TRIALING LAMELLA CLARIFIER

KYAKA II REFUGEE SETTLEMENT, UGANDA, 2021-22

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PROJECT AIM

GLOBAL

Develop an improved bulk water treatment system, and alternative to batch treatment. Continuous flow system therefore:

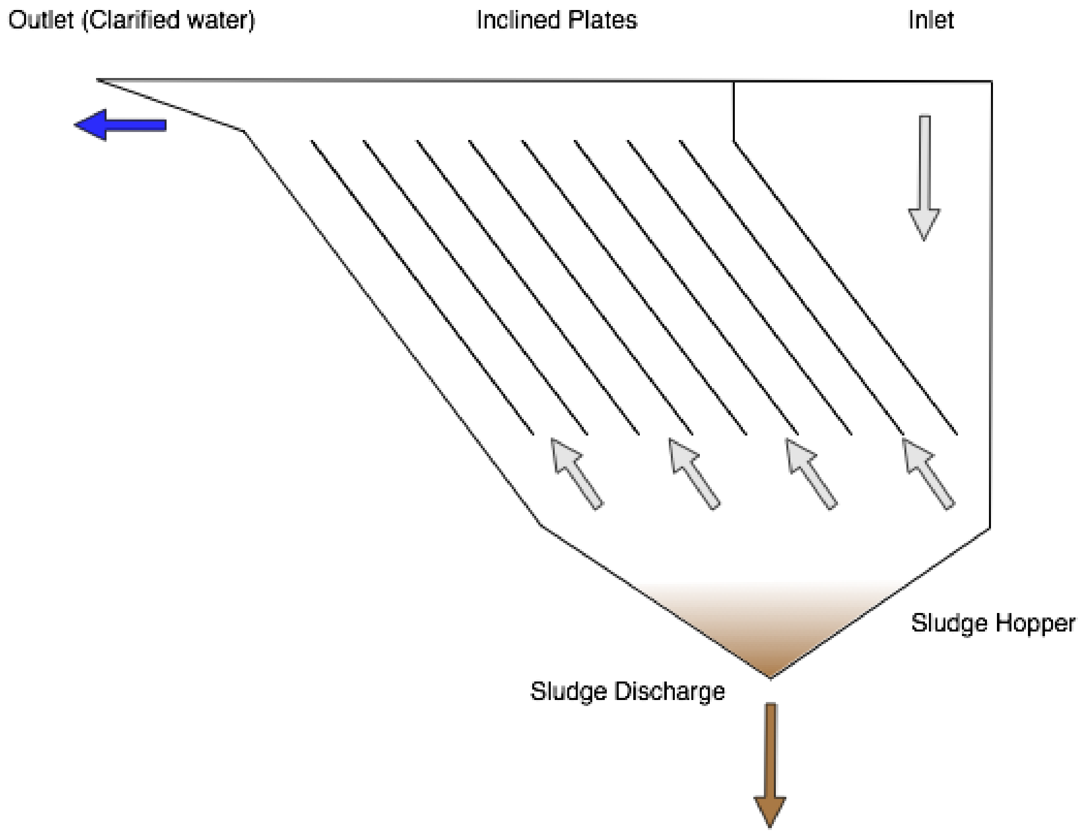
- Smaller footprint
- Simpler and cheaper to operate.
- Higher Output
- Less chemicals

UGANDA

Increase production to meet needs in the refugee settlement

Potentially replace existing emergency SWTP with a more cost effective, durable solution

PRINCIPLE OF LAMELLA CLARIFER SYSTEM



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HIF LAMELLA "INCLINED PLATE SETTLER"

Trialled in Juba 2018. 5m3/hr capacity, partial success

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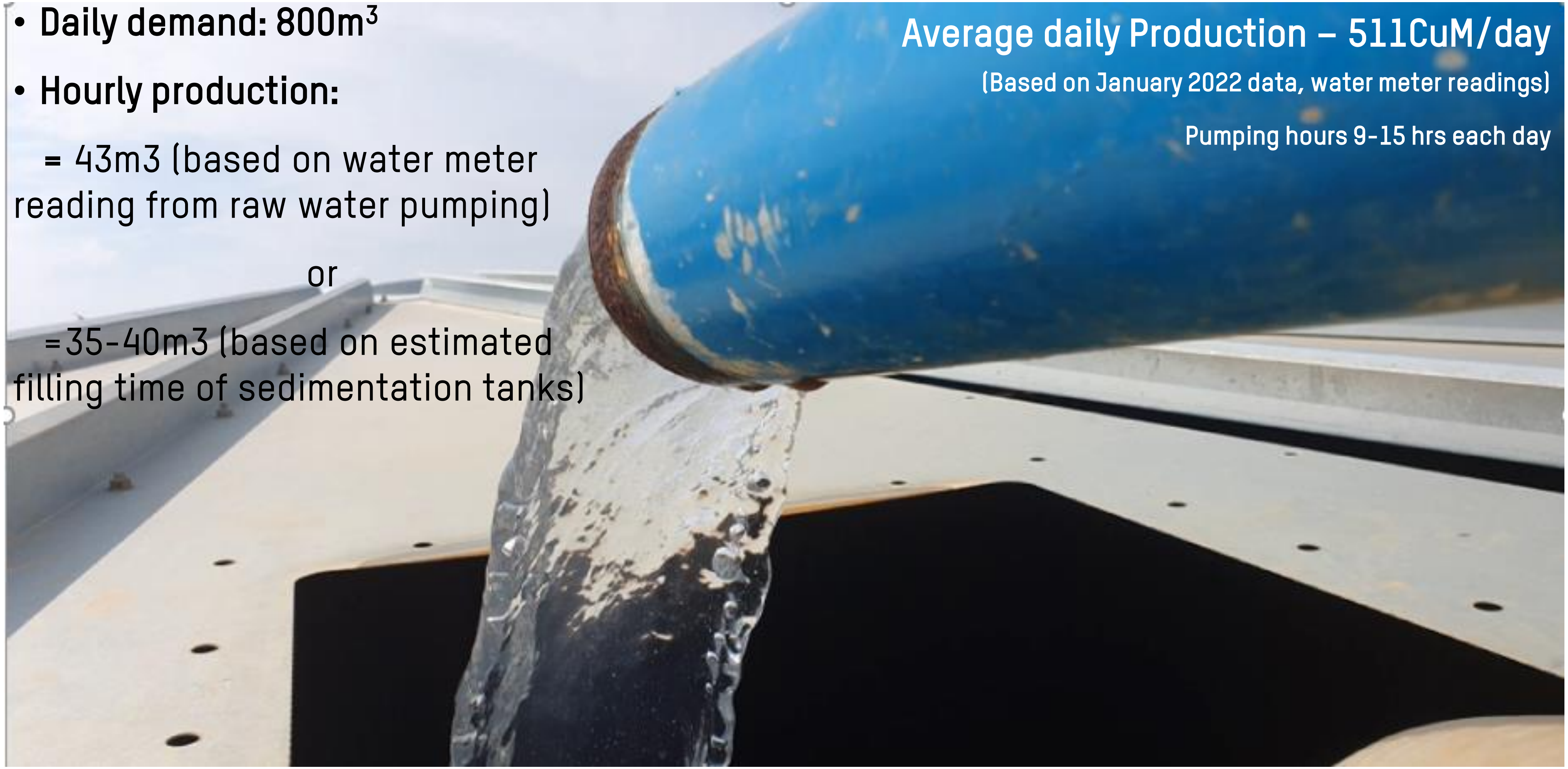
WATER SOURCE – SWESWE, KYAKA II

Earth Dam with unknown volume of water- level remains fairly constant with high natural occurrence of iron and manganese indicating its springfed.

Variable raw water turbidity: 50-150 NTU

Floating intake but depth of inlet pipe unclear (surface turbidity is lower than inlet turbidity)

DEMAND AND SUPPLY



- **Daily demand: 800m^3**
- **Hourly production:**

= 43m3 (based on water meter reading from raw water pumping)

or

=35-40m3 (based on estimated filling time of sedimentation tanks)

Average daily Production – 511CuM/day

(Based on January 2022 data, water meter readings)

Pumping hours 9-15 hrs each day

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WATER TREATMENT: AERATION-SEDIMENTATION-DISINFECTION

- Aerator: removal of iron and manganese through oxidation and precipitation (35-40m3/hr capacity)
- Coagulation – Flocculation - Sedimentation
- Alum added at a rate of 10Kg per T70 tank
- Daily Alum used – 60Kg, costing USD 60/day
- Daily alum to meet daily demand – USD 120/day or 120kg per day.
- Lime (3kg per 70m3),18kg costing USD 15/day
- Gravity flow to 3 T70 clear water tanks after 3 hrs sedimentation.
- Pumping from clear water tanks (chlorination is not carried out at this site except for direct filling of water tankers)

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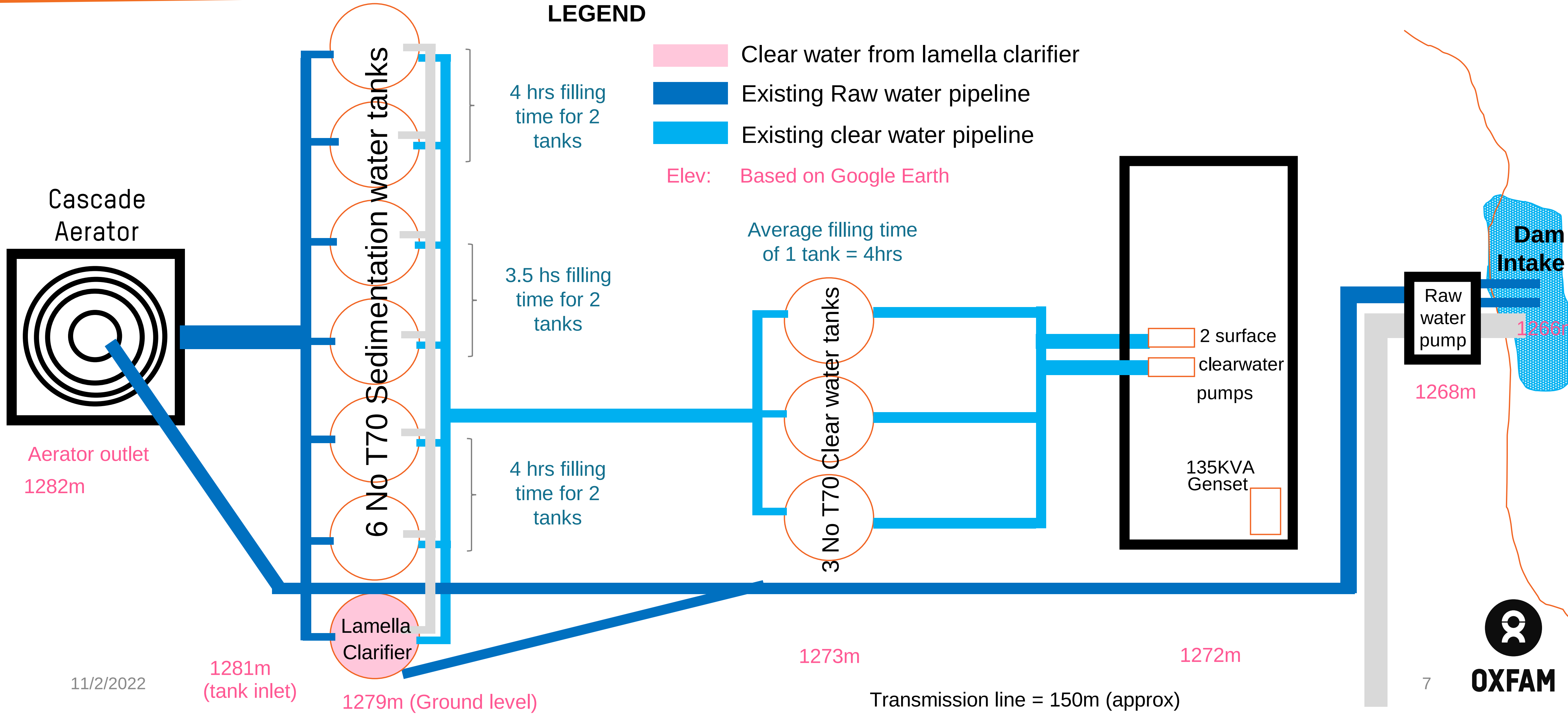
SITE LAYOUT- SWESWE SURFACE WATER TREATMENT PLANT



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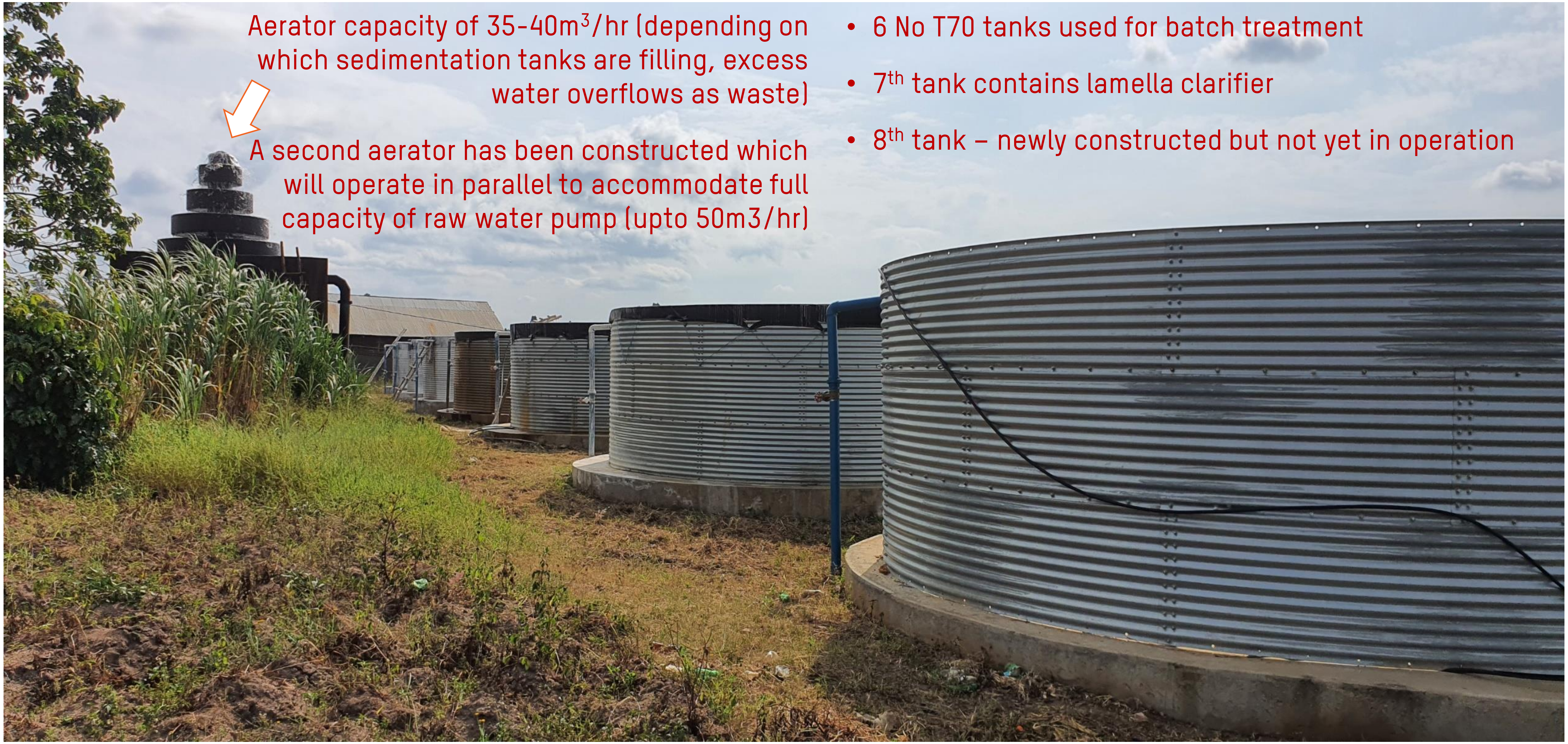
SEDIMENTATION TANKS



Aerator capacity of 35-40m^3/hr (depending on which sedimentation tanks are filling, excess water overflows as waste)

A second aerator has been constructed which will operate in parallel to accommodate full capacity of raw water pump (upto 50m3/hr)

- 6 No T70 tanks used for batch treatment
- 7th tank contains lamella clarifier
- 8th tank – newly constructed but not yet in operation

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CLEAR WATER TANKS

- 3 No T70 tanks in operation
- 2 newly constructed T70 tanks

- It takes between 3 and 5 hours (4 hrs average) to drain a sedimentation tank and fill the clear water tank by gravity.
- The treatment cycle (for 2 x T70 tanks) (pumping/sedimentation/decanting) is 10-12 hours.
- There are two pumping lines for clearwater which operate alternatively pumping water to elevated tanks.
- The only chlorination done at this site is for water tankers which are filled.
- Chlorination is done in proximity of the elevated tanks within the refugee settlement.

EXISTING BATCH TREATMENT PROCESS

- Alum added at a rate of 10Kg per 70m^3 (raw water has pH of 5.12)
- Mixed in 2 buckets and added to tank when nearly ¾ full.
- It is not the optimal process but it is simple and effective.
- 3 kg of lime added to re-balance pH and ensure clearwater is 6.8-7.1.
- Minimum 3 hours settlement time before gravity feed to clear water tanks.

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A.E.T. LAMELLA CLARIFIER WATER TREATMENT KIT

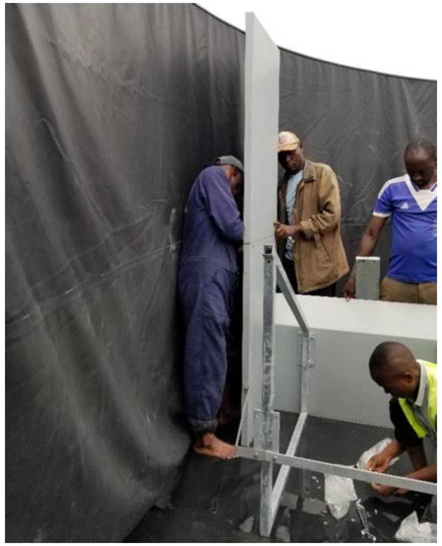





- Lightweight polypropylene lamella tubes.
- Nests and stacks for ease of transport
- Tongue and groove/weld assembly on site
- Prototype kit designed to fit in Oxfam tanks
- Designed by US based company (Aqua Equip Technologies) which specialising in tube settler water treatment systems

ASSEMBLY

- Assembly is relatively straightforward.
- Structure sits on a mat to protect liner from damage.
- Main concern was the gap between the lamella structure and the side wall and risk of short circuiting.
- Total assembly time was 3 days. With experience future systems could be assembled more quickly.
- Significantly the kit was not supplied with any inlet or outlet configuration which has required on site improvisation.



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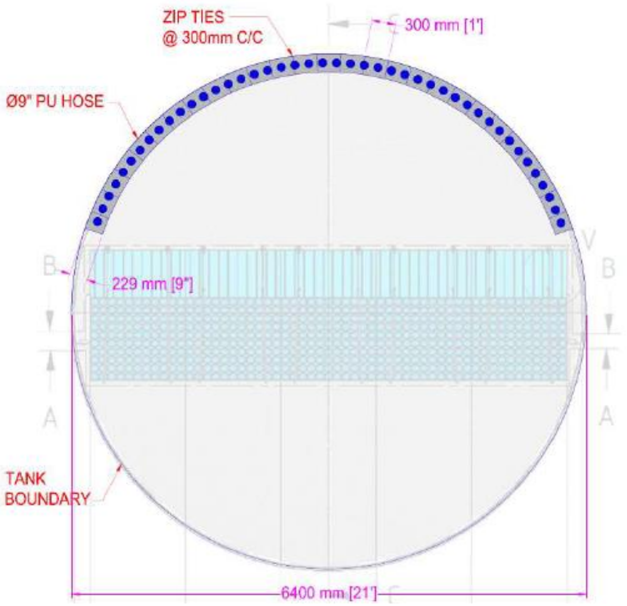
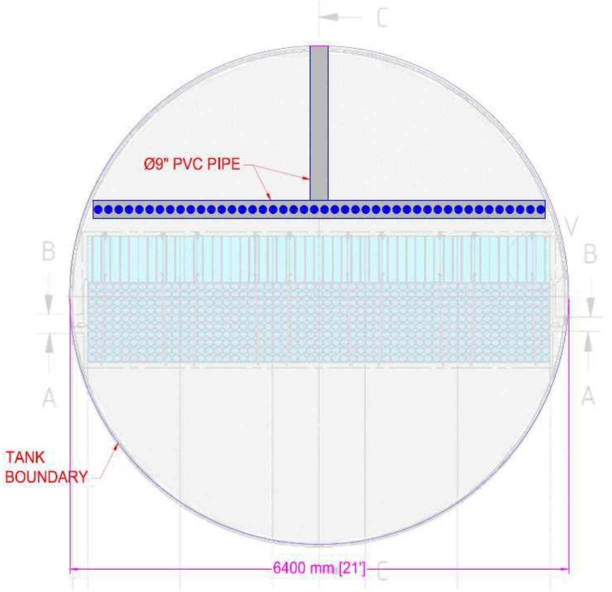
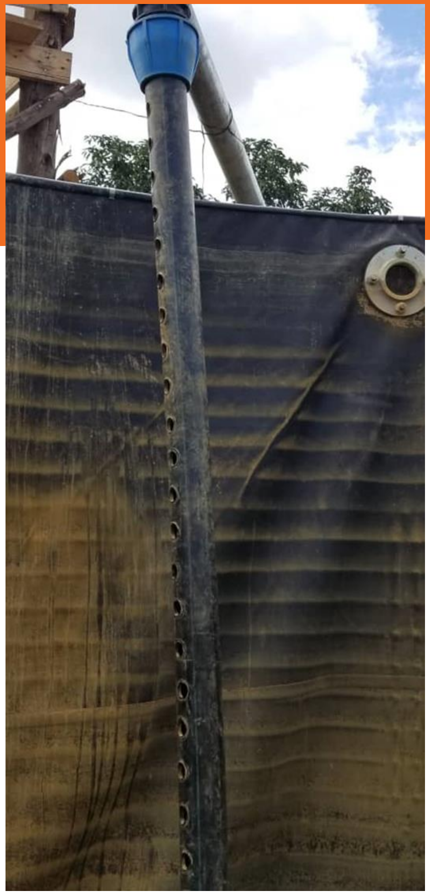
INLET







(Above) inlet arrangement used by Bangladesh team.

- An inlet or baffle arrangement did not form part of the supplied kit so had to be improvised.
- The supplier suggestion to use 9 inch hose was impractical due to availability of materials and weight of pipe when tank is filling.
- Several different arrangements have been tested.
- Outlet needs to control discharge, encourage slow stirring of water, whilst avoiding high velocity/turbulence that may break flocs or lead to scouring and re-suspension of sediment

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INITIAL TESTING – MAY 2021

(Above) Alum was applied via suction side dosing at the raw water pump at the same rate as batch treatment.

(Left) tank filling, steady state flow is reached when only the top 2 layers of tubes are visible

- When filling tank there is seepage underneath and around the lamella structure such that the water level rises equally on both sides of the tank without flow passing through the lamella tubes, i.e. high turbidity water is "short circuiting" the system.
- Once the tank was full and operating under continuous "steady state" flow, the water in the centre of the tank directly above the tube outlets was visibly clearer but the desired turbidity could not be achieved.
- At a pumping rate of 35m3/hr, and raw water turbidity (influent water) between 70-80 NTU, output (effluent water) was 25-30 NTU.

SEALING GAPS/ADDRESSING SHORT CIRCUITING

(Above) Bangladesh team solution to reduce leakage along side of tank.

- Flat metal plate added behind liner at point of contact with lamella structure to remove corrugations. All gaps (Floor, walls and base of lamella tubes) sealed with expanding foam.
- Influent pipe simplified with outlets directed along perimeter of tank to create circular flow and slow stirring to encourage floc formation.
- Initial filling of tank confirmed that structure cannot withstand hydrostatic forces and pressure imbalance when only filling inlet side of the tank, both sides need filling at the same time.

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TEST 2 & 3 (AFTER SEALING GAPS)

- Slightly more encouraging results but still visible flocs passing through some tubes.
- Highest tubes have noticeably clearer flow but floc flow through the lower lamella tubes is very visible. This confirmed vast majority of turbid flow is through the lowest 7 tubes, the upper 15 tubes are clear.
- Test 3 was at reduced flow rate to 20m3/hr and modified inlet to raise water jets to reduce the risk of disturbing sediment and pushing it through tubes.
- Overall, slight improvement with outflow turbidity measured at 23 NTU, with 15 NTU achieved by skimming sections of highest tube outlets.
- The highlighted breakthrough of turbid water is short circuiting at the joint between 2 lamella blocks.

CONCLUSION

- The initial trials have not resulted in the expected water quality improvements (final turbidity of 20, compared to target of 5).
- Considerable time and effort was spent setting up the system and trying to address what are clearly design flaws within the prototype unit. This ultimately limited the testing time and resulted in inconclusive results whereby it it is not clear why the system is not performing as expected.

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MARCH 2022 – CONTINUATION OF FIELD TRIALS

AIM:

Trouble shooting to identify factors contributing to the under performance of the lamella system. Where possible take mitigation measures to optimise performance.

Focusing on:

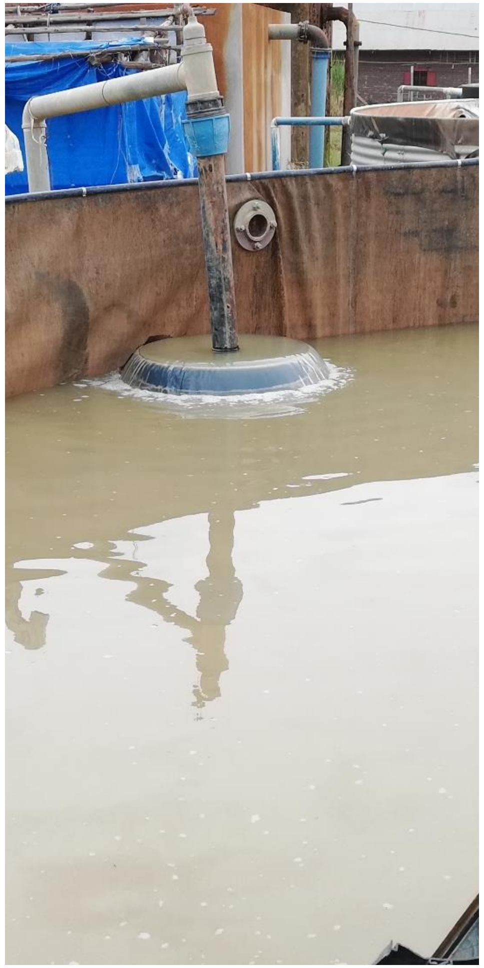
1) Dosing - ensuring correct concentration of alum solution is being applied for optimum floc formation

2) Coagulation – ensure system is set up to ensure rapid mixing

3) Flocculation - ensure slow stirring occurs, required for good floc formation and settlement.

INLET MODIFICATION



- Inlet pipe discharges into bottom of 2 x 200 litre drums welded together.
- Upflow and more controlled outlet into influent side of tank.
- Purpose – reduce turbulence and risk of scouring sediment.

OUTLET MODIFICATION

- A membrane (pond liner) was hung and wrapped around the outlet side of the lamella tubes and clamped at sides with angle iron frame to isolate tube outlets from short circuiting flow around the tank walls.
- New outlet pipe arrangement to offtake water emerging from the highest point of the tank above the lamella tube outlets.
- Purpose – ensure outlet only removes water which has risen through the lamella tubes.

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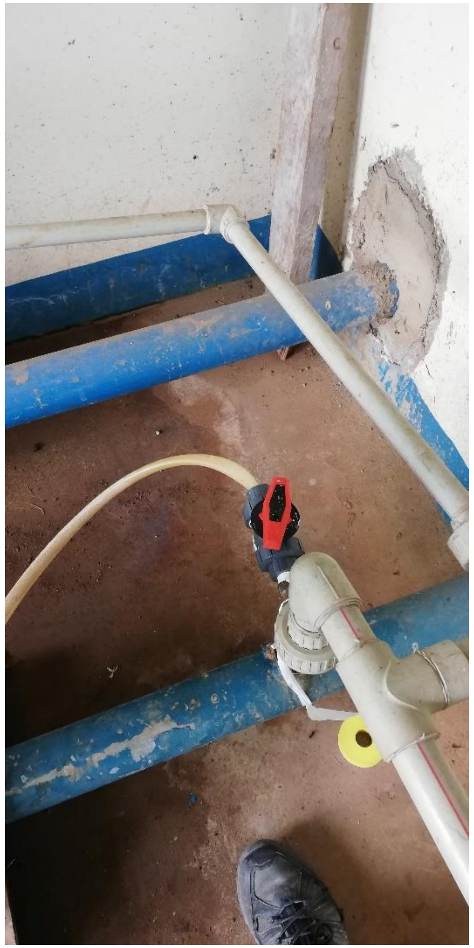
DOSING MODIFICATION & CONTROL



- A fresh jar test conducted in laboratory indicated an optimal dosing rate of 110mg/l.
- 10% alum solution (5kg alum-50 litres water) mixed and topped up a 100L suction side dosing tank.
- A high precision metering ball valve was added for improved regulation of alum solution.
- Regular monitoring of flow rate undertaken during test.

OPERATING UNDER "STEADY STATE" FLOW

- Although a temporary improvisation, the colour of water in the photo illustrates that the hanging liner was effective in isolating and enabling draw off of water directly above the lamella tubes.
- As tank is filling (from left) and the lower lamella tubes start discharging water to the effluent side (right), the positive pressure from the inlet side displaces the lower quality water already on the outlet side of the tank into the partitioned dead storage area.
- The new outlet pipe arrangement ensures the offtake of water from the highest point of the tank above the lamella tube outlets.
- This highlights an obvious design flaw of the current prototype, in not optimising the tank volume - 50% of the tank is dead storage and under utilised, while the mixing area and settlement time (on the inlet side) are unnecessarily constrained.

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FLOC FORMATION

- This video clearly shows that flocs are forming on the inlet side of the tank.
- The camera pans briefly to the outlet side where the water is visibly clearer. As expected no flocs are breaking through the lamella tube outlets but turbidity is still higher than hoped.

- Still shot illustrating difference in water quality between inlet (left) and outlet (right) sides of the tank. This video clearly shows that flocs are forming on the inlet side of the tank.

TEST RESULTS

Filling Outlet side of tank with water to ensure structural stability

Blockage in dosing flow regulator

Risk of overtopping lamella (and short circuiting) if inflow is too high

TEST 1 (20/03/2022)

09.50hr pump started, tank filling (both inlet and outlet sides for tank stability

12.00hrs tank full (flow rate - 35m3/hr)

Flow reduced (estimated at 25+m3/hr) to prevent overtopping.

14.30 – 35 NTU

15.00 – 30 NTU

15.31 – 26 NTU

16.04 – 14 NTU

16.36 – 14.NTU (test then stopped)

TEST 2 (27/03/2022)

09.45 pump started

10.10: turbidity = 60NTU

10.50: turbidity = 60 NTU

12.00: Turbidity = 47/48 NTU

Power changeover required, flow reduced slightly, airlock in outflow causes brief overtopping & short circuiting.

13.30: Turbidity = 33NTU

LUNCH

14.30: flocs stopped forming, turbidity increasing. Test stopped to troubleshoot.

Blockage in regulator valve identified as problem due to absence of strainer or sieve

TEST 3 (28/03/2022)

Raw water source at surface = 48 NTU, Raw water at inlet (measured at pump washout) = 70NTU

Initial turbidity at start of test 17NTU increasing

45 mins of continuous operation NTU = 30

1 hr 20 mins NTU = 22

2 hrs 50 mins NTU = 20

5 hrs 30 mins NTU = 18

6 hrs NTU = 14

Strong wind/heavy rain, NTU starts to increase, test terminated

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RESULTS AND CONCLUSIONS

- Optimum alum dosing is being applied and thorough mixing is taking place in transmission line during the 3.5 minute journey from pump to tank inlet.
- Flocs are forming on the inlet side of tank with no observed breakthrough up lamella tubes (as expected).
- A steady improvement in turbidity occurs and was observed stabilising between 4 and 6 hours of continuous operation.
- A final NTU of 14 remains although a significant (75-80%) improvement, is below the 5 NTU required to have full confidence of effective chlorination.
- It is worth noting that water quality continued to improve in the clearwater tank which the lamella discharged. This was measured at <5NTU the following morning and pumped into the water network after lime pH rebalancing.
- Interruptions in flow due to power outage seem to disrupt turbidity, similarly when a new test commences the initial turbidity is higher that the end of the previous day. Best results are obtained based on continuous operation.
- There are significant design flaws in the current system (discussed in subsequent slides) which are causal factors in the test results.
- The supplier had remained engaged and has been responsive during testing however their design has fallen well short of expectation and with hindsight Oxfam was too trusting. These limitations prevent the current system being fit for operational use and in all likelihood mean further improvement is unlikely/not worth pursuing for this prototype.
- On one hand this is disappointing – the project aim was not to experiment and test a prototype, the expectation was to provide a solution for water supply in Kyaka II refugee settlement by boosting production, and in doing so develop an improved bulk water treatment kit that can be widely used in future emergency responses as a preferred alternative to batch water treatment.
- However there has been a considerable amount of learning from this project that provides a pathway forward. It would be relatively easy to address all identified flaws in the current system, and it is reasonable to assume that if done this would result in improved performance and a product that we are seeking. These are outlined in the following slides.

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DESIGN FLAWS (1)

1) "SHORT CIRCUITING"

- This is the process of water finding preferential flow pathways from tank inlet to outlet with necessary time for mixing and settlement and by passing flow through the lamella tubes.
- In the current design these pathways are too numerous to mention. Significant gaps exist between i) the lamella and the T70 tank (floor and walls); ii) lamella blocks and their support structure; iii) individual lamella blocks (there are a total of 5 blocks so 4 internal joints).
- It is particularly frustrating as Oxfam queried this at the planning stage but was assured by the supplier that any seepage would be insignificant - once steady state operating conditions have been reached. Even if this was true, it would still take several hours to "prime" the system after filling to dispose or recirculate the poor quality short circuited water in the system.
- Logic and actual observation confirms water will always take the path of least resistance, so as long as short circuiting is possible, optimal performance in a small circular tank will never be achieved.
- Considerable resources has been spent by Uganda (and Bangladesh) teams to overcome the problem. Despite this, as this video from the most recent test shows there is visible sediment breakthrough between lamella blocks (which sit flush against each other but are not explicitly glued), essentially giving a direct pathway from inlet to outlet pipe (shown) which are only 3 metres apart.

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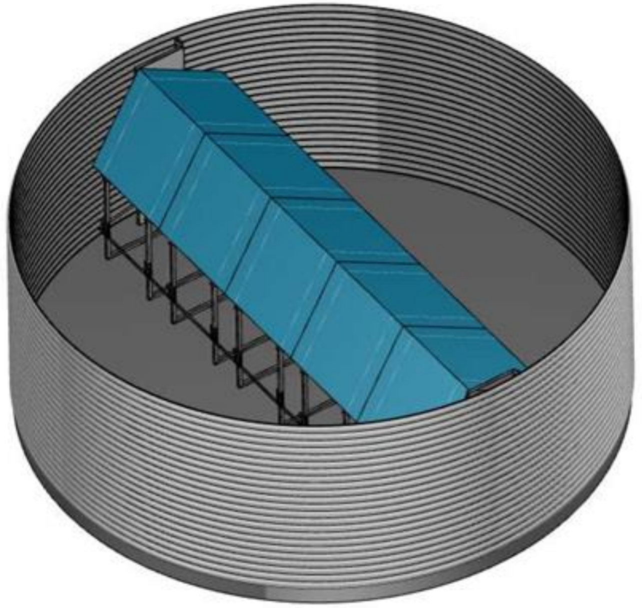
DESIGN FLAWS (2)

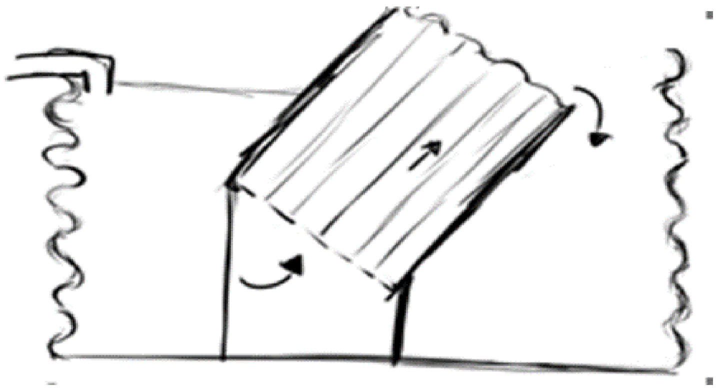


2) TANK STABILITY

- Addressing leakage and stopping short circuiting creates a new problem, namely tank instability. Water only starts flowing through the lower lamella tubes when the inlet side of the tank is about 2/3s full and neither the tank or the lamella are structurally designed to deal with this pressure difference. Consequently the system needs to be filled by adding water to both the inlet and outlet sides of the tank, and conversely when emptying – water needs to be drained from both sides to balance hydrostatic pressure. Operationally this is time consuming, adds an unnecessary complexity for priming the system.

3) DEAD STORAGE

- Having the lamella structure spanning the diameter of the tank - splitting it in half - reduces the mixing and settlement time. The field trial has demonstrated that the best quality water is directly above the lamella tube outlets. Additional water on the outlet side is essentially dead storage It would be a much better use of a circular tank to increase the volume of water on the influent side to increase mixing, retention and settlement time.



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DESIGN FLAWS (3)

4) INLET/OUTLET ARRANGEMENTS

- The current prototype did not contain any inlet or outlet provision.
- The supplier subsequently suggested 2 potential inlet designs (9 inch hose with 44 no. x 5cm dia. orifices – see slide 13). The recommendation was based on limiting water velocity to <0.15m/s to prevent flocs from breaking. However Oxfam understanding is that the the relatively short (3.5mins) transit time within the transmission line immediately following alum dosing is favourable for rapid mixing and coagulation to occur (destabilising electrical particles charges) but the process of flocculation only starts once water reaches the tank which coincides with reduction in water velocity and turbulence and slow stirring of the larger water body which is conducive for floc formation.
- Locally improvised solutions have been devised but these are not optimal.
- The improvised perforated pipe outlet resting on the upper lamella tubes attempted to mimic a launder which skims "supernatal" water uniformly from the top surface only. However because it was not possible to level this pipe precisely it was taking water from the top few cms and at preferential points with implications for drawing lower water quality into the outlet.

DESIGN FLAWS (4)

5) OPERATIONAL COMPLEXITY, SERVICING AND DESLUDGING

- For a lamella system to be fit for purpose (and preferred to the existing batch treatment) in addition to producing water of the equal or better quality and quantity, it also needs to be of comparable operational simplicity. The major flaw of the current system is the time required to fill and prime the system for operational use and linked emptying to desludge and clean.
- The cleaning process for desludging between the two systems is similar and requires operators entering the tank to remove sludge and clean the liner.
- Batch treatment has a regular daily cycle of filling and emptying a tank. Cleaning (typically done weekly) fits within this cycle when the tank is empty and only requires a tank to be taken out of service for 1 hr.
- A lamella system operates on a continuous flow cycle with full tank. Cleaning requires emptying of the tank and then refilling/repriming before the system can come back into operation. Although this wasn't done as part of the pilot testing, realistically it is likely to take a full day and results in significant wastage of water, if the tank water cannot be recycled.
- Commercial lamellas typically contain a sludge cone enabling sediment to be released simply by opening a gate valve. This would be an essential requirement to the viability of a lamella within Oxfam programmes.

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PROPOSED SOLUTIONS

- The very first concept shared by AET for a T11 lamella contained a baffle inlet, offtake and sludge cone.
- The preliminary design for the T70 tank had the lamella structure rested on pillars and the inflow water flooded the whole footprint of the tank. Ultimately assembly of a lamella structure with curved perimeter edge (and therefore multiple unique profile shapes) was considered too complicated and therefore dropped in favour of the current linear design.
- Both designs would have avoided some of the challenges experienced during the trial and provide a basis for solutions.
- Whilst Oxfam has to accept some responsibility, it is particularly disappointing that a company specialising in lamella solutions did not anticipate the issues mentioned.

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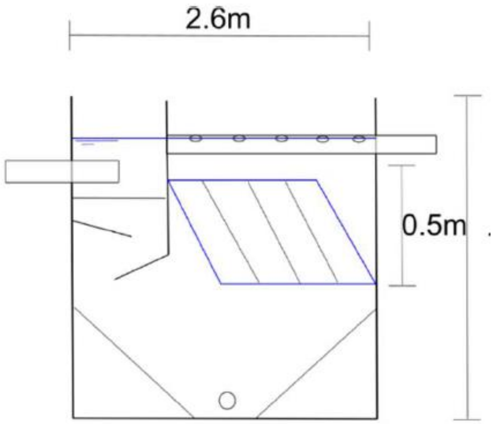

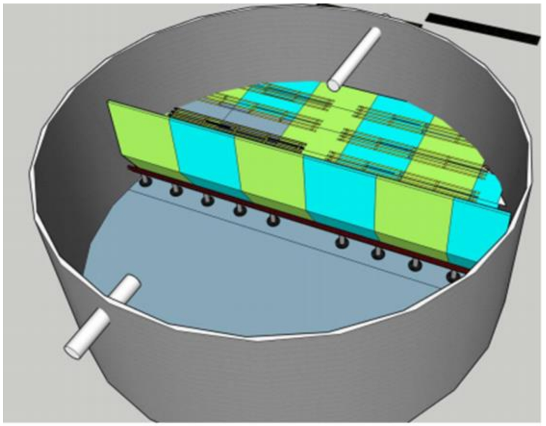

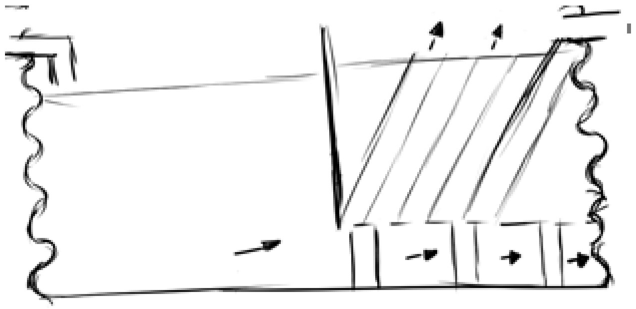

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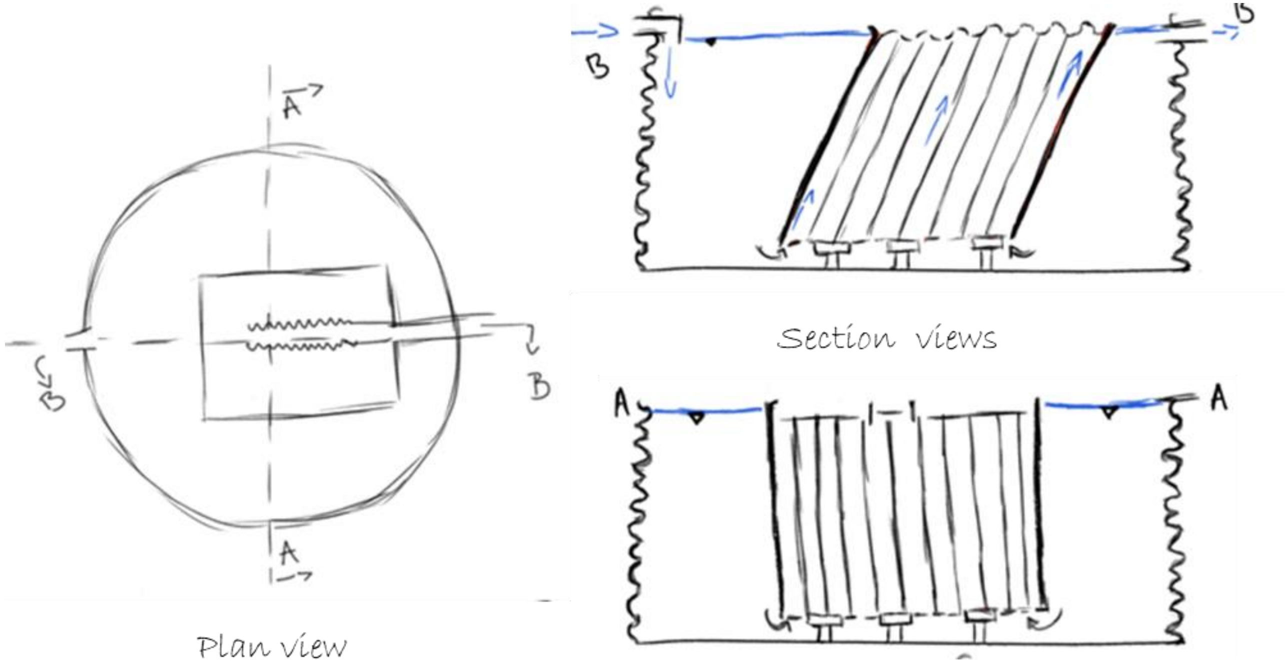
PROPOSED SOLUTIONS

ADDRESSING STABILITY, SIMPLICITY AND SHORTCIRCUITING

- Locating the lamella blocks as a central island within the tank, with elevated perimenter edge and offtake directly above the tube outlets addresses all of the above issues. When filling there would be uniform water level, so no pressure difference, within the tank or differential force acting on the lamella blocks. The only requirements for this is that the lamella block must have water tight seals around its external side walls to ensure the only route from inlet to outlet is through the tubes.
- An additional benefit is that this makes full use of the tank and a larger mixing area and circular flow of water will increase retention and mixing time and should result in improved floc forumation..



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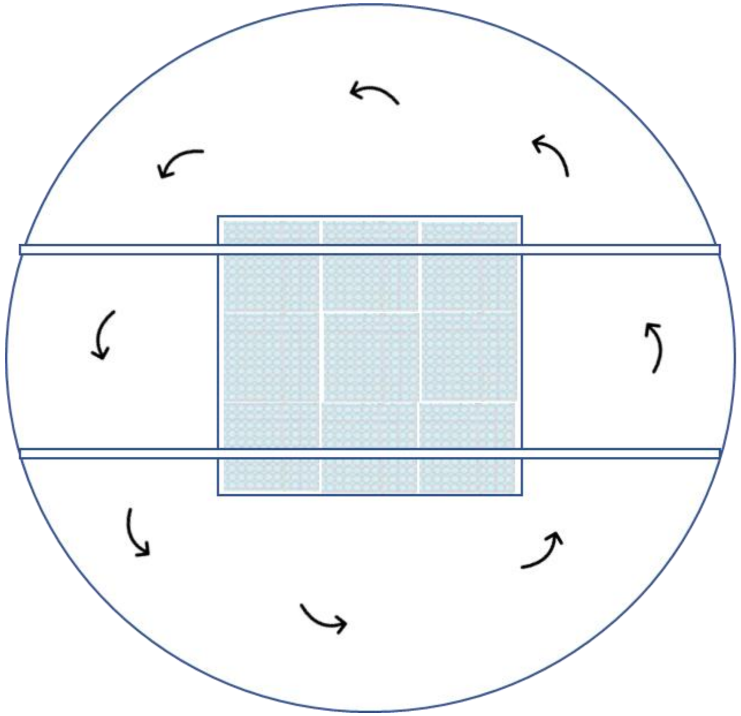
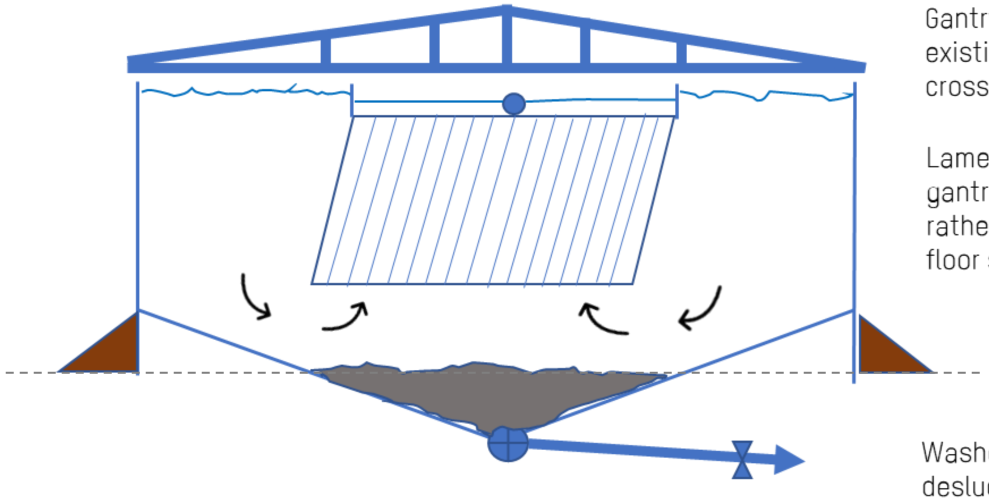
LAMELLA CLARIFIER V.2





DESIGN IMPROVEMENTS

- Lamella becomes a central island. This removes the need for a partition, utilises the full circular footprint and addresses stability issues.
- Full circular area/motion intuitively likely to improve slow mixing and floc formation.
- Gantry provides fixing for inlet and enables fine adjustment and levelling of outlet.
- Inlet and offtake form part of kit for ease and speed of assembly and quality control.
- Simple design with single route for water through lamella tubes eliminates risk of short circuiting.
- Sloping floor so desludging doesn't require draining of water or operator to enter into tank.

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LAMELLA CLARIFIER VER.2 (CONT)

ISSUES REQUIRING FURTHER CONSIDERATION.

Liner/sump options?

- Use larger T95 liner in T70 tank.
- On flat ground or where ground does not allow excavation of sump and desludging by gravity flow, consider using T95 tank to house lamella and raise sloping floor above surrounding ground level.
- Manufacture bespoke liner compatible with conical floor.

Inlet configuration

- Consider multiple options and observe which creates largest flocs i) single outlet parallel to tank wall, ii) multiple vertical outlets parallel to tank wall, iii) multi horizontal outlets to distribute in flow evenly.

WAY FORWARD

GO-NO GO?

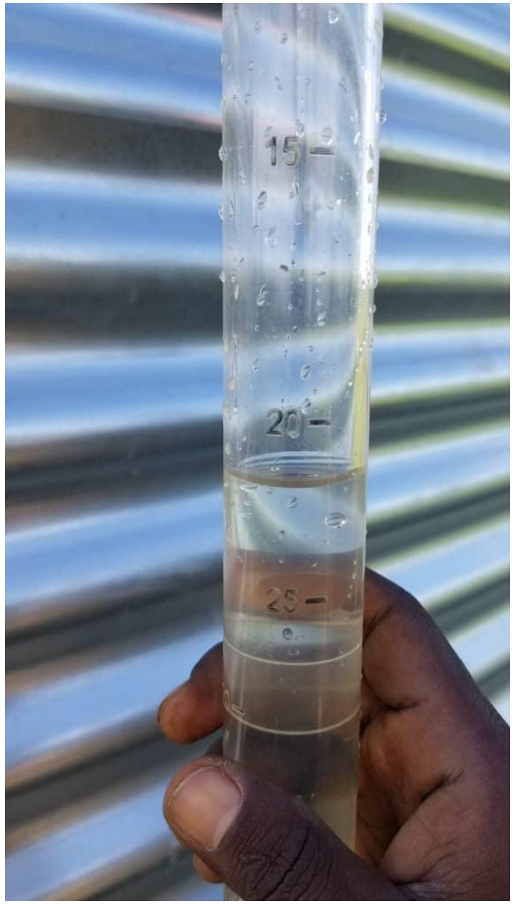
- The decision to continue should be a collective one by Oxfam engineering team (advisors, HSPs and Country staff who have been involved in Uganda and Bangladesh field trials).
- Oxfam has already invested considerable effort over a 10+ year period to find a replacement to the "upflow clarifier" including HIF funding and a WIF grant. If the majority view is that we are on the right lines/close to a solution then it makes sense to continue. But there has to be an endpoint and an objective assessment to determine when to stop and avoid the risk of throwing good money after bad.
- It is worth noting previous criticism of WASH innovations – that we come up with ideas but often don't see them through to completion.

FUNDING.

- This Uganda test which utilised existing infrastructure in place in Kyaka II cost £40,000.
- The cost of the lamella was £9,400. Once all export requirements and shipping costs are factored in the total cost to get equipment to Kampala was £17,300.
- The cost of an upgraded system should not be substantially more as the design if anything is simpler. Factoring in global inflation of materials and budgeting for a new T70 tank and liner a budget of £50,000 is realistic which includes required technical supervision.
- UNHCR has a vested interest in this project and has expressed some interest in funding but a follow up WIF project would be the most likely source.

PROCESS

- A negotiated procedure whereby Oxfam PHE & Supply teams develop a technical specification and ask known suppliers to submit an expression of interest for supply.



IS THE LAMELLA CLARIFIER APPROPRIATE FOR KYAKA II SWESWE WATER TREATMENT SYSTEM?

- Sweswe water treatment plant is unique in that the source water is high in iron and manganese so in addition to removal of suspended colloids and organic matter, aeration of water is an additional treatment step to oxidise and remove these undesirable elements, prior to final chlorination.
- Due to head difference and pipe diameter constraints, to achieve the desired test flow conditions through the lamella, it was necessary to by-pass the aerator and pump raw water pump directly to the lamella tank for the duration of the testing (consequently treated water is low in turbidity but remains high in iron and Manganese so unsuitable for long term water supply).
- During the test, flow was split with 20m3/hr directed to the lamella tank and the remaining 15-20m3 (dosed with alum) passing through the aerator before collection in one of the T70 sedimentation tanks. Logically it was expected that the aerator would destroy any flocs that had been formed but turbidity was monitored to see if flocculation would happen post aeration in the sedimentation tank. 2 hours after filling, turbidity was measured at 130 NTU, confirming suction side dosing is not compatible with aeration. Additional alum was required before this water could be used.
- The current set-up for the lamella tank allows a flow of less than 10m3/hr if connected by gravity to the aerator. To be compatible with the existing treatment set-up, it would be necessary to site the lamella tank below the existing elevation of sedimentation tanks and add a continuous feed alum doser at the outlet of the aerator.
- The site topography should allow this and because the lamella outlet is at the top of the tank the head difference between with the clear water tanks should still be sufficient to cope with a flowrate of 20-30m3/hr.

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