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WATER, SANITATION, ENVIRONMENT and DEVELOPMENT

Water treatment in Northern Ghana

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Present situation

The Ghana Water and Sewerage Corporation (GWSC) is in the process of rehabilitating water supply systems in the Northern Region of Ghana with external financial and technical support. This programme foresees also the rehabilitation and extension of water treatment plants of 13 towns whose projected population ranges between 5,000 and 73,000 inhabitants. Nine towns use as raw water source impounded reservoirs fed by non-perennial surface runoff. The other 4 towns draw their raw water from rivers.

The three existing conventional plants whose treatment processes comprise flocculation, sedimentation, rapid sand filtration, and chlorination, are only partly operational. The sedimentation tanks at one treatment plant have serious design deficiencies, and the construction of the rapid sand filters have never been completed. Consequently, the alum flocs are washed straight into the clear water tank and, thereafter, pumped into the distribution network. At the other two sites, the filter medium in the rapid sand filter is missing. Hence, only partly treated water is distributed to the consumers. The other towns have to rely on package plants, which include a 3-tank system composed of sedimentation tank, rapid sand filter pressure tank and clear water tank. The package plants are installed as closed system in the raw water line in front of the high level tank. Alum, lime and bleaching powder are added to the water by chemical dosers. The package plants are not functioning well or are out of operation. Difficulties with the supply of chemicals, partly broken dosage equipment or uncontrolled operation of the package plants result in an unreliable water quality. After less than one year of operation, a package plant which had been submitted to major rehabilitation was only partly functional. Maintenance of the installations and dependency on the import of foreign material are serious problems faced by GWSC.

Treatment options

For the large water supply schemes, the preliminary design report (1) of the rehabilitation project proposes to either extend or construct new conventional treatment plants with flocculation, sedimentation, rapid sand filtration, and chlorination as treatment processes. The existing package plants in smaller water supply schemes should be rehabilitated and additional units running in parallel should be added if necessary. Furthermore, construction of one slow sand filter plant was planned for one water supply scheme.

As a result of the experienced difficulties with conventional water treatment plants and with the installed package plants, GWSC embarked on field tests with small slow sand filter units. Since slow sand filtration has, so far, not been applied in the project area, field tests were carried out at two sites to gain practical experience with this treatment process.

As slow sand filtration is a simple and reliable water treatment process making greatest use of locally available resources, it is considered an appropriate technology for developing countries. However, reasonable filter operation is only possible with raw water of low turbidity. Pretreatment of surface water is generally necessary to achieve slow sand filter runs of 1-2 months or more. Sedimentation combined with chemical flocculation is applied in conventional water treatment for the reduction of turbidity and separation of solid matter. Chemical flocculation, however, is a rather sensitive and unstable process difficult to control. Flocs often escape the sedimentation tanks and rapidly clog the subsequent slow sand filters. Chemical flocculation should therefore never directly precede slow sand filtration without the use of another intermediate pretreatment step.

Filtration is an alternative and efficient pretreatment process for the removal of solid matter. Roughing filters use coarse filter material, do not require sophisticated mechanical equipment and are operated at low filtration rates without the addition of chemicals. Roughing filters, which were developed over the last decade, are now used worldwide as efficient and appropriate pretreatment process prior to slow sand filtration (2). The layout of a treatment scheme adequate for rural water supplies is illustrated in Fig. 1.

Pilot plant tests

Motivated by the simplicity of the horizontal-flow roughing filter design, the GWSC project team tested this pretreatment process in combination with slow sand filtration at two sites. Preliminary and valuable practical experience (3) was made with the installation of a pilot plant and the carrying out of field tests at Damongo, a district town supplied by an impounded reservoir. Although the raw water turbidity was found to be low (20 - 30 NTU), iron problems from both natural (dissolved iron concentration in the raw water abstracted from the reservoir's bottom ranged between 0.4 and 1.8 mg/l) and man-made sources (iron release by laterite filter material and rusty steel drums) impaired the field tests. The growth of iron bacteria in the roughing and slow sand filters hindered a satisfactory filter performance. The gravel of the roughing filter units and the rusty steel drum used as slow sand filter unit were replaced by adequate filter material and by an asbestos cement pipe respectively. Reasonable slow sand filter runs of 70 days were then achieved with the pilot plant. For the full-scale treatment plant, however, abstraction of the raw water at the reservoir's surface by a floating intake and separation of the dissolved iron by efficient aeration (cascades) and sedimentation prior to filtration is recommended.

The lessons learnt at Damongo were applied in the design of the second pilot plant constructed at Salaga where river water is used as raw water source. An aeration/precipitation unit consisting of a tray aerator and a sedimentation tank was constructed prior to the two horizontal-flow roughing filter units built in concrete block work and four slow sand filter units installed in asbestos cement pipes. The filter units were operated at filtration rates of 0.75 and 1.5 m/h, and of 0.1 and 0.2 m/h respectively. According to the field tests (4) carried out in the dry season, the relatively low raw water turbidity ranging between 15 and 30 NTU was reduced in the pilot plant to generally less than 5 NTU (5.8 - 1.3 NTU). However, during the rainy season the raw water turbidity increased to 350 NTU but was then reduced to 150 NTU by the horizontal roughing filter, and to 120 - 140 NTU by the slow sand filter units. Fine colloidal particles in the treated water were the cause for the low removal efficiency in the slow sand filters. Bacteriological analyses, however, revealed a satisfactory and acceptable water quality. After 6 months of operation, the headlosses in the roughing filters increased to only 1 cm and the four slow sand filters, except for one unit, never had to be cleaned during this period. Apart from some aesthetic water quality deficiencies caused by removal difficulties of the colloidal particles, the field tests proved the operational viability of the tested treatment process. Other field tests in the project area carried out with a horizontal-flow roughing filter unit by the Village Water Reservoirs Project revealed that turbidity could generally be reduced from approx. 500 NTU to 170 NTU (5). However, it was observed that the cyclopes acting as host for the guinea worm larvae were not fully separated by single filtration. Complete cyclopes removal would therefore require the addition of slow sand filters.

Two full-scale treatment plants consisting of horizontal-flow and slow sand filters were constructed in Ghana at Mafi Kumase and Katamanso and complement the experience made with the above-mentioned pilot plants. In Mafi Kumase, the guinea worm disease could be eradicated and the slow sand filters reveal with a running time of 6 months an excellent performance.

Alternative pretreatment options

In Ghana, only horizontal-flow roughing filters have so far been used as prefilters. This filter type, however, consisting of a relatively large filter bed of usually 5-7m length, is generally used for the pretreatment of highly turbid water. For the pretreatment of raw water with low and moderate turbidity, smaller filter structures can be applied. Alternative prefilters types such as intake and dynamic filters, as well as upflow roughing filters are illustrated in Fig. 2. Hence, the raw water of impounded reservoirs will generally have to undergo pretreatment in small prefilters (intake or dynamic filters) and in upflow roughing filters.

Cost comparison

Construction and operation costs of a new treatment plant at Damango with a design capacity of 1110 m3/d and a projected population of 16,600 inhabitants for the year 2000 were estimated on the basis of preliminary designs (1, 6) for the following treatment plant options:

a) conventional treatment plant comprising flocculation tanks (Td 30 min.), sedimentation tanks (Td 4 hrs), rapid sand filters (vF 6 m/hr), and dosage of alum, chlorine and lime

b) alternative treatment plant comprising horizontal-flow roughing filters (vF 1.1 m/hr, Ltot 10 m (!)), slow sand filters (vF 0.11 m/hr), and dosage of chlorine

c) modified alternative treatment plant comprising aeration towers, sedimentation tanks (Td 30 min.), upflow roughing filters (VF 0.8 m/hr, Ltot 1 m), slow sand filters (VF 0.15 m/hr), and dosage of chlorine

(Td detention time, vF filtration rate, Ltot total filter length)

Designs a) and b) are based on design guidelines recommended in the literature, whereas design c) applies the recommendations made on the basis of the pilot test results (3, 6). The results suggest that substantial cost reductions can be achieved especially with the type of pretreatment since low turbidity records enable a shift from large horizontal-flow to much smaller upflow roughing filters. A relative cost comparison is given in Table 1. In general, the foreign currency demand of the alternative options is about half of that required by the conventional treatment system. With respect to the construction costs, the modified alternative treatment plant (c) is competitive to the conventional treatment plant (a) which, however, requires almost half of the investment costs in foreign currency for its installation. As regards to the operation costs, the roughing filter options (b, c) are significantly cheaper due to the lower chemical demand. Finally, the specific per capita construction and operation costs for the treatment facilities are also indicated (price basis 1992, 1 US $ = 400 Cedis).

Implementation

Rehabilitation of the water supply schemes should be demand-oriented rather then supply-oriented and geared towards community self-managed systems. Therefore, community meetings were held and "willingness-to-pay" surveys carried out in order to determine and enhance communal managerial skills and assess its financial capacity necessary for the implementation and successful operation of the water projects. Additional field tests with pilot plants are proposed in order to assess the performance of the treatment schemes and to develop economic designs of the full-scale plants. The pilot plants could also be used as demonstration units for the first communities to be supplied with roughing and slow sand filtered water. The water quality produced by the pilot plants, especially its appearance, taste and odour will be judged by the consumers whereas the operators will be able to familiarise themselves with the type of treatment process and maintenance work they will have to carry out. Full-scale treatment plants can serve as demonstration units to other communities once the treatment process is introduced in the region.

If water supply projects are fully implemented in one phase they require considerable investment within a short period. This approach is neither flexible with regard to future modifications, nor does it make allowances for the rather slow development and consolidation of community management. Involvement of the community in the design, decision and participation process is limited and can therefore seriously endanger the sustainability of water supply projects. Phased implementation, however, keeps pace with community development and is thus a solution to the above-mentioned problems. Such an approach, which will gradually increase the service level of the water supply, will develop the interest, management capacity and financial strength of the community. A phased implementation might include the following steps:

- pilot plants to demonstrate treatment processes
- full-scale treatment plant supplying a clear water well furnished with handpumps
- construction or rehabilitation of the distribution network equipped with public standpipes
- extension of the distribution network and possible installation of private connections
- extension and, if required, upgrading of the treatment facilities

Simple and reliable treatment processes in rural areas are essential for sustainable water supply schemes. However, the construction of a water supply scheme is also a process during which building of local management capacity is equally important.

References

(1) Preliminary design report, Wardrop, July 1991

(2) The decade of roughing filters, M. Wegelin at al, AQUA, No. 5/1991

(3) Damongo slow sand filtration pilot project, GWSC, March 1992

(4) Horizontal-flow roughing and slow sand filtration pilot plants experience in the Northern Region, Ghana, Ch. Berhoh, International workshop on roughing filters for water treatment, Zurich, June 1992

(5) Horizontal roughing filtration, Experimental Report, J. Addy and A. Ligtenberg, Village Water Reservoirs Project, July 1991

(6) Potential of slow sand filters in the northern region of Ghana, M. Wegelin and K. Dorcoo, Field report No. 7, Wardrop. April 1992

Table 1.
Cost comparison for different treatment options

treatment scheme	construction costs			operation costs			specific costs	
	local	foreign	total	local	foreign	total	constr.	operation
flocculation, sedimentation rapid sand filtr., chlorination	54%	46%	**100%**	21%	73%	**100%**	14.4$/c	1.0$/c.yr
horizontal-flow roughing filtr., slow sand filtr., chlorination	160%	18%	178%	32%	37%	69%	25.5$/c	0.7$/c.yr
aeration/sed., upflow rough. filtr. slow sand filtr., chlorination	66%	18%	84%	25%	37%	62%	12.1$/c	0.6$/c.yr

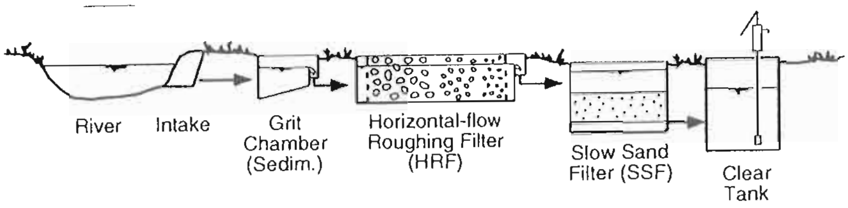

Figure 1. Layout of a self-reliant water treatment plant

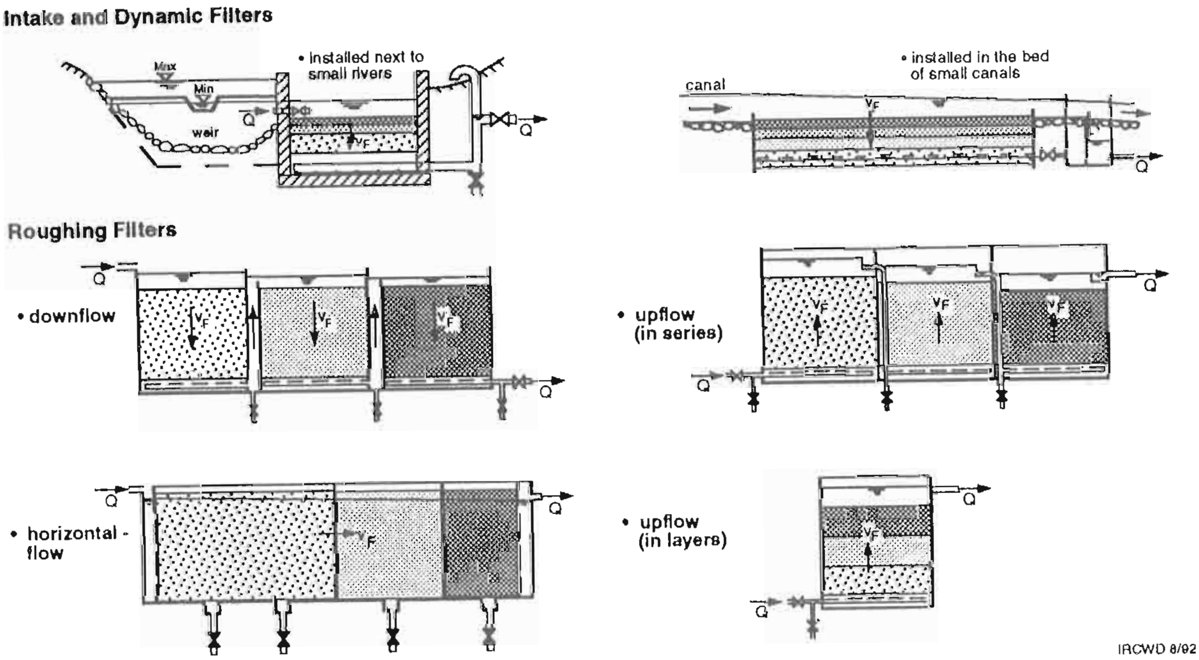

Figure 2. Layout of different roughing filters