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International Reference Centre for Waste Disposal
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Ueberlandstrasse 133
CH-8600 Duebendorf/SWITZERLAND

Tel.: + 41 - 1 - 823 52 86
Fax: + 41 - 1 - 823 53 99

The "IRCWD News" informs about the activities of the IRCWD team and is published on an irregular basis.

The lead article of this IRCWD News summarizes the experience of case studies presented at an international workshop on "Roughing Filters for Water Treatment" held in Zurich, Switzerland in June 1992. This workshop, which was attended by more than 100 specialists from over 15 countries, marked the end of a 10-year active phase devoted to an IRCWD research and development project on roughing filtration in developing countries.

We should also like to take this opportunity to inform our readers that although IRCWD has moved to new premises of the Swiss Federal Institute for Environmental Science and Technology (EAWAG), our address and phone number remain the same but ***our fax number has changed to: +41-1-823 53 99.***

CONTENTS

Roughing Filters for Water Treatment

Martin Wegelin and Roland Schertenleib

ABSTRACT:

Roughing filters are used for the separation of solid particles. Similar to slow sand filters, they rely on natural water treatment processes. In Europe, roughing filters are applied in combination with slow sand filters for the artificial recharge of groundwater whereas in developing countries, the filter combination is used in rural water treatment. Since the roughing filter technology underwent a significant development these past 10 years, an international workshop was held in Zurich in June 1992 to enhance information exchange. Four case studies presented at the workshop on roughing filter application in Europe are summarized in this article. The roughing filter technology, further improved in developing countries, is briefly described. This publication intends to enhance the application of the roughing filter technology as a simple, reliable and sustainable water treatment process.

Introduction

The use of roughing filters in water treatment is not a new invention. Gravel and sand are key components in "natural" water treatment processes. This technology was applied long before chemical water treatment methods such as chlorination and flocculation were discovered and utilized. In the last century in fact, with the outbreak of cholera epidemics in Europe, several waterworks discovered the benefits of slow sand filtration and the possibility to pretreat turbid raw water by sedimentation tanks and coarse gravel filters. At the end of last century and the beginning of this century, coarse gravel filtration was extensively used in Europe as reported by Baker (1). As time passed, these roughing filters were virtually converted into rapid or mechanical sand filters. Coagulation in combination with sedimentation and, more recently, direct filtration were introduced as pretreatment methods. Since the early 1960s, the roughing filter technology has been revived in Europe through its use in artificial groundwater recharge plants and, over the last decade, roughing filtration has been thoroughly studied in developing countries and has become a simple and reliable pretreatment method prior to slow sand filtration.

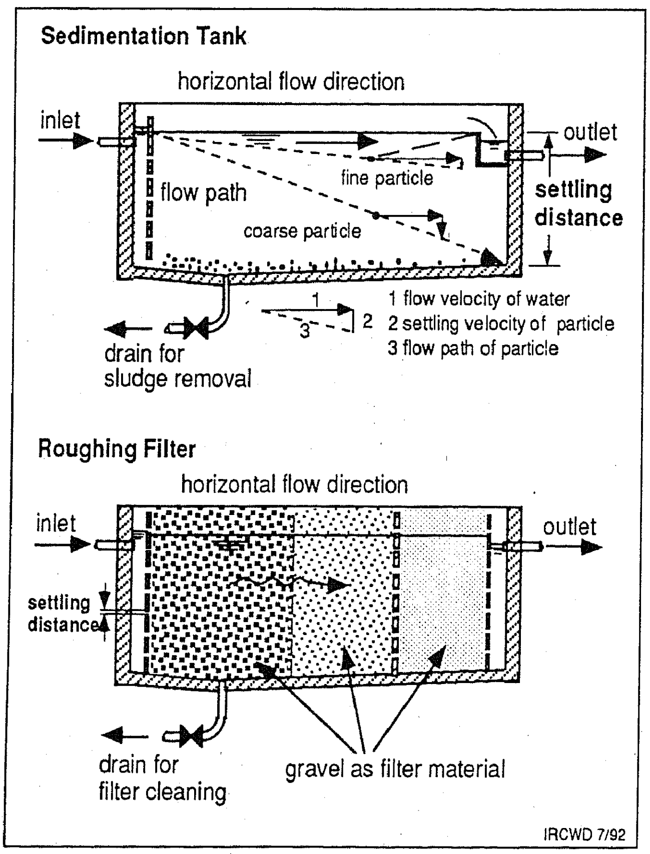


Fig.1 Conceptional Layout of Sedimentation Tanks and Roughing Filters

Roughing filters are mainly used for the removal of fine solid matter which would otherwise impair the operation of slow sand filters. Roughing filters are filled with differently sized filter media - usually 3 gravel fractions ranging from 20 to 4 mm in diameter - and operated either in horizontal or vertical flow direction. Compared to sedimentation tanks, the solids removal efficiency of such filters is significantly increased due to the settling distance which is, in turn, greatly reduced by the filter media as illustrated in Fig. 1. The fine solids crossing an ordinary sedimentation tank have to overcome a vertical settling distance of 1 to 3 metres before reaching the tank bottom. The same solids flowing through a filter will settle on the gravel surface already after a few millimetres. Hence, filtration is a more effective process for solids removal due to the presence of a small pore system and the large filter surface area available for sedimentation, adsorption, as well as chemical and biological processes.

Application in Europe

Artificial groundwater recharge is used in water resources management as a tool to compensate man's impacts on the groundwater. The main quantitative problems arise from the progressive sealing of the ground by settlements and roads or by the overuse of the groundwater resources. Infiltration of polluted surface water or the extensive use of fertilizers and pesticides in agriculture endanger the groundwater quality. Aquifers are therefore often recharged with treated surface water in order to counteract these man-made adverse effects. The surface water is usually treated without the use of chemicals by natural purification processes such as prolonged storage, sedimentation, roughing filtration, and slow sand filtration. Some case examples applying roughing and slow sand filters are briefly described hereafter.

To prolong the filter runs of the slow sand filters installed in the groundwater recharge basins, the **Waterworks of Dortmund**, Germany, revived the horizontal-flow roughing filter process in 1958 as described by Kuntschik (2). The small water level difference between raw water intake and recharge basins called for the installation of pretreatment processes requiring a low demand of hydraulic head. Hence, sedimentation troughs and flat prefilters were constructed as illustrated in Fig. 2. The horizontal-flow roughing filters of 50-70 m length are installed in compacted clay basins filled with coarse gravel of 32-64 mm in diameter. This approx. 1-m deep filter bed is covered by a 40-cm thick layer of 8-16 mm gravel size. The raw water is aerated by cascades, presettled in the sedimentation troughs and infiltrates, as shown in Fig. 3, through the small-sized gravel surface into the horizontal-flow roughing filters. The water flows at approx. 15-20 m/h filtration rate through the coarse gravel

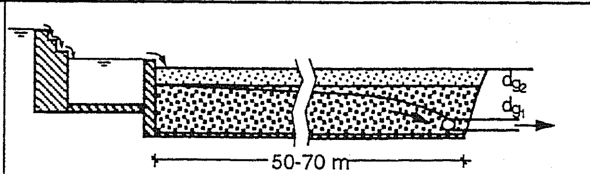
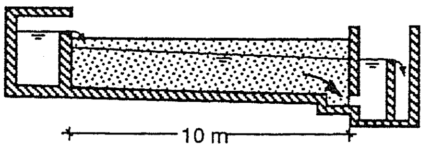
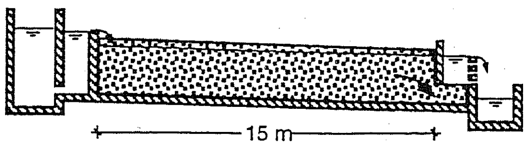
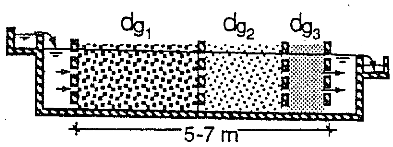
water supply	longitudinal section	filtr. rate v_F	gravel size d_g
Dortmund, Germany		15-20 m/h	d_{g1} = 32 - 64 mm d_{g2} = 8 - 16 mm
Graz, Austria		14-18 m/h	d_g = 8 - 32 mm
Aesch, Switzerland		5-10 m/h	d_g = 50 - 80 mm
Developing Countries		0.5-1 m/h	d_{g1} = 12 - 18 mm d_{g2} = 8 - 12 mm d_{g3} = 4 - 8 mm

Fig. 2 *Layout of Horizontal-flow Roughing Filters in Europe and in Developing Countries*

filter and is collected by drainage pipes at the end of the filter bed. Intermittent operation of the filters prevents the growth of algae and enables aeration of the filter medium, thus enhancing biological treatment processes. Solid matter gradually clogs the infiltration area which eventually moves towards the end of the filter with progressive filtration time. Periodic scraping of the fine gravel layer regenerates the filter and enables filter runs of 10-12 years. The clogged filter layers are removed, cleaned in a transportable gravel washing installation and refilled in the basin. The prefilters reduce turbidity by 85 % and enable to achieve 5 times longer filter runs with the continuously operated slow sand filters. Apart from solids removal, a great variety of processes occur as 90 to 99% of the bacteria are removed, 15 % of the DOC and more than 50 % of the heavy metal concentration.

In Austria, the **Graz Water Supply Authority** has been successfully operating two groundwater recharge plants for more than 10 years. Prior to the construction of the plants, field tests reported by Nickl (3) were carried out with horizontal-flow roughing filters to assess the solid removal efficiency of different filter material. The river water is pretreated in grit chambers and by horizontal-flow roughing filters before it is recharged into the aquifer either by slow sand filter basins, infiltration trenches or flooded fields. The schematic layout of the the horizontal-flow roughing filters constructed in Graz is sketched in Fig. 2. The 10-m long roughing filter tanks are filled with a mixed

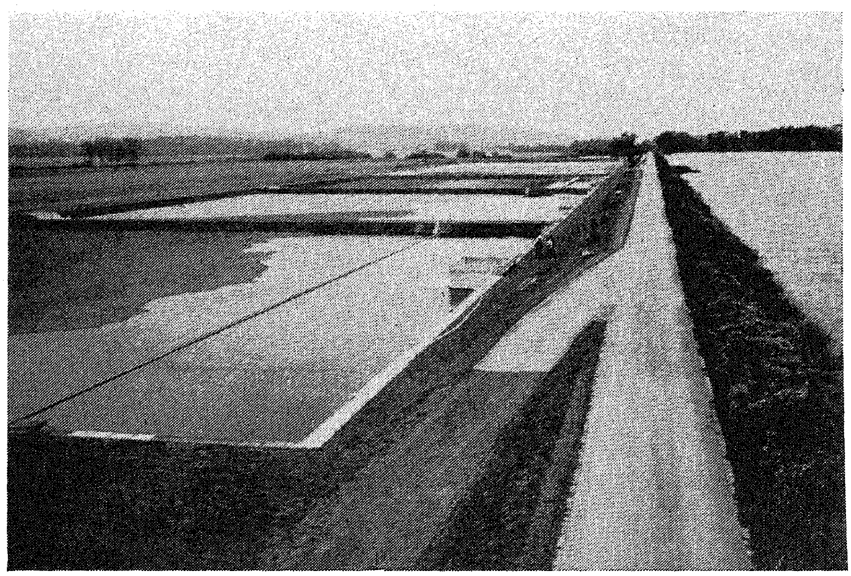


Fig. 3 *Horizontal-flow Roughing Filter in Dortmund, Germany (Photo Waterworks of Dortmund)*

gravel fraction of 8-32 mm in diameter and operated at a filtration rate of 14-18 m/h. Similar to the roughing filters in Dortmund, the presettled water flows through the filter surface located next to the inlet weir into the gravel bed. The prefiltered water was originally conveyed through a bottom outlet into the outlet channel. This special design caused operational problems as the roughing filters were drained completely during operational interruptions and part of the accumulated solids was flushed out of the filter when operation was restarted. This caused rapid clogging of the succeeding filters, especially of the infiltration trenches operated at high rates. A fixed level outlet now prevents complete drainage of the roughing filters. Ramps for dredgers and trucks ease the access to the filter material which is replaced about every 3.5 years. Operation of the groundwater recharge plants is interrupted during periods of high raw water turbidity. The suspended solids concentration in the prefiltered water is always less than 5 mg/l and enables an efficient recharge of the groundwater. This is then supplied to the town without any further treatment or disinfection.

Several groundwater recharge plants with horizontal-flow roughing filters were constructed in Switzerland. The last one, which was installed in **Aesch**, south of the city of Basle, started operation in 1976. The raw water pumped from the river Birs is stored for about 4 hours in a lagoon for coarse solids separation, prefiltered by 15-m long horizontal-flow roughing filters containing a uniform gravel size of 50-80 mm at a filtration rate of 5-8 m/h before being supplied to the confined aquifer through the slow sand filter basin connected to a series of recharge wells. Fig. 2 also shows the schematic layout of the horizontal-flow roughing filters constructed in Aesch. The plant performed well during its first years of operation. However, different operational problems led to a gradual clogging of the recharge wells and endangered the long-term use of the plant. Extensive field tests were carried out over the last 4 years to study possibilities to improve the solid matter separation. The field tests revealed that a conversion of the existing horizontal-flow roughing filters into upflow roughing filters could significantly improve the solid removal efficiency. Furthermore, the running time of the slow sand filter could considerably be prolonged by a dual media slow sand filter using either a layer of small gravel or non-woven synthetic fabric mats on top of the sand bed.

Dual media slow sand filters have also been installed at **Hardhof's groundwater recharge plant in Zurich**, Switzerland. In slow sand filters, which are known to act as surface filters, fine solid matter is retained on top of the slow sand filter bed and develops a skin of low permeability with progressive running time. The so-called "Schmutzdecke" is able to build up filter resistances of over 1 m within a few cm of the sand bed. In recent years, investigations have been conducted to study possibilities of prolonging the running time of slow sand filters. A porous matrix placed on top of the sand bed expands the zone in which fine solids accumulate and, thus, prevents the formation of the impervious skin. Non-woven synthetic fabric mats, tested in the laboratory (4, 5) and now used in full-scale treatment plants (6), could provide such a matrix. The installation of a granular medium is another possibility to protect the slow sand filter and can be considered as a special roughing filter application. As reported by Schalekamp (7), Zurich's water supply had formerly installed a 10-cm thick layer of activated carbon of 0.5-2.5 mm grain size on top of the 3 slow sand filter recharge basins. A 1.2 mm fabric mat protected the activated carbon from blowing away. Infiltrated groundwater from the river Limmat is pumped by a series of wells to the recharge basins which are usually not flooded. With the fabric mat protection and the activated carbon, the slow sand filters had an outstanding filter running time period of 10 years. During this the fabric mat had to be replaced only two or three times. The weather-beaten and costly activated carbon gradually disintegrated and was replaced by a 7.5-cm thick layer of inexpensive gravel 3-6 mm in size in 1990. On this occasion, a 7.5-cm thick layer of soiled top sand was also exchanged for clean sand. After restart of operation, the headlosses in the dual media slow sand filter exhibited the same low values as 10 years ago. Zurich's water treatment plant is a example of a successful and new roughing filter application.

In the presented case examples, filter operation is interrupted during periods of high raw water turbidity. Furthermore, settleable solids are separated prior to roughing filtration since sludge removal from open basins is less troublesome than from filter material. So far, horizontal-flow roughing filters are predominantly applied as natural pretreatment process in groundwater recharge plants. The efficient solid matter removal of these filters enable long slow sand filter runs of at least 6 months. Today, there is a tendency to reduce filter length and filter material size when designing horizontal-flow roughing filters. Furthermore, alternative types of prefilters such as upflow roughing filters or dual media slow sand filters are introduced as new pretreatment processes in groundwater recharge plants.

Application in Developing Countries

The supply of sufficient water is the main problem faced by many water authorities in developing countries. Since groundwater is frequently scarce or not available at all, the population has to rely on surface water, which is, however, exposed to contamination and therefore in need of treatment. The use of simple and reliable water purification processes in rural areas of developing countries is an essential requirement for a sustainable water supply. Since slow sand filtration is a simple and reliable treatment process, it is considered an appropriate technology for developing countries. However, reasonable filter operation can only be expected with raw water turbidities below 20-30 NTU (Nephelometric Turbidity Units) and suspended solids concentrations of less than 5 mg/l. Permanent or seasonally high turbidity is a characteristic of tropical rivers and, therefore, pretreatment of such raw water is required prior to slow sand filtration. For the reduction of turbidity and the removal of solid matter, sedimentation, usually combined with chemical flocculation, is applied in the conventional water treatment technology. Yet, chemical flocculation is a rather sensitive and unstable process. Difficulties with chemical supply and dosage as well as uncontrollable hydraulic problems, such as short-circuiting and "boiling" effects caused by temperature gradients, can significantly reduce the solid removal efficiency of flocculators and sedimentation tanks. Such adverse but often experienced operational conditions allow flocs to escape from the pretreatment step and rapidly clog the subsequent slow sand filters. Hence, the use of chemical flocculation as pretreatment process greatly endangers the operation of slow sand filters and should, if at all, not precede these filters without any other intermediate pretreatment step.

Prefiltration is an alternative and efficient pretreatment process for the removal of solid matter. Roughing filters do not require sophisticated mechanical equipment and are operated at low filtration rates without the addition of coagulants. They are thus an adequate pretreatment technology which is well-adapted to slow sand filtration. Stimulated by the simplicity of the horizontal-flow roughing filter design, the process was tested in the laboratory and in the field by different institutions in developing countries to assess the potential of this filter to reduce highly turbid surface water down to a turbidity level required by slow sand filters. These investigations started about 15 years ago and are described in articles published earlier in AQUA (8, 9).

Compared to the filter layout used in European groundwater recharge plants, the design of horizontal-flow roughing filters applied in developing countries has been modified as shown in Figs. 2 and 4. The coarse and uniform gravel is replaced by finer filter material of usually 3 gravel fractions ranging in size from approx. 18 to 4 mm. The application of smaller filtration rates in the order of 0.5-1.0 m/h allows for a reduction of the total filter length to approx. 5-7 m. Inlet and outlet structures of the horizontal-flow roughing filter are designed for a uniform flow distribution over the entire filter cross-section. High-rate drainage facilities are finally provided to clean the filter by hydraulic flushing.

Through a demonstration programme, IRCWD has been promoting the dissemination of horizontal-flow roughing filters in different developing countries in Asia, Africa and Latin America as illustrated in Fig. 5. In more than 20 countries, over 60 horizontal-flow roughing filters have been constructed during the last 6 years. The technology is designed predominantly for rural water supplies. Since the small filtration rates of 0.5-1.0 m/h require relatively large

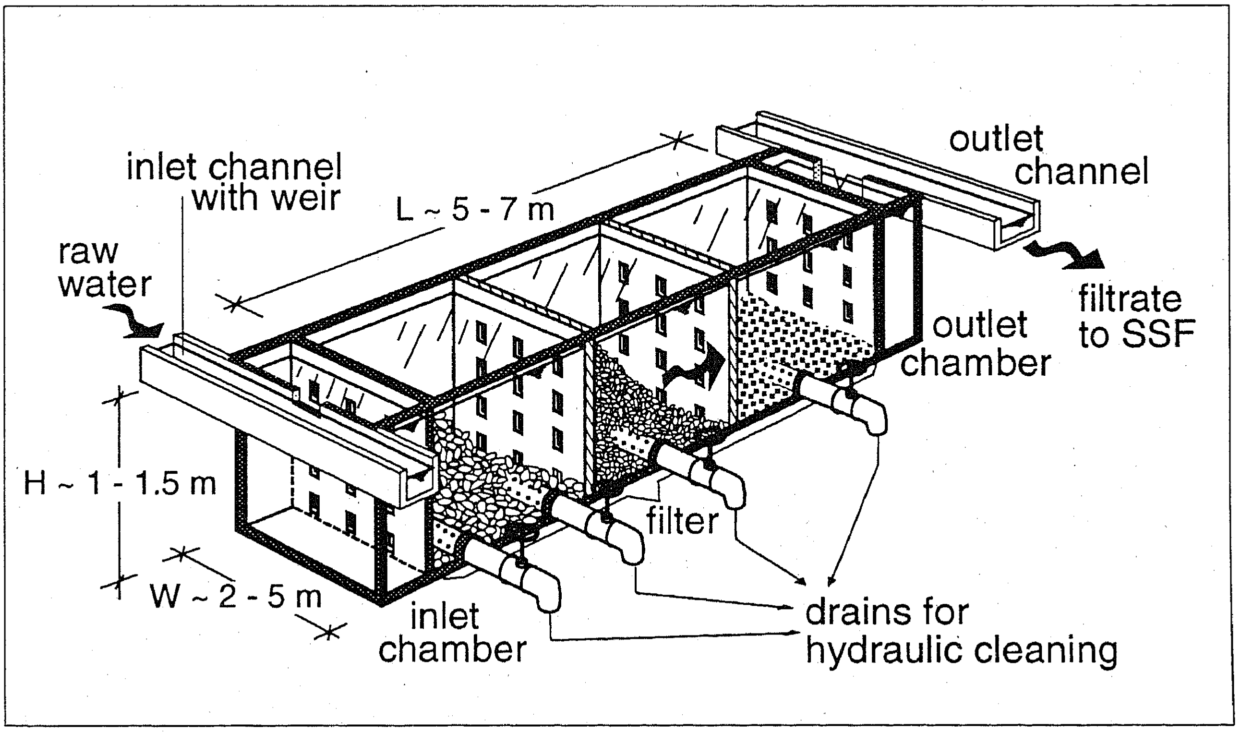


Fig. 4 Layout of a Horizontal-flow Roughing Filter

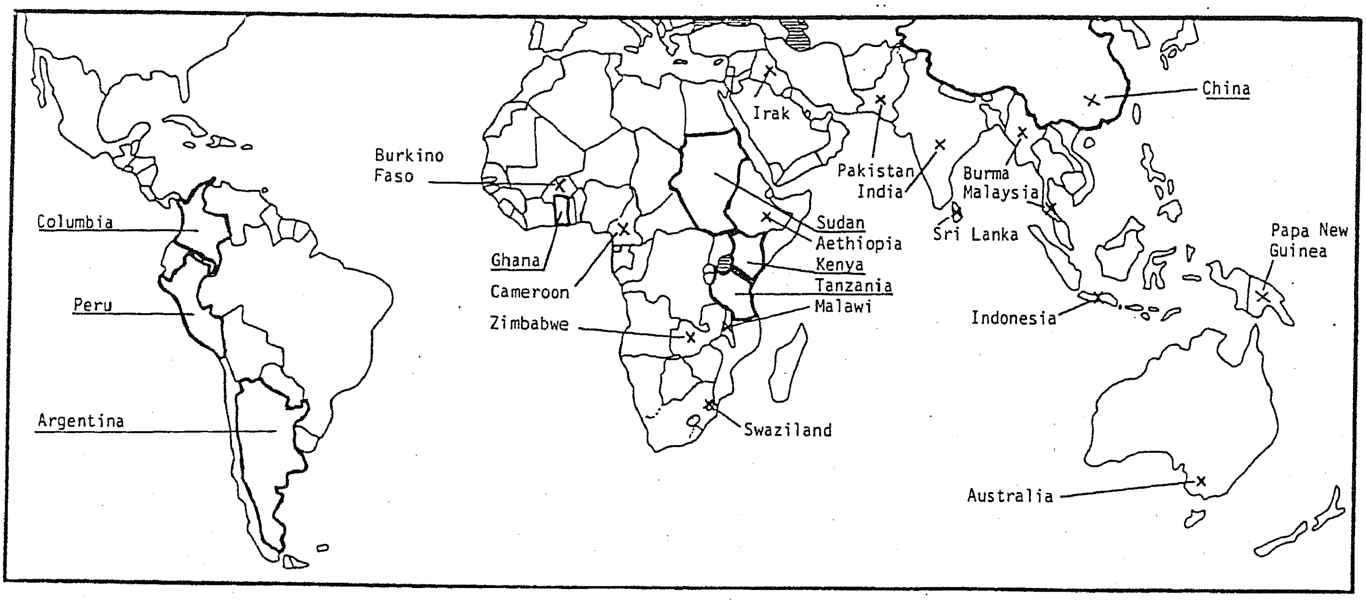


Fig. 5 Geographical Distribution of Horizontal-flow Roughing Filters

installations, the filters can hardly be applied in large urban water supply schemes. Typical design capacities range between 50 and 200 m³/d. However, two examples exceeding this range are briefly described hereafter.

Thirty filter plants with a design capacity of 5-10 m³/d were constructed by the **Blue Nile Health Project** for the Gezira irrigation scheme in the Sudan. The small water supply schemes cover the water demand of rural low-income settlements of 200-500 inhabitants. The raw water flows from secondary irrigation canals through a horizontal-flow roughing filter and a slow sand filter into the clear water tank. A handpump, which is installed on top of this tank, allows the villagers to draw treated water from the installation. The horizontal-flow roughing filter consists of 3 compartments. Due to the scarcity of gravel in the project area, the first two compartments are filled with broken bricks.
The roughing filter with a total length of 4.4 m is operated at a 0.3-0.6 m/h filtration rate. Presedimentation is not required since settleable solids are retained in the irrigation scheme. The raw water turbidity ranges between 30 and 200 NTU in the dry season and 1000 and 2000 NTU in the wet season. Basit and Brown report (10) of a satisfactory filter efficiency since the turbidity of the treated water amounts to 5-10 NTU and the E. coli counts of 200 to several 1000/100 ml in the raw water are reduced to 10-30 /100 ml. The filters are cleaned manually by the villagers twice a year.

Guder's treatment plant in Ethiopia with a 2,200 m³/d design capacity supplies a local industry and a town of presently 10,000 people. The raw river water flows through a treatment system consisting of 2 sedimentation tanks, 6 horizontal-flow roughing filters and 4 slow sand filters. The approx. 21-m long roughing filters of trapezoid cross-section are remarkably constructed in stone masonry walls and plastered according to the low-cost ferrocement technique. The relatively long roughing filters are filled with 4 gravel fractions ranging from 22 to 4 mm in size and designed for a filtration rate of 2 m/h. As reported by Shenkut (11), the raw water turbidity is as low as 30 NTU during the dry

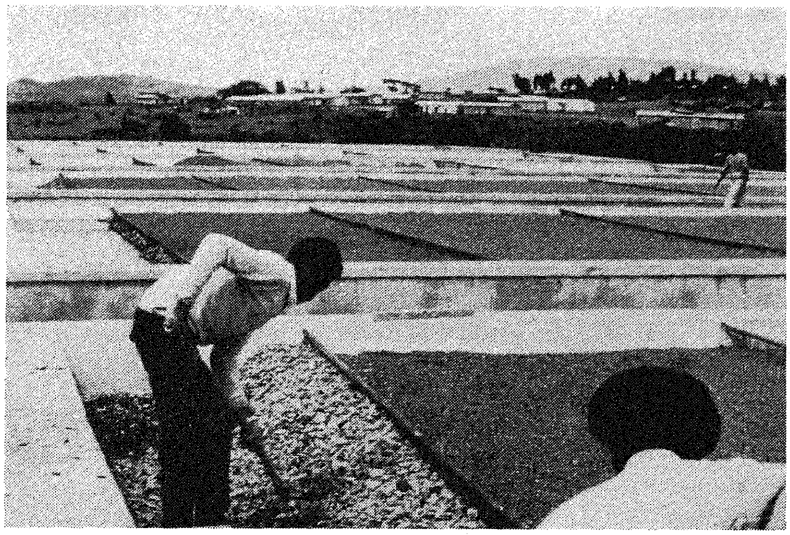


Fig. 6 Horizontal-flow Roughing Filter with 4 Gravel Fractions in Guder, Ethiopia (Photo Ethiopian Water Works Construction Authority, Addis Ababa)

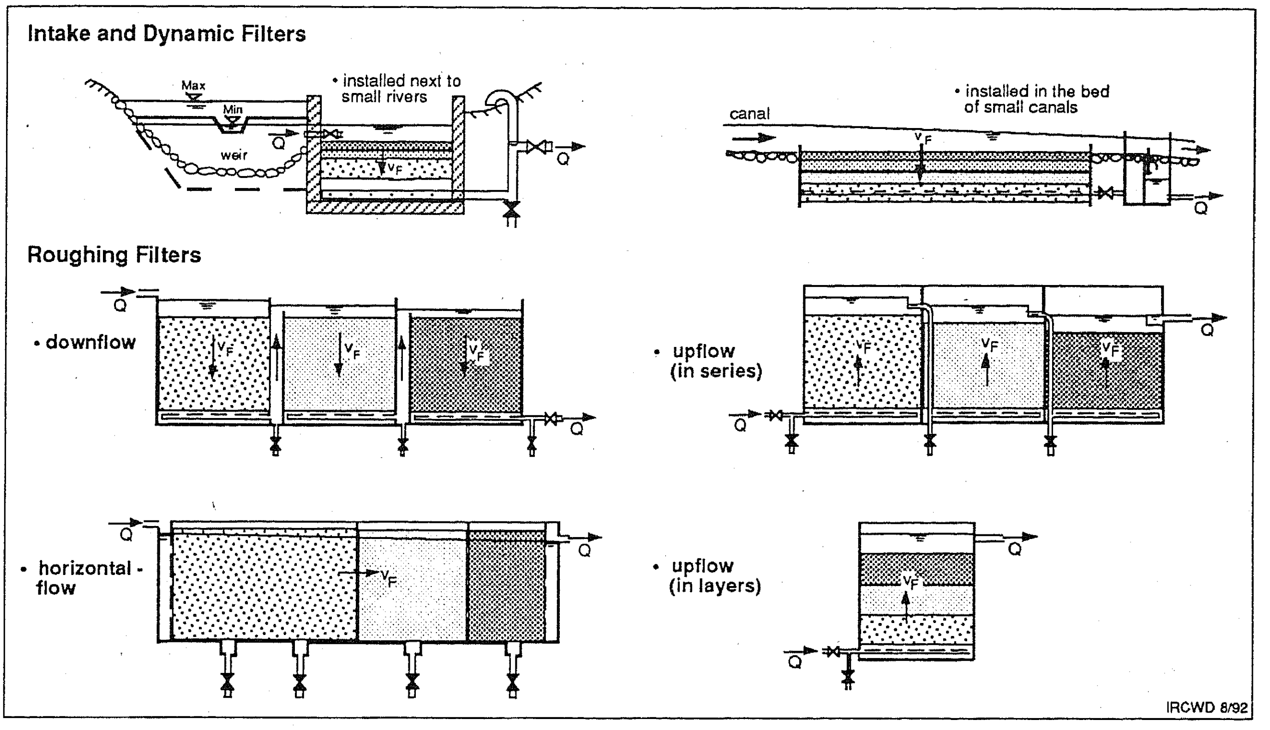


Fig. 7 Layout of Different Roughing Filters

season and rises to over 1000 NTU during the wet season. Heavy rains erode soil into the river that carries then large silt loads over a short period. Operation of the treatment plant is, therefore, stopped during such periods. The treated water turbidity is below 10 NTU in the dry season and fluctuates between 15 and 30 NTU during the rainy season. The growth of algae has started to cause operational problems, particularly during periods of low turbidity. Roofing of the sedimentation tanks and the slow sand filters is, therefore, planned.

New Roughing Filter Designs

The application of prefilters is not limited to horizontal-flow roughing filters as shown in Fig. 7. The different filter types are classified according to their location within the water supply scheme, their main purpose of application as well as their flow direction. Intake and dynamic filters, which often form part of the water intake structure, differ from actual roughing filters that are generally located at the water treatment plant. Roughing filters are further subdivided into downflow, upflow and horizontal-flow filters. Finally, upflow filters are classified according to the way the gravel layers are installed.

An overview of the pretreament processes and current experience is presented in (12). Different roughing filter designs are currently being field-tested on a comparative basis (13) at a research pilot plant in Cali, Colombia, where CINARA (Centro Inter-Regional de Abastecimiento y Remoción de Agua) is studying, in collaboration with IRC (International Water and Sanitation Centre, The Hague) and other international technical institutions and supporting agencies, filter efficiencies and possibilities to simplify the design of the prefilters.

Recent effort to improve the roughing filter technology in developing countries will certainly promote the implementation of these simple and sustainable treatment processes. The multiple barrier concept is considered as an appropriate method for surface water treatment. The use of small prefilter can substantially reduce the solid matter load of the subsequent roughing filters. Hence, pretreatment in 2 stages by prefilters and roughing filters is often the most favourable option with regard to costs and operation. Roughing filters enable adequate operation of slow sand filters even when treating highly turbid surface water. Their simple and reliable operation contributes to the sustainability of water supply systems in developing countries.

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Treatment of Sludges from On-Site Sanitation Systems ("SOS")

(previously named as "SNM", Septage and Nightsoil Management)

Martin Strauss

Since the appearance of IRCWD News in March 1992, the project's first phase has progressed; i.e. areas and sites have been identified where field research on faecal sludge treatment could be carried out in collaborative arrangements with local authorities and research institutions. Two contact and case-study visits were made; one to Ghana and Benin and one to South Africa, Lesotho and Botswana. More visits are planned to South-East Asia. Also, processes and technologies have been identified which are considered potentially sustainable for faecal sludge treatment in developing countries.

Photo: Road Sign to Accra's 200 m³/day Faecal Sludge Treatment Plant at Achimota

In **Accra, Ghana**, septage, nightsoil and latrine sludges have been discharged untreated into an estuary until a few years ago. In 1989 and 1990, respectively, two plants were taken into operation which now treat totally 360 m^3/day of faecal sludges in sedimentation and anaerobic stabilisation ponds. The sludge produced is co-composted with sawdust. In **Cotonou, Benin,** where excreta disposal is exclusively by on-site sanitation systems, a stabilisation pond system has been constructed to treat the city's faecal sludges. Up until now, the sludges were simply disposed of in non-engineered storage lagoons in the coastal tree belt. In **Maseru, Lesotho,** a high percentage of housholds use ventilated pit latrines which are emptied periodically by the city's vacuum tankers. For many years, the sludges have been dumped into trenching grounds outside the town. Lagoons have been recently constructed to store and dry the faecal sludges. These will be applied in 30 cm layers. This thickness should not be exceeded in order to allow thorough drying of the material. In **Gaborone, Botswana**, as well as in other towns in the country, the contents of pit latrines and septic tanks are co-treated with municipal wastewater in waste stabilisation pond systems. In many small towns where latrines have recently been installed in large numbers, no suitable low-cost solutions for treating the sludges from the latrines have been found yet. A large percentage of the black urban population in **South Africa** lives in unsewered township houses. To date, the prevailing strategy for disposing of the faecal sludges in a safe way generally consisted in co-treating them with wastewater in activated sludge treatment plants. Alternative technologies are only recently being evaluated. One rather successful test carried out in Rini near Grahamstown, Cape Province, consists in co-composting bucket latrine sludge and municipal refuse. Unsorted refuse and pre-settled faecal sludge are piled in static, aerated windrows. The 3-week old compost is subsequently sieved and used by the town's garden department. In **Addis Ababa**, Ethiopia, two thirds of the population depend on on-site sanitation systems (pit latrines and septic tanks). 30 percent have no formal sanitation whatsoever. The sludges are dumped into a stream outside the city. As part of the recent sanitation master plan study, in-depth investigations have been conducted on the characteristics and treatability of the sludges. Due to their age of 6 months to 7 years, anaerobic digestion is unsuitable as treatment process. Other methods of treatment such as lagooning, co-composting and co-landfilling with refuse are also being ruled out for various reasons. A pilot project is now being conceived whereby the sludges would be used without prior treatment as soil conditioner and fertilizer for reaforestation. After 1-2 days of drying it will be ploughed to a depth of 35 cm.

Settling of raw faecal sludge with subsequent treatment of the supernatant liquid in **waste stabilisation ponds** appears to be one of the promising technological options. Similarly, **co-composting of sludge and refuse** might prove feasible if it can be accomplished with simple means. Both treatment systems shall be field-tested in Africa. Other sustainable treatment options are: Drying lagoons and drying beds, co-treatment with wastewater in stabilisation ponds, separate or co-treatment with sewage treatment plant sludge using anaerobic digestion. More sites are being sought which would lend themselves to carrying out field research with one or more of these processes. Important criteria for the selection of an appropriate system or technology are, among others, the required effluent quality (discharge or reuse ?) and the economic, institutional and human resource potential in the particular area or country.

Water Disinfection by Solar Energy

Martin Wegelin

1. Introduction

At least one third of the population in developing countries has no access to safe and reliable drinking water. This lack of inadequate water supply consequently exposes the unserved communities to numerous water-related diseases. Diarrhoea, which is mainly transmitted through consumption of contaminated water, is the most widely spread infectious disease. About 875 million cases of diarrhoea are registered each year of which 4.6 million end in death. The affected population has to deal with this water quality problem on its own.

The stated problems require the development of effective, practical and simple alternative treatment techniques that can be applied by individuals or households. Solar water disinfection might be such an alternative. The treatment process is simple as it makes use of solar radiation to inactivate and destroy pathogenic microorganisms present in water. Solar water disinfection aims at treating small quantities of drinking water; i.e., in the order of 2 litres per person and day or about 10 to 15 litres per family and day. The treatment consists in filling water into clean and transparent containers, placing them in full sun in the morning and leaving them exposed for several hours. Solar energy, which is universally available and free of charge, is the basis of this low-cost and sustainable technology. Hence, solar water disinfection might contribute to solving the water quality problems of those without access to reliably treated water in developing countries.

However, also solar water disinfection has its limits. Solar radiation is dependent on the geographic location, climatic conditions and undergoes diurnal and annual variations. However, one of the main problems of solar water purification is its basic simplicity. In fact, exposing a small quantity of contaminated water to solar radiation is a complex interaction of probably physical, chemical and biological reactions not yet clearly understood.

2. Research Objectives and Programme

The research carried out so far on solar water disinfection reveals that the technique works. However, the inherent mechanisms and the main parameters influencing the efficiency of the process are still not clearly understood. Since some basic questions have not been fully addressed by earlier research (1, 2, 3), EAWAG/IRCWD has decided to embark on laboratory and field test studies on solar water disinfection in order to find answers to open questions such as:

1. Which wavelengths of the terrestrial solar radiation are responsible for the inactivation of microorganisms?
2. What fluence (dose) of solar radiation is required to inactivate a given concentration of specific microorganisms ? Which indicator organisms should be used to monitor the efficiency of solar water disinfection ?
3. Does the water temperature influence the process of solar water disinfection ? If so, what is the threshold water temperature ? Are the effects of solar radiation and water temperature of synergetic or of additive character ?
4. Will dissolved natural organic matter enhance or hinder solar water disinfection ?
5. Does methylene blue used as photosensitiser support the process of solar water disinfection ?

The first phase of the research carried out in Switzerland focused on the photochemical and microbiological aspects of solar water disinfection. The next phases will comprise field tests in developing countries to confirm and complement the acquired information. Thereafter, answers will have to be found to technical (e.g. shape of container, mode of operation) and socioeconomic aspects (e.g. acceptability and affordability) which are important for the implementation of the technology.

3. Preliminary Results

The results of EAWAG/IRCWD's laboratory and field tests are summarised as follows:

1. The UV-A light (320-400 nm) is mainly responsible for the inactivation of microorganisms. The violet light (400-450 nm) in combination with UV-A light induces synergetic effects and increases the inactivation rate of *E. coli* by a factor 3. However, violet light alone is hardly bactericidal.

2. A fluence (dose of solar radiation integrated in the 350-450 nm wavelength range) of approx. 2,000 kJ/m² or 555 Wh/m² is required to achieve a 3-log reduction of *E. coli* at water temperatures between 20 and 40 °C. The same amount of fluence reduces bacteriophages to a similar order of magnitude when exposed to solar radiation at 30 °C water temperature. The required fluences for the inactivation of other investigated microorganisms (*Streptococcus faecalis, Enterococci*; enteroviruses and rotaviruses) indicate that *E. coli* and bacteriophages are suitable indicator organisms to monitor the efficiency of solar water disinfection as regards bacteria and viruses inactivation.

3. Water temperatures between 20 and 40 °C do not affect the inactivation of bacteria exposed to UV-A and visible light radiation. Synergetic effects were observed at a threshold water temperature of 50 °C. Compared to lower water temperatures, the required fluence to inactivate *E. coli* is more than 3 times smaller at this temperature. Viruses, however, are more sensitive to water temperature changes. The inactivation rate for bacteriophages increased by a factor 2 when the water temperature was shifted from 20 to 40 °C. Enteroviruses and rotaviruses are even more sensitive to the same water temperature change; i.e., the inactivation rates increased by a factor 2.4 and 3.7, respectively.

4. The tested bacteria showed no photosensibilisation to natural organic matter (NOM). Instead, a decrease of the lethal efficiency of light was observed with increased NOM concentrations as a result of reduced light transmittance of the cell suspensions.

5. The efficiency of light in killing bacteria is considerably increased with methylene blue. The dye absorbs part of the visible light and transfers its energy to other substances that can undergo chemical reactions. Exposure time to solar radiation for *E. coli* inactivation can be reduced by a 1:20 factor when 1 ppm methylene blue is added to the exposed water, and by a 1:10 factor, respectively at a 0.1 ppm methylene blue dose.

4. Outlook

Additional field tests are planned in collaboration with CINARA in Cali, Colombia, to verify and complement the research results. Based on this work, appropriate equipment and procedures for solar water disinfection will then be developed and field-tested. Finally, once the developed water treatment process has proven its efficiency and sustainability, it will be promoted and disseminated on a large-scale by demonstration projects .

Institutions working or interested in solar water disinfection are invited to contact Martin Wegelin, IRCWD Project Officer.

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Community Involvement in Municipal Solid Waste Collection in two West African Cities - Findings of a Mission

Werner P. Meyer

A mission to Ouagadougou, the capital of Burkina Faso, and to Abidjan, the capital of the Ivory Coast, was carried out in April/May '93 to analyse the current situation and experiences of community involvement in municipal solid waste collection. The mission was combined with a visit to different community-based primary refuse collection (COPRICOL) schemes. The future role of community involvement was assessed in order to increase coverage of solid waste management (SWM) to unserved urban areas. This article describes the visited schemes and summarises the main findings and lessons learnt.

Definitions:

Primary collection (PRICOL): Refuse collected from households and transported to a communal collection point

Secondary collection: Refuse collected from communal collection points and transported to a transfer station or disposal site

Municipal collection: Refuse collection managed by the municipality. The operator is either municipal or private

Communal collection point: Public refuse collection site serving as interface between primary and secondary collection systems

Community-based primary collection (COPRICOL): Scheme managed and operated by local representatives of the community of residents.

1. OUAGADOUGOU (BURKINA FASO)

In Ouagadougou the refuse collection service coverage is estimated at less than 25%. About half of the collection is carried out by the municipality, the remaining service is provided against fees by a semi-public corporation, various small private enterprises and by cooperatives. Due to rather high collection fees, these services are mainly used by upper-income households and commercial enterprises.

The city is divided into five districts called "communes" in French. They are, in contrast to Abidjan, not involved in SWM. Ouagadougou has sufficient space for urban expansion and a liberal settlement policy. This led to the development of large peri-urban residential areas with a low population density. Ouagadougou has a planned regular urban settlement pattern and a vast road network. Due to the large urban area and low population density, the technical infrastructure such as roads, water and sanitation systems, including SWM services, are still underdeveloped. The natural earthen roads limit regular house access for heavy collection trucks, and long collection distances cause high transportation costs especially in peri-urban low-income areas.

In unserved areas, families usually dump their refuse on nearby uncontrolled public land, vacant lots or carry it to one of the roughly 80 common dumping grounds, and/or burn it. To prevent flood damages resulting from clogged storm water surface drains with indiscriminately dumped refuse, the population was recently sensitized to change its disposal practices.

To increase the municipal (secondary) collection capacity in Ouagadougou, the 2nd Urban Development Project (UDP), financed by the World Bank, will soon provide an additional fleet of seven refuse collection trucks and 113 skip containers. Although the consequences of this new collection fleet on the existing heterogeneous collection system are still unpredictable, it will certainly influence the future development of primary collection schemes and community participation.

COPRICOL in Wogodogo (Baskuy)

A different approach regarding an increased coverage in underserved municipal areas has been applied by a COPRICOL pilot project assisted by CREPA (Centre Régional pour l'Eau Potable et l'Assainissement à Faible Coût) and IAGU (Institut Africain de Gestion Urbaine). In Wogodogo, a typical residential area of the Baskuy "commune", a local waste management committee has been formed to manage and operate a primary collection scheme. Households have been requested to subscribe to a biweekly collection against a monthly fee. The door-to-door collection is carried out by local collectors with indigenously designed and produced donkey carts (see Photo 1). This type of collection was introduced in Wogodogo only in April '93.

A current problem of the COPRICOL scheme is the accumulation of refuse at the communal collection point. The present municipal (secondary) collection is irregular and

Photo 1: Door-to-Door Collection in Wogodogo by Locally Developed Donkey Cart

insufficient. This situation expresses the missing link between the primary and secondary collection schemes. Complementary private transportation to a nearby landfill can be financed if COPRICOL subscriptions develop as predicted. With the new secondary collection fleet, which will be extended by the additional vehicles of the 2nd UDP, the local management committee hopes to find a more economical solution.

CREPA/IAGU will further assist the local committees with the solving of initial problems to gradually improve the COPRICOL systems and monitor the process. The experiences made with this pilot project and with the additional municipal collection fleet of the 2nd UDP will provide a good basis for the SWM programme of the planned 3rd UDP.

2. ABIDJAN (IVORY COAST)

In contrast to Ouagadougou, refuse collection in the seaside capital of Abidjan reached a high coverage level of 77% when the city was serviced by a French company over a period of 30 years. The contract was phased out in 1990. After an interim collection phase of low coverage by the municipal and communal services, a private company (Société "H"), was contracted again by the municipality in mid '92 to provide collection service.

Abidjan is divided into ten "communes" whose administrations are actively involved in SWM. They have to financially contribute to the municipality to cover the refuse collection costs and help ensure the general cleanliness of their area. Abidjan extends over a large urban area interrupted by lagoons, large forests and plantations. The city has a varied settlement pattern ranging from fully-serviced modern commercial areas with skyscrapers and vast luxury residential areas to poorly accessible high-density squatter areas packed with fugitives and migrants from conflict-stricken areas of the region. An excellent urban road network which highly facilitates municipal refuse collection and transportation, connects the sub-centres and provides house access in all planned areas. However, recently urbanised peripheral areas and a few incorporated old villages with dense irregular settlement patterns are still suffering from a lack of adequate road, water and sanitation infrastructure, including a refuse collection service.

To increase refuse collection coverage in such unserved areas, COPRICOL pilot projects were initiated in the settlements of Avocatier, Adjoufou II and Alladjan, located in different "communes" and assisted by different donors. (A comparative overview of the COPRICOL schemes is given in a table at the end of this paper.)

COPRICOL in Avocatier (Abobo)

Avocatier is a rapidly expanding low-income area in the "commune" of Abobo. A primary collection pilot scheme was set up in 1991 with the technical assistance of the EEC (Commission of European Economic Community). Seriously eroded local lanes were improved in collaboration with the technical service of the "commune". A local cooperative and a small enterprise were given a few simple one-axle wooden handcarts to rapidly increase the capacity of the primary collection service. Meanwhile, the handcarts are being replaced by more efficient two-axle handcarts (see Photo 2). The household refuse is collected daily by local collection teams from subscribed families, transported to one of the communal collection points at the border of Avocatier and transferred into mobile container skips of about 6 and 14 m^3 capacity. These skips are then collected by the "Société H" which is in charge of the municipal collection service.

The "commune's" administration officially assigns the collection areas to local enterprises and inspects the general cleanliness, however, it is not actively engaged in promoting a community-based approach. Participation of the community of residents is limited to paying primary collection fees and maintaining public cleanliness within the household's direct living environment. Since there is no active community management, this cannot be considered a typical "community-based" primary collection scheme.

However, the primary collection services in Avocatier have been fully operative for more than two years. Private initiatives to improve the collection efficiency were observed. Furthermore, several other small enterprises have taken up the idea and started to offer primary collection services in other unserved areas of Abobo.

COPRICOL in Adjoufou II (Port Bouët)

In the coastal irregular resettlement area of Adjoufou II in Port Bouët, bordering Abidjan's airstrip, a different primary collection system was set up in 1991 with the technical assistance of the EEC and the technical service of the "commune". A local sanitation committee was formed to discuss the main problems and decide on optimal solutions. In the meantime, the collection scheme was operated by the local committee which included mainly young unemployed residents appointed by the local chiefs of the different ethnic groups. The primary collection system, which comprised several hundred refuse barrels located in all neighbourhoods, reduced the walking distance to less than 30 m to each house. Households were motivated to throw their refuse into those refuse drums. The collection teams used two-wheeled barrows to transport the full standard barrels to the nearest communal collection point. The barrows were pushed on a ramp to a platform from where the drums were tipped into standardized skip containers of the secondary collection system. This type of system served every family regardless of its willingness or ability to pay for the weekly fees. Despite of all the information campaigns, willingness to pay declined and resulted in a decrease in cost recovery. The teams offered additional services such as toilet/bathroom cleaning etc. to improve cost recovery.

Photo 2: Locally developed two-axle hand cart of about 1 m^3 capacity after tipping operation at the communal collection point in Avocatier

The COPRICOL scheme stopped functioning in autumn '92 when the new private municipal collection company, the "Société H", changed its method of secondary collection from communal skip containers to direct collection by compacter trucks along the main road. The compactor trucks now announce their service by tooting and stopping every 50 meters to accept domestic refuse. In a first phase, many households preferred to carry their refuse over long distances (up to 250 m) to a by-passing collection truck rather than to pay for primary collection. Meanwhile, willingness to bring the refuse is declining. This leads to a decrease in coverage and to a deterioration of the environment. Discussions on the reintroduction of the COPRICOL systems are under way, especially among those officials at local and municipal government level who really want to increase refuse collection coverage in low-income areas.

COPRICOL in Alladjan (Port Bouët)

In the traditional densely populated and irregular fishing village of Alladjan in the "commune" of Port Bouët, a management committee was formed in collaboration with a local NGO, the AMCAV (Association pour l'Amélioration et l'Aménagement de la Commune de Port Bouët) and an international NGO, the CHF (Cooperative Housing Foundation based in the USA). A local sanitation committee was formed consisting of selected representatives of the main ethnic groups. The committee and the AMCAV operated the primary collection system which was set up with minimum financial input. Locally produced two-wheeled light push-carts holding four small barrels were introduced. Collection teams comprising two collectors announced their daily arrival in the neighbourhood by whistling. Women and children would hand over their garbage to the primary collection team. The full barrels were then transported by push-carts to one of the communal collection points equipped with skip containers of 6 to 14 m^3 capacity of the secondary collection service. The teams collected the service fees on a weekly basis. Their salary, consisting of 80% of the collected fees, motivated them to attain a high cost recovery rate. The COPRICOL scheme functioned on a high cost recovery basis for more than a year.

The "commune's" administration of Port Bouët, headed by a judicious mayor, took up an active role in improving the living conditions in squatter areas. In order to promote self-help activities through community participation beside governmental programmes, a separate NGO, the AMCAV, was founded in the mid 1980s. Its main concern is health education as well as water and sanitation improvement, including community-based primary refuse collection. The AMCAV has been sharing the financial management of primary collection in order to overcome the local political power constraints. CHF has put stress on continuous monitoring of the processes.

Nevertheless, the COPRICOL scheme stopped functioning in autumn '92 for the same reasons as in Adjoufou II. The mayor of Port Bouët has not resigned and hopes to negotiate with the municipal government and the "Société H" to return

Photo 3: The COPRICOL scheme in Alladjan stopped functioning because of the new collection system by compactor truck. Women and children carry their refuse over long distances to a collection truck

to the previous skip container secondary collection system which is being successfully used in other inaccessible areas of Abidjan and in many other cities.

3. MAIN FINDINGS

1. Community involvement

The level of community involvement of the four schemes varies considerably. High level community-based decisions and community managed collection operations have been observed in Wogodogo, Adjoufou II and Alladjan. These community-based primary collection schemes enjoy a high level of collection coverage. The Adjoufou II scheme for instance enjoyed full (100%) collection coverage. However, community involvement and mobilisation in these pilot schemes are or were always promoted by external support agencies.

In contrast, a low level of community involvement prevails in Avocatier. Due to missing community involvement and lack of communal support, the private primary collection operators of Avocatier face enormous difficulties with regard to an increase in coverage. In order to increase the number of clients, the small enterprises extend their services to other collection areas.

A direct relation has been identified between the level of community involvement and the collection coverage rate.

2. Financial viability

The Avocatier scheme, served by the two small enterprises, could reach full cost recovery in primary collection. Their basic motivation is to generate their own income, reach full cost recovery and even become profitable. In the Alladjan scheme the collectors, which are employed by the committee, had a personal incentive to reach a high cost recovery rate as their salaries were directly dependent on it.

A low cost recovery rate in primary collection was reached in Adjoufou II. The local decision-making committee was, in the meantime, in charge of collection operation. Main emphasis was therefore placed on full collection service coverage and on local job creation opportunities. Non-paying households could not be excluded from the collection services due to the system's design. Willingness to pay for provided primary collection services decreased when families realised that there is no legal obligation to pay for the services. The scheme remained dependent on external financial resources.

3. Collection coordination at the interface

All four primary collection schemes had difficulties in linking with the secondary collection scheme. The problems are apparent at the communal collection points; i. e., the "interfaces" between the two schemes: Uncollected refuse piles up at the communal collection points in Wogodogo. In Avocatier, the same constraints of uncollected refuse appear but are not so apparent due to indiscriminate dumping into a nearby gully.

The main reason for the interruption of the primary collection schemes in Alladjan and Adjoufou II was the change effected at the interfaces of the secondary collection method without agreement of the partners.

4. LESSONS LEARNT

1. There are conflicting public and private interests as regards the reaching of full community collection coverage and full cost recovery.
2. To reach a high level of refuse collection coverage in unserved poor areas, the active involvement in community decisions regarding primary refuse collection has been experienced as a promising approach.
3. Mixing of community involvement with collection organisations to reach a high level of cost recovery in primary collection operation, however, does not necessarily provide the best form of organisation for reasons of conflicting communal and individual interests. Small local enterprises contracted by communities have shown to be quite an appropriate form of

organisation. Direct incentives and private sector initiative have shown to be important tools for reaching high efficiency and high cost recovery.

4. Active coordination and enforcement efforts by the responsible local and municipal governments are required to link the technical and institutional interfaces between primary and secondary collection schemes.

TABLE : Overview of the Characteristics of the Visited Schemes

Community area "Commune": Municipality:	*Wogodogo Baskuy Ouagadougou*	*Avocatier Abobo Abidjan*	*Adjoufou II Port Bouët Abidjan*	*Alladjan Port Bouët Abidjan*
PRICOL - responsibility:	CBO	LGO	CBO	CBO
PRICOL - coverage:	20% increasing	30%	100% 1991/1992	70% 1991/1992
PRICOL - operator:	CBO board	- cooperative - small enterprise	CBO	CBO board/ NGO
PRICOL - cost recovery rate:	(low) increasing	high profitable	low	high
Operation period:	since April '93	since '91	91- Sept. '92	91- Sept. '92
Operational condition:	operational	operational	suspended	suspended
Link to secondary collection:	irregular insufficient	regular insufficient	interrupted since July '92	interrupted since July '92

Abbreviations: CBO Community-Based Organisation; LGO Local Government Organisation (French: Commune); NGO Non-Governmental Organisation; PRICOL Primary Collection

Important Events in the Hygiene Sector

From May 18-20, 1992 a **WHO Informal Consultation** on Interventions to Improve Water- and Sanitation-Related Hygiene Behaviours took place in Geneva, Switzerland under the title:

Improving Water and Sanitation Behaviours for the Reduction of Diarrhoeal Diseases.

Epidemiologic evidence has accumulated in recent years which refines our knowledge of water-related hygiene behaviours associated with increased risk of diarrhoea. At the same time, information has increased on the implementation of various programmatic interventions and their success in promoting improved hygiene. In view of the awareness that this information needed to be reviewed in a way that facilitated its programmatic application, an informal consultation was jointly organized by WHO's Diarrhoeal Disease Control Programme (CDD) and Community Water Supply and Sanitation Unit (CWS) to:

- **Define and recommend a minimum complex of water- and sanitation-related hygiene behaviours which should be promoted to reduce diarrhoea morbidity**
- **Identify and recommend approaches to the promotion of improvements in water-related hygiene behaviours.**

A large number of factors have been associated with increased transmission of diarrhoea pathogens. This complexity, coupled with difficulties in measuring and assessing their relative importance, might easily lead to confusion and misdirection when choosing where to intervene. Too often hygiene education interventions involve far too many behaviours targeted for change or address behaviours that would have limited impact in terms of reducing the disease burden.

This informal consultation called upon the expertise of epidemiologists, anthropologists, sanitation engineers, health education, and communications experts to review the evidence and provide recommendations for further action. The epidemiological review indicated that transmission might be better controlled at each end of the spectrum of faecal-oral transmission, i.e., at the deposition of faeces in the environment and at the level of the new host. Programs should focus on preventing the faecal contamination of the environment and removing or destroying the pathogenic organisms prior to contamination of the new host.

Recommendations on key water-related hygiene behaviours, approaches to hygiene promotion and on the implementation of water-related hygiene education interventions were stated.

The Report of this informal Consultation is available free of charge from the Division of Environmental Health Service of Information, WHO, CH-1211 Geneva.

Publication Announcements

- **Environmental Management of Schistosomiasis Control.** River-Flushing - A Case Study in Namwawala, Kilombero District, Tanzania, by Martin Fritsch, 1992, 200 pp, illustrated, ISBN 3-7281-1940-7, paperbacked about SFr. 40.- .
  Available from vdf Verlag der Fachvereine, Auslieferung, Postfach 566, CH-6314 Unterägeri, Switzerland, Tel. +41-42/72 10 26; Fax +41-42/72 13 33.
- **Reuse of Human Wastes in Aquaculture - A Technical Review**, by Peter Edwards, 1992, 350 pp.
  Available from UNDP-World Bank, Water and Sanitation Program, Water and Sanitation Division, 1818 H Street, N.W., Washington, D.C. 20433, USA.
- **The Poor Die Young: Urbanization without Health**, by Sandy Cairncross, Jorge Hardoy and David Satterthwaite, 1990, 309 pp, ISBN 1- 85383-019-4.
  Available from Earthscan Publications Ltd., 3 Endsleigh Street, London WC1H 0DD, U.K.
- **A Guide to the Development of On-Site Sanitation**, by R. Franceys, J. Pickford and R. Reed, 1992, 237 pp, ISBN 92-4-154443-0, SFr. 47.-/US $42.30, in developing countries: SFr. 32.90.
  Available in English and French (Spanish in preparation) from World Health Organization, Distribution and Sales, CH-1211 Geneva 27.
- **Insect and Rodent Control Through Environmental Management. A Community Action Programme.** An innovative kit containing all the information needed to help communities take action against urban insect and rodent pests, 1991, 107 pp + 62 cards + 7 games, ISBN 92-4- 154411-2, SFr. 90.-/US $ 81.00, in dev. countries: SFr. 63.-.
  Available in Englisch and French (Spanisch in prepration) from World Health Organization, Distribution and Sales, CH-1211 Geneva 27.
- **Actions Speak, The study of hygiene behaviour in water and sanitation projects**, Marieke T. Boot and Sandy Cairncross, Editors, 1993, 139 pp, figs., tabs., ISBN 90-6687-023-0, US $ 32.00.
  Available from IRC, Inter. Water and Sanitation Centre, P.O.Box 93190, 2509 AD The Hague, The Netherlands, Phone: +31-(0)70-33 141 33, Fax: +31-(0)70-38 140 34.

Editors:
Brigitte Hauser and Sylvie Peter
"IRCWD NEWS"
Swiss Federal Institute for Environmental Science and Technology (EAWAG)
Ueberlandstrasse 133
CH-8600 Duebendorf / SWITZERLAND

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[ ] Community Water Supply [ ] Sanitation [ ] Municipal Solid Waste Management