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Waterworks operation: how designers can help

Statistics have often been quoted during the Decade to show what fraction of the world has access to a supply of safe water. But in fact they do not give the numbers who receive safe water from their taps. The figures refer to those who are served by a water supply system that has the potential of offering safe water, if properly operated. A treatment plant that is not run correctly may produce water of an unsatisfactory standard such that the health of the community suffers. Operational aspects must therefore be given careful attention if the full beneficial potential of the world's water supply systems is to be realised.

In this paper the authors show how decisions made at the design stage influence the ease with which a water treatment plant can be operated; they also make recommendations for designers based on their observations of operational problems in Africa, Asia, and England. Observations regarding operational techniques will be the subject of another paper; this one concerns design.

1. RIVER INTAKES. Screens should be designed for easy cleaning. They should preferably be inclined to facilitate raking, with no cross bracing or lips to obstruct the path of the rake before the debris is clear of the screen. (Some intakes do not even provide a place for the operator to stand while cleaning the screens). Fixed screens with openings smaller than 25mm should not be used because of the difficulty of cleaning them.

The regular removal of silt must be made as easy as possible. Silt will collect in areas of low velocity. Silt pumps have a very local effect unless the silt is first stirred or fluidised.

River channels move. The low flow channel of a meandering river may take a different route each year (Cotton and Sanousi, 1983) and extraction of sand from the river bed or flood control works may lower the water levels experienced during the dry season. The careful designer will examine such possibilities.

2. PUMPING. Many modern pump motors run at much higher temperatures than older models, so that operators in hot climates are reluctant to run them continuously. The designer should verify that the motors are suitable for the expected ambient temperatures. It is wise to choose a motor that can deliver ten percent more power than is required.

Pump chambers should be sized to allow access to every nut and bolt. Pipe diameters should be increased to the full delivery main size as close as possible to the pump. Floors of dry wells should slope to a sump, with perhaps a handpump to keep them dry.

3. AERATION. Aerators seem to be incorporated in some plants more out of habit than out of necessity. Bypasses should be fitted so that pumping heads are lower when the aerators are not needed.

4. CHEMICAL DOSING. Flows of chemicals should be visible and easily measured (for checking calibrations). Tanks containing lime suspension need constant stirring; if this is not possible a soluble chemical such as sodium carbonate should be used if the pH needs to be raised. Pipes carrying lime suspension are prone to blockages and so should be as short as possible and either have ports for rodding or be flexible. Lime pipes should be duplicated so that treatment can continue when one pipe blocks. Provision should be made for flushing the pipes with clear water.

Rapid mixing of the chemicals should not depend on electric stirrers, because of maintenance problems. A reliable system that operates well over a range of flowrates is the addition directly above a weir - the downstream turbulence quickly disperses the coagulant. (Reactions between water and coagulants take place very quickly, so mixing must be immediate). It is advisable to spread the coagulant across the channel

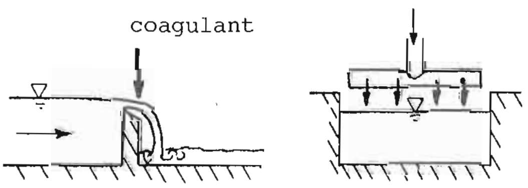

Figure 1 Addition of Coagulant

as shown in Figure 1.
The optimum position for lime dosing is best

determined experimentally and so the operator should be allowed some freedom in this.

5. VERTICAL FLOW CLARIFIERS. Clarifiers which rely on a floc blanket which is held in suspension by an upwards flow of water should only be used where the flow is continuous - 24 hours a day, 7 days a week. When the flow through such clarifiers stops, the floc blanket falls, and it will take hours to form again (if it does at all) after the flow is restarted. So the designer should satisfy himself that the power supply is dependable and that pumping will be continuous before specifying such a process. (If the flow may be intermittent a horizontal flow sedimentation tank should be selected). Control of the floc blanket is a delicate operation, and so the operator must be able to observe easily the nature and colour of the sludge as it is drawn off. The inlet pipe of a hopper-bottomed tank must be located exactly on the axis of the tank so that flow is uniform, and a satisfactory sludge concentrator for such a tank is a canvas cone, suspended near the middle of the tank. (Figure 2). Clarifiers for small treatment plants should preferably not rely on electric motors - the authors remember several plants where, in each case, the only clarifier was out of action at the time of their visit because of mechanical failure.

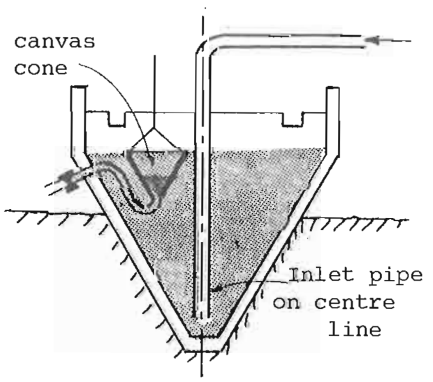

Figure 2 Hopper-bottomed Clarifier

6. HORIZONTAL-FLOW SEDIMENTATION TANKS. Such tanks are strongly recommended when the flow is not likely to be continuous. They must be preceded by an adequate flocculation stage. The flocculation in many plants is insufficient, resulting in poor sedimentation. Attention should be given to the velocity gradients or shear within the flocculator (which should be high enough to promote inter-floc collisions but not so high that large delicate flocs are ruptured) and to the retention time within the flocculator (Barnes et al(1981) state that typical retention times are 20 to 40 minutes). Again the simple is better. A hydraulic flocculator, in which the water flows around baffles, is to be preferred to a system of motors and impellers which will one day need repair. The hydraulic flocculator should be designed to be satisfactory at expected low flows as well as high flows. Proponents of mechanical flocculators claim that a variable speed motor makes the mechanical system much more flexible than the baffled channel, but flexibility can be a curse rather than a benefit. (One author vividly remembers a works where the electric flocculator was turned on for him to see it, and then turned off. Few small plants have staff who are sufficiently trained to tune the equipment to its peak efficiency on a daily basis, so that it is quite possible that it might be running at an unsuitable rate, and the extra cost and complexity of variable motors or transmissions are a further disadvantage to weigh against the potential benefit of flexibility).

Sedimentation tanks are best cleaned manually, for which a 1 in 50 floor slope is appropriate. A large plant, supplying 400 Mgd (1800 Ml/d) and recently commissioned in Manila, uses manually cleaned horizontal tanks, so it appears there is no upper limit on the size of works that can use manually cleaned tanks. There should always be at least two tanks so that one can be on-stream while the other is being cleaned.

7. RAPID SAND FILTERS. A lot can be deduced about the health of a rapid filter from observation of the washing process; therefore pressure filters are not recommended because their filter beds are out of sight. Pressure gauges are very unreliable and cannot be depended on to tell the condition of the sand. Manually-operated rotating rakes within a pressure filter can give a 'feel' for the condition of the sand but the gland around the rake shaft may give trouble.

In an open, gravity filter a ladder or step irons leading to the filter bed might encourage operating staff to monitor and maintain the condition of the filter bed more regularly.

Flowrate controllers at most works visited have been inoperative, though the float-and-lever types seem to be more reliable than those actuated by a venturi. Because of the unreliability of these devices the outlet of the filter should be marginally above the bed level so that the bed is always immersed and filtering properly. The filtrate from each unit in a bank of filters should be kept separate until it can be sampled or observed, so that the state of each filter bed is known - if the filtrates are mixed a turbid product from one bad filter could be masked by the high quality water from the others. The quality of the filtrate is impaired by sudden changes in filtering rate caused by poorly maintained flowrate controllers, or rapid adjustments of hand-operated valves. (Variable-head declining-rate filtration avoids such sudden changes by controlling the flow through the filter by changes in the level of the water above the bed, so that all flowrate changes are gradual).

Water temperature has a significant effect on the flowrate necessary for effective backwashing - warmer water must be pumped at a higher rate to give the same bed expansion. Washwater collection troughs are sometimes undersized, perhaps because they were designed for cooler climates.

8. SLOW SAND FILTERS can produce an excellent quality water provided the water they treat has a low turbidity (less than 30NTU). Simple pretreatment systems such as bankside filtration, plain sedimentation, vertical flow roughing filters or horizontal gravel filters may be used to lower the turbidity. The high quality of the filtered water means that failures in the disinfection system will not be a serious threat to public health.

The downstream pipework should be so arranged that the water surface in the filter cannot fall below the top of the sand bed if the filter is left unattended at night or if the filtrate is running to waste (Figure 3.) It should also be possible to fill the filters

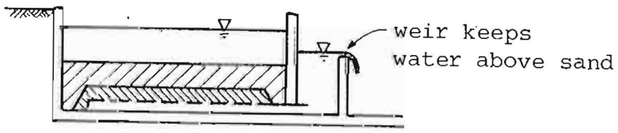

Figure 3 Slow Sand Filter

from below. It is necessary to monitor the quality and flowrate of the filtrate from each individual unit.

Flow down the easy path next to the walls should be discouraged by roughening the walls or inserting a horizontal groove, and by stopping the underdrains and gravel short of the walls.

A platform level with the top of the filter wall is necessary for the removal of dirty sand.

9. DISINFECTION. If chlorine gas is used the cylinders should be stored in a cool, well-ventilated place. The chlorinator should be at a higher ambient temperature than the store and the temperature gradient of the chlorine gas feed line should never be reversed since this would cause the chlorine to condense. The feed line should be as short as possible. Cylinders should be firmly secured because a very dangerous leak would result from a cylinder falling and fracturing the feed pipe.

If bleaching powder is used separate mixing and dosing tanks should be provided so that solid deposits do not clog the dosing mechanism. A point of application at the entry to the contact tank should be provided and the dose at the point of application should be visible.

10. GENERAL. The designer should endeavour to make all water levels and flows easily visible for casual observation. Provision should be made for measuring flows of chemicals. White tiles and direct sunlight aid in quick observations of turbidity. Where inspection covers are necessary they should be easy to move; otherwise they will be always left on or always left off.

All tanks need cleaning; this should be allowed for by providing falls to the tank floors and sumps or drains, and easy access. Weirs must be exactly horizontal and so adjustable weir plates are recommended to compensate for inaccuracies in the concrete. Splitting a flow into equal portions is not easy to achieve and so provision for measuring and modification should be made so that the commissioning engineer can make the necessary adjustments to obtain an equal division of the flow.

The simplest control systems are the best. Pneumatic actuators for remote control may cause maintenance problems, and prevent the operator from seeing the result of his action. Manually-operated valves are robust and encourage observation.

11. CONCLUSION. Conventional engineering education has laid great stress on design and on the efficiency of equipment under ideal conditions, rather than on actual conditions and operational experience. Designers are thereby taught to think of their plant as it will be in the first week of its life, rather than as it might be after fifteen years of arduous use. This shortcoming in a designer's formal education can be overcome by giving him operations experience and by encouraging him to visit schemes he has helped to design that are now in operation.

It is hoped that the comments made in these notes may form the beginnings of a checklist for designers. These observations are offered in the hope that they will strengthen friendships between operators and designers!

12. REFERENCES

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COTTON A & SANOUSI M A; "Water Supply for Gedaref; Are Infiltration Galleries the Answer" Proceedings, 9th WEDC Conference, Harare; WEDC 1983.