
Credit: WaterAid/ Kate Holt

Louisa Fearn, Raphaël Formarier, Colette Génevaux, Alex Hunter

Supervisor: Kristell Le Corre Pidou

Optimisation of a low-cost urine treatment system for resource recovery

Background

Current sanitation challenges require new alternatives to conventional sewerage systems. Among them, the reuse of source-separated urine could help mitigating poverty and malnutrition by providing an in-country supply of fertilisers. In this context, consultant engineers Paul Foulds and Ivana Rusnakova developed a low-cost system producing urea from urine for agricultural purposes. This innovative design combining solar powered urine pasteurisation and evaporation won the 2013 Young Engineer Award co-organised by the Society of Public Health Engineers (SoPHE) and WaterAid UK.

Aims & Objectives

This project aimed to assess the efficiency of the evaporation stage of the system in producing urine-derived urea and the potential recovery of water. Overall, the applicability of this approach in Tanzania and more generally in developing countries was evaluated.

Approach

Initially a comprehensive literature review examined the principle of urea crystallisation and identified existing technologies and approaches of urine reuse for nutrient recovery. Preliminary analysis of urine chemical composition was carried out in order to compare the results with the literature. An evaporation unit for the production of urea from urine was then developed and tested at lab-scale (*Figure 1*). Its performance was tested using non-pasteurised and pasteurised urine samples. In particular, the influence of temperature and surface area of the prototype on evaporation and the quality and nature of the final product were investigated.

Five experiments using urine collected on five different occasions were performed and referred to as experiments 1 to 5. They had variable parameters, as described in *Table 1*. The surface area was controlled by using 1 of 2 tray sizes. The temperature was altered by moving the light height and switching on the ventilation inside the fume hood.

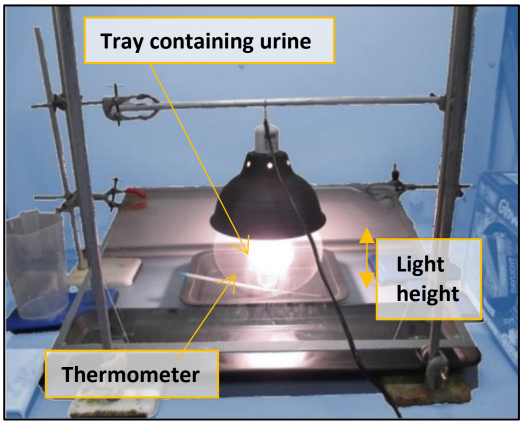

Figure 1 Lab scale evaporation unit

Table 1 Summary of experiments

N°	Urine type	Surface area (cm²)	Temperature (°C)	Duration (hours)
1	Non-pasteurised	61.6	35	41
2	Pasteurised	61.6	22	28
3	Pasteurised	75.4	23	23
4	Non-Pasteurised	75.4	33	71
5	Pasteurised	61.6	16	52

Cell tests were conducted on seven components in order to determine the concentration of specific chemicals (ammonium, nitrogen, nitrates, sulfates, total phosphorus and chemical oxygen demand).

Overall results show little difference between pasteurised and unpasteurised samples. Nitrogen is the exception (Figure 2), its concentration is much higher in the pasteurised samples which would confirm the key role of the pasteurisation process in the nitrogen conservation.

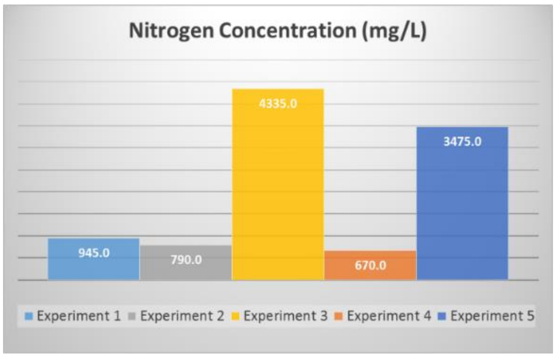

Figure 2 Nitrogen concentration in experiments 1-5

Metal concentrations were tested (aluminium, sodium, potassium, magnesium, calcium) and the results are all of the same order of magnitude. Some variations with the literature data were observed which could be related to the diet and hydration of the urine donors.

Yield

The efficiency of the prototype has been evaluated through the evaporation rate values. It appears that the pasteurised samples reached dry conditions faster, and that the use of the deeper tray rather than the shallow one also makes the evaporation more efficient. However, the lack of repeats mean this would need further work.

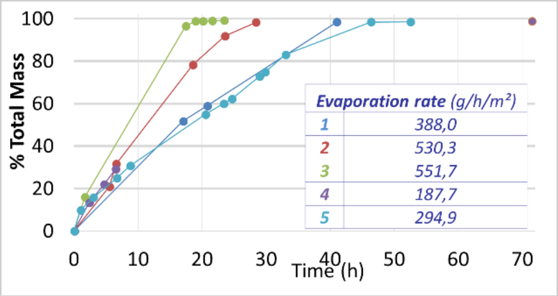

Figure 3 Evaporation rate

The average yield measured is 13 g/L, which is a low value if the objective is to produce sufficient amount of urea for fertiliser use.

Presence of urea in the end product

Analysis of the dry product (shown in *Figure 4*) by optical microscope and XRD (*Figures 5 and 6*) confirm that urine evaporation leads to a dry product that contains urea (*Figure 5*).

Figure 4 Dry product

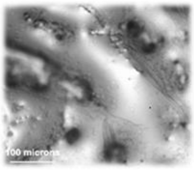

Figure 5 Optical microscope image

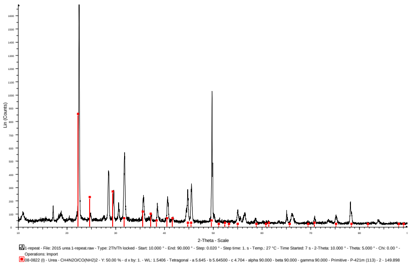

Figure 6 XRD spectrum of the end-product (in black) showing a match for urea (red-pattern)

The samples behave very differently depending on how they are prepared and stored. The evaporation process needs to be complete and the sample perfectly dry in order to obtain urea crystals. However, achieving a fully dry and stable product is very challenging. The effect of pasteurisation and varying evaporation temperatures on crystal growth and urea content cannot be concluded from the analysis and results of these experiments.

Business Case in Tanzania

The price of the urine-derived urea would have to compete with the price of industrially produced urea. Currently urea from China ranges from 38,000-100,000 TSh per 50 kg bag. However, a urea fertiliser plant is due to open in Tanzania which would decrease the cost of the commodity (Oirere, 2014).

The Tanzanian government has a history of subsidising urea fertilisers through voucher schemes but reports state that the scheme was suspended in May 2014 (Domasa, 2014). Further information on fertiliser subsidies and the domestic supply of urea is needed to fully understand whether urine derived urea would be able to compete with industrial urea.

Recommendations

Our findings suggest that the implementation of the current system is not viable. Further research is specifically required to optimise the process. Specific area that would benefit from further research include:

- Yield. Our work showed that urine evaporation is a **slow process producing limited amounts of urea.** The average yield from the experiments is 13g/ L.
- Quality of the final product. Consider addition of technology alongside solar pasteurisation to improve the nitrogen yield such as acidification or adding ash.
- **Stability of the final product.** The crystals absorb moisture when the humidity is 80% and temperature reaches 18°C, meaning it would be a problem throughout the year in Tanzania. A solution to this problem would be to consider coating the dry product or packaging in an innovative way.
- The focus of this study was the evaporation stage but the pasteurisation stage was covered in the literature review. **Clogging of the pasteurisation system** by inorganic precipitates of magnesium and calcium is associated with hydrolysing urea. **Moving the storage stage to after the pasteurisation stage** seems a logical solution to avoid nitrogen losses by hydrolysis.
- Temperature. For pasteurisation to be successful **temperature needs to be high** and therefore the pasteurisation stage requires further optimisation.

References

Domasa, S. IPP Media: Blow to farmers as government freezes subsidies. Available at http://www.ippmedia.com/frontend/?l=67734

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Oirere, S. (2014). 'Nigeria and Tanzania Moving Forward with Fertilizer Projects'. Engineering News- Record. 4th August 2014.

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