Solve Challenge 2

Management of Sludge from Water Treatment Plants

Aquavators Report

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Introduction

Small private water operators (PWOs) in Cambodia face significant challenges in managing sludge in a safe and sustainable manner. Limited water source access and evidence of climate change impacts during the dry season exacerbates existing issues.

Aquavators provides an approach combining operator training, process optimisation, infrastructure adaptation, and beneficial reuse, to offer a low-cost, scalable, and climate-resilient solution for Cambodian PWOs to reduce sludge volume and improve sludge quality.

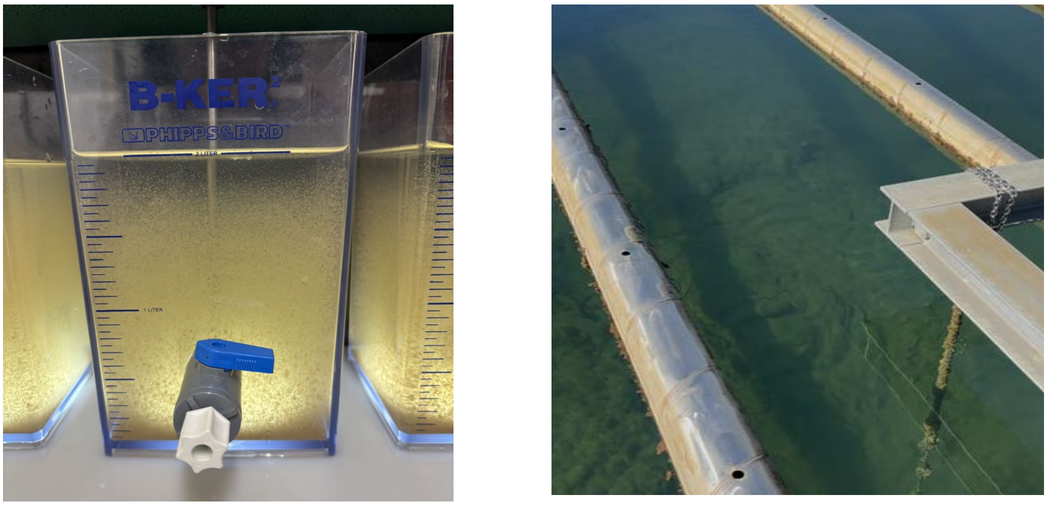
Our Approach

Engagement, Communication and Education

Working with PWOs and providing them with required knowledge is crucial. We propose a 4-stage education and training program to educate PWOs on optimising their water treatment process.

The program will consist of pre-recorded short videos that allow PWOs to learn at their own pace, from their location, minimising disruption to daily operations. This format ensures geographically dispersed operators can access consistent, best-practice guidance without costly travel or time away from their duties.

The content is practical and will build operator capability and confidence in optimising water treatment and sludge management practices. Examples of an optimal jar test and sludge output are provided in Figure 1. Content can be regularly updated, ensuring the training remains relevant and scalable across the sector.



(a) (b)

Figure 1: (a) optimal jar test outcome; and (b) optimal sludge output.

The program will also give PWOs the chance to provide feedback and ask questions. We have developed a sample program outline (see Appendix A) and jar test video, teaching operators the critical skills they need to serve their communities.

Sedimentation Tank Retrofit

Retrofitting sedimentation tanks with baffles or curtains reduces turbulence and short-circuiting to improve retention time and sedimentation efficiency, as shown in Figure 2 [1]. Low-cost baffle designs can improve suspended solids removal and optimal baffle placement significantly enhances settling performance and flow uniformity [2]. PWOs in higher turbidity locations may see greater effectiveness in implementing inclined tube settlers. However, greater maintenance efforts are required to prevent clogging, involving weekly hosing of the tube settlers.

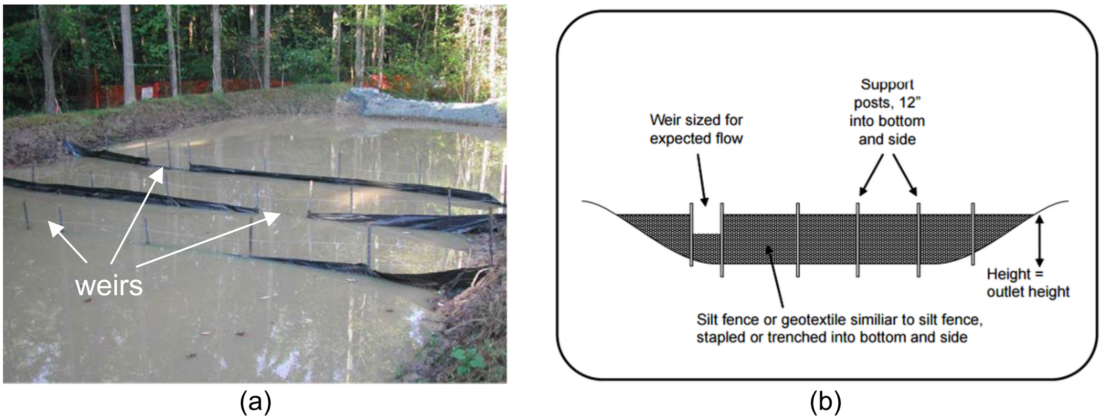


Figure 2: (a) baffle retrofit application; and (b) baffle design diagram [3].

Materials, such as plastic sheeting, wood, bottles and PVC pipes, are readily available and costs can be reduced by leveraging local labour and trades. Success has been seen in rural Nepal and Thailand and are provided in Appendix B [4, 5]. These retrofit options are ideal for improving water treatment performance whilst remaining conscious of limited capital and physical footprints for all PWOs.

Coagulant

Selecting the right coagulant is critical for balancing cost, treatment efficiency, and sludge management. Following operator training, it is recommended that alternative coagulants be trialed to improve final water quality and reduce sludge production [6, 7].

Alum is commonly used due to its low purchase price; however, the resulting sludge volume creates disposal and operational challenges [8, 9]. Alternative coagulants, including synthetic polymers, offer opportunities to improve performance and reduce sludge production [7, 10]. Pilot trials are recommended to confirm dosing rates and performance of the assessed coagulants under local raw water conditions (see Appendix C).

Suneo Chem Cambodia is a chemical distributor that has local availability of cationic polyacrylamide (CPAM) in powder form. Other international distributors include Sinofloc (China), Chinafloc (China) and Camachem (Vietnam). CPAM can be used alone or used with alum to improve sludge thickening and sediment removal. The Australian Drinking Water Guidelines can be used for guidance.

Sludge Dewatering

Settled solids from supernatant and backwash water will be removed using an industrial water vacuum. Wastewater from the vacuum process will be pumped to a storage tank, where polymer may be added and mixed by natural flow if required. From the tank, the wastewater will discharge into a geofabric bag for dewatering as shown in Figure 3.

Figure 3: Sludge-filled geofabric bag.

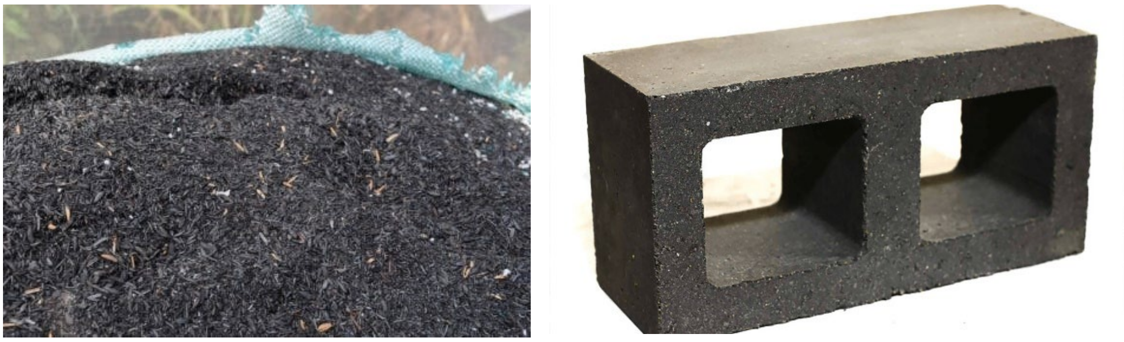
Using the vacuum system prevents the water treatment process from being taken offline and eliminates safety risks for staff associated with entering the sludge pit. To reduce saturation during heavy rain periods, the geofabric bag may be housed under a simple roof structure built from locally sourced materials.

The geofabric bags and resulting dried solids can be reused. Any water runoff from the bags will be captured and returned to the head of the plant.

Sludge Reuse Opportunities

Surplus sludge can be manufactured into composite building materials. This would introduce circular economy and develop PWOs' infrastructure.

Composite bricks can be made from water treatment sludge and rice husk ash (RHA). In 2024, Cambodia produced 13 million tonnes of rice [11]. 70% of Cambodia's land is dedicated to rice production and surplus may be available for brick production [12]. A study found that composite bricks exhibit superior mechanical properties compared to conventional bricks, however, have higher water absorption rate, making them less durable [13]. Further details can be found in Appendix D.



(a) (b)

Figure 4:(a) RHA; and (b) RHA brick [14,15].

Alternatively, sludges may be spread on land and have beneficial effects on soils, however, it's vital that regulatory and precautionary limits are observed. Aluminium phytotoxicity is a concern especially in acidic soils of pH 5 or less. There is incomplete information on polymer effects on agricultural land although research shows they break down slowly. The products of PAM breakdown are highly biodegradable in soil and surface waters, but not in deeper groundwater. Taking a precautionary approach, guidance for sludge disposal limits on agricultural land may be taken from other countries, such as the German Sewage Sludge Ordinance, which has a limit of 5 tonnes per hectare over an average of 3 years.

Conclusion

Aquavators proposes a holistic approach to sludge management for PWOs. Operator education, improved coagulant and flocculant choice, optimising dosing and increasing contact time with sedimentation tank retrofitting, as well as improved dewatering process to make sludge output easier to handle and transport.

Each part of our solution can be implemented alone or altogether – depending on operator capacity and resources and may be further supplemented by reuse in agriculture or construction materials to create a circular economy.

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Appendix

Appendix A. Sample Operator Training Outline

Module	Video Title	Learning Outcome
Intro	Series Overview	Understand purpose, benefits, and what will be learned
Module 1: Understanding the Basics	1.1 – What's in Dirty Water?	Recognise turbidity, colour, and contaminants visually
	1.2 – How Clean Water is Made	Understand the water treatment process and operator's role
Module 2: Coagulation and Flocculation	2.1 – What Happens When We Add Chemicals	Understand how coagulants work to form flocs
	2.2 – The Jar Test: Your Best Tool	Perform a simple jar test using basic materials
	2.3 – Common Mistakes and How to Spot Them	Visually identify under/overdosing and poor floc formation
Module 3: Simple Monitoring Tools	3.1 – Checking Turbidity by Eye	Estimate turbidity visually or with a simple meter
	3.2 – What pH Tells You	Use pH strips/meters to check if dosing conditions are right
	3.3 – A Good Habit: The Water Log	Maintain basic daily records for monitoring
Module 4: Sludge Management	4.1 – What Good Sludge Looks Like	Recognize good-quality sludge (dense, compact, odour-free)
	4.2 – Drying Sludge the Easy Way	Set up and manage geofabric bags for passive drying
	4.3 – What to Do With Dried Sludge	Reuse or dispose of sludge safely and legally
Module 5: Bonus / Recap	5.1 – One Operator's Daily Routine	Reinforce learned behaviours through a real-world example

Appendix B. Sedimentation Tank Retrofit Case Studies

Other countries have seen success in retrofitting sedimentation tanks with tube settlers with limited resource availability in tropical and monsoonal environments. There is limited literature on the implementation of baffles in existing tanks.

Nepal Water for Health (NEWAH) and Engineers Without Borders Australia (EWB) completed a project in partnership with Nepal to design a simplified inclined plane settler which has a small footprint in the rural region. This design is optimal for treating water of highly variable turbidity, suitable for seasonal changes in raw water conditions in Cambodia in the monsoon season and tropical surface waters. The report demonstrates the feasibility of construction and operation of the settlers with limited capacity in operations and maintenance, which can be directly transferred to the retrofitting of small tanks in rural Cambodia.

A pilot scale study was completed at the Bang Khen water treatment plant in Bangkok, Thailand to determine benefits of inclined tube settlers. When compared to a conventional sedimentation tank, the construction costs amount to 75% with tube settlers and maintains a short detention time whilst occupying a small physical footprint. However, it should be noted that this detention time will remain longer than that of a smaller tank without modifications.

Appendix C. Coagulant Desktop Assessment and CPAM Risks

Three coagulants were assessed for a 1,000 kL/day surface water plant: alum, PolyDADMAC, and cationic polyacrylamide (CPAM) [9, 10]. A summary of the coagulants is provided below in Table B.1.

Table B.1:Summary parameters of three coagulants – alum, polyDADMAC and CPAM.

Parameter	Alum	PolyDADMAC	CPAM (Cationic Polyacrylamide)
Dose	40 mg/L	15 mg/L	2 mg/L
Daily usage	40 kg	15 kg	2 kg
Bulk cost/kg	$0.30	$5.00	$6.00
Daily chemical cost	$12	$75	$12
Cost per m^3	$0.01	$0.08	$0.01
Sludge production	High – precipitated $Al(OH)_3$	Low – polymer floc	Very Low – minimal polymer floc
Dewatering	Poor – sticky, slow to dry	Good – flaky, faster drying	Excellent – dense, quick drying
Turbidity removal	Good if well-dosed	Very good	Excellent
pH sensitivity	High – lowers pH	Moderate	Low – broad pH tolerance
Residuals risk	Aluminium residuals possible	Low (NSF certified)	Low (NSF certified)
Storage/transport	Bulky, liquid or powder	Concentrated liquid	Powder – long shelf life

Alum, dosed at 40 mg/L, is the most common and costs just $0.012/m³ treated. However, it produces large volumes of aluminium hydroxide sludge, often representing 80–90% of total sludge, which is sticky and slow to dewater [8].

PolyDADMAC, a cationic polymer, was evaluated at 15 mg/L. It produces far less sludge and settles rapidly, improving dewatering efficiency [7, 10]. However, at $0.075/m³, the daily chemical cost is substantially higher than alum, which may limit adoption by smaller PWOs [9].

CPAM, applied at 2 mg/L, achieves excellent turbidity removal with minimal, dense sludge that dries quickly [7, 16]. At $0.012/m³, the cost is comparable to alum, while significantly reducing sludge handling requirements [10]. CPAM is also pH-tolerant, easy to store in powder form, and requires smaller transport volumes [7].

While alum remains the cheapest conventional option, its high sludge production presents significant operational and environmental burdens [8]. CPAM offers the best overall balance between cost, sludge reduction, and performance, making it well-suited for PWOs with limited sludge management infrastructure [17, 18].

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It should be noted that the risks associated with the use of polymers are not fully understood. While Polyacrylamide (PAM) is considered non-toxic, however its constituent monomer, acrylamide, is a known neurotoxin. Monomer risk exposure occurs in PAM degradation after use and incomplete polymerisation during manufacture.

Appendix D. Detailed Analysis of Composite Brick Composition

This appendix contains a further detailed analysis of the study outlined in Sludge Reuse Options. Table C.1 shows the percentage compositions of the bricks used in the study. Each brick was fired at four different temperatures, 900°C, 1000°C, 1100°C and 1200°C giving a total of 16 possible brick combinations.

Table C.1: Percentage weights for composite bricks.

	WTS (%)	RHA (%)	Clay (%)
Clay Brick	0	0	100
25% Sludge Brick	25	75	0
50% Sludge Brick	50	50	0
75% Sludge Brick	75	25	0

The water absorption test results are shown in Figure C.1. All composite bricks exhibit a higher water absorption percentage than the traditional clay brick, which leads to them being less durable. Furthermore, as bricks are fired at a higher temperature their water absorption percentage decreases. This is due to the higher firing temperatures leading to the completion of the crystallization process and closing of the opening pores [13].

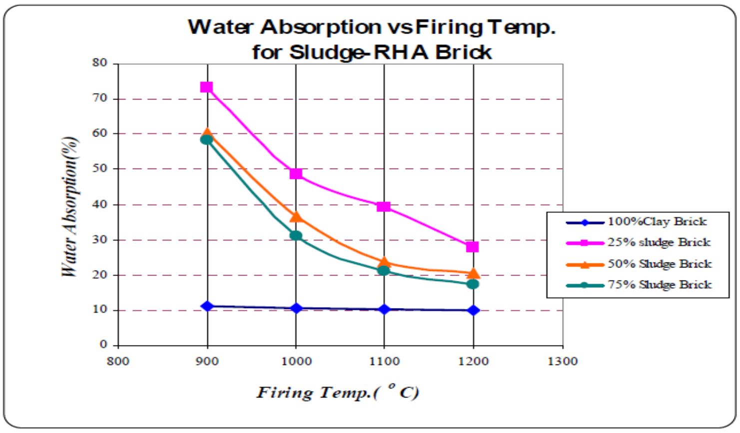

Figure C.1: Water Absorption test results [13].

Efflorescence, which is the measure of dissolved salts in the bricks was rated as 'Nil' for all samples. This indicates there will be no potential of sulfates in the bricks which could later attack the mortar joints. All composite bricks have a lower apparent specific gravity than conventional bricks as shown in Figure C.2.

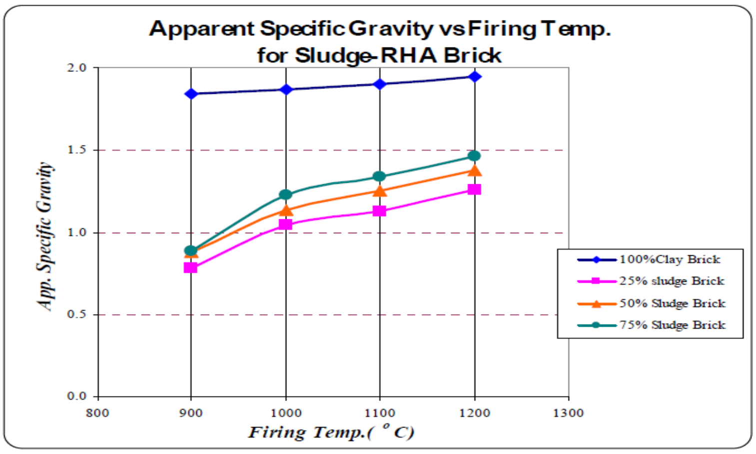

Figure C.2: Apparent Specific Gravity test results [13].

This means they will be lighter and easier to handle. Finally, only 1 composite brick sample exhibited a higher compressive strength compared to the conventional bricks as shown in Figure C.3. This means that precautions must be taken to ensure the correct water treatment sludge RHA ratio is met for the bricks to be up to standard.

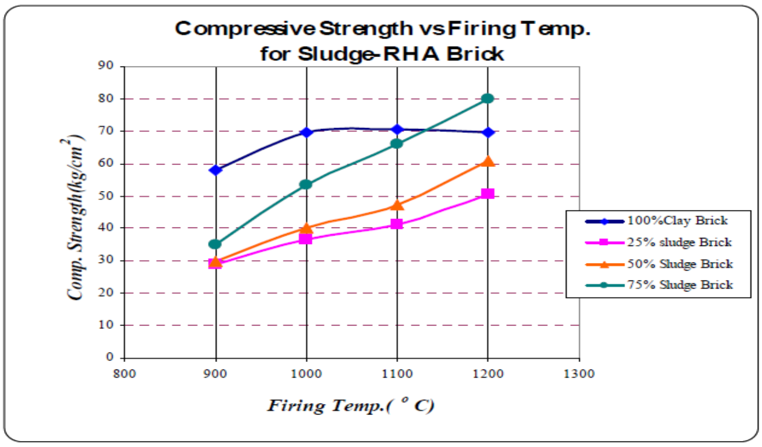

Figure C.3: Compressive Strength test results [13].

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