Low-cost Struvite Reactor

Construction Manual

Eawag – Swiss Federal Institute of Aquatic Science and Technology

UN-HABITAT – United Nations Human Settlement Programme

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This document contains the building plans for a 200 litre struvite reactor developed by the STUN project in Nepal. With the information in this document copies of this reactor can be built.

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1 Introduction

Construction of a low-cost struvite reactor with readily available materials

During the STUN (struvite from urine in Nepal) project, a low-cost reactor to reclaim phosphorus from urine in the form of struvite has been developed (Figure 1). The process of making struvite is described in other STUN publications (available from www.eawag.ch/stun). The aim of this publication is to present and discuss the design drawings, from which a struvite precipitation reactor can be built. In addition, a breakdown of the building costs and some suggestions for improvements are presented.

Figure 1: *After precipitation, the struvite powder can be filtered out from the urine with a simple nylon filter bag.*

Acronyms

Eawag	Swiss Federal Institute of Aquatic Science and Technology
MAP	Magnesium ammonium phosphate (also called 'struvite')
NRs	Nepalese Rupee (96 NRs ≈ 1 Euro)
P	Phosphorus
PP-R	Polypropylene random copolymer (plastic piping material)
STUN	Struvite recovery from urine in Nepal
Sandec	Department for Water and Sanitation in Developing Countries at Eawag
UN-Habitat	The United Nations Human Settlement Programme

Units & Symbols

In general, the metric system and ISO units are used throughout this report.

2 Background

Struvite harvesting key features and STUN's starting points

2.1 What is struvite?

Struvite (magnesium ammonium phosphate) is a white odourless powder (Figure 2). If magnesium salts or a magnesium solution are added to an ammonium and phosphate containing liquid, struvite precipitates. When applied to crops, struvite is a slow releasing phosphate fertilizer that can replace chemical phosphate fertilizers currently made from phosphate rock (Römer, 2006). Urine contains both phosphate and ammonium. By adding magnesium to urine, struvite is produced and can be filtered out, in order to produce a valuable fertilizer product. The process of making struvite and the history of the reactor design are discussed in other STUN reports (*www.eawag.ch/stun*, Etter et al., 2011).

2.2 Why this manual?

As part of the STUN project, a low-cost reactor was designed to remove the phosphate present in urine by means of producing struvite. Depending on factors such as the local availability of magnesium, the amount of urine available, and local costs of chemical fertilisers (subsidy policies etc.), struvite production can deliver a sustainable fertiliser, reduce the costs of sanitation and provide an opportunity for small business (Kunz et al., 2011). With the information in this manual, researchers or business owners can construct a 200-litre struvite reactor of the model developed in the STUN project.

2.3 How to use the manual?

The reactor is made out of several components that have to be assembled at the work-site (appendix A). In the appendices of this manual, a design drawing is presented for every component. In the main text of the report, every component is discussed to help interpret the drawings. Since the reactor was designed for Nepal, it is possible that not all materials are available in other locations. However, since the design is simple, it should be possible to adapt the design to locally available materials.

Figure 2: *Struvite powder can be processed into granules using a rotating steel drum.*

3 Reactor components

Local manufacturing of all components

3.1 Reactor vessel

The reactor vessel (appendix B) is a barrel with a tapered bottom (Figure 3). As urine is very corrosive, the vessel needs to be made from a corrosion proof material. The reactor vessel that was used in our research, is made out of galvanized sheet metal. The first prototype reactor was built 2 years ago. Despite of regular use, no signs of corrosion have been detected.

To avoid damaging the galvanized layer, the seams in the vessel are soldered rather then welded. It proved necessary to seal some of the seams with silicon seal as the soldering was not completely watertight.

On drawing 04-200-01 views and sections of the vessel are given together with final dimensions and details for joints and seams. On the sheets 04-200-02 and -03 the expanded sheet metal sizes are given.

Figure 3: *The struvite reactor vessel is installed on top of a stand with access ladders on both sides.*

3.2 Stirring mechanism

To produce struvite, it is necessary to mix the urine and the magnesium (Etter et al., 2011). This is done with the stirring mechanism (appendix C – Figure 4); a long vertical shaft with 3 blades (Figure 5) submerged in the urine and a handle on the top. By turning the handle, the blades turn in the urine and act as a mixer. Because welding is unavoidable on this part, it was made from normal mild steel in our reactor. This means a good paint system is really necessary and regular repainting will have to be done. If the shaft and blades can be made out of galvanised steel, this will reduce the maintenance costs, as the painting can be reduced to the welded areas.

Before welding the handle on the shaft, a piece of loose pipe has to be fitted over the shaft. The shaft will turn in this piece of pipe and it should thus not be welded to the shaft.

On sheet 04-300-02, the parts required to fix the stirring mechanism in the reactor vessel is specified. The piece of pipe fitted loosely on the shaft mentioned above is welded to the centre of the fixing bars, so that the stirring mechanism is centred in the reactor vessel. The cross-shaped fixing bars are bolted to the top edge of the reactor vessel.

3.3 Reactor stand

The reactor has to be high enough above ground to fit a filter bag and an effluent collection bucket under the reactor vessel. To achieve this, the reactor vessel is placed on a metal stand (appendix D – Figure 6). The stand is a simple frame made from one inch diameter metal pipe. On either side of the metal stand, equally interspaced rungs allow to acces the top part of the reactor. As with any part of this reactor, it should be painted with high quality paint and the paint should be maintained regularly.

3.4 Access platform

To be able to fill the reactor, add the magnesium and operate the stirrer, one needs to be able to have access to the top of the reactor vessel. To provide a good working space, an access platform has been added to the reactor (appendix E). Here also the metal parts should be conserved with high quality paint.

3.5 Outlet valve arrangement

At the bottom of the reactor, a valve is needed. The valve is opened after stirring to drain the urine through the filter bag. To avoid corrosion, the selected valve material was PP-R (Appendix F). The outlet valve is attached to the reactor vessel by means of silicon seal. The metal outlet pipe that is part of the reactor vessel should fit tightly inside the PP-R pipe. Below the outlet valve, a metal four-pronged hook is attached. from this hook, the filter bags can be suspended on loops attached to the bags. This is an improvement over our experimental reactor where the bags were just tied to the outlet pipe (as can be seem in the pictures in this report). For the 200-litre reactor, we found that the weight of a filter bag full of urine was too big for the old system.

3.6 Filter bag

The filter bag (appendix G) is also modified from the design used in previous STUN research, the bag is now tapered towards the top with four strong loops to hang it from the hooks on the underside of the outlet valve. The bag should be made out of a strong but neither wind nor waterproof nylon cloth. Along the top edge of the bag, a hem of stronger material is required. Onto this hem, the four loops should be sown. The loops must be made out of strong material, for example the belts used for backpack straps.

Figure 4: *Top view on the reactor with the stirring crank and a simple pipe bearing.*

Figure 5: *The blades are welded with a 90° offset to the stirring mechanism shaft.*

Figure 6: *A dettachable platform (to the left) facilitates operation of the reactor.*

4 Building costs

Detailed cost break down of the reactor construction

In Table 1 below, a breakdown of the reactor building costs is given. The reactor was built in Kathmandu, Nepal in 2010. In general, the material costs in Nepal are relatively high, because most materials are imported. Labour costs, however, are low (approximately 500 NRs per day).

All items were contracted on a lump sum basis; no data on the exact distribution of labour versus material costs is available. However, based on knowledge of local material costs and labour rates, an estimate of this breakdown was incorporated in the table. Prices are in Nepalese Rupees (NRs) and Euros. At the time of writing, 1 Euro was equal to 96 NRs. Euro values are rounded.

Table 1: *Struvite reactor cost breakdown*

component	component cost		labour cost
Currency	*NRs*	*€*	*€*
Struvite reactor:			
Sheet metal reactor vessel	8000	83	25
Stirring mechanism	1500	16	6
Reactor stand	2500	26	10
Access platform	3000	31	13
PP-R outflow assembly	630	7	2
Filter bags (2 pieces)	300	3	1
Total for built reactor:	**15930**	**218**	**74**

In Table 2 below, an estimate is given for the additional costs associated with the improved hanging system for the filter bags included in this report:

Table 2: *Estimated additional cost new fastening system*

component	component cost		
Currency	*NRs*	*€*	
Bag fastening system:			
PP-R male socket	450	5	
Metal hook assembly	500	5	
Extra cost filter bags (2 pieces)	100	1	
Total for improved fastening:	**1050**	**11**	

5 Outlook and possible improvements

5.1 General

The reactor, as built by STUN, worked well. The only problem encountered was with the attachment of the filter bags. A solution for this has already been incorporated in this report. Further improvements presented here are to reduce the workload of the reactor operator, enabling him to run more than one reactor efficiency.

5.2 Automated stirring

If the reactor has to be operated simultaneously with other reactors or activities in a multi-reactor set-up, manual stirring will not be very convenient. In this case, automated stirring could be envisioned with the aid of a 12 volt motor from the windshield wiper of a car.

5.3 Level switch

If the reactor is filled with a machine driven pump, it would be convenient to fit the reactor vessel with a level switch that switches of the pump automatically, when the 200 litre level is reached. This will prevent overflowing.

5.4 Process control

To reduce operation costs and increase user-friendlyness, a process control system could be designed for the struvite reactor. Such as system would automate the struvite production process from reactor filling over magnesium dosing to filter handling. However, electronic systems are expensive and might not be competitive with low-cost labour, as in Nepal.

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Further readings

More information on the project and manuals for operation please look on: *www.eawag.ch/stun*

You may find following documents on the website:

- Low-cost Rotating Biological Contactor: Operation and Maintenance Manual
- Low-cost Rotating Biological Contactor: Construction Manual
- Low-cost Struvite Recovery: Operation and Maintenance Manual

Other reports about the STUN project, on the production and economy of struvite, the re-use of effluent and the construction of a struvite reactor.

For more in-depth information of the nitritatation/anammox process, please refer to the publications to the right.

Appendices: Drawings

Drawings

All drawings are available as PDF or AutoCAD files (.dwg) on the STUN website:

www.eawag.ch/stun

Refer to the format specifications on the drawings (A2/A3/A4) for correct scale.

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