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Inclined plate settling for emergency water treatment: towards optimisation

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Previous work revealed the potential of an inclined plate settler (IPS) for water treatment in emergency relief applications. Whilst preliminary data demonstrated the tested IPS prototype's capacity to achieve stable turbidity reductions, further optimisation was warranted. This paper reports on the optimisation and preliminary field testing of an IPS prototype. Trials revealed that after system modification, treatment objectives with regards to turbidity reductions (i.e. < 5 NTU) could be achieved. Such positive results were largely due to the addition of a hydraulic flocculation (conditioning) stage.

Introduction

Water treatment and supply plays a vital role, alongside hygiene promotion and sanitation, in the prevention of diarrhoeal diseases during humanitarian crises. For this, there is a need for both larger quantities (i.e. for personal hygiene) and "safe" water quality (i.e. for hydration purposes) according to the WHO (2005) and The Sphere Project (2011). Therefore, centralised "bulk" emergency water treatment systems should prioritise the production of larger quantities of relatively good (i.e. safe) water rather than smaller volumes of very high quality water. From this perspective, a new humanitarian emergency water treatment system based on inclined (lamella) plate settling has been developed.

Photograph 1. Original IPS prototype in Pune (India)

Previous work (Dorea and Bourgault 2013) demonstrated the potential of an inclined plate settler (IPS) prototype (Photograph 1) in achieving emergency water supply (i.e. water quantity and quality) objectives in a cost-efficient manner. However, there was still scope for improvement of treated effluent turbidity. During the full-scale prototype trials in India, turbidities in the order to 100 to 300 NTU could be consistently reduced by approximately 90 % for prolonged periods of time. Yet, the treatment objective of less than 5 nephelometric turbidity units (NTU) was not achieved systematically. One possible explanation for this was that the lack of an adequate flocculation stage hindered the formation of readily settleable flocs in the settler. A 60 m length of 3” layflat hose was used to promote coagulant mixing based on other emergency water treatment system designs. However, the hydraulic regime and mixing times (i.e. < 2 minutes) may have had more resemblance to a rapid mixing stage than a flocculation step. This paper reports on efforts to optimise the IPS with regards to turbidity reductions.

Materials and methods

An inclined plate settler prototype was originally built in mild steel for a maximum design flow rate of 3 m^3/h (Photograph 1). However, further testing revealed similar treatment performance could also be achieved at higher flow rates of up to 6 m^3/h. The characteristics of the original full-scale IPS and testing facilities are detailed elsewhere (Dorea and Bourgault 2013). Desired turbidities between 50 and 300 NTU were generated using kaolin as a surrogate for suspended particulates used in the optimisation tests.

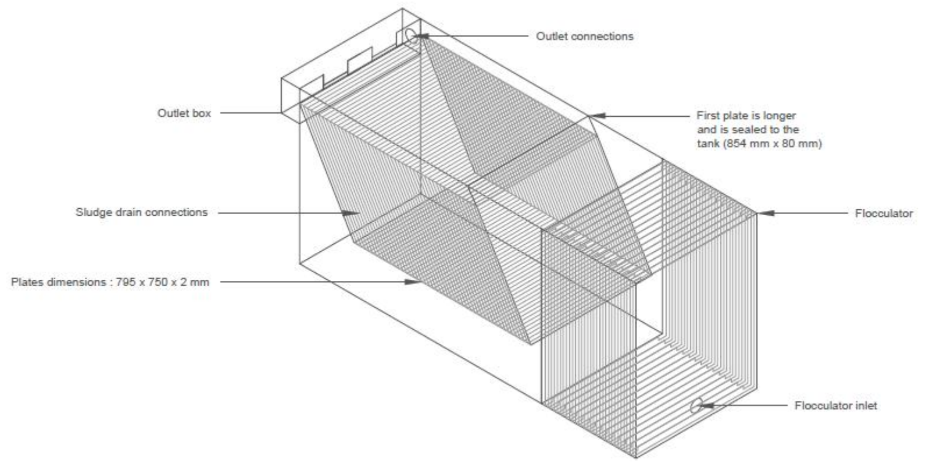

Figure 3. Turbidity profile for field trial run

Photograph 2. Modified IPS prototype with hydraulic flocculator extension and overflow lauders

The original prototype was modified by the addition of an “over and under” type hydraulic flocculator ahead of the inclined plate settling module (Figure 1 and Photograph 2). The hydraulic flocculation was achieved by vertical plastic sheets held at adjustable spacing in order to assess different hydraulic flocculation configurations. Visual food dye tracer tests revealed preferential flow patterns (i.e. potential hydraulic short circuiting) on the original prototype. Thus, an overflow lauder was also fitted over the inclined plates for a better flow distribution. In addition, preliminary field trials were conducted on a natural surface water to assess the performance of the modified prototype. Typically, terminal disinfection would be practiced by chlorination of the IPS effluent so as to guarantee the potability of the treated water with regards to microbial water quality. During these trials, such step was not undertaken as the main objective was to assess the IPS performance with regards to turbidity reductions. This parameter is thought to be a limiting factor in the performance of many emergency water treatment kits (Luff 2004; Dorea et al. 2006).

Results

Trials following the modification (i.e. hydraulic flocculator and overflow launders) of the IPS prototype demonstrated and overall improvement of the system performance with regards to the original configuration (Figures 2 and 3). Although a variety of hydraulic flocculator configurations were tested, higher turbidity reductions could not necessarily be correlated with and mixing time and intensity of the hydraulic flocculator (i.e. number and spacing of baffles) as theoretically described by Haarhoff and van der Walt (2001). This could be in part due to the experimental setup used and its limitations. As most of the mixing occurs at the extremities of the baffles (i.e where the direction changes), the chosen flocculator configuration (i.e. over and under) did not make an optimal use of the reactor volume; thus, possibly reducing the effective flocculation times. Even though higher turbidity reductions could be achieved in general at higher flow rates, trial times had to be shorter, as there was a limited amount of test water available per day. This limitation also caused peaks of raw water turbidity every time kaolin had to be added to the raw water tank (as seen in Figure 3). However, such peaks did not seem to affect the effluent turbidity, confirming the system stability also observed previously.

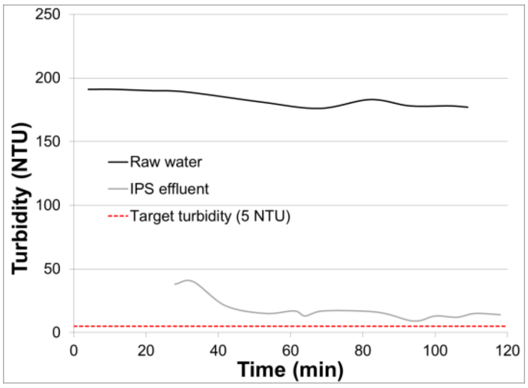

Figure 2. Typical turbidity profile from an original IPS run at 3 m^3/h

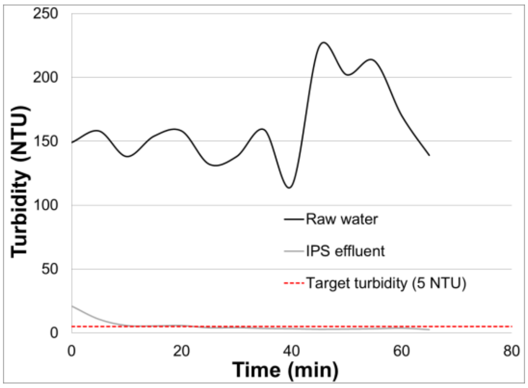

Figure 3. Turbidity profile from a modified IPS run at 6 m^3/h

Photograph 3. Test site for IPS field trial

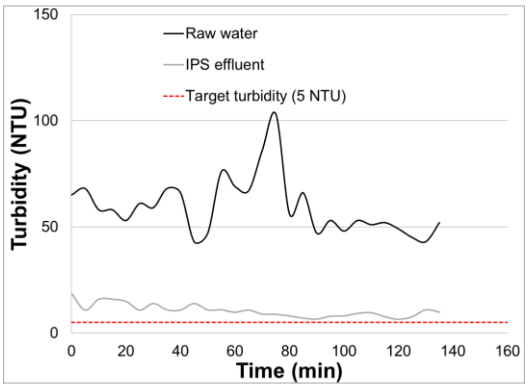

Figure 4. Turbidity profile for field trial run

The system stability was also confirmed during the field trials (Photograph 3). Initially, poor floc formation likely resulted from the low source water alkalinity (not measured), as the coagulated water pH was below 5. This was corrected by the addition of a second vessel containing an alkalizing agent to the suction side dosing arrangement upstream of the coagulant dosing point. Once the coagulation pH was adjusted to near neutral, floc formation and turbidity reductions improved (Figure 4). However, IPS effluent turbidities during field tests averaged around 10 NTU.

Conclusions

Turbidity reductions of an inclined plate settler prototype were improved. This is largely attributed to the addition of a hydraulic flocculation stage upstream of the settling unit. Trials revealed that after system modification, treatment objectives with regards to turbidity reductions (i.e. < 5 NTU) could be achieved. However, further work is needed to “fine tune” the floc conditioning conditions in order to consistently achieve such water treatment targets. Field tests were also conducted on the prototype. Such tests confirmed the stable effluent turbidities that were observed during pilot trials under experimental conditions (i.e. using synthetic raw waters).

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