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SLOW SAND FILTRATION FOR CERCARIAL CONTROL IN NORTH CAMEROON VILLAGE WATER SUPPLY

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ABSTRACT

People of North Cameroon must look for water at great distances from their homes during the dry season of the year. To provide water closer to villages series of internationally and bilaterally financed dams are being built to impound water in reservoirs. The Ministry of Health of the Government of the Republic of Cameroon is concerned that the dams do not increase health problems. One concern is the control of cercariae of human schistosomes. This paper reports on the literature survey on past filtration studies, presents data on filtration experiments, and gives design parameters for slow sand filtration plants to be built in North Cameroon.

KEYWORDS

Water treatment, water supply, cercarial control, schistosomes, slow sand filtration, North Cameroon.

INTRODUCTION

In the whole of the country of Cameroon water supply is a problem of no small proportion. According to the April 1976 General Population and Housing Census a mere 6.1% of the population was said to have decent water supply facilities at home, while only 16% uses street fountains. The greater majority (75.8%) draws its water from springs, wells, streams, and rivers. When the urban sector is taken out, the picture for the rural sector shows 4.3% of the population with water supply at home, 4.0% supplied from street fountains and 91.7% depending on springs, wells, streams and rivers. This, however, does not represent the North Cameroon situation for while the south is in the tropical rain forest, the north is geographically characterized as desertic steppes and barren mountains.

Much of the Department of Margui-Wandala is in the Mandara Mountains. The census figures show the population density to be 69.6 per square kilometer while the average density of the country is 16.5 per square kilometer. The hydrological information shows the average annual rainfall to be approximately 900 mm. The rains start in June and end in September. From September into June it is dry.

Water related diseases are endemic in the Department. Schistosomiasis hematobium, schistosomiasis mansoni, onchocerciasis, dracontiasis, malaria, amoebic dysentery, and diarrheal diseases are prominent in the morbidity statistics. Contaminated water and lack of sufficient water from sources at reasonable distance have been mentioned frequently as possible direct or indirect causes of many of these diseases. In the fall of 1980 an epidemic of cholera occurred in the Department. The initial case was reported to have been a woman who had gone over into Nigeria to attend the funeral of a relative. She had evidently carried back to her village the *Vibrio* to seed the epidemic in North Cameroon. Once seeded, the disease spread as people from affected villages visited in other villages. Water contaminated with the *Vibrio* was believed to be the vehicle of transmission. On the other hand, Mokolo, the principal town of the Department, has a modern water plant operated by the national water corporation of Cameroon. The drinking water for the town is treated by coagulation, sedimentation, filtration and chlorination. Cholera did not occur in the town.

In the Mandara Mountains during the rainy season sources of water are to be found reasonably close to the compounds of the village families. Water sources close to villages begin to dry up as the dry season progresses and the drawers of water are forced to seek water from distant sources at lower elevations. In some areas, the distance becomes as great as ten kilometers. Most of the water is collected by women and children who make two or more trips during the rainy season and four or more trips during the dry season. The provision of water readily available to the population to alleviate the drudgery of hauling water was one of the many development goals for this region by the central government. To provide water for the population throughout the year in these mountains, impounding water behind dams was found to be necessary and also effective and appropriate. Dam projects were, therefore, proposed, sites were studied, and designs were undertaken. Some dams financed by the World Bank and other funded by the Agency for International Development are today in stages of construction.

The need for water to be safe for human consumption made it necessary to give thought to treatment, but with due attention to appropriate technology. One of the concerns was the exposure to viable cercariae of schistosomes. In the deliberation slow sand filtration was considered the desired process for two reasons: one, it is not an unduly complex process and two, the villagers in the region understand the filtration of water. It has been observed that when drawers of water go to rivers of the region for water, they would dig into the sandy river bed and collect water that seeps into the depression even while surface water is available close by.

LITERATURE SURVEY

An exhaustive search of the literature revealed that there is little information that sheds light on design of slow sand filters to control cercariae. Early studies in filtration were conducted by Leiper in Cairo. Leiper (1915) tested a "shallow barrel sand-filter" with a 4 inch (10.2 cm) depth of desert sand as medium and found that cercariae had no difficulty in passing the barrier. Leiper (1916) also passed alum-coagulated water through a 30 inch (76.2 cm) column of sand of grain size "ordinarily used by the Cairo Water Works" and found that neither the "vital layer" on the surface of the sand nor the depth of sand was able to prevent cercariae from passing through. These papers unfortunately contained little in the way of experimental details.

Witenberg and Yofe (1938) conducted studies using cercariae of *Schistosoma mansoni* and *Schistosoma hematobium*. They used pipe columns 6 cm in diameter which could be assembled in such manner as to build filter columns from 10 cm to 75 cm high. Their study showed that neither the sand bed of 75 cm nor the floc formed when calcium hydroxide and aluminum sulfate were added could retain the cercariae. Their paper also did not give sand analysis and operating parameters.

Jones and Brady (1946) tested a model filter with diatomaceous silica as the filter medium. When diatomaceous silica had been deposited on the cylinder and it was subsequently challenged with cercariae, no cercariae could be recovered at filtration rates that ranged from 0.2 to 7.5 liters sec^{-1} m^{-2} and at pressures from 0 to 1.2 kg cm^{-2}.

Unrau and Richards (1961) experimented in Puerto Rico. They employed one inch (2.5 cm) glass tubes about 50 inches (1.3 m) long. Three grades of creek bed sand were placed into these tubes to 12 inch (30.5 cm), 18 inch (45.7 cm) and 36 inch (91.4 cm) depths: fine (0.1-0.4 mm), medium (0.3-0.7 mm), and coarse (0.5-1.3 mm). The sand columns were initially saturated with pond water and then challenged with cercariae. Except for the initial saturation of the column there was no pre-conditioning of the filters. Further, the model constructed did not allow for continuous operation. As the water level in the column dropped more pond water was added with a pitcher. The study showed that medium and coarse sand grains, shallow depths, and high flow-through rates were factors that worked against preventing cercarial passage. The only set of conditions that effectively held cercariae back was the 0.91 m sand column with fine sand grains. The calculated flow-through time was 1.14 m h^{-1} which is a filtration rate intermediate between conventional slow sand and rapid sand filtration. Unrau (1974) repeated the Puerto Rico experiment in St. Lucia using 2.5 cm diameter plexiglass tubes. He employed two naturally occuring sands: a river sand with effective size of 0.37 mm and uniformity coefficient of 13.0 and beach sand with effective size of 0.22 mm and uniformity coefficient of 1.73. Three sand depths were used. The columns were initially wetted and then challenged with about 10,000 cercariae in 200 ml of water. This was followed by water rinses. Since the system was not dynamic the flow-through time varied. At 0.67 m depth of sand the calculated filter rates were 40 m h^{-1} for river sand and 3.1 m h^{-1} for the beach sand. Even after the river sand was allowed to stand 6 weeks to enable biological growth on the sand grains, the coarse, less uniform river sand was found to be unsuitable. The beach sand, on the other hand, was an effective filter medium not allowing the passage of cercariae. The calculated filter rate for the latter was noted to be intermediate between the conventional slow sand and rapid sand filtration rates.

Benarde and Johnson (1971) conducted their filtration experiments in the laboratory on a horizontal filter. Their unit was made from a 5.1 cm diameter Lucite tube laid horizontally with 95.2 cm length of sand positioned in it. They prepared 5 separate uniform sand grains for tests and ran series of experiments by challenging the system with cercariae. Cercariae were recovered at the effluent of the horizontal filter. The results of the tests showed that no cercariae penetrated the 95.2 cm length when sand grains were 0.35 mm or finer even at filter rate up to 1.0 m h^{-1}.

Unrau (1979) also experimented with horizontal filters. He built his filter 30 cm wide x 30 cm deep and 1.5 m long with river sand (0.37 mm effective size and 13.0 uniformity coefficient). Following a few days of conditioning, he challenged the system with cercariae and found the filter to prevent the passage of cercariae.

It was to be seen in the literature survey that filtration studies of the past often gave little information on sand characteristics and operating parameters. There were no indications in the papers reviewed that filter rates were ever controlled. Many experiments were made without pre-conditioning the filters, and the model filters employed were rather small in diameter giving a high wall surface to cross-sectional area ratio. A better designed and controlled filtration study was needed.

SLOW SAND FILTRATION STUDY

To arrive at design parameters for slow sand filters, three filter columns were constructed out of 6 inch (15.2 cm) nominal diameter PVC pipes. A Type I Camp filter nozzle supplied by the Walker Process Division of Chicago Bridge and Iron Company was installed in the bottom of each unit. The filter sand was provided by the Northern Gravel Company. It was mixed with finer fractions also supplied by the same company to achieve three distinct effective sizes: 0.2 mm, 0.3 mm, and 0.4 mm. The uniformity coefficients for the filter media were respectively 2.3, 1.8 and 1.75. The filter columns were equipped with valves and rotameters to control filtration rates. Initially these rates were selected to be 0.4 m h^{-1}, 0.12 m h^{-1}, and 0.04 m h^{-1}. Two depths of sand bed, 1.2 m and 0.6 m, were studied. Cercarial recoveries were made by passing the entire filter effluent through Sterifil assemblies (Millipore Corporation) in two hour time segments. For the assay of infectivity Swiss albino mice were exposed to the filter effluent. Mice were placed into Lucite mouse holders which in turn were placed into styrofoam flotation collars so that the lower halves of mice were immersed in the water. The exposure period was one hour. Seven weeks post-infection, mice were sacrificed, autopsied, and infections were determined.

Results of Experiments

The recovery of cercariae in the water flowing through the empty filter columns at the three selected filtration rates was studied to determine the effect, if any, of the rate of flow of water. The PVC columns were opaque so that cercariae were not affected by light. In their active stage they are normally found to be negatively geotropic. Countering this was the flow of water from the surface to the bottom of the columns. The theoretical flow-through times at the designated filtration rates with total water depth of 2.4 m were from low rate to high: 60 hours, 20 hours, and 6 hours. Two test runs were made with 2,000 one to two hour post-emergent cercariae seeded at the tops of each column. Very few cercariae came through the column operated at 0.04 m h^{-1} filter rate appearing only after 4 hours. At 0.12 m h^{-1} and 0.4 m h^{-1} rates cercariae passed through in larger numbers with peaks occuring normally around 3-4 hour interval of time. In one of two runs at 0.12 m h^{-1} the peak occurred sometime after two hours. See Table 1.

As slow sand filters become clogged, water is drawn down, few centimeters of the surface sand are scraped, and the filters are put back into operation. Therefore, the depth of sand becomes less and less. To determine cercarial removals at low sand bed depth, experiments with 0.6 m deep sand beds were conducted. Filter sands of three effective sizes, as described above, were placed into the columns and filter runs were made at 0.12 m h^{-1} and 0.4 m h^{-1} filtration rates. Experiments were conducted at room temperature. The system was dynamic with 2.4 m constant head. 2,000 one to two hour old cercariae were placed at the top of each column at the start of each run. Two test runs were made at the 0.4 m h^{-1} rate and four at the 0.12 m h^{-1} rate. In Table 2 cercarial recoveries at the 0.4 m h^{-1} filtration rate are given. For the 0.2 mm sand column the earliest time period that a cercaria was recovered was between 2-3 hours. In the water passing through 0.3 mm and 0.4 mm effective size sand bed few cercariae were recovered at 1-2 hour interval. The pattern of cercarial passage through 0.4 mm sand bed was about the same as through the empty column, but the numbers were fewer. When the filtration rate was at 0.12 m h^{-1} less cercariae were found to pass through the beds. All other conditions were identical. Few cercariae were recovered at 0-2

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TABLE 1 Cercariae Recovered in Water Passed Through Empty Columns at Three Flow Rates, in Percent

Time, h from-to	Flow Rate		
	$0.04\ m\ h^{-1}$	$0.12\ m\ h^{-1}$	$0.4\ m\ h^{-1}$
0 - 1	0.0	0.0	0.0
1 - 2	0.0	0.3	0.6
2 - 3	0.0	11.8	4.6
3 - 4	0.0	6.4	13.6
4 - 5	0.2	3.9	5.7
5 - 6	0.2	2.8	3.9
6 - 7	0.1	0.6	2.0
0 - 7	0.5	25.8	30.4

Average of two runs

TABLE 2 Cercariae Recovered in Water Filtered Through Three Sizes of Sand, 0.6 m Deep, at $0.4\ m\ h^{-1}$, 2.4 m Constant Head, in Percent

Time, h from-to	Filter Sand Effective Size		
	0.2 mm	0.3 mm	0.4 mm
0 - 1	0.0	0.0	0.0
1 - 2	0.0	0.08	0.1
2 - 3	0.02	0.4	0.8
3 - 4	0.4	0.3	8.3
4 - 5	0.6	0.8	4.1
5 - 6	0.6	0.7	1.8
0 - 6	1.62	2.28	15.1
Head losses, cm	25-30	28-30	16-20

Average of two runs

hour time interval in only one of four test runs. Through the 0.4 mm effective size sand filter bed in two of four runs cercariae were recovered in the 8-10 hour time interval. See Table 3.

After each test run water levels in the columns were drawn down to just above the sand surface. After the first run the drain hose in the column containing 0.3 mm

TABLE 3 Cercariae Recovered in Water Filtered Through Three Sizes of Sand, 0.6 m Deep, at 0.12 m h^{-1}, 2.4 m Constant Head, in Percent

Time, h from-to	Filter Sand Effective Size		
	0.2 mm	0.3 mm	0.4 mm
0 - 2	0.10	0.11	0.06
2 - 4	0.0	0.0	0.0
4 - 6	0.0	0.0	0.0
6 - 8	0.0	0.0	0.0
8 - 10	0.0	0.0	0.12
Head losses, cm	7.5-15	5-17.5	5-12.5

Four test runs were made for columns with 0.2 mm and 0.4 mm effective size sand. Three valid test runs were made in column with 0.3 mm effective size sand.

effective size sand became unsecured dropping the water level to the bottom of the bed. The bed was not refilled immediately and remained in that state for several days prior to Run No. 2. It is presumed that the sand very likely may have pulled away from the column wall in places to allow ready passage of cercariae. In this one test run for the one column, cercarial passage was high. In the 4-6 hour time interval alone greater than 5% of the seeded cercariae passed through the bed. This emphasizes the absolute necessity of maintaining the conditioning of the bed and not allowing the bed to be without water for prolonged period of time.

Mice were exposed to filtrates of the three columns. All other conditions were identical to previous experiments for cercarial recovery. Three test runs were made. In the first test run 2,000 one to two hour old cercariae were employed. In Runs No. 2 and 3 this was increased to 10,000 cercariae. Filtrates were collected for four hours and mice were exposed for six hours. Mice exposed to filtrates of columns with 0.2 mm and 0.3 mm sand did not develop infections. However, half of the mice exposed to filtrates of column with 0.4 mm sand developed light infections. All of the controls developed heavy infections with heavy granulomatous livers. The head losses through the sand beds were 25-30 cm for 0.2 mm sand bed, 10-12.5 cm for 0.3 mm sand bed, and 5 cm for 0.4 mm sand bed.

Since the numbers of cercariae recovered in the filtrates passing through 0.6 m deep beds were exceedingly few, a simple check run was made on cercarial recovery through the sand beds at a greater depth of 1.2 m. No cercariae were captured on the filter paper. Attention was, therefore, turned toward mice exposure tests with 10,000 one to two hour post-emergent cercariae seeded at the tops of each column. At the highest filtration rate of 0.4 m h^{-1} with raw water at 2.4 m constant head, in four test runs with procedures as described above, none of the test mice developed infections. The controls in three runs developed heavy infections; in the fourth, developed moderate infections. Head losses through the beds ranged 94 to 127 cm, 15 to 36 cm, and 5 to 15 cm in the three columns with 0.2 mm, 0.3 mm, and 0.4 mm effective size filter sand, respectively.

Design Parameters

In the light of the results of these tests prudence dictated the selection of sand grains of uniformity coefficient less than 2.0 and effective size of 0.3 mm or less. The filter was designed at 1.2 m depth initially. During its period of use it may be scraped down in depth, but to a depth never to be less than 0.6 m. The filtration rate must be controlled; the design rate was selected to be 0.12 m h^{-1}. All filters are to be thoroughly conditioned before being placed on line, and at no time should the sand bed be allowed to be without water. The underdrains will be simple in construction with precast concrete filter slabs supported on concrete ribs similar to the suggested systems by Huisman and Wood (1974). The flat slabs are to be laid with 5 mm open joints. Over the slab will be a graded gravel course and this, in turn, will support the filter medium. The total filter unit depth will be 3.2 m which includes freeboard, supernatant depth, filter sand, supporting gravel, and underdrains. For flexibility of operation, a minimum of two filters will be built. A storage reservoir will follow the filters.

Sand from a river bed in the area has been put to a sieve analysis and the sample showed that with a minimum of effort it may be used as filter medium. Little washing and discarding grains greater than 0.60 mm produced a medium of 0.3 mm effective size and 1.72 uniformity coefficient. The loss of weight of the sand on exposure to concentrated hydrochloric acid for 24 hours was below the allowable limit.

Field capability for microbiological quality testing has also been incorporated into the project. Where needed, simple chlorination process will be added in the treatment train to provide multiple barriers to assure water quality.

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