Guide to Inclined Plate Settlers


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The QUESTOR Centre

Applied Technology Unit

Report on behalf of Mud Blaster Systems Ltd.

Guide to Inclined Plate Settlers

Prepared by

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Checked by

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Summary
After an initial site visit and testing it was concluded that there were fundamental design flaws that prevented the efficient operation of the MUDBLASTER system. At this point it was decided not to prepare a Standard Operating Procedure (SOP) and to instead prepare a report that would contain essential training information for staff at Mudblaster Systems Limited and also make recommendations to improve the overall performance of the system. If and when these recommendations are implemented then a SOP will be prepared and issued.

Introduction
Following initial contact, Paul Coyle, Managing Director of Mud Blaster Systems Limited came to the QUESTOR offices to discuss the project on Friday 31st October. Julie-Anne Hanna, Ciarán Prunty and Simon Murray attended the meeting on behalf of the QUESTOR Applied Technology Unit (ATU).

Site Visit
On the morning of Friday 7th November 2008, Simon Murray and Ciarán Prunty from the ATU travelled to MUDBLASTER’s demonstration site; a construction site of the new A4 dual carriageway between Dungannon and Ballygawley, Co. Tyrone. There they met with Paul Coyle and observed the operation of the MUDBLASTER system. The ATU staff found the system to be a single tank (Figure 1) containing an array of wooden inclined plates (Figure 2). The tank was fed by pumping collected runoff from a depression in the ground (Figure 3) and effluent passed through a lagoon (Figure 4) before being discharged to a nearby stream.
Samples were collected from the tank inlet zone, effluent pipe, feed reservoir and discharge lagoon. No visual difference in the wastewater was observed between any of the sample locations. Subsequent solids analysis of these samples found no significant difference in the solids concentration in the influent and effluent samples (Table 1). Solids concentrations were somewhat lower in the MUDBLASTER tank than in the pumping sump or effluent lagoons but this may be due to the action of the pump and/or environmental conditions.
Table 1: Suspended solids results

<table>
<thead>
<tr>
<th>Sample</th>
<th>Suspended solids (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inlet</td>
<td>836</td>
</tr>
<tr>
<td>Outlet</td>
<td>832</td>
</tr>
<tr>
<td>Pumping sump</td>
<td>1158</td>
</tr>
<tr>
<td>Lagoon</td>
<td>1370</td>
</tr>
</tbody>
</table>

**Justification of changes to scheme of work**

Following the site visit it was concluded that there were fundamental problems associated with the design and operation of the MUDBLASTER system and that in it’s current state it was incapable of performing efficiently. Rather than proceed with the project as planned, it was decided that the best course of action was to prepare a Report that would provide essential training information for staff at Mudblaster Systems Limited in the design, construction and operation of lamellar plate settling tanks. The Report also makes recommendations to improve the design and construction of the MUDBLASTER System. This was put to Mr Coyle at a meeting on October 31st and agreed by him on November 25th 2008 (see attached). INI approval was received in December and work began in early February.

A document, explaining the operation of inclined plate settlers and recommending several improvements to the MUDBLASTER system was prepared. This report was subsequently presented to Mudblaster Systems Ltd.

The final section of planned work (Using the procedures developed in Section 08Q138.3 and 08Q138.4 to optimise current sites) was removed and Coyle Fabrications were invoiced for the work that had been completed. It is hoped to revisit this project and complete the cancelled sections in the future.
**Settling – Theory and Application**

**Introduction**
The MUDBLASTER system achieves solids removal from wastewater via a process called settling. This document explains the process of settling, factors that influence the viability and rate of settling, and makes recommendations which would improve and extend the range of wastewaters that can be successfully be treated with the MUDBLASTER system.

**What is settling?**
Settling is the separation from water, by the action of gravity, of particles that are heavier than water. It is also called sedimentation or clarification and particles that can be removed by the process are called settleable solids. Until these solids are settled out, they are suspended in the liquid.

**How does it work?**
Fast moving water causes mixing and turbulence that keeps particles in suspension. When water is slowed below a critical value, known as the settling velocity, the particles fall out of suspension and settle to the bottom, forming a sludge or sediment.

The settling velocity depends on the size, shape and density of the solid particles.

**How long will it take?**
Slowing the water is not enough; the water must be kept in the tank for a minimum time to allow all of the particles to settle out.

Maintaining the water velocity below the settling velocity is not in itself sufficient to ensure settling. A minimum residence time in the settler, known as settling time must also be in order to achieve the desired amount of solids removal. The minimum settling times for a range of particle types are shown in the table below (based on a tank depth of 3 metres):

<table>
<thead>
<tr>
<th>Nature of solid</th>
<th>settling velocity (m/s)</th>
<th>settling time (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay, silt</td>
<td>0.07</td>
<td>720</td>
</tr>
<tr>
<td>Primary organic waste</td>
<td>0.42</td>
<td>120</td>
</tr>
<tr>
<td>Aluminium and iron flocs</td>
<td>0.83</td>
<td>60</td>
</tr>
<tr>
<td>Activated sludge flocs</td>
<td>2</td>
<td>25</td>
</tr>
<tr>
<td>Grit</td>
<td>20</td>
<td>2.5</td>
</tr>
</tbody>
</table>

**Table 3: Settling times of common particles in 1 metre of water**

<table>
<thead>
<tr>
<th>Particle</th>
<th>Size</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>House Brick</td>
<td>100mm</td>
<td>2 seconds</td>
</tr>
<tr>
<td>Fine Sand</td>
<td>0.1mm</td>
<td>80 seconds</td>
</tr>
<tr>
<td>Silt</td>
<td>0.01mm</td>
<td>110 minutes</td>
</tr>
<tr>
<td>Bacteria</td>
<td>0.001mm</td>
<td>180 hours</td>
</tr>
<tr>
<td>Colloidal Particle</td>
<td>0.0001mm</td>
<td>2 years</td>
</tr>
</tbody>
</table>
What are Inclined Plate Settlers?

As stated above, solids removal efficiency is related to the settling velocity and not the depth or volume of settling tanks. Therefore, settling tanks should be constructed as shallow as possible to achieve maximum settling efficiency. However there are a number of practical considerations which limit the use of extremely shallow basins (area etc.) – lamella or inclined plate settlers offer a practical solution, offering large settling areas without associated large footprints. The MUDBLASTER system can be considered to be an inclined plate settler.

Inclined plate settlers consist of an array of overlapping plates, which provide increased settling area without increased footprint. In Figure 5, the set of plates provide the settling area shown above the plates, whilst only occupying the footprint shown below the plate.

How does the MUDBLASTER system work?

The plates effectively split the settling tank into a large number of small settling tanks, and give reductions in settling times due to a lessening of the vertical distance a particle must fall to be removed from suspension – instead of falling the entire height of a settling tank (anything up to 3 m), they must only fall the distance between the inclined plates, typically approximately 5 cm.

Once removed from suspension the solids slide down the surface of the inclined plate under the action of gravity and are collected at the bottom of the tank before periodically being removed. The clarified water rises to the top of the plates and leaves the unit through the overflow weir.
Terminology

**pH** – pH is a measure of the concentration of hydrogen ions in a solution; acidic solutions will have a high concentration of hydrogen ions and alkaline solutions will have a low concentration of hydrogen ions. The pH scale ranges between 1 and 14, acidic waters have low pHs (lower than 7) and alkaline waters have high pHs (greater than 7). Those with a pH of 7 are termed ‘neutral’.

**Coagulation** – coagulation is a process in which the electrical charge on microscopic particles is neutralised so that these micro-particles are capable of sticking together. A coagulant is a chemical whose addition speeds this process.

**Flocculation** – flocculation is a process by which small particles formed by coagulation are brought together into larger particles called flocks, which can then be removed by gravity settling. This process is brought about by addition of a flocculant.

The terms coagulation and flocculation are often used interchangeably, due in part to the fact that the two processes often take place simultaneously in the same tank and chemicals are available which act as both coagulants and a flocculants.

**Coagulation/Flocculation**

Fine particles in suspension are often too small to be settleable. In order to achieve gravity settling, it is necessary to bring the particles together into substantially larger particles, achieved by the processes of coagulation and/or flocculation.

Coagulants with charges opposite to those of the suspended solids are added to neutralise the charge on the suspended solids, making them capable of sticking to each other. The slightly larger particles formed by this process are called microflocs, and are not visible to the naked eye. A contact time of 1 to 3 minutes is typical for coagulation.

Following coagulation, a second process call flocculation occurs. The added flocculant binds the microscopic particles together to produce large visible solids, which can then be removed by gravity settling. Contact times of 15 to 20 minutes are typical for flocculation processes.
1. Small, negatively charged particles will not bind together to form settleable solids.
2. Addition of positively charged coagulant neutralises charge on particles, which bind together forming microflocs.
3. Addition of flocculant binds microflocs into settleable solids.

Figure 7: Coagulation and flocculation theory

Improvements to MUDBLASTER system

How can solids removal

Recommendations for Improving the Performance of the MUDBLASTER system

Flow rate
For any given wastewater, there is a maximum flowrate that the MUDBLASTER settler can treat in order to achieve the required settling velocities in the settling zone. As stated above, smaller, lighter particles will take longer to settle out of suspension, and therefore the MUDBLASTER system must be operated at lower flowrates in order to obtain the required velocities and retention times required to achieve this. Operating the system above these maximum flowrate will lead to particles being carried into the overflow.

Flow patterns
The inclined plate settler must be designed and operated in such a way as to ensure even flow between each set of plates. In the MUDBLASTER system, the flow is distributed between the plates through the channels which run alongside each side of the plate pack. This arrangement should achieve even flow distribution in the MUDBLASTER provided it is ensured that the tank is completely level.

Turbulence (caused by fast flowing water), under the plates should be avoided as this can lead to resuspension of previously settled solids and poor removal efficiencies.

During the visit carried out by QUESTOR personnel on November 7th 2008, it was observed (Figure 8) that the desludging valve

Figure 8: Desludging valve in MUDBLASTER unit
is located in an area of the tank which experiences high levels of turbulence from the inlet flow (see photo above). This could lead to previously settled material being resuspended. It is recommended that alterations be made to the tank to avoid contact between influent wastewater and collected sludge by moving the desludging valve so that it is shielded by the splash plate.

Additionally, the tank should be placed away from any sources of vibrations, which may also disturb settled material.

**Plate spacing and angle of inclination**

- Decreasing plate spacing will give greater solids removal (less distance for particle to fall), but will increase the likelihood of solids build up causing the flow channel to block.
- A high angle of inclination is required in order to keep the plates self cleaning (less likely for solids to stick to plate surface), although higher removal rates will be achieved at lower angles (less vertical distance between plates). An angle of 55° is often employed as a compromise between these two competing demands.

**Materials of construction - plates**

The plate material must be smooth to ensure that settled material slides down the surface to the sludge collection zone. It must also be rigid enough to prevent warping under the weight of a full tank of water – warping would lead to narrowing of the flow channels which could reduce performance due to increasing water velocities and uneven flow distribution. Commonly used materials include polypropylene, polyvinylchloride and steel. The wooden plates in use during the QUESTOR site visit of November 7th 2008 (Figure 9), are unsuitable as the textured surface of the wood is not sufficiently smooth to be self cleaning – solid particles adhere to the plates which can lead to a decrease of efficiency.

**Desludging and cleaning**

The unit will require periodic desludging and cleaning to prevent efficiency becoming compromised. Despite good design and following the operational guidelines above, sludge can build up on the plates and narrow the flow channels. This has the effect of increasing water velocity that in turn has an effect on the solids the system can remove.

The frequency of these operations will be dependant on the type of wastewater. Wastewaters containing higher concentrations of solids will require desludging more often and those with
‘stickier’ solids require cleaning more often. Cleaning often consists of removal of adhered sludge with high pressure water from a hosepipe.
Coagulation and flocculation

The amounts of coagulants and flocculants which are needed will vary depending on the characteristics of the wastewater, and can be determined by jar tests. Consideration must also be given to cost of coagulant/flocculant, effect on downstream treatments, cost and method of sludge disposal when selecting coagulant/flocculant type.

If it was decided to add coagulation/flocculation to the MUDBLASTER system, it would require the addition of a mixing tank where the coagulant/flocculant would be added. Figure 10 shows how this is achieved in the Parkson Lamella® Gravity Settler.

Table 4: Common coagulant/flocculants

<table>
<thead>
<tr>
<th>Coagulant/Flocculant</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alum</td>
<td></td>
</tr>
<tr>
<td>Ferric Sulphate</td>
<td>Iron salts often produce coloured wastewater</td>
</tr>
<tr>
<td>Ferric Chloride</td>
<td></td>
</tr>
<tr>
<td>Ferrous Sulphate</td>
<td></td>
</tr>
<tr>
<td>Sodium Aluminate</td>
<td></td>
</tr>
<tr>
<td>Polyelectrolytes</td>
<td>Expensive</td>
</tr>
</tbody>
</table>

pH Adjustment

pH adjustment, carried out by the addition of small amount or acid or alkaline, may also be of benefit to the MUDBLASTER system.

Some waste streams may suffer from extreme (acid or alkaline) pH and high suspended solids concentration, but require limited biological treatment. The MUDBLASTER system would be suitable for the treatment of such streams, if pH control, either of the influent or effluent, was added to the system.
Additionally, pH adjustment may be required to the influent, in order to make the process more effective, and effluent, in order to make it suitable for discharge, if coagulation/flocculation is employed.

**Flow Control**
As stated previously, the influent flowrate greatly influences the water velocity through the settling zones and hence the settling efficiency of the system. A method of flowrate control, either through the use of variable speed pump or a flow control valve, would be beneficially to the system, increasing the range of particle sizes that can be removed.

**Jar Tests**
Jar tests were carried out on the effluent water samples collected during the QUESTOR site visit on November 7th 2008, as a demonstration of how the improvements suggested above would be of benefit to the MUDBLASTER system and it is recommended that these be continued.

The tests consist of two stages:

- **pH adjustment**;
  
  small amounts of acid/alkali are added to adjust the samples to a range of pHs (3, 5, 7 & 9), followed by 20 minutes of settling

- **trials with different coagulants and flocculants at optimum pH found in stage 1**;
  
  different wastewaters achieve different levels of settling with different coagulants – in this case the best solids removal was achieved through addition of an anionic polyelectrolyte.
Figure 11: Jar tests – solids removal achieved through acid dosing to pH 3 (left – 30 mins settling) and through acid dosing + addition of anionic polyelectrolyte (2 mins settling)

Table 5: Suspended solids results

<table>
<thead>
<tr>
<th></th>
<th>settling time (min)</th>
<th>Suspended solids (mg/l)</th>
<th>Relative improvement (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>collected sample</td>
<td>zero</td>
<td>942</td>
<td>n/a</td>
</tr>
<tr>
<td>pH adjusted to 3</td>
<td>30</td>
<td>76</td>
<td>91.9</td>
</tr>
<tr>
<td>pH adjusted to 3 + 1.2 ml anionic polyelectrolyte</td>
<td>2</td>
<td>22</td>
<td>97.7</td>
</tr>
</tbody>
</table>

Figure 12: Silt deposited when 50 ml of collected sample, pH adjusted and poly-coagulant are filtered
Although the use of anionic polyelectrolyte was found to be the most suitable with this particular water sample, this will not be the case for all waters that cannot be clarified solely through the use of the MUDBLASTER settler. Carrying out a series of jar tests to determine which type (if any) and how much polyelectrolyte is most effective will be required for every problematic waste.

**Consent levels**
The Water (Northern Ireland) Order 1999, and other similar legislative measures, prevents pollution affecting waterways and groundwater. This involves the placing of consent levels (maximum concentrations), which must not be exceeded by the discharged effluent.

If the MUDBLASTER system is being used purely for solids removal, it is likely that it will not be necessary to place a consent on the discharge from the system. When coagulation/flocculation and/or pH adjustment occurs, consents may be placed on the effluent to prevent damage to the environment.

In all cases, however, it is recommended that MUDBLASTER liaises with the Rivers Agency and/or Environmental Protection Agency before the MUDBLASTER unit becomes operational at a site, and inform them of any proposed changes to the operation during operation.

**Further information**
Do you need consent to discharge trade effluent?

The Water (Northern Ireland) Order 1999