Struvite from Urine in Nepal (STUN)

A new project in Nepal examines whether the production of fertiliser from urine can inspire residents to take up improved sanitation, while reducing their dependency on imported chemicals. By harvesting urine and converting it to "struvite", the farmers of Siddhipur may better resist the coming years of fertiliser shortages. Elizabeth Tilley, Bastian Etter, Basil Gantenbein, Raju Khadka, and Kai M. Udert

Introduction

Chemical fertilisers, along with irrigation and improved seeds, were one of the main pillars of the "Green Revolution" that allowed the post-war world to support a booming population by ever increasing food output on ever scarcer and deteriorating land. However, phosphorus is a finite resource like oil and, as such, severely depleted and increasingly difficult to extract. The price of diammonium phosphate (DAP, a common fertiliser) increased over five times between 2007 and 2008 [1], meaning that many farmers who could not afford it saw their crops fail or fall short of an adequate price. Along with record oil prices, the price and availability of fertiliser led to the food riots of 2008.

Could improved sanitation be the answer to the global food and fertiliser crisis? The question is not as far-fetched as it may seem.

The average human excretes about 1 g of phosphorus and almost 10 g of nitrogen a day; the majority of which (about 60 % and 80 %, respectively) is excreted through urine [2]. In fact, urine is one of the only known renewable sources of phosphorus, as it has no sufficiently fast natural renewal cycle (like carbon or nitrogen). Urine can be used directly on fields as a liquid fertiliser, though it is heavy to transport, requires significant storage space, is unpleasant to work with, and is variable in composition, thus making it difficult to estimate the proper quantity. Moreover, application of urine as a fertiliser is further hampered by the volatilisation of ammonia.

The STUN (STruvite from Urine in Nepal) project is looking at the possibility of extracting a phosphorus-based fertiliser called "struvite" (magnesium ammonium phosphate hexahydrate, $MgNH_4PO_4{\cdot}6H_2O$) from the urine collected from the Urine-Diverting Dry Toilets (UDDTs) currently used in the Kathmandu valley. As of 2006, 73 % of the people in Nepal still lacked access to improved sanitation [3]. By creating a market for urine, we hope sustainable sanitation will spread and help the farmers to become more nutrient independent.

Struvite

Struvite is a bioavailable fertiliser, which can be stored indefinitely, transported easily and applied with sureness in its composition. Furthermore, it is easy to produce, as it only requires a high pH solution (which is naturally occurring in stored urine) and a soluble magnesium source. The magnesium binds with the phosphorus in solution and the struvite precipitates in less than ten minutes. Over 90 % of the phosphorus can be recovered with this simple method. Due to the low technological requirements, struvite precipitation is an ideal application in the developing world, especially where electricity is limited.

The resulting powder is odourless, dense, compact, and efficient to transport. It can be stored during winter or the dry season, used when needed and the nutrient quantity is consistent. Struvite from urine offers the simplicity and quality of chemical fertilisers without the high cost or technical requirements.

Study site

Siddhipur is a farming village located about 10 km south east of Kathmandu. Of the 6 000 residents, almost 90 % of them work in agriculture. Although there is a sewerage network in Kathmandu proper, Siddhipur is not connected. There are currently 100 family-owned UDDTs, i. e. toilets that collect urine and faeces separately in the absence of water. Siddhipur has a strong Water Supply and Sanitation User Committee (WSSUC) that was already active in the operation and management of the water supply, sanitation and solid waste programmes of the community. By working co-operatively with the WSSUC, the researchers were better able to understand the immediate needs for and limitations of a community-scale struvite reactor.

We would like to thank **UN-HABITAT Nepal**, specifically Dr Roshan Shrestha and Anjali Sherpa for their unending support. Furthermore, we deeply appreciated the enthusiasm and curiosity shown by Jiban Maharjan in supporting this work with his own land. We are also much obliged to the whole community of Siddhipur who has welcomed us so warmly. We acknowledge the assistance provided by the **Swiss National Centre of Competence in Research (NCCR) North–South**: Research Partnerships for Mitigating Syndromes of Global Change and **Eawag's Directorate** for supporting our project with discretionary funding.
Contact: elizabeth.tilley@eawag.ch

Photo 1: Bastian Etter at struvite headquarters.

Photo 2: Not quite the milkman: Raju Khadka proudly presents the "pee-cycle".

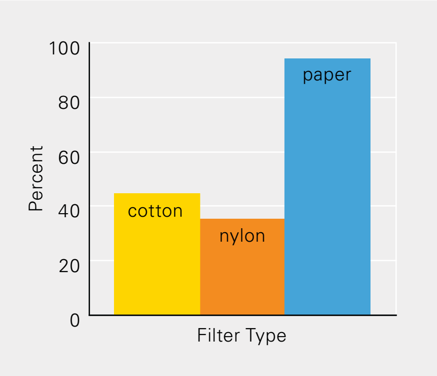

Figure 1: Percentage of struvite recovered from the reactor filter using either a nylon filter (pore size < 100 µm), cotton filter (pore size < 200 µm) or standard paper coffee filter.

Photo 3: Ideally, the struvite will have a uniform, pellet-like shape for easy application and spreading.

Results

The initial phase of the study focused on determining the quality, quantity and current uses of urine to calculate the potential production of struvite. Daily monitoring of household collection tanks revealed that approximately 360 L of urine could be produced per person per year, which would generate over 160 000 L of urine per year from the current UDDTs in use, and over ten times as much if everyone had a UDDT.

However, struvite production is not only related to the volume of urine, but also to the amount of phosphorus contained in the urine. Random samples were taken from 14 different urine tanks: ten were mixed into a composite sample and the remaining four were analysed individually. The results were surprising: the average phosphorus content was 260 mg/L with the lowest measurement being 123 mg/L. The most commonly reported values are somewhere between 600–800 mg/L [4]. Obviously, the concentration of phosphorus in the urine was unexpectedly low, so 14 samples of fresh urine were taken to determine if and by how much the urine was diluted with water. The results showed that in fact the urine was naturally very dilute and probably only diluted by around 15 % (based on a phosphorus balance).

Based on this data, we determined that about 327 kg of struvite could be produced annually in Siddhipur at current production levels, though significantly more could be envisaged if further toilets and therefore urine production were implemented.

Reactor design

Commercial struvite reactors are available but require significant energy and training to operate. For the purposes of the pilot project in Siddhipur, a hand-powered reactor was built using a 50-L polypropylene tank, which was modified with a welded stirring paddle and support casing (Photo 1).

Struvite was produced using the urine from some volunteer families. It was picked up from their home with the "peecycle" (a bicycle retrofitted to carry two 20-L jerry cans of urine) as illustrated in Photo 2. Bittern, a waste product from salt manufacturing that is rich in magnesium, was used as a magnesium source. To filter the precipitated and settled struvite, the bottom of the reactor was fitted with a wire mesh upon which either a nylon filter (pore size < 100 µm) or cotton filter (pore size < 200 µm) was laid. After approximately ten minutes of mixing and 24 hours of settling, the filter tray was removed and the struvite was left to dry in the sun (Photo 3).

Based on an analysis of the effluent produced, we determined that over 95 % of the phosphorus was removed in the form of struvite; however, the quantity (i. e. the mass) was significantly lower than expected. The cotton filter, though larger in pore size, retained a higher percentage of solids, although both filters performed poorly compared to a paper coffee filter, which was capable of removing over 90 % of the struvite produced. The results are summarised in Fig. 1.

Thus, the limiting factor to recovering large quantities of struvite is not the precipitation step but rather the solid-liquid separation. A Masters project is currently addressing this in further detail. Economic factors will ultimately determine the sustainability of this project and the feasibility of scaling it up. Some 500 L of urine are needed to produce 1 kg of struvite. The current price of a similar nitrogen-phosphorus fertiliser is available in Siddhipur for just about half a Euro (€ 0.5 or NRp 40–50). Therefore, to be profitable (or cost-recovering), the cost to produce struvite must be lower than this amount, which is currently not possible. However, with increased trade restrictions, reduced energy availability and lower fertiliser quality on the market, the possibility of producing high quality, renewable and affordable fertiliser – also promoting the use of sustainable sanitation – does not seem so far off.

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