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# "Appropriate technologies" for drinking water supply in developing countries

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## Abstract

In order to ensure maximum consumer benefits (e.g. public health, livelihood), drinking water supply technologies in developing countries should be adopted taking into consideration locally available skills, resources as well as cultural and environmental settings. This paper presents case-studies from several developing countries in different geographical regions of water supply projects utilizing methods ranging from biological treatment offered slow sand filtration systems to chemically-assisted clarification. These examples reveal successes and lessons learnt in several research projects conducted under different settings (e.g. international development and humanitarian emergencies). In addition, the importance of capacity building for successful implementation of water treatment technologies is also illustrated.

## Keywords

Appropriate technology; coagulation; development; emergencies; slow sand filtration; water treatment

## INTRODUCTION

Health risks associated with drinking-water, particularly microbial, are a major concern in water treatment. Particularly in developing countries where resources for a minimally adequate and reliable water supply are many times lacking. Therefore, drinking water treatment and supply projects should make the most of the accessible resources by adopting the most adequate technologies available. The term “appropriate technology” is commonly used in the context of water treatment and supply in developing countries to refer to water purification techniques that can be implemented (sometimes), operated, and maintained by the beneficiary community.

Appropriate technology usually refers to situations where there is a relative stability and time for the involvement and capacity building of the local community (i.e. development projects). Locals are consulted on their preference of technology and factors such as locally available skills and resources are taken into consideration together with the cultural and environmental settings. However, in situations such as humanitarian emergencies an appropriate technology may refer to water treatment methods that can be quickly and easily implemented (usually by a foreign aid agency) in locations with limited resources (e.g. energy source, chemical supply, spare parts).

Three case studies are presented on use of appropriate technologies for water treatment in developing countries, varying from rural community slow sand filtration systems to chemically-assisted emergency water treatment kits. Both successes and lessons learnt are illustrated in each case study from varied geographical locations (i.e. Sub-Saharan Africa, South Asia, and South-East Asia) and contexts (i.e. development and humanitarian emergency).

## **CASE STUDY 1: MULTI-STAGE FILTRATION IN RWANDA**

### **Multi-stage filtration**

Slow sand filtration (SSF) has been well established as a biological process for drinking-water treatment that can achieve significant improvements in water quality. However, it is sensitive to influent waters of high turbidity. This limitation has the implication of hindering the reliability of the process in terms of continuity or negative effects on the biological activity. This shortcoming to SSF can be dealt with the incorporation of pre-treatment stages. Gravel (or roughing) pre-filters are units filled with gradually finer graded media with varying bed depths (or lengths). They have been used together with SSF due to their effectiveness, simplicity, and reliability as pre-treatment, providing (together with SSF) a multiple-barrier system; otherwise known as multi-stage filtration (MSF) systems. Such a treatment approach relies on more than one purification stage (or barrier) during the treatment process progressively removing contaminants and consistently producing safe and wholesome water (Galvis et al., 1994).

### **Study area**

The study area is situated in the communities of Nyabwishongwezi and Ntoma in northeast of the country bordering Uganda and Tanzania. The two multi-stage filtration (MSF) water treatment plants (WTPs) are located in a hilly terrain and utilize the river Umuvumba that runs through the border of Uganda and Rwanda. The Nyabwishongwezi WTP is a multi-stage filtration plant consisting of four parallel storage tanks followed by two parallel two-stage gravel (roughing) pre-filters and four parallel slow sand filter units. Choice of such treatment system was based on the inadequacy of groundwater as a source in terms of quantity and quality (i.e. high iron content). This WTP was designed for a population of 18000, mainly returnees from the 1994 genocide. The neighboring Ntoma WTP was commissioned by a different non-governmental organization (NGO) shortly after the construction of the Nyabwishongwezi WTP. It is said to have been a “blueprint copy” of the Nyabwishongwezi WTP; mainly differing in the fact that the water is pumped from the river intake to conventional rectangular (horizontal-flow) sedimentation basins, in contrast to the batch (i.e. fill-draw) storage tanks of the Nyabwishongwezi WTP. This is followed by two-stage up-flow gravel pre-filters and slow sand filters.

### **Field visit outcomes/findings**

Despite having no terminal disinfection, the finished water produced by the MSF system in Nyabwishongwezi was substantially better in terms of turbidity and microbiological quality in comparison to the polluted source water (Figure 1). The water quality assessment was done in conjunction with the plant operating staff that received water quality training during the first field visit to the system in 2002. However, some design/operational problems were also noted (Bertrand et al., 2003; Dorea et al., 2004), some of which could be simply remedied (e.g. floating outlets to storage tanks, drainage system for gravel pre-filter cleaning); while others would require a substantial investment (e.g. adequate intake structure, insufficient number of gravel pre-filter units).



**Figure 1: Improved water quality along MSF system (samples from: raw water, settling tank, pre-filter, slow sand filter – left to right).**

Subsequent visits to the Nyabwishongwezi WTP in 2003 and 2004 saw improvements with regards to the simple deficiencies. It was also noticed that the continuing operation of the WTP was being affected mainly by issues relating to the tariff system. There was a low revenue collection due to seasonally low water usage (i.e. rainy season). Notably, the tariff system (by demand of local authorities to comply with National tariff model) did not factor the depreciation and replacement of items (e.g. diesel pump). Moreover, by 2003, the increase in fuel costs, attributed to the events occurring in the Middle East, was already affecting the community's capacity to purchase diesel to run the pumps. A final visit to the system revealed that the Nyabwishongwezi system was not operational due to the breakdown of the pumps.

The Ntoma WTP shared as well many similarities in terms of design shortcomings that could have been avoided with consultation. Most notably was the choice of sedimentation basin. Conventional rectangular (horizontal-flow) settling basins require a constant flow in order to be effective. However, due to the positioning of the WTP and the topography of the region a constant supply of water would require a non-stop pumping regime; which is unfeasible for this type of rural scheme. Unfortunately, no information on the operation of this water treatment plant was available, as it is said to only have operated for the two days in which the implementing NGO was present (Dorea et al., 2004)!

## **CASE STUDY 2: EMERGENCY “CLARIFIER” IN INDONESIA**

### **Oxfam Field Up-flow “Clarifier”**

The supply of safe drinking water during disasters can be compromised and is one of the top priorities in public health interventions that must be reestablished to prevent the spread of disease. When the speedy establishment of adequate water supplies is beyond the capacity of local authorities, emergency response and equipment from external relief agencies can often provide timely interim solutions while more durable long-term repairs are being planned. The Oxfam Field Up-flow Clarifier Kit is an emergency water treatment kit that is one type of treatment option deployed to emergencies in the event of disasters (Dorea et al., 2006). The Clarifier relies on the principles of up-flow blanket clarification and is driven by a single pump; requiring only fuel and aluminum sulfate, which are typically widely available. Detailed description and performance of the Clarifier is available elsewhere (Dorea et al., 2007).

### **Study area**

Following the Asian Tsunami of December 2004, two Clarifier units were deployed to the affected villages of Lamno and Meulaboh on the island of Sumatra (Indonesia). In Lamno, pre-coat (diatomaceous earth) filters were being used for emergency relief water supply. Yet, the effectiveness of these units was being compromised by the increasing turbidity of the source river, due to the approaching of the monsoon season. This prompted the installation of an Oxfam Field Up-flow “Clarifier” Kit to aid in the water production in May 2005 (Dorea et al, 2007). In Meulaboh a unit had already been installed, but required optimization and operator training.

### **Field visit outcomes/findings**

Operator training was provided for the unit installed in Lamno before being handed over to the local Public Health Engineering. It was later reported that high turbidities could be effectively reduced to the recommended potable drinking water limits (i.e. below 5 turbidity units), as per Sphere Project (2004). Such unit was still running for more than two years when it was last visited in 2007. On that occasion it was noticed that the (unskilled) operators had been successfully running the Clarifier with only the training received when the unit was installed (Figure 2). The unit installed in Meulaboh was also visited and optimized. Operators there received training in field jar-testing for coagulant dose determination, as explained by Dorea (2007). Simple concepts delivered in the training proved to be effectively assimilated by the operators. A sign of this was that during a 103 day (unsupervised) period following the training, the logged Clarifier performance revealed that the treated water turbidity was always below recommended potable drinking water limits (Dorea et al., 2007).



**Figure 2: Operator training on simplified jar-test procedures for coagulant dose determination.**

## **CASE STUDY 3: EMERGENCY BATCH WATER TREATMENT IN PAKISTAN**

### **Emergency batch water treatment**

Batch mode emergency water clarification is usually carried out in storage tanks by adding the coagulant (e.g. alum) the incoming water. Once the tank is full, the water is left to settle; after which the settled water is then decanted, stored, and disinfected prior to distribution. Despite limited process control, turbidities in the hundreds can be reduced to what is considered to acceptable by the Sphere Standards, i.e. < 5 NTU. This is a simpler (in comparison to the Clarifier) and most common form of emergency water treatment (Dorea, 2007).

### Study area

In the aftermath of the October 8 2005 earthquake in Pakistan two rural filtration systems were visited in the Jehlum Valley region near Muzaffarabad (AJK, Pakistan). Both plants were similarly designed and operated by the local governmental water authority. Of the two, the Gahri Dupatta WTP was the worst hit; having its pumping station, settling basin and slow sand filters structurally affected. Further upriver, the Hattian Bala WTP was still operational relying on an undamaged slow sand filter bed. Both systems relied on river abstraction by pumping in to plants consisting of baffled hydraulic flocculators followed by conventional rectangular sedimentation basins and slow sand filters. Whilst the rehabilitation of the Gahri Dupatta treatment plant was being commissioned, the damaged settling basin was by-passed and alum-assisted batch emergency sedimentation tanks were used for the emergency relief efforts (Figure 3).



Figure 3: Emergency batch sedimentation tanks used in Gahri Dupatta.

### Field visit outcomes/findings

A few design issues were observed, particularly with regard to the choice of sedimentation basin and pre-treatment method for the slow sand filters. Similarly to what was observed in Ntoma, the location of the WTP on a hillside should have proscribed against the choice of settling basin. The electric pumps operated intermittently due to the constant power shortages experienced in the region (even before the earthquake). Such operating regime most likely would have caused the stirring up and carry over of previously settled particles into the slow sand filters every time the flow was started; thereby shortening the duration of the filter runs. In addition, the choice of an alum-based pre-treatment method was perhaps not ideal considering the rural settings and availability of other non-chemical pre-treatment techniques (i.e. gravel or roughing filtration). Anyhow, it was noticed that operators in both plants assimilated well the simplified jar-test procedures for coagulant dose determinations, as had been observed previously in Indonesia. Prior to the training sessions, the operators would add the entire daily coagulant “requirement” was added at once directly into the incoming flow of water in the baffled flocculator. Noting that the alum “requirement” was arbitrarily decided depending on the perceived color of the river.

## SUMMARY AND CONCLUSIONS

The case studies presented give abridged descriptions of research/field work with appropriate technologies for water treatment in developing countries. In the field visits where rural supply schemes were encountered (Rwanda and Pakistan), the importance of proper design and adequate choice of treatment unit processes (e.g. sedimentation basin) is illustrated. Such examples of *by-the-book* designs are great, but only if they fit within the local context and can be properly operated as recommended *by-the-book*! In the context of areas with limited resources, coagulant-based water treatment processes are not viewed as appropriate technologies; such was the case observed in Pakistan. However, experiences also indicated that in extreme circumstances, such as in the aftermath of disasters, local (and mainly unskilled) operators can successfully operate coagulant-based processes. Noting that these were short-term measures only utilized whilst a supply of chemicals was available from the implementing aid agency. The main key to the successful operation of these systems in emergencies was the adequate training and capacity building of operators. Finally, another non-technical factor to take into account when selecting a technology is the cost-recovery of the running expenditure. This should include in the tariff system for the successful long-term operation of a water supply scheme.

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