction, operation and maintenance" (Technical Paper No. 24). Information is also included from IRC's Development and Demonstration Programme on Slow Sand Filtration (SSF project) and from a recent project on pre-treatment technology. In the latter project which is carried out by the Centro Inter-Regional de Abastecimiento y Remoci6n de Agua (CINARA), Cali, Colombia in collaboration with IRC, comparative testing is underway of different pre-treatment systems. Good progress has been made in identifying and field testing suitable and simple pre-treatment systems, including: Upflow Roughing Filtration, Downflow Roughing Filtration, Horizontal-flow Roughing Filtration and Dynamic Filtration.

I.2 THE SLOW SAND FILTER SYSTEM

Basically, a slow sand filter consists of a tank constructed of reinforced concrete, ferrocement or stone/brick masonry, containing:
- a supernatant layer of raw water;
- a bed of fine sand;
- a system of underdrains;
- an inlet and outlet structure;
- a set of filter regulation and control devices.

The water flow in a slow sand filter may be controlled at the outlet, or at the inlet of the filter (Figure 1), and the method chosen may slightly affect the structure and the control devices.

In the filter the water percolates slowly through a porous sand bed. During this passage the physical and biological quality of the raw water imporves considerably through a combination of biological, biochemical and physical processes. In a mature bed a thin layer forms on the surface of the bed. This filter skin (schmutzdecke) consists of retained organic and inorganic material and a great variety of biologically active micro-organisms which break down organic matter. When after several weeks or months the filter skin gets clogged, the filtration capacity can be restored by cleaning the filter, i.e. by scraping off the top few centimetres of the filter bed including the filter skin.



a: Valve for raw water inlet and regulation of filtration rate
b: Valve for drainage of supernatant water layer
c: Valve for back-filling the filter bed with clean water
d: Valve for drainage of filter bed and outlet chamber
e: Valve for delivery of treated water to waste
f: Valve for delivery treated water to clear water reservoir
g: Inlet weir
h: Calibrated flow indicator

Figure 1. Basic components of an inlet-controlled slow sand filter[8]

DESIGN CONSIDERATIONS

Design of a slow sand filter plant is an art which needs to be supported by science. This is even more so if one tries to maximise the use of local materials. So it is not surprising to see so many different types of SSF plants throughout the world.

Therefore, design criteria as presented by different authors should clearly be seen as guidelines making it essential to understand the rationale behind the presented values. Table 1 presents some general design criteria as a framework, based on the results of the SSF project and on information from the literature. Following these criteria a suitable plant can be designed provided the raw water quality is appropiate and the designer always keeps in mind that operation and maintenance is the crucial factor in producing safe water and should be facilitated as much as possible.

I.3 OPERATION AND MAINTENANCE

One of the most attractive aspects of slow sand filtration is its simplicity of operation. Provided that the plant has been well designed and constructed, the performance of the filter will depend on the conscientiousness of the operator carrying out the daily routine. As part of the planning and implementation process a maintenance schedule has to be established. This schedule will be different for each plant, as it depends on site specific

Table 1: General design criteria for slow sand filters in rural water supply[8]

DESIGN CRITERIA	RECOMMENDED LEVEL
Design period	10-15 years
Period of operation	24 h/d
Filtration rate in the filters	0.1 - 0.2 m/m^2.h
Filter bed area	5-200 m^2 per filter, minimum of 2 units
Height of filter bed:	
initial	0.8 - 0.9 m
minimum	0.5 - 0.6 m
Specification of sand:	
effective size	0.15 - 0.30 m
uniformity coefficient	< 5 preferably below 3
Height of underdrains including gravel layer	0.3 - 0.5 m
Height of supernatant water	1 m

variables such as: the size of the plant, type of supply and prevailing government norms and regulations. It is very important to draw up the maintenance schedule in co-operation with the operator(s) as this will increase their understanding and commitment.

Proper training and supervision are essential, as the operator will have the responsibility of ensuring that water supplied to the community is safe and attractive in appearance. Particularly in developing countries the training should go beyond technical and management aspects. In these countries the operator should also understand the concept of community participation and health education. Operators can be selected from the village or be employees from the water agency. Formal education is an advantage, but not really necessary to operate most village water supply systems. Other factors such as their being likely to stay in the job for a decent length of time, having the respect of the community, receiving an adequate wage and being trained, are far more important. Next to training it is necessary to give the operator back-up and supervision when needed.

I.4 APPLICABILITY OF SLOW SAND FILTRATION

From the considerations set out in Table 2, it is clear that the application of slow sand filtration should be carefully evaluated when designing a water supply scheme. When surface water is more readily available than groundwater, slow sand filtration will frequently prove to be the simplest, most economical and realible method of preparing safe drinking water.

Table 2: Summary of considerations in slow sand filtration[12]

CONSIDERATION	COMMENTS
Quality of treated water	*Best single process to improve the physical, chemical and biological quality* of surface water. In many rural areas, slow sand filtration combined with pre-treatment may be the only feasible treatment process.
Ease of construction	The relatively simple design facilitates construction from local materials using local labour. Little or no special pipework or equipment is required.
Cost of construction	Construction from local materials using local labour reduces costs considerably. Imported materials and equipment are usually not required.
Ease of operation and maintenance	After a short period of training, local caretakers with little formal education can operate the system.
Cost of operation	Operation costs and energy requirements are lower than for other systems. No chemicals are required.
Reliability	The process is reliable and mechanical failures are minimal. Fluctuations in quality of raw water can be accommodated without disrupting the efficiency of the process.
Cleaning	The cleaning process is simple but somewhat labour intensive. Although the cost may be low, in most developing countries, labour may not always be available at the required time.
Large surface area	A fairly large area is required for the filters: about 0.02 - 0.08 m^2 per consumer. Because of the low cost of land in many rural areas, this may represent only 1 - 2% of total construction costs. However, this may be a constraint in areas where land is scarce.
Rapid clogging of the filter when turbidity is high	High turbidity or raw water may cause rapid clogging of the filters. This may often be overcome by simple pre-treatment.

The slow sand filtration process has the enormeous advantage that it can produce an effluent of low turbidity, free from offensive dissolved impurities and more important, virtually free from harmful entero-bacteria, entero-viruses and protozoan cysts. However, slow sand filtration is not a panacea for all water quality problems in all circumstances.

I.5 MULTI-BARRIER TREATMENT

Slow sand filters have a high efficiency for removing a wide variety of substances, but do not necessarily remove all harmful substances to the extent required. The literature gives a range of treatment efficiencies brought about by slow sand filters for different water quality parameters (Table 3). The reported efficiencies concern filter units operated at hydraulic loading rates ranging from 0.04 to 0.2 m/h at temperatures above 5°C, with a sandbed depth greater than 0.50 m and filled with sand with an effective size between 0.15 and 0.30 mm.

Table 3 Typical treatment efficiencies of slow sand filters[1,5,6,8].

PARAMETER	TYPICAL REDUCTION (%)
Entero-bacteria	90 - 99.9% or even higher, however coliform removal efficiency is reduced under low temperature conditions, increased hydraulic rate, use of coarse filter sand, shallow depth of sand bed, decreased contaminant concentration and just after removal of the biological filter skin;
Cercariae of schistosoma	Virtually complete removal
Protozoan cysts	99 - 99.99% removal even after filter scraping
Turbidity	Generally reduced to less than 1 NTU
Colour	30 - 90% with 30% being mentioned as the most usual efficiency
Organic matter	COD 30 - 70%; TOC 15-30%. Organic matter such as humic acids, detergents, phenols, and some pesticides and herbicides are being removed from 50 to more than 99%
Iron, manganese	Largely removed
Heavy metals	30 - 90% or even higher

The efficiencies indicated in Table 3, however cannot always be fully realised and much will depend on the characteristics of the substances in the water. For example turbidity is usually largely removed even if caused by colloidal material, particularly if intensive biological activity takes place in the filterbed. Nevertheless, Bellamy reports examples of low removal efficiencies ranging from 0 - 40% for SSF plants treating water flowing from clay-bearing catchment areas having a turbidity below 10 NTU, made up of colloidal material and very small particles below 0.5 µm.

Even if high removal efficiencies can be obtained, frequently slow sand filtration alone will not be able to produce a filtrate wich meets consistently the prevailing drinking water quality standards. Raw water sources in many locations are so deteriorated that a combination of treatment processes is required. It was therefore decided to establish pilot experiments in Colombia with different pre-treatment techniques to improve the water quality before it was passed on to the slow sand filters. The results were very promising because the pre-treatment systems did remove a considerable part of the suspended solids, reduce faecal coliforms counts and even true colour levels.

The subsequent construction of full-scale plants confirmed the performance of the pre-treatment systems and the slow sand filters. The systems thus constructed perfectly match with the multi-barrier concept which, as Craun states has a long history and has evolved from water supply treatment practices and experiences. Under this concept, reliance is placed on more than one stage of treatment to produce safe water for the consumers. Together these stages progressively produce a safe and wholesome drinking water. Ideally water low in sanitary risk should be obtained before the final treatment stage which then would be considered as a safety barrier (adapted from Lloyd). Disinfection with chlorine or an alternative disinfectant is normally the last line of defense or final barrier. For disinfection to be an effective safety barrier, the preceding barriers must virtually remove harmful microorganisms and possible interfering substances, so that therminal low-dose disinfection will be an efficient safeguard, wherever it could be continuosly and properly applied.

The multi-barrier concept makes it possible to take advantage of the great potential of slow sand filter technology. It makes it possible to overcome many of the earlier limitations and to meet drinking water quality requirements.

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Other Related titles available for IRC

Slow Sand Filtration for Community Water Supply

(TP 24), 1987

Prepared by J.T. Visscher, R. Paramasivam, A. Raman and H.A. Heijnen
This book presents established information on slow sand filtration, as well as guidelines resulting from ten years experience in demonstration projects in developing countries. It is aimed at project planners, professional engineers and non-technical personnel working with slow sand filtration. Particular attention has been paid to the filter process, the effect of sand diameter, inlet controlled filters, costs, involvement of communities, and operation and maintenance. 164 pages. Also available in French and Spanish (forthcoming).

Partners for Progress: An Approach to Sustainable Piped Water Supplies

(TP 28), 1990

Prepared by IRC
Concise overview of the state of the art in piped supplies for small communities, with a strong emphasis on software and a community-oriented approach rather than on technical aspects. Emphasizes the "partnership approach" where responsibility for projects is shared between agency and user community. The comprehensive text integrates activity supportive subjects like hygiene education and women involvement - by phase - in the project cycle, rather than dealing with these subjects separately. 230 pages.

Slow Sand Filtration Manual for Caretakers

(TS 1), 1985

Prepared by J.T. Visscher and S. Veenstra
This is a manual aimed to provide caretakers of slow sand filtration plants and their trainers with a basic understanding of information on the slow sand filtration process and the roles of the caretaker and the community. Furthermore, it provides detailed schedules for operation and maintenance, cleaning and resanding, record keeping in drawings with limited text. 73 pages. Available also in French, Hindi, Spanish (forthcoming).

Slow Sand Filtration: Guide for Training of Caretakers

(TS 6), in print

Prepared by IRC
This guide serves as basis and guide for instructors or supervisors of training courses on operation and maintenance of slow sand filters for caretakers in developing countries. It consists of a set of guidelines for planning, implementing and evaluating local training programmes and is to be used jointly with the "Manual for Caretakers of Slow Sand Filtration" (IRC Training Series, No. 1). 62 pages.