Risk of clogging of drip-line emitters during urine fertilization through drip irrigation equipment

KDF – Khotang Development Forum

Eawag – Swiss Federal Institute of Aquatic Science and Technology

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This report presents the finding of systematic field experiments about the risk of clogging of emitters when combining urine fertilization with micro irrigation through a standard Nepalese drip irrigation set.

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Abstract

Stored human urine can be used as a balanced fertilizer in agriculture. However there are some challenges related to field application of urine. Using urine as a liquid fertilizer through drip irrigation could help overcome some of these challenges. In this report we describe the results of a field study aimed at testing two possible ways of combining urine fertilization and drip irrigation. The main finding is that a system in which the water / urine mix is allowed to settle in the tank of the irrigation system for 45 minutes does not lead to more work for the farmer in terms of inspecting and unblocking the emitters in the drip lines than using only water. A second system, where irrigation with urine and water was done in sequence, did not function well. The most likely reason for this problem is a lack of pressure in the system when pure urine was used.

For situations where a different type of drip irrigation system is used and for places with hard water (high calcium content) we recommend further small scale testing before investing in a large system.

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1 Introduction

Urine fertilization through drip irrigation lines

Applying urine as liquid fertilizer through drip irrigation systems can be a cost-effective way of fertilization in agricultural areas where fertilizer availability is low, for example in the highlands of Nepal (Bastakoti et al., 2011). At the same time, the collection of human urine helps to promote sanitation in rural areas and prevents open defecation. However, there are concerns that the drip irrigation equipment will get blocked as a result of mineral precipitates formed when urine and water are mixed (Von Münch et al., 2009). With this research project, we wanted to determine whether it is possible to combine urine fertilization and drip irrigation without excessive clogging of emitter holes in the drip irrigation system.

Based on our own experience with struvite precipitation and earlier experiments with urine in drip systems within Eawag's STUN project (STUN: struvite recovery from urine in Nepal), two methods were proposed to combine urine and drip irrigation. In the first method urine and water were mixed and then the solids were allowed to settle before the urine-water mixture was allowed to flow through the irrigation system. The second method used sequential irrigation with urine and water to prevent mixing of the two inside the drip lines. These methods were tested in a field experiment using drip irrigation equipment available in Nepal and compared with a reference experiment using water only. To obtain reliable data, each method was tested in duplicate and each drip set was used 25 times. Further, some small experiments were done to try to explain some of the effects found in the study.

The research includes measurements to determine the composition of the urine and water used in order to provide more insight into the chemistry of the mixing process. To further frame the boundary conditions of the experiment basic meteorological data are also presented.

The research was carried out in Khotang District in the hill zone of Nepal, approximately 100 km east of Kathmandu. Khotang is characterized by steep hills with terraces for agriculture Normally, there is sufficient rainfall, but there is an increasing depletion of nutrients in the soil. Agriculture is mainly on a subsistence level as lack of road access reduces agricultural inputs, such as chemical fertilizers and high yielding seeds. Also the terrain is not suitable for large-scale mechanization. Khotang was selected because our local partner, Khotang Development Forum (KDF), has a research facility where water, land and urine were available to carry out the experiments.

2 Project background

Precipitates may cause clogging in drip lines

2.1 The STUN project

During a two-year research project, the Struvite recovery from urine in Nepal (STUN) project has developed a low-tech way of recovering phosphate from human urine through struvite precipitation (Etter, et al., 2011). As part of this research, different treatment and re-use options for the effluent of the struvite reactor were also investigated (www.eawag.ch/stun). One of the investigated methods was the use of the struvite reactor effluent as nitrogen fertilizer in a drip irrigation system. This research compared the behavior of source-separated urine and struvite effluent in the drip irrigation pipes. The hypothesis was that struvite effluent would cause less clogging problems, because nearly all phosphate was removed. Due to the short duration of the experiments, the results were not conclusive, but the research led to some ideas on how to combine urine fertilization and drip irrigation without excessive clogging of the drip lines.

2.2 Urine fertilization

Among other substances urine contains nitrogen, potassium, phosphate and sulfur in plant available forms. Because these minerals are all essential for plant growth, urine can be a good fertilizer (Richert et al., 2010), if applied correctly and if the hygienic safety is ensured, i.e. storage of 6 months according to the WHO guidelines (WHO, 2006). In Nepal, farmers in many remote areas do not have access to synthetic fertilizers or only have access to urea, which does not provide a well-balanced nutrient supply to the plants. Urine, which contains all three major plant nutrients is available to every farmer. Thus, urine can play an important role in improving food security and sustainable soil management in Nepal and other countries.

When using urine as fertilizer, some challenges have to be addressed:

- Using watering cans to spread urine on the field is labor intensive and urine has an unpleasant smell, which makes using watering cans unpopular.
- Urine has a low nutrient to weight ratio, which makes transport difficult or labor intensive.
- There may be traditional taboos on excreta use.
- If urine is not incorporated into the soil after application, there will be nitrogen losses due to evaporation of ammonia.
- Urine storage and application has to ensure that no hygienic risk is created.

2.3 Drip irrigation

The main benefit of drip irrigation, especially in dry and hot climates, is water savings: up to 50% less water is needed compared to other irrigation practices like: spraying or flood/furrow irrigation (Palada et al., 2011).

Through a network of drip lines and emitters, water is delivered close to the plants, so there are no losses from over-spray and there is little evaporation. Other advantages include: less growth of weeds between plants, less nutrient leaching and reduced soil erosion compared to spraying (Ibid.). Furthermore, in comparison with sprinkler systems, drip irrigation can reduce the spread of plant diseases as mildews and anthracnose. Many areas in Nepal experience increasing water scarcity, so drip irrigation could be very beneficial there. Adding fertilizer to the water used in drip irrigation is a logical step; it saves time, water and fertilizer (Marr, 1993). The combination of drip irrigation with fertilization is known as fertigation (ibid). In India, fertigation with synthetic fertilizers through large drip systems is quickly gaining popularity.

2.4 Combining drip irrigation and urine fertilization

2.4.1 Advantages

At the site where we did our research, urine is mixed with water and then applied to the soil with watering cans or buckets; this is a widely recommended practice (Richtert et al., 2010). The use of urine trough drip irrigation has the following potential benefits over the existing practice:

- Reduced urine transport, because urine only has to be brought to the drip irrigation tank.
- Much less time spent with the “smelly” urine, no need to walk around the field with a watering can.
- Much less chance of urine spilling on the body, which is not a health hazard if the WHO guidelines are followed but the smell and the connotation with excreta is unpleasant.
- It is a modern technology, which can help farmers to overcome the stigmas connected to excreta use.
- Unless the urine is covered with soil after manual application, ammonium losses due to evaporation are higher with bucket application than with drip irrigation (John Kashekya, 2009).

2.4.2 Threats

Urine contains: ammonium, potassium, phosphate, magnesium, sulfate and other dissolved minerals (mainly salt, NaCl) (Udert et al., 2006). During storage of urine, nearly all magnesium precipitates as struvite (MAP, $MgNH_4PO_4 \cdot 6H_2O$) crystals, while calcium precipitates as calcium phosphate (e.g. hydroxyapatite, $Ca_5(PO_4)_3OH$ (Udert et al., 2003). When urine is mixed with water, the addition of calcium and magnesium (contained naturally in the water) results in the formation of additional struvite and calcium phosphate particles.

There are concerns that these minerals will block the emitters of drip irrigation sets when urine fertigation is attempted. Some researchers described a successful combination of urine and drip irrigation (Comoe in Richert, et al., 2010 and Gensch et al., 2011), but to our knowledge, no systematic research regarding blocking of emitter lines during urine fertigation with drip irrigation equipment has been reported so far.

3 Materials & methods

Use water and urine simultaneously or consecutively?

3.1 Location

The research was carried out at the Nahima agricultural research facility of the Khotang Development Forum (KDF), near Diktel, Khotang, Nepal. The location was chosen because urine separation is practiced by the students and staff living at the KDF hostel and sufficient land and water for the experiments were available at Nahima. The research also had linkages with KDF's own work on urine use and their promotion of vegetable, fruit and tea growing in the area. Therefore, the project included knowledge transfer to the students and teachers of KDF.

3.2 Field, urine and water used for the experiments

3.2.1 Field used for experiments

Nahima is in the hill-region of Nepal and the land is terraced. For the experiment, the drip lines were laid out parallel to the terrace rim. At the time of the experiments, no crops were grown on the selected field but the soil was covered with grass (Fig. 1). A fallow field was selected for fear of over-fertilizing any crops that may have been growing. The experiment required a large number of repetitions in a short time, therefore a high amount of urine was put on the field. The fact that the field was covered with grass had the additional benefit that during rains very little mud splashed onto the drip lines. Mud may also contribute to emitter clogging, which would have interfered with the aim of specifically determining the risk of clogging by mineral precipitation.

Figure 1: *Field with drip sets.*

3.2.2 Urine

At Nahima, urine is collected from simple uni-sex urinals (Fig. 2) and with chamber pots, which are normally sold for hospital use (Fig. 3). At KDF, urine collection and use is practiced both by the male and female students. This practice was started after the founder of KDF discovered the value of urine as a fertilizer from own experience and various on-line sources. Declining soil fertility is one of the major challenges in this area (Rai, 2011). At present, no urine diversion toilets are in use. Though more urine could be collected in urine diversion toilets (UDTs) the advantage of this system is the elimination of fecal cross contamination. The urine used for the experiments was usually between 12 and 36 hours old, sometimes mixed with urine from a long-term storage tank. For a later application of urine fertigation we strongly recommend to consult the WHO guidelines for safe excreta usage (WHO, 2006) or to analyze the urine regularly for pathogens. If urine from UDTs is used, longer storage times will be necessary.

3.2.3 Water

The water was supplied from a small natural spring at Nahima. Normally the water was clear, samples were taken and later analyzed at the Eawag laboratory in Switzerland (see chapter 4). After heavy rains the water was slightly cloudy. Whenever possible, the particles in the water were allowed to settle overnight in a storage tank. Some dirt accumulated in the storage tank and it is likely that some of the particles ended up in the drip systems during the filling of the drip sets.

Figure 2: *Uni-sex urinal made from a watering can.*

Figure 3: *Chamber pots.*

Figure 4: *Urine collection tank.*

3.3 Drip irrigation equipment

The drip equipment used for the experiments was a standard model sold in Nepal by: "Thapa mould and die, Ltd., Kathmandu, Nepal". The design of the drip sets was developed by International Development Enterprises (IDE) in India. A typical set consists of the following parts:

- 60 liter drum, with a hole for the tap (Fig. 5)
- Tap with a filter and a level indication tube (Fig. 6)
- Main and lateral lines (the tube between the tap and the drip lines) (Fig. 7)
- Drip lines with nozzles (Fig.8).

The critical elements for this study are the drip lines and the nozzles (Fig. 7 and 8). The drip lines in the Nepalese set are round (Outer diameter is approximately 8 mm and wall thickness 0.5 mm.), with emitter holes pre-punctured at 60 cm intervals. Every hole is covered with a "nozzle"; a horseshoe-shaped piece of plastic that covers the hole. Because there is a small groove inside the nozzle (Fig. 8), the hole is not completely covered and thus the water drips slowly from the nozzle. The main functions of the nozzles are to keep dirt from blocking the hole and to prevent the water from jetting out of the drip-line, so that the water drips close to the line. The combination of hole and nozzle is referred to either as emitter or nozzle in this report.

Other drip irrigation equipment may use different models of emitters, such as micro tubes or "drippers" integrated in the tube. The latter have a very small "labyrinth" style emitter inside the drip line (for more technical information see websites of commercial suppliers). We expect that for micro tubes there should not be much difference with the results presented here, but for integrated dripper types of emitters, more extensive testing is recommended.

The Nepalese drip set comes with four drip lines and each line has 20 emitters. Due to space constraints, only 2 lines per drip set were used in the experiments.

At the research location, bamboo stands were made for the drums, so that the tap of each set was 1.10 meter above the field. This height provides the pressure that pushes the water through the whole length of the drip-line and out of the emitters.

Figure 5: *Tank with main line.*

Figure 6: *Tap with filter and level tube.*

Figure 7: *Drip lines with emitters.*

Figure 8: *Nozzle.*

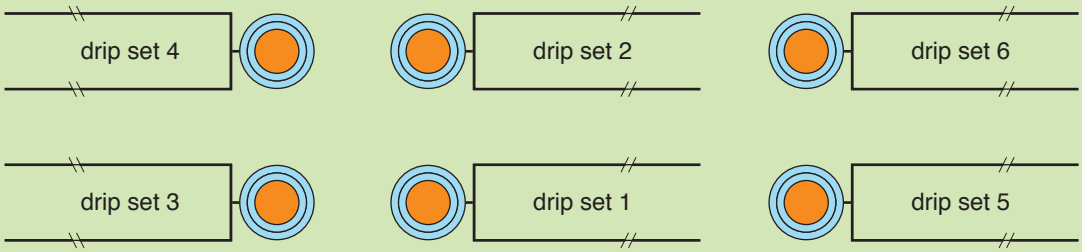


Figure 9: *Schematic of experiment layout.*

3.4 Experiment plan

3.4.1 Number of tests and repetitions

During the experiment, three different "drip regimes" were tested. Each regime was tested in duplicate, therefore a total of six drip sets were used (Fig. 9). With each drip set, 25 tests, or runs, were done. As far as practical, one test (for each drip set) was done every day; this does not correspond to normal farming practice, where water-only irrigation will be done between fertigation runs. We chose to do daily fertigation runs to enforce the differences between the different methods.

3.4.2 Different drip regimes

Three different drip regimes were tested:

A. Water only

B. Water and urine mixed

C. Urine and water sequential

For a overview on each strategy see the column to the right.

A. Water only

In drip sets 1 and 2, 40 liters of water were used for each run. The data from these sets were used as control for the fertigation strategies (B and C).

B. Water and urine mixed

In sets 3 and 4, a mix of 10 liters of urine and 36 liters of water was used (this specific mix was used because of the tank geometry), which corresponds to a 1 to 3.6 urine water mix and was therefore close the 1 to 3 dilution which is usually recommended in Nepal by various sanitation promoting NGOs, such as Enpho and Wateraid. The urine and water were mixed inside the tank for 1 minute. The mixture was then allowed to rest for 45 minutes to let newly formed precipitates and other small particles settle to the bottom of the tank. Since the outlet of the tank was about 5 cm above the bottom, we assume that almost all of the settled precipitates remained in the tank during emptying. After the test, the remaining liquid with the precipitates (the part below the outlet) was removed from the tank.

C. Urine and water sequential

In drip sets 5 and 6, a method without mixing urine and water was tested. In this regime, 10 liters of urine were run through the drip set followed by 30 liters of water. With this experiment, we wanted to determine whether consecutive application of urine and water could lead to increased precipitation due to small scale mixing in the drip lines or at the emitters.

For a detailed description of each strategy, see appendix A.

3.5 Analytical methods in the field

3.5.1 pH measurements

pH Measurements were done with a hand held pH meter; pHep+ (Hanna instruments, Woonsocket, USA.)

3.5.2 Electric conductivity measurements

Electric conductivity (EC) was measured with a portable meter; LF 330/Set with a Tetracon 325 probe (WTW, Weilheim, Germany) including temperature measurements. EC was corrected for temperature according to the formula:

$$EC_{25} = EC / (1 + \alpha(T - T_r))$$

With: EC_{25}*: EC compensated to reference temperature 25°C*
EC*: measured EC*
α*: temperature correction coefficient = 0.02**
T_r*: reference temperature 25°C*
T*: measured temperature of solution*

* Value for water samples according to (Standard Methods, 2006)

3.5.3 Phosphate measurements

Orthophosphate was measured with a spectrophotometer DR/2000 (Method 8048, Hach-Lange, Denver, USA). Before analysis, samples were filtered through at 0.4 µm pore size paper filter (Macherey-Nagel, Düren, Germany).

Analytical deviations were corrected by measuring standard solutions (Appendix B). The method's standard deviation is 0.0336 $mg \cdot L^{-1}$. Samples were diluted 1:250, so the final standard deviation is: $0.0336 \cdot 250 = 8.4\ mg \cdot L^{-1}$. All results are presented as the phosphate fraction (PO_4-P).

3.5.4 Emitter blocking verification

The blocking of emitters was verified by putting pieces of paper (approximately 6X8 cm) under each nozzle (Fig. 11). If the emitter worked, the paper became wet. However, an emitter was also considered to be blocked if only a small amount of liquid dripped out of the emitter. In practice, there usually was a period of lesser efficiency (flow) of an emitter before it was fully blocked; the point at which an emitter was considered blocked was therefore somewhat arbitrary.

3.5.5 Drip set flow rate

The drip sets have a level indicator tube attached to the tap. Behind each of the indicator tubes, a scale was drawn on the tank (Fig. 12). The zero point of the scale was taken as when the tank only contained the dead volume (approximately 6 L below the tap) (Fig. 10). Unless stated otherwise, the zero point is meant when stating that the tank is empty. The mark intervals for the tank volume were 2.5 L. The end time of the run was taken as the moment in which the last liquid disappeared out of the indicator tube.

3.6 Analytical methods in the lab

During the field work, some urine and water samples were collected. These were later analyzed at the Eawag lab. Due to logistical constraints, the samples could only be transported and analyzed 5 months after the field work. The samples were kept under refrigeration (appr. 6°C) for these 5 months. The samples were analyzed at Eawag following standard lab procedures (Table 1).

Table 1: *Analytical methods at the Eawag lab.*

Ions	Analytical method
NH_4^+, NO_2^-, NO_3^-, PO_4^{3-}, SO_4^{2-}	Ion chromatograph (IC 881 Compact IC pro, Methrom, Zofingen, Switzerland)
K, Ca, Mg	Optical emission spectroscopy (OES) with inductively coupled plasma (ICP) (ICP-OES, Siros, Spectro Analytical Instruments, Kleve, Germany)
P_{tot}	Digested samples with Oxisolve to dissolve crystals, then analyzed photometrically with a flow injection analyser (FIA) (Foss, Hillerød, Denmarky)

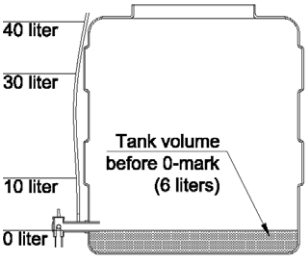


Figure 10: *tank levels.*

Figure 11: *Indicator paper.*

Figure 12: *Scale on tank.*

3.7 Measurement plan

3.7.1 Urine data and urine/ water mix data

Before each test, the following properties of the urine were measured:

- Phosphate content
- Electric conductivity
- Temperature
- pH

For tanks 3 and 4, we tried to determine the precipitation rate of phosphates in the urine water mix. The following data were measured twice; after mixing and before opening the tap.

- pH
- Electric conductivity and temperature
- Phosphate content

Measurements and samples were taken near the top of the tank.

3.7.2 Drip set flow rate and emitter clogging

At 5 minute intervals the liquid levels in the tanks were recorded, also total run times and the number of blocked emitters were recorded every run for every drip set at the end of every run.

4 Results & discussion

4.1 General observations on drip irrigation equipment

The new sets exhibited some differences with respect to the individual emitter flow (no data available). The differences were caused by variations in the nozzles, i.e. the placement over the hole and tightness of the connection to the tubing. Furthermore, the nozzle sizes and the tubing diameter varied slightly. As a result of the small size differences some nozzles could easily move away from the hole. When this happened, too much water came out of the emitter.

4.2 Meteorological data

The experiments were carried out during the pre-monsoon season, which in Khotang meant daily maximum temperatures just above 25°C and average minimum temperatures of around 15°C at dawn. Because there is no weather station in the area no exact data for minimum and maximum temperatures are available. On average, the start temperature was 25 ± 2.0°C and the end temperature was 26 ± 3.0°C. In appendix C, a table with the temperatures at the start and end of each experiment are given.

Because the experiments were carried out in the morning and early afternoon, the end temperatures give a good indication of the maximum daily temperatures. The pre-monsoon season in Khotang was relatively wet this year, with an afternoon thunderstorm approximately every 3 days and 1 rainy day on which no experiments could be done. One day, the experiment was interrupted by a thunderstorm and completed late in the afternoon.

4.3 Urine and water data

4.3.1 Characterization of urine from the field

During the experiment, regular measurements were made of the urine that was used. The results are summarized in table 2, for the complete data set refer to appendix D.

Table 2: *Urine properties, data from field experiments.*

Parameter	n	Average	Stand. dev.
pH	15	9.0	± 0.2
Temperature	25	22.1°C	± 1.9°C
EC_{25}	25	26.9 mS/cm	± 2.0 mS/cm
PO_4-P	20	226 mgP·L^{-1}	± 40 mgP·L^{-1}

The pH values measured correspond well with values found in literature for stored urine. Therefore, we assume that all urea was hydrolysed. The phosphate levels are at the lower end of what is usually reported in literature, but correspond well with STUN experience in Nepal (Etter at al., 2011). It should be noted that the phosphate measurement does not include phosphate that already precipitated as struvite or calcium phosphate during storage. The total phosphate in the urine (including crystalline forms) could be up to 30 % higher than the measured values (Ibid).

4.3.2 Characterization of urine from lab analysis

Table 3 summarizes the concentrations of the five urine samples analyzed at Eawag. Note that as a result of the long storage time, ammonia and sulfate concentrations possibly decreased. The full data for all samples are presented in appendix E.

Table 3: *Urine properties, data from lab analyses.*

Parameter	Average	St. dev.
	[]mg·L^{-1}]	*[mg·L^{-1}]*
Nitrogen (NH_4-N)	2777	± 172
Phosphate (PO_4-P)	185	± 26
Total phosphate (P)	239	± 37
Potassium (K)	812	± 83
Sulphate (SO_4^{2-})	603	± 31
Calcium (Ca)	10	± 3.9

Though the urine was practically undiluted, the nitrogen values (as ammonium) are much lower than for fresh urine. Similar values have been found by other Eawag researchers, both in Switzerland and in Nepal (Etter, et al., 2011 and Udert, et al., 2011). As the urine collection drums in Khotang always contained some old urine, it is likely that even within 12 hours, the urea was fully hydrolyzed to ammonium and carbonate (the measured pH supports this assumption). Because the tanks had no proper covering for most of the experiment, we assume that some ammonia volatilized.

The values for phosphate content are similar to those found in the reports referenced above. The PO_4-P measured at Eawag is lower than the field measurements, possibly as a result of further precipitation.

For potassium Udert found higher values in stored urine in Switzerland and Etter also reports higher values in fresh urine in Nepal, though the latter ones have a large standard deviation indicating large differences between samples. For a table comparing urine properties measured by Etter, Udert and this research, see appendix F.

It is also interesting that there is still 10 mg·L^{-1} calcium left in the urine after the samples were stored for 5 months. This seems to indicate that calcium phosphates form only very slowly, at least at these low calcium concentrations. As shown below, the calcium concentration in the water samples analyzed is even lower. Therefore, calcium phosphates are not very likely to have formed during the fertigation experiments.

4.3.3 Results of water analysis

Three water samples were analyzed at the Eawag lab. In table 4, the results are summarized:

Table 4: *Analyses of water used for experiments*

Parameter	n	Average	St. dev.
		[mg·L^{-1}]	*[mg·L^{-1}]*
Chlorine (Cl)	3	2.3	± 0.1
Nitrite (NO_2-N)	1	5.2	
Nitrate (NO_3-N)	3	3.3	± 4.6
Ammonium (NH_4-N)	1	6.5	
Sulphate (SO_4^{2-})		N/A	
Sodium (Na)	2	16.7	± 2.1
Calcium (Ca)	2	3.7	± 0.0
Magnesium (Mg)	2	1.3	± 0.3

For this research, the most interesting values are the magnesium content and the calcium content. Both calcium and magnesium content are very low. Udert et al. (2003) for example reported 80 mg·L^{-1} and 10 mg·L^{-1}, respectively, for tap water at Eawag. It is possible that the results of this research are therefore not representative for a place with water with a high calcium content.

4.3.4 Precipitation during mixing and settling

To investigate the phosphate precipitation during mixing water and urine, phosphate and EC were analyzed. EC and temperature (for EC correction) were measured for both drip sets and phosphate only for set 3. Measurements were taken twice; just after stirring and after the settling time.

For both tanks, no difference of EC after stirring and after settling was observed (see appendix G). This means, that if there was a difference in phosphate concentration between the two measuring times, it must have been very small. The results of the phosphate measurements varied more and were inconsistent. The accuracy of the method is not sufficient to draw conclusions regarding the amount of phosphate that reacted during the settling time. Though it could not be measured, we assume that all magnesium reacted with phosphate to form struvite during stirring because this reaction is fast in stored urine (Udert et al. 2003b). Based on the magnesium content of the water and the assumption that at pH 9 all magnesium in the urine had precipitated as struvite during storage, we estimate that during stirring about 470 mg struvite was formed in each tank (see appendix H).

One interesting observation is that scaling of the storage tanks with a layer of either struvite or calcium phosphates could be observed. However, no scaling was observed in the tanks of the drip sets or the ends of the drip lines.

4.4 Drip set performance

In this paragraph, the measurement results for total elapsed time per run and the number of blocked emitters are given. They are presented as graphs indicating an overall trend throughout the experiment. For the exact data, refer to appendixes I and J.

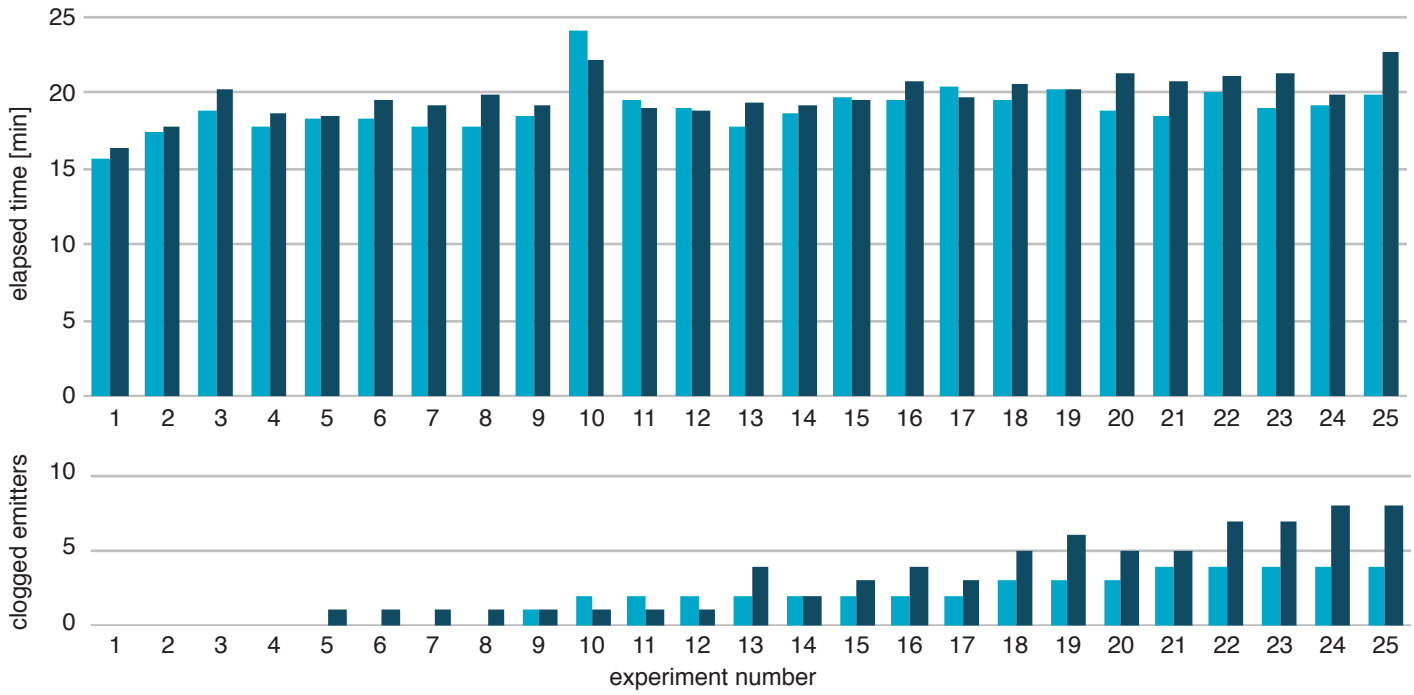
It was found that the filters sometimes collected dirt to the point that it started to influence the run time. All filters were cleaned after experiments: 3, 10 and 17.

4.4.1 Regime A, water only

In drip sets 1 and 2, water only was used to provide a basis for comparison with the urine drip regimes, these sets will be referred to as Water 1 and Water 2. The total elapsed time (time from start to finish) for each experiment is shown in figure 13 (top); further in figure 13 (bottom) the total number of blocked emitters for each run is presented. The total elapsed times for all runs with Water 1 and Water 2 were similar. For Water 1, they were between 15.8 and 24.0 minutes and for Water 2 between 17.9 and 22.6 minutes.

Figure 13 (bottom) shows a slowly increasing number of blocked emitters for Water 1, with a maximum of 4 blocked emitters at the end of the experiments. For Water 2, there is a stronger increase with a maximum of eight blocked emitters. Sometimes blocked emitters started to function again; this could have been due to rainwater cleaning the emitters. However, it seems more likely that blockages were just washed out by irrigation water going through the drip line.

Figure 13: *(top) run times and (bottom) number of blocked emitters for "Water 1" and "Water 2"*



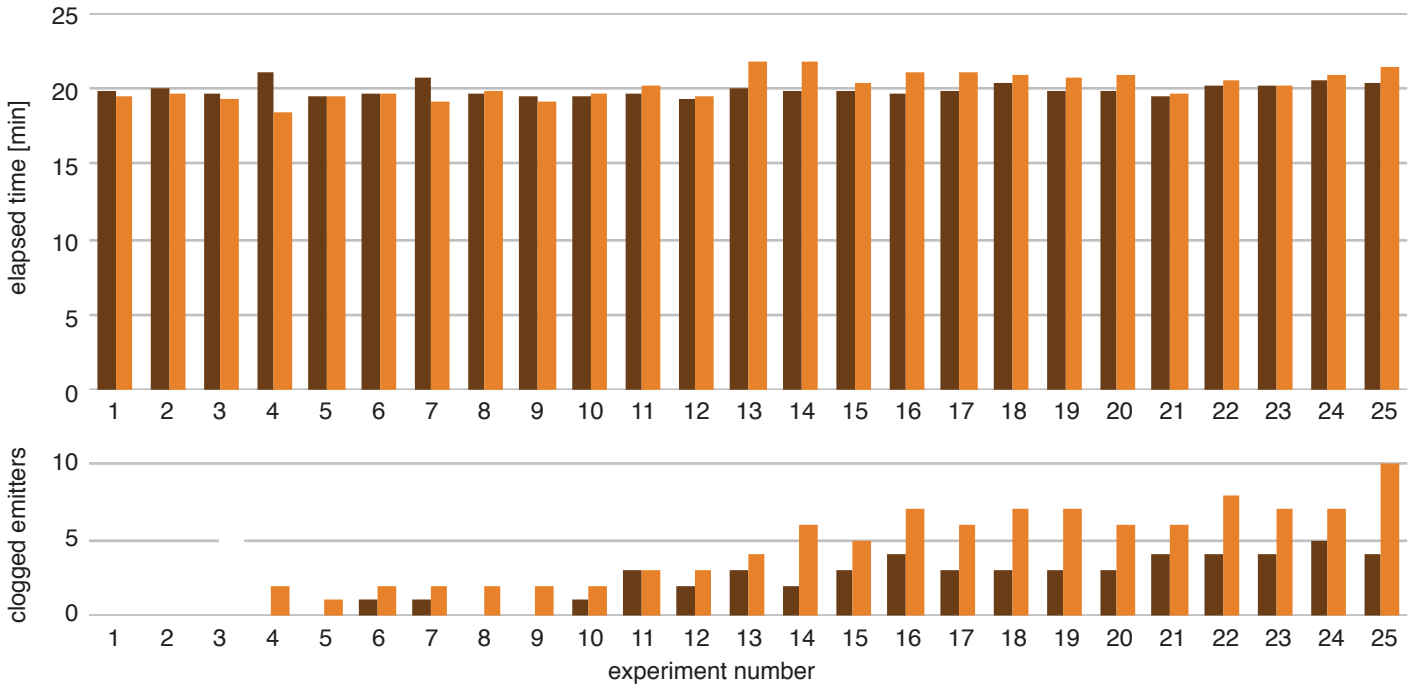
4.4.2 Regime B; Urine water mix

In this method, urine and water were mixed in the tank of the drip set. After mixing, particles were allowed to settle on the bottom of the tank. The results for the sets used with a mix of urine and water (referred to as Mix 1 and Mix 2) are presented in figure 14.

For Mix 1, the elapsed times per run varied between 19.5 and 21.1 minutes. For Mix 2, the elapsed times varied between 19.2 and 21.8 minutes. As can be seen from figure 14 (top), the elapsed times for Mix 2 were usually a little higher than those for Mix 1. This reflects the larger amounts of blocked emitters, as can be seen from figure 14 (bottom).

For Mix 1, the highest number of blocked emitters was 5 during test 24. For Mix 2, the highest number was 10 during run 25. For both tanks, there was an occasional decrease in the number of blocked emitters. Also, sometimes one emitter would unblock while another one would get blocked; this does not show in the graphs, but can be seen in appendix H. In most cases, once an emitter was blocked, it stayed blocked.

Figure 14: *(top) run times and (bottom) number of blocked emitters for "Mix 1" and "Mix 2"*



4.4.3 Regime C, Urine and water sequential

In this system, 10 liters of urine were sent through the drip set first, followed by 30 liters of water. The drip sets used for this regime are referred to as Seq. 1 and Seq. 2. The total elapsed times for both urine and water are given in graphs 15 and 16. The elapsed times for water were consistent, but those for urine showed large variations. For Seq 1, the times were usually between 3 and 5 minutes with occasional longer runs of up to 17 minutes. For Seq. 2, the picture was reversed; most runs were longer than 15 minutes, with occasional run times around 4 minutes. For Seq 2, there is no elapsed time for run 3, because after 25 minutes, there was still more than 5 liters in the tank (probably because the filter in the tank was blocked) and the experiment was stopped.

The number of “blocked” emitters show a similar pattern; for urine, the number of emitters without flow were high (around 13 to 20) for those runs with long run times. However, for the water run that followed the urine, the number of blocked emitters was comparable to those in the water only and mixed tanks. The conclusion is that during a 10 liter urine run, the liquid may not always flow through the whole system and that the non-functioning emitters during these runs were not actually blocked. Possible reasons for the lack of flow with urine are discussed below. In the rest of the report, if the blocked emitters for these two tanks are mentioned, this indicates the number of blocked emitters during the water run. The reasons for the limited flow during some of the urine runs were further investigated in two experiments. The initial suspicion was that the filters had become blocked by impurities in the urine. Therefore, after run 3, some measures were taken to eliminate or at least reduce this effect:

- The filters were cleaned (also after run 10 and 17).
- From experiment 3 onwards, the urine was pre-filtered through a funnel with a strainer to make sure that the filter did not get clogged by large impurities in the urine.
- The urine collection tanks and toilets were cleaned to get rid of dirt and flies accumulated over time.
- A settling time of 45 minutes was observed between pouring the urine into the tank and opening the tap, to allow solids to settle like in regime B.

Figure 15: *Sequence 1, (top) run times and (bottom) number of blocked emitters for "Urine" and "Water"*

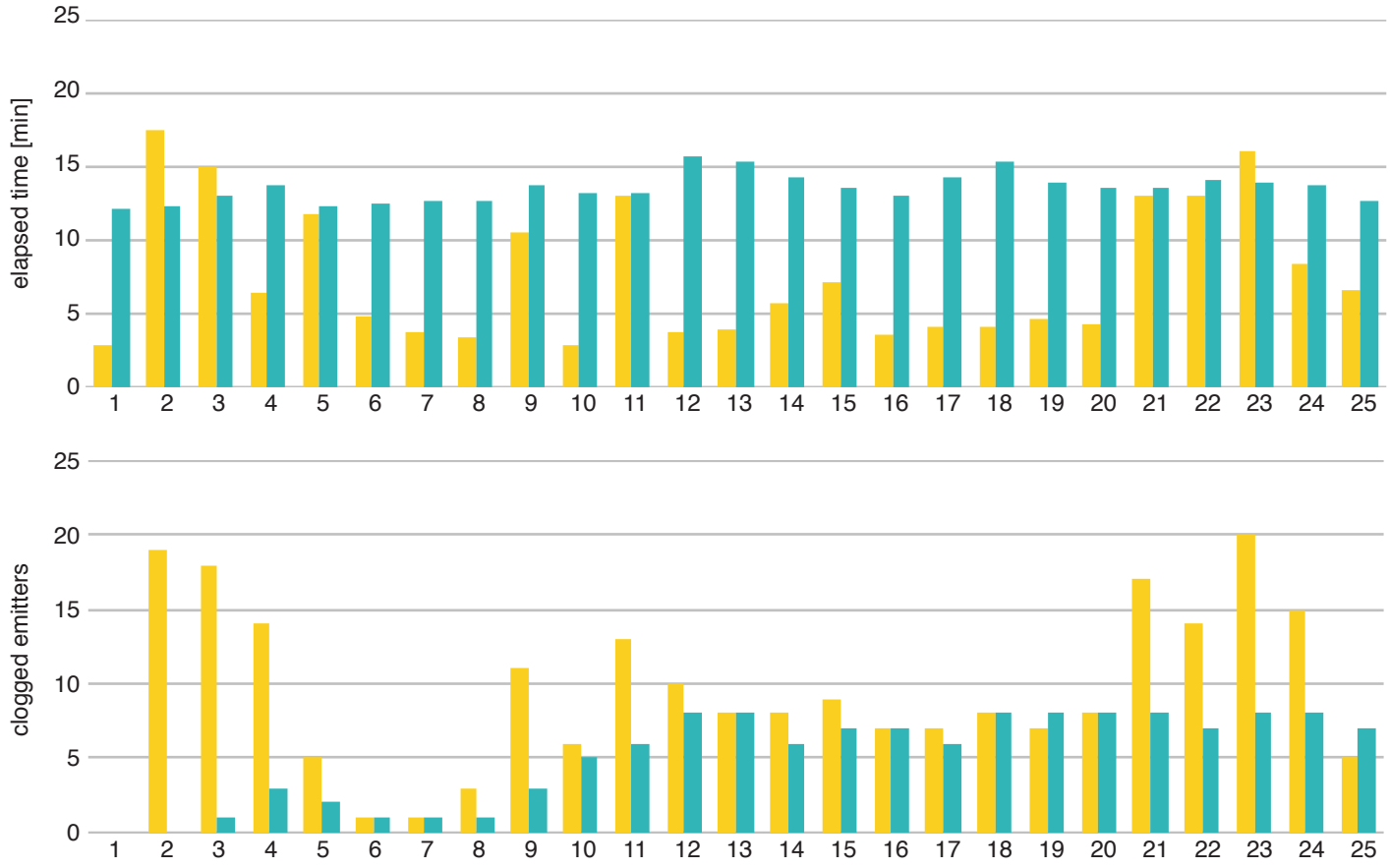
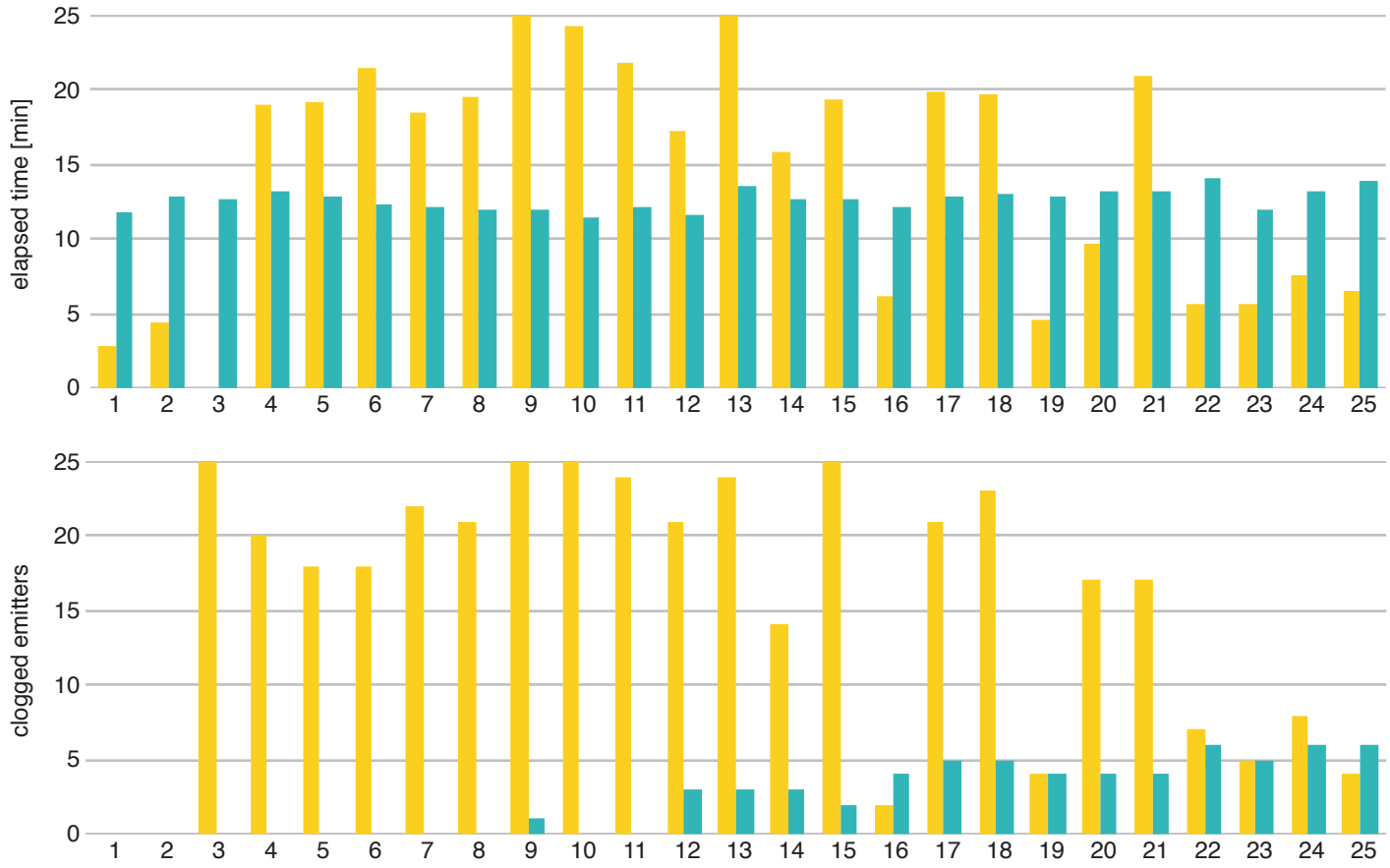


Figure 16: *Sequence 2, (top) run times and (bottom) number of blocked emitters for "Urine" and "Water"*



None of these measures improved the situation. Therefore, two theories were proposed to explain the problem:

1. Urine has some properties, for instance viscosity, that restrict its flow through the pipes.
2. If there is only 10 liters of liquid in the tank, the pressure (head) above the filter is not enough for the flow to get started adequately at all times.

A third theory, that the flow did not go through the whole length of the drip lines because the volume of liquid is too small in comparison to the drip-line volume, was rejected on the basis that a significant amount of liquid remained in the tank for a long time and the fact that often times the urine flowed freely.

Since theory 2 was easier to test, some experiments were conducted to verify this idea. At nine occasions, after the 30 liter water run, tanks 5 and 6 were filled with water to the 10 liter mark and then a run was done to simulate the water flow under the same pressure as for urine. We assume that the additional amount of water (i.e. about 20 % more liquid) did not influence the final outcome with respect to emitter blocking. In figure 17, the total run-times for the 10 liter water checks are presented, the results show a similar wide variation in elapsed times as the 10 liter urine runs. In table 4, the average time for all 10 liter runs, urine and water, are given in Table 5.

Table 5: *Averaged run times for 10 L water and urine runs with Sequence 1 and Sequence 2.*

Experiment	n	av. run time	st. dev.
[-]	*[-]*	*[min]*	*[min]*
Seq. 1, urine 10 L	25	7.6	± 4.7
Seq. 1, water 10 L	9	8.0	± 5.0
Seq. 2, urine 10 L	24	15.4	± 8.1
Seq. 2, water 10 L	9	5.4	± 5.0

A t-test of the data showed that in Seq. 2-with urine is the only significantly (p=0.05) different data set. This makes the check inconclusive, one set shows no significant difference between 10 L water or urine and one does. It is not possible to say why Seq. 2 behaves different with 10 L urine, especially because with 10 L water it does not behave significant different than Seq. 1..

Based on this analyses we think that the pressure in the system was somehow not sufficient when starting with only 10 liters of water in the tanks. It seems that the reduced pressure makes the force of the liquid too small to push remaining liquid and air bubbles or possibly particles through or out of the drip lines. Further support for this theory can be found in Appendix J, where an overview of the working emitters is given. For the 10 liter urine runs that took a very long time there were also a large number of not working emitters. In those cases, one could see that the liquid came to a certain point in the line and then no further, because after that point all emitters were blocked. It is interesting that with 10 liters of water set 6 (Seq. 2) worked better than set 5 (Seq. 1), which with urine was the reverse.

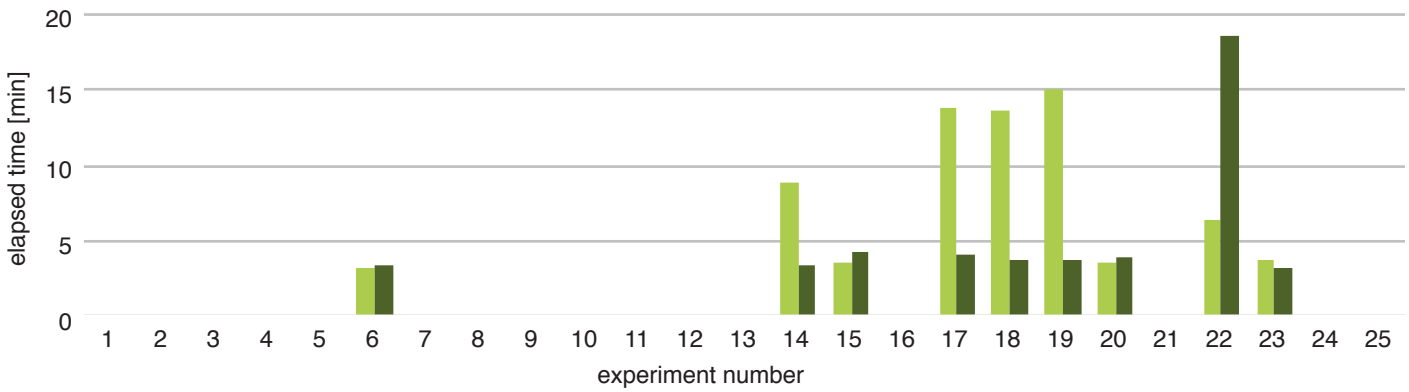
A second experiment to verify, whether the properties of urine were responsible for the varying run times was done after the 25 regular experiments. This experiment was only done with set 6, which had the longest run times for urine during the regular experiments. The tank was filled with urine to the 30 liter mark and then the run was started. This experiment was only repeated 3 times; the run times are given in the table 6.

Table 6: *Run times for 30 L urine runs with Seq. 2*

Date	Run time
[-]	*[min]*
1 Jun 2011	14.6
2 Jun 2011	13.8
3 Jun 2011	14.1

The elapsed times for these 3 runs corresponded well with the time required for 30 liters of water to go through the set and were consistent. Though 3 repetitions are not sufficient do draw conclusions, these experiments gave additional evidence that the results with 10 liter were affected by the lack of head rather than the properties of urine.

Figure 17: *10-litre water tests for sequence 1* *and sequence 2*



4.5 Discussion of drip set performance

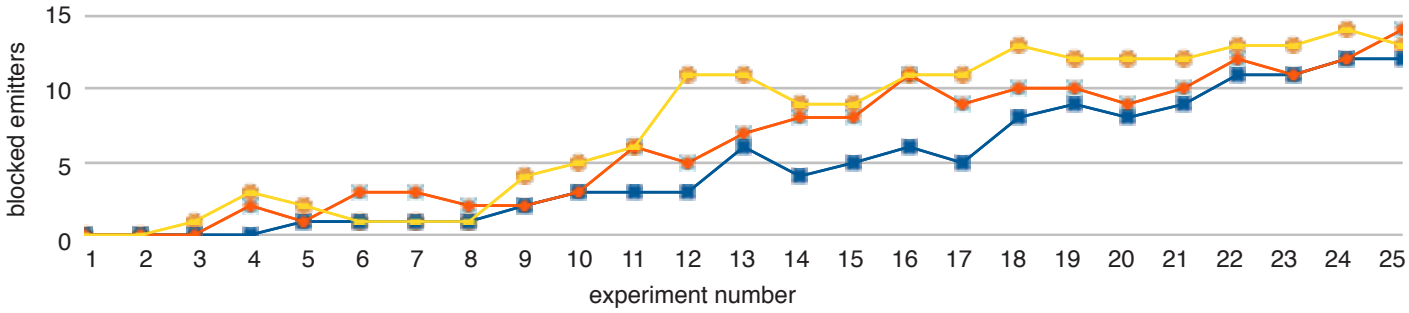
In figure 18, the total number of blocked emitters per regime are compared. From the graph, we can see that the total numbers of blocked emitters for Water 1 and Water 2 combined and for Mix 1 and Mix 2 combined are not very different.

The largest difference is 5 blocked emitters after 16 runs, which is lower than the difference between Mix 1 and Mix 2 (6 blocked emitters) after 25 runs. From the comparison, it seems that water quality and coincidence play a bigger role than whether urine is added to the mix. For a complete overview of the numbers of blocked emitters, see appendix J.

Regime C has the problem with the 10 liter urine runs. The low volumes do not allow for sufficient pressure to ensure even flow through the drip lines. If we look at number of blocked emitters during the water runs (Appendix J) Seq. 1 is similar to the Mix 2, which is the most blocked of regime B. Seq 2 has less blocked emitters but in this set, the urine did often not flow through the full length of the drip lines. The low number of blocked emitters could therefore be an experimental artifact.

In none of the methods used, complete blocking of the emitters or drip lines occurred after 25 runs. In the worst case, the fraction of blocked emitters was 25%. In every setup, including water only, regular checking and unblocking of emitters is necessary. The urine water mix did not perform substantially worse than water only. Therefore, this system can be used without causing extra work inspecting and unblocking emitters.

Figure 18: *Comparison number of blocked emitters between regimes: Water 1 & 2* — *Mix 1 & 2* — *Seq. 1 & 2*



4.6 Precipitation of minerals for Mix 1 and 2

4.6.1 Observation of precipitates

After each run, there was an amount of yellowish-white precipitate left in the tanks used for Mix 1 and Mix 2 (Fig. 19). No thorough analysis of the precipitates was done, but some simple washing in a beaker revealed that there were larger grains of sand and a finer off-white powder. The sand probably entered the urine collection system via the toilets. The fine white powder is assumed to consist of phosphate-based crystals. It was not possible to determine how much of this precipitate was formed when urine and water were mixed in the drip set and how much had already been formed in the urine collection tanks. Since the amount of precipitates formed during mixing and settling is probably fairly constant and not very large (because of the low Ca and Mg levels in the water), it seems that most of the precipitates are already present in the urine.

Figure 19: *Precipitates in tank 4.*

4.6.2 Filter efficiency

It is important to observe a settling time, as the amount of precipitates in the tank was often considerable. A simple test was done to see if the precipitates could go through the filter and into the drip lines. The precipitates were collected in a beaker and poured through the filter (Fig. 20). This way the filter was used in the opposite direction of normal flow but since the pore size remained the same the result gives a good indication of how much of the precipitates could go through. A conservative estimate was that at least 80% of the precipitates went through the filter. This means that the settling time is important to prevent them from going into the drip lines, even though it is not sure if they would have actually block the emitters or just passed through.

Figure 20: *Filtering precipitates.*

4.7 Distribution of blocked emitters along drip lines

Usually, the emitters at the end of the drip line got blocked first. This makes sense, because the amount of fluid going through the hose, and with it the flow rate, decreases along the length of the hose. Therefore, solids had the best chance to settle at the end of the line. Another explanation could be that particles aggregate and cannot pass through the emitter holes. As a result, they would accumulate at the end of the drip-line. After the 25 tests, the ends of the drip lines were checked for scaling on the inside walls and for particle accumulation, but none could be found.

For every test, it was recorded which emitters were blocked, the full data can be found in appendix J. Figure 21 presents the situation for Water 2 after 21 runs and can be considered as a representative case.

Most blockages occurred at the end of the line, with blockages progressively moving towards the tank as more emitters at the end got blocked. Also, there were some blocked emitters further away from the end, usually about mid-way of the line.

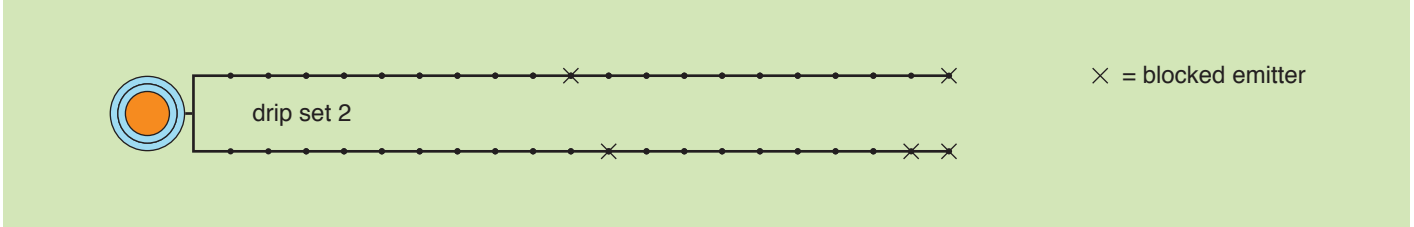


Figure 21: *: Schematic blocked emitters, drip set 2 after 21 experiments.*

5 Conclusions & recommendations

5.1 Conclusions

- Blocking of emitters happened with all 3 regimes, also if only water was used. Therefore farmers always have to check for blocked emitters when using this type of drip equipment.
- For Regime B, where water and urine are mixed, the total number of blocked emitters is not significantly higher than for water only. This means that the amount of work for farmers to check and unblock emitters is comparable to normal drip irrigation. This is especially true when we consider that in normal practice, water-only runs will be done in between the fertigation runs. Therefore, quality of the water, in terms of being free of solids that may block the emitters, seems to be more important than precipitates formed as a result of mixing urine and water.
- It could not be determined whether the mixing of water and urine actually leads to significant amounts of extra struvite in the mix. In Khotang, there was not sufficient calcium in the water for the formation of calcium phosphates, which in other places may happen. Also the magnesium concentrations were very low, we estimate that approximately 470 mg struvite was formed in the tanks of the drip-set during each run. Even if no significant amounts of new crystals are formed when mixing water and urine, there is always a certain amount of dirt and crystals already present in urine. Therefore, it is good to observe a waiting time between stirring the mix and opening the tap.

5.2 Recommendations

- Based on our findings, we recommend using urine in drip irrigation according to Regime B; which means to mix the water and urine at an approximate 1:3 ratio, stir briefly and then let the mix settle for 45 minutes. This method will be most effective if the tap is mounted a few centimeters above the bottom of the tank, as is the case with the Nepalese sets.
- Regime C, where urine and water are used in sequence, did not work well. When only 10 liters of liquid (urine) are present in the tank, the pressure is too small for the system to work properly. As a result, fertilization would be very uneven with this method. It is likely that if larger amounts of urine could be used, this problem would be solved, but at the risk of over-fertilization. Further, there is as much blocking of emitters with this system as with the other methods tested. Therefore, we do not recommend this method.
- The tests were performed with a specific type of drip set in a particular climate and with soft water. It is advisable to repeat the tests with other drip equipment and especially with water that contains more magnesium and calcium before implementing large drip irrigation systems with urine fertigation. Especially for larger drip systems using “integrated drippers” (where the emitter is a micro scale labyrinth that reduces flow to a drip), the results of this research may not be applicable due to differences in emitter design. However, such systems usually have a much better filter between the mixing tank and the drip lines.
- The liquid that remains in the drip tanks with the recommended mixing system contains phosphate rich precipitates. This liquid should preferably be used to water plants that need more phosphate, or very young plants.

Further publications

Brochures explaining the process have been made in Nepali and English (see appendix L). They have been printed by Enpho (Environment and public health organization, *www.enpho.org*) in Kathmandu and are available through there office. Soft copies can be downloaded at *www.eawag.ch/stun*.

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7 Appendices

Appendix A – Detailed work plan for each drip regime

A.1 Regime A, Water only

Step 1 Fill tank with water – up to the 40 liter mark.

Step 2 Open tap

Step 3 Record water level in tank every 5 minutes and check which emitters are blocked.

Step 4 Note total time elapsed for drum to empty.

Step 5 Empty the remaining liquid out of the drum after flow has stopped. For water only this would normally not be necessary but it was done to minimize the differences between the regimes. In normal practice, we would also recommend this step to prevent accumulation of dirt and growth of algae in the drum, both of which may contribute to blocking.

A.2 Regime B, Urine and water mix

Step 1 Fill tank up to the 30 L mark with water (note: this means the actual amount of water in the tank is 36 L).

Step 2 Add 10 liters of urine.

Step 3 Stir and mix for 1 minute.

Step 4 Measure electric conductivity, temperature and pH of mixture and take sample for phosphate measurement.

Step 5 Leave the mix for 45 minutes to allow all solids to settle on the bottom.

Step 6 Measure electric conductivity, temperature and pH of mixture and take sample for phosphate measurement.

Step 7 Open tap.

Step 8 Record water level in tank every 5 minutes and check which emitters are blocked.

Step 9 Note down total time elapsed for drum to empty.

Step 10 Empty the remaining liquid and solids out of the drum. This liquid is high in phosphates, so it can be used on plants that need extra phosphates.

As mentioned above there was always 6 liters liquid in the tank before the zero level was reached. The mixing ratio was not 1 part urine and 3 parts water, as is usually promoted in Nepal, but 1 part urine and 3.6 parts water. It was decided not to try to mix as close as possible to 1 to 3 because the measuring scale on the drum was not sufficiently accurate. This way, the mixing ratio was as consistent as possible for all experiments.

A.3 Regime C, urine and water sequential

Step 1 Fill drum to 10 liter mark with urine.

Step 2 Open tap.

Step 3 Register remaining liquid level in tank every 5 minutes and check which emitters are functioning.

Step 4 Note down total time elapsed for drum to empty.

Step 5 Empty remaining urine out of tank (back into storage jerrycan).

Step 6 Fill drum to 30 liter mark with water.

Step 7 Open tap.

Step 8 Register remaining liquid level in tank every 5 minutes and check which emitters are functioning.

Step 9 Note down total time elapsed for drum to empty.

Step 10 Empty remaining water out of drum.

Appendix B – Correction of phosphate data from field experiment

B.1 Introduction

During research into the combination of urine fertilisation and drip irrigation, orthophosphate measurements were taken from urine samples used. During experiments to validate the data with measurements of standard solution, it was found that there was a large discrepancy between the measured data and the calculated concentrations. This note presents the way in which the results were corrected based on ISO norm 8466 with linear correction and determines a standard deviation for the corrected data.

B.2 Materials and methods

Analytical methods

PO_4^{3-} was measured with a spectrophotometer; DR/2000 (Hach-Lange, Denver, USA). The method used (number 8048) works with powder pillows; orthophosphate reacts with molibdate and ascorbic acid to create a blue colour in the sample.

The standard solution used was Merck, Certipur phosphate standard solution, concentration: PO_4^{3-} = 999 mg·L^{-1} ± 2.

The samples were diluted in 2 steps:

1. Dilution of standard solution to stock solution = 1:50. (concentration PO_4^{3-} = 20 mg·L^{-1})
2. Dilution of stock solution to different concentrations according to the table below:

vol. stock solution	diluted volume	final concentration
mL	*mL*	*mg PO_4·L^{-1}*
0.200	50	0.08
0.800	50	0.32
1.600	50	0.64
2.400	50	0.96
3.200	50	1.28
4.000	50	1.60
5.000	50	2.00
6.000	50	2.40

Calculations

It was found that the results of the spectrophotometer tests were quite different from the calculated values, but that the variation was close to linear (see results section). A second test was done with the same dilutions and yielded similar results. Based on data, it was decided that a linear correction for the measured values should be possible; the formula for corrections was determined according the method described in the ISO 8466 norm.

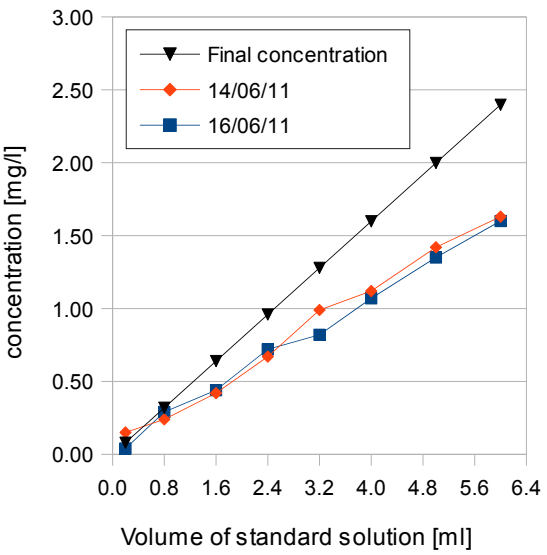
1. For each dilution the measured values for both series of standard tests were averaged, resulting in a table with the theoretical concentrations versus the average measurements of both series.
2. ISO 8466 describes a standard method to calculate a relation between a series of measurement signals and the know concentrations of the samples from which the measurements were taken. In this note the a linear relation is used. The measurement signal is taken as the average of both series.
3. The standard deviation of the method is calculated according to the same ISO standard, also based on the linear calculation methods.

B.3 Results

Measurement results

The results of both sets of measurements with standard solution are presented below, both as a table and a graph.

final concentration	measured concentration PO_4	
	14 June 2011	16 June 2011
mg PO_4·L^{-1}	*mg PO_4·L^{-1}*	*mg PO_4·L^{-1}*
0.08	0.15	0.04
0.32	0.24	0.29
0.64	0.42	0.44
0.96	0.67	0.72
1.28	0.99	0.82
1.60	1.12	1.07
2.00	1.42	1.35
2.40	1.63	1.60



Calculation of correction curve

The next step was to create a table of the actual concentrations and the averaged measurement results and determine the relation between the two.

Actual sample concentration	Average values of 2 tests
mg $PO_4 \cdot L^{-1}$	*mg $PO_4 \cdot L^{-1}$*
0.080	0.10
0.320	0.27
0.640	0.43
0.960	0.70
1.280	0.91
1.600	1.10
2.000	1.39
2.400	1.62

The relation between the measurement signal and the actual concentrations is described by the formula:

f(x)= 1.509 x – 0.070

With:

f(x) = Actual concentration

x = Measured concentration

The table below gives the actual concentrations and the corrected measurement values:

Actual sample concentration	Average values of 2 tests
mg $PO_4 \cdot L^{-1}$	*mg $PO_4 \cdot L^{-1}$*
0.080	0.08
0.320	0.34
0.640	0.58
0.960	0.99
1.280	1.30
1.600	1.59
2.000	2.03
2.400	2.37

Determination of standard deviation

The standard deviation for the process was calculated according to the method described in the referred ISO standard. In the table below the most important parameters of the calculation method are summarised:

Working range		0.080 - 2.400 mg/L
Number of concentration levels		8
Calculated blank (first intercept)	a_0	0.0461
Slope of calibration line	a_1	0.66
Correlation coefficient	R^2	0.9985
Residual standard deviation	s_y	0.02 mg/L
Standard deviation of method	s_{x0}	0.0336 mg/L
Rel. standard deviation of method	V_{x0}	2.90 %
Lower limit of calibration	x_p	0.29 mg/L

As can be seen from the table above the standard deviation for the method is 0.0336 mg/L. Because we know the deviations are bigger at the lower ranges we will use this value for all measurements in the range and thus have a larger uncertainty for lower values.

Results

The orthophosphate concentrations measured during the field trials can be corrected with the formula:

$PO_4^{3-} = PO_4^{3-}{}_m \cdot 1.509 – 0.070$

With:

PO_4^{3-} *= Corrected concentration of orthopohosphate*

$PO_4^{3-}{}_m$ *= Measured orthophosphate concentration.*

The values derived from the formula above have a standard deviation of 0.0336 mg/L

Appendix C – Meteorological data

Date:	Temp at start	Temp at end	General observations:
[-]	*[°C]*	*[°C]*	*[-]*
03.05.11	26	31	Sunny throughout experiment
04.05.11	24	29	Sunny at the start, later low clouds
05.05.11	24	29	Sunny throughout experiment
06.05.11	20	28	Sunny first, partially cloudy later
07.05.11	26	29	Sunny first, partially cloudy later
08.05.11	27	27	Sunny first, partially cloudy later
09.05.11	24	27	Sunny first, partially cloudy later
10.05.11	22	19	Cloudy, later heavy clouds
11.05.11	26	27	Sunny first, partially cloudy later
12.05.11	25	28	Sunny throughout experiment
13.05.11	23	25	Sunny with clouds
14.05.11	28	31	Sunny throughout experiment
16.05.11	24	29	Cloudy with occasional sun
18.05.11	24	25	Cloudy
19.05.11	23	24	Cloudy
20.05.11	22	25	Sunny throughout experiment
21.05.11	28	24	Cloudy, later heavy clouds
22.05.11	27	29	Sunny throughout experiment
23.05.11	29	30	Sunny throughout experiment
24.05.11	21	23	Cloudy
25.05.11	27	27	Sunny first, partially cloudy later
26.05.11	23	24	Cloudy
27.05.11	28	19	Experiment interrupted by thunder storm
30.05.11	22	26	Sunny throughout experiment
31.05.11	25	27	Cloudy with occasional sun
average:	**25**	**26**	
st dev	**2**	**3**	

Appendix D – Urine data from field experiments

Experiment #	pH	Temp	EC_{25}	PO_4^{3-}-P
[-]	*[-]*	*[°C]*	*[mS]*	*[mg/l]*
1	9.0	22.9	28.5	224
2	9.3	20.2	28.8	208
3	9.3	20.9	30.9	170
4	-	21.8	27.5	259
5	-	22.3	25.2	162
6	-	20.4	26.0	259
7	-	19.1	27.5	263
8	-	20.6	27.3	271
9	-	22.2	26.7	221
10	-	22.7	25.6	190
11	-	22.2	25.2	173
12	-	21.3	28.9	-
13	-	20.2	28.1	208
14	9.2	20.8	25.8	-
15	9.0	21.2	31.9	328
16	9.0	22.5	28.4	-
17	9.0	22.1	25.7	253
18	9.0	23.9	24.7	-
19	8.9	28.5	26.1	215
20	9.0	21.5	24.3	-
21	8.6	23.2	26.0	253
22	9.1	21.6	24.4	219
23	9.0	26.1	24.8	229
24	9.0	22.1	25.9	207
25	9.2	23.0	28.6	208
Average:	**9.0**	**22.1**	**26.9**	**226**
Standard dev.	**0.2**	**1.9**	**2.0**	**40**

Appendix E – Data from Eawag lab analyses for urine

sample date	ammonium	potassium	ortho-phosphate	total phosphate	sulphate	calcium	chloride	sodium
	NH_4^+-N	K^+	PO_4^{3-}-P	P	SO_4^{2-}	Ca^{2+}	Cl^-	Na^+
	[mg N·L^{-1}]	*[mg·L^{-1}]*	*[mg P·L^{-1}]*	*[mg·L^{-1}]*	*[mg·L^{-1}]*	*[mg·L^{-1}]*	*[mg·L^{-1}]*	*[mg·L^{-1}]*
08/05/2011	2850	820	153	248	211	11	4020	2490
21/05/2011	2903	880	181	314	207	10	4000	2553
02/06/2011	2934	900	180	252	207	13	4022	2660
02/06/2011	2530	760	225	238	194	15	4023	2585
02/06/2011	2670	700	186	249	187	4	3846	2456

Note:

Five samples were analyzed at the Eawag lab in Switzerland, for logistical reasons the samples could only be analyzed 5 months after they were taken in the field. The first two samples were taken on day 6 and 17 of the experiment, while the last 3 samples were taken at the last day of the experiment. At the KDF hostel there is no refrigeration available and the first 2 samples were stored in water of around 15 °C until the last day of the experiment. After the field work was finished the samples were kept under refrigeration at around 6 0C.

Appendix F – Comparison of plant nutrient concentrations

Based on:

1. Etter, B., Tilley, E., Khadka, R., Udert, K. M. (2011): Low-cost struvite production using source-separated urine in Nepal, Water Research 45-2, 852-862.
2. Udert, K.M., Waechter, M. (2011) Complete nutrient recovery from source-separated urine by nitrification and distillation, Water Research (2011), doi:10.1016/j.watres.2011.11.020
3. Findings in this report

source	urea	ammonium	ortho-phosphate	total phosphate	potassium	sulphate	pH
-		NH_4^+-N	PO_4^{3-}-P	P	K^+	SO_4^{2-}	-
-	*mg·L^{-1}*	*mg·L^{-1}*	*mg·L^{-1}*	*mg·L^{-1}*	*mg·L^{-1}*	*mg·L^{-1}*	-
Etter et al., 2011; Siddhipur, Nepal, fresh urine, 14 samples	4450 ± 1730	438 ± 207	388 ± 251	-	1870 ± 976	878 ± 379	5.6 ± 0.4
Etter et al., 2011; Siddhipur, Nepal, stored urine, 10 samples	-	-	195 ± 65	-	-	-	9.0 ± 0.1
Udert et al., 2011; Stored urine, Dubendorff, Switzerland	-	2390 ± 250	-	208 ± 49	1410 ± 320	778 ± 184	8.96 ± 0.11
This report, Khotang, Nepal, field data	-	-	226 ± 40	-	-	-	9.0 ± 0.2
This report, Khotang, Nepal, Lab analyses.	-	2777 ± 172	185 ± 26	239 ± 37	812 ± 83	603 ± 31	-

Appendix G – Electric conductivity data set 3 and 4

Analyses of Conductivity data for drip set 3 (Mix 1)

Date:	Experiment #	EC_{25} after mixing	EC_{25} after waiting	Delta EC (EC_1-EC_2)
[-]	*[-]*	*[mS]*	*[mS]*	*[mS]*
03.05.11	1	7.01	7.00	-0.013
04.05.11	2	7.21	7.20	-0.010
05.05.11	3	7.59	7.56	-0.034
06.05.11	4	6.99	6.98	-0.011
07.05.11	5	6.22	6.22	0.004
08.05.11	6	6.40	6.43	0.031
09.05.11	7	6.81	6.78	-0.033
10.05.11	8	6.72	6.72	0.003
11.05.11	9	6.53	6.53	-0.001
12.05.11	10	6.42	6.42	-0.006
13.05.11	11	6.19	6.19	-0.003
14.05.11	12	7.01	7.02	0.006
16.05.11	13	6.93	6.91	-0.017
18.05.11	14	6.18	6.16	-0.010
19.05.11	15	7.79	7.80	0.013
20.05.11	16	6.83	6.81	-0.016
21.05.11	17	6.20	6.23	0.026
22.05.11	18	6.28	6.31	0.027
23.05.11	19	6.53	6.54	0.016
24.05.11	20	5.99	6.00	0.011
25.05.11	21	6.88	6.93	0.049
26.05.11	22	6.29	6.32	0.030
27.05.11	23	6.54	6.55	0.009
30.05.11	24	6.40	6.35	-0.055
31.05.11	25	7.34	7.30	-0.035
Average delta EC				**-0.000794**
Standard deviation				**0.024**

Analyses of Conductivity data for drop set 4 (Mix 2)

Date:	Experiment #	EC_{25} after mixing	EC_{25} after waiting	Delta EC (EC_1-EC_2)
[-]	*[-]*	*[mS]*	*[mS]*	*[mS]*
03.05.11	1	no data	no data	
04.05.11	2	7.72	7.70	0.021
05.05.11	3	7.58	7.55	0.031
06.05.11	4	7.07	7.02	0.043
07.05.11	5	6.42	6.42	-0.001
08.05.11	6	6.39	6.39	-0.008
09.05.11	7	6.84	6.81	0.030
10.05.11	8	6.65	6.66	-0.002
11.05.11	9	6.84	6.83	0.005
12.05.11	10	5.73	5.73	0.007
13.05.11	11	6.65	6.65	-0.006
14.05.11	12	7.44	7.44	0.004
16.05.11	13	7.63	7.61	0.015
18.05.11	14	6.37	6.37	0.002
19.05.11	15	7.93	7.94	-0.012
20.05.11	16	7.00	6.86	0.140
21.05.11	17	6.26	6.63	-0.370
22.05.11	18	6.44	no data	
23.05.11	19	6.47	6.47	0.010
24.05.11	20	5.99	6.00	-0.011
25.05.11	21	6.40	6.42	-0.016
26.05.11	22	6.40	6.42	-0.016
27.05.11	23	6.57	6.57	-0.002
30.05.11	24	6.37	6.37	0.003
31.05.11	25	7.35	7.30	0.051
Average delta EC				**-0.003537**
Standard deviation				**0.087**

Appendix H – Estimate of amount of MAP formed during mixing in tanks

Magnesium content water	1.3	$mg \cdot L^{-1}$
Percentage Mg used	100	%
Volume water	36	L
Total magnesium present	47	mg
Magnesium molar weight	24.31	$g \cdot mol^{-1}$
Total mol magnesium	0.0019	mol
Chemical formula MAP (struvite)	$MgNH_4PO_4 \cdot 6H_2O$	
Therefore 1 mol magnesium:	=> 1 mol struvite	
Struvite molar weight:	245.41	$g \cdot mol^{-1}$
Weight of struvite formed	472	mg

Appendix I – Total run-times for all drip sets

run	Set 1	Set 2	Set 3	Set 4	Set 5	Set 5	Set 6	Set 6	Set 5	Set 6
					10 L urine	30 L water	10 L urine	30 L water	10 L water	10 L water
[-]	*[mm:ss]*	*[mm:ss]*	*[mm:ss]*	*[mm:ss]*	*[mm:ss]*	*[mm:ss]*	*[mm:ss]*	*[mm:ss]*	*[mm:ss]*	*[mm:ss]*
1	15:45	16:22	19:47	19:25	02:55	12:05	02:47	11:48		
2	17:29	17:52	19:57	19:40	17:35	12:20	04:24	12:50		
3	18:48	20:17	19:36	19:22	14:55	13:05	stopped	12:37		
4	17:46	18:37	21:09	18:28	06:21	13:40	19:05	13:10		
5	18:21	18:32	19:35	19:25	11:45	12:19	19:15	12:48		
6	18:23	19:37	19:42	19:37	04:47	12:26	21:32	12:18	03:09	03:22
7	17:45	19:08	20:43	19:12	03:50	12:40	18:25	12:05		
8	17:50	19:53	19:46	19:49	03:28	12:43	19:35	11:55		
9	18:25	19:12	19:34	19:12	10:28	13:48	27:37	11:55		
10	24:02	22:09	19:35	19:42	02:52	13:18	24:17	11:26		
11	19:37	19:06	19:41	20:09	13:02	13:18	21:55	12:09		
12	19:03	18:52	19:24	19:35	03:48	15:47	17:18	11:41		
13	17:45	19:17	19:57	21:48	03:56	15:26	27:43	13:37		
14	18:41	19:08	19:51	21:47	05:41	14:12	15:52	12:42	08:49	03:24
15	19:43	19:36	19:52	20:23	07:13	13:32	19:26	12:44	03:28	04:11
16	19:36	20:49	19:41	21:09	03:32	13:03	06:08	12:07		
17	20:25	19:43	19:47	21:08	04:03	14:13	19:53	12:55	13:44	04:08
18	19:29	20:34	20:27	20:56	04:02	15:17	19:38	13:03	13:33	03:47
19	20:14	20:14	19:55	20:42	04:39	13:54	04:39	12:55	15:03	03:46
20	18:52	21:23	19:55	21:00	04:21	13:36	09:42	13:09	03:31	03:58
21	18:29	20:42	19:27	19:44	13:05	13:39	20:54	13:09		
22	20:08	21:12	20:08	20:37	13:07	14:08	05:35	14:00	06:26	18:35
23	18:56	21:17	20:14	20:14	16:04	13:54	05:36	11:56	03:46	03:12
24	19:12	19:56	20:37	20:56	08:21	13:47	07:31	13:08		
25	19:53	22:41	20:25	21:32	06:35	12:37	06:35	13:55		

Appendix J – Blocked emitters

J.1 Emitter status set 1

Experiment	1		2		3		4		5		6		7		8		9		10		11		12		13		14		15		16		17		18		19		20		21		22		23		24		25	
Line	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Emitter 1	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 2	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 3	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 4	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 5	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 6	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	x	o	o	o
Emitter 7	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o
Emitter 8	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 9	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 10	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 11	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 12	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 13	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 14	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 15	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 16	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 17	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	o	o	o	o
Emitter 18	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	x	o
Emitter 19	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	x	o	x	o	x	x	x	o	x	o	x	o
Emitter 20	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	o	x	o	x	x	x
Clogged emitters	0		0		0		0		0		0		0		0		1		2		2		2		2		2		2		2		3		3		3		4		4		4		4		4	

J.2 Emitter status set 2

Experiment	1		2		3		4		5		6		7		8		9		10		11		12		13		14		15		16		17		18		19		20		21		22		23		24		25	
Line	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Emitter 1	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 2	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 3	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 4	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 5	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 6	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 7	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 8	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 9	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 10	o	o	o	o	o	o	o	o	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x
Emitter 11	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	x	o	x	o	x	o	o
Emitter 12	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	o	o	o	o	o	o	x	o	x	o	o
Emitter 13	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 14	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 15	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 16	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	o	o	x	o	x	o	x	o	o	o	x	o	o	o	o	o	o	o	o	o	o	o
Emitter 17	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o
Emitter 18	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 19	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	o	o	o	x	o	x	o	x	x	o	x	x	x	x	x	x	x	x
Emitter 20	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	x	o	x	o	x	o	x	o	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Clogged emitters	0		0		0		0		1		1		1		1		1		1		1		1		4		2		3		4		3		5		6		5		5		7		7		8		8	

J.3 Emitter status set 3

Experiment	1		2		3		4		5		6		7		8		9		10		11		12		13		14		15		16		17		18		19		20		21		22		23		24		25	
Line	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Emitter 1	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 2	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 3	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 4	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 5	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 6	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 7	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 8	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 9	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 10	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 11	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 12	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 13	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o
Emitter 14	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 15	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 16	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 17	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	o	o
Emitter 18	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 19	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	o	o	x	o	o	x	o	o	x	o	o	x	o	x	x	o	x	o	x	o	x	x	x	o	x	x
Emitter 20	o	o	o	o	o	o	o	o	o	o	x	o	x	o	o	o	o	o	x	o	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Clogged emitters	0		0		0		0		0		1		1		0		0		1		3		2		3		2		3		4		3		3		3		3		4		4		4		5		4	

J.4 Emitter status set 4

Experiment	1		2		3		4		5		6		7		8		9		10		11		12		13		14		15		16		17		18		19		20		21		22		23		24		25	
Line	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Emitter 1	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 2	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 3	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 4	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 5	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 6	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 7	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 8	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	o	o	o	o	o	o	o	o	x	o	o	o	o	o	x	o	x	o	x	o
Emitter 9	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 10	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x
Emitter 11	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 12	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 13	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x
Emitter 14	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	o	o	o	o	o	o	o	o	o	o
Emitter 15	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x
Emitter 16	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	o	o	o	o	o	o	o	o	o	o
Emitter 17	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 18	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	o	o	x	o	x	o	x	o	o	o	x	o	x	o	x	o	x	o	x
Emitter 19	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	x	x	x	x	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	x	x	o	x	x
Emitter 20	o	o	o	o	o	o	x	x	x	o	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	o	x	x	x	x	x	x	x	x	x	x	o	x	x	x	x	x	x	x	o	x	x
Clogged emitters	0		0		0		2		1		2		2		2		2		2		3		3		4		6		5		7		6		7		7		6		6		8		7		7		10	

J.5 Emitter status set 5

Urine experiments

Experiment	1		2		3		4		5		6		7		8		9		10		11		12		13		14		15		16		17		18		19		20		21		22		23		24		25	
Line	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Emitter 1	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 2	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 3	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 4	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 5	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	o	o	o	o	o	o	x	o	o	o	o
Emitter 6	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	x	o	o	o	x	o	x	o	x	o	x	o	x	o	o	o	o	o
Emitter 7	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 8	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 9	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 10	o	o	o	o	x	o	x	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	o	o	o	x	o	o	o	o
Emitter 11	o	o	x	o	x	o	x	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	x	o	x	o	x	o	o	o
Emitter 12	o	o	x	x	x	o	o	x	x	x	o	x	o	x	o	x	o	x	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	x	x	x	x	x	x	o	x	o
Emitter 13	o	o	x	x	o	x	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	x	x	x	o	o	o
Emitter 14	o	o	x	x	x	x	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	x	x	x	o	o	o
Emitter 15	o	o	x	x	x	x	x	o	o	o	o	o	o	o	o	x	o	o	o	x	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	x	o	x	x	x	o	x	x	x	o
Emitter 16	o	o	x	x	x	x	x	x	o	o	o	o	o	o	o	x	o	o	o	x	o	x	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	x	x	x	x	x	o	x
Emitter 17	o	o	x	x	x	x	x	x	o	o	o	o	o	x	o	x	x	x	o	x	x	x	x	x	o	x	o	x	o	o	o	o	o	o	o	o	o	o	x	x	x	o	x	x	x	o	o	o
Emitter 18	o	o	x	x	x	x	x	x	o	o	o	o	o	o	x	x	x	x	x	x	x	x	o	x	o	x	o	x	o	o	o	x	o	o	o	o	o	o	x	x	x	o	x	x	x	o	o	o
Emitter 19	o	o	x	x	x	x	x	x	x	o	o	o	o	o	o	x	x	x	o	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	o	x	x	x	x	x	o
Emitter 20	o	o	x	x	x	x	x	x	x	o	o	o	o	o	o	x	x	o	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	o	x	x	x	x	x	x	x	x	x	x	x	x
clogged emitters:	0		19		18		14		5		1		1		3		11		6		13		10		8		8		9		7		8		8		7		8		17		14		20		15		5	

Water experiments

Experiment	1		2		3		4		5		6		7		8		9		10		11		12		13		14		15		16		17		18		19		20		21		22		23		24		25	
Line	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Emitter 1	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 2	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 3	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 4	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 5	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 6	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	x	o	o	o	o	o	o	o	x	o	o	o	x	o	x	o	o	o	o	o	o	o	o
Emitter 7	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 8	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 9	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 10	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 11	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 12	o	o	o	o	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x
Emitter 13	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	o	o	o	o	o	o	o	o	x	o	o	o	o	o	o	o	o	o	o	x	x	o
Emitter 14	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 15	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 16	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	x	o	x	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	x	x	x	x	o
Emitter 17	o	o	o	o	o	o	x	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o
Emitter 18	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	x	o	x	o	o	o	o	o	o	x	o	x	o	o	o	o	o	o	x	o	x	x	o	o	o	x	o	x	o	o
Emitter 19	o	o	o	o	o	o	x	o	x	o	o	o	o	o	o	o	o	x	o	x	x	x	x	x	x	o	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	o	x	o
Emitter 20	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	x	x	x	x	x	x	x	x	o	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Clogged emitters	0		0		1		3		2		1		1		1		3		5		6		8		8		6		7		7		6		8		8		8		8		7		8		8		7	

J.6 Emitter status set 6

Urine experiments

Experiment	1		2		3		4		5		6		7		8		9		10		11		12		13		14		15		16		17		18		19		20		21		22		23		24		25	
Line	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Emitter 1	o	o	o	o	o	o	x	o	o	o	o	o	o	x	o	x	x	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 2	o	o	o	o	o	x	o	o	o	o	o	o	x	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 3	o	o	o	o	o	x	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 4	o	o	o	o	o	x	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	o	o	o	o	o	o	o	o	o	o	o	x	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 5	o	o	o	o	o	x	x	o	x	o	o	o	o	o	o	x	o	o	o	x	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 6	o	o	o	o	o	x	x	o	x	o	o	o	o	o	o	x	o	o	x	x	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 7	o	o	o	o	o	x	x	o	x	o	x	o	x	o	x	o	x	o	x	x	o	x	o	o	o	o	o	o	x	o	o	o	o	o	x	o	o	o	x	o	x	o	o	o	o	o	o	o
Emitter 8	o	o	o	o	o	x	x	o	x	o	x	o	x	o	x	o	x	o	x	x	o	x	o	x	o	x	o	o	x	o	o	o	x	x	x	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 9	o	o	o	o	o	x	x	o	x	o	x	o	x	o	x	o	x	o	x	x	o	x	o	x	o	o	o	o	x	o	o	o	x	x	x	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 10	o	o	o	o	x	x	x	o	x	o	x	o	x	o	o	o	x	x	o	x	x	x	o	x	x	o	o	o	x	x	o	o	o	x	x	x	o	o	x	o	x	o	o	o	o	o	o	o
Emitter 11	o	o	o	o	x	x	x	o	x	o	x	o	x	o	x	x	x	x	x	x	o	x	o	x	x	o	o	o	x	x	o	o	o	o	x	x	o	o	x	o	x	o	x	o	o	o	o	o
Emitter 12	o	o	o	o	x	x	x	o	x	o	x	o	x	o	o	o	x	x	x	x	x	x	o	x	o	x	x	o	o	x	o	o	x	o	x	x	o	o	x	o	x	o	o	o	o	o	o	o
Emitter 13	o	o	o	o	o	x	x	o	x	o	x	o	x	o	x	o	x	x	x	x	x	o	x	o	x	x	o	o	x	x	o	o	x	o	x	x	o	o	x	o	x	o	o	o	o	o	o	o
Emitter 14	o	o	o	o	x	x	x	o	x	o	x	o	x	o	x	x	x	x	x	x	x	o	x	x	x	x	o	o	x	x	o	o	x	o	x	x	o	o	x	o	x	o	o	o	x	o	o	o
Emitter 15	o	o	o	o	x	x	x	o	x	o	x	o	x	x	x	o	x	x	x	x	x	x	x	x	x	x	o	x	x	o	o	o	x	o	x	x	x	o	x	o	x	o	o	x	o	x	o	x
Emitter 16	o	o	o	o	x	x	x	x	x	o	x	o	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	o	x	x	x	x	x	o	x	x	x	x	x	o	x	o	x	x	x	o
Emitter 17	o	o	o	o	x	x	x	o	x	o	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	o	o	x	x	x	x	o	o	x	x	x	x	o	o	o	o	o	x	o
Emitter 18	o	o	o	o	x	x	x	o	x	o	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	o	x	x	x	x	o	x	x	x	x	o	x	o	x	o	x	o	x	x
Emitter 19	o	o	o	o	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	o	o	x	x	x	o	o	x	x	x	x	o	o	o	x	x	o	o	o
Emitter 20	o	o	o	o	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	o	o	x	x	x	x	o	x	x	x	x	x	o	x	o	x	x	x	x
Clogged emitters	0		0		29		20		18		18		22		21		31		25		24		21		24		14		25		2		21		23		4		17		17		7		5		8		4	

Water experiments

Experiment	1		2		3		4		5		6		7		8		9		10		11		12		13		14		15		16		17		18		19		20		21		22		23		24		25	
Line	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Emitter 1	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 2	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 3	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 4	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 5	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	x
Emitter 6	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 7	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 8	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 9	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 10	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 11	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 12	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 13	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 14	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 15	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	o	o	o	x	o	o	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o
Emitter 16	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	x	o	o	o	x	o	x	o	x	o	x	o	o	o	x	o	x	o	x	o	x	o	x	o	x
Emitter 17	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Emitter 18	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	o	o	o	o	x	o	o	o	o	o	x	o	x	o	x	o	o	o	x	o	x	o	x	x	o	x	o	o	x
Emitter 19	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	o	x	o	o	o	o	o	o	o	o	o	o	o	o	x	o	o	o	o	o	o
Emitter 20	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	x	o	o	o	x	x	x	x	x	x	x	o	x	o	o	o	x	x	x	o	x
Clogged emitters	0		0		0		0		0		0		0		0		1		0		0		3		3		3		2		4		5		5		4		4		4		6		5		6		6	

Appendix K – Overview numbers of blocked emitters

Run	Blocked emitters								
	Water 1	Water 2	Mix 1	Mix 2	Seq. 1	Seq. 2	Water 1 & 2	Mix 1 & 2	Seq. 1 & 2
1	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0
3	0	0	0	0	1	0	0	0	1
4	0	0	0	2	3	0	0	2	3
5	0	1	0	1	2	0	1	1	2
6	0	1	1	2	1	0	1	3	1
7	0	1	1	2	1	0	1	3	1
8	0	1	0	2	1	0	1	2	1
9	1	1	0	2	3	1	2	2	4
10	2	1	1	2	5	0	3	3	5
11	2	1	3	3	6	0	3	6	6
12	2	1	2	3	8	3	3	5	11
13	2	4	3	4	8	3	6	7	11
14	2	2	2	6	6	3	4	8	9
15	2	3	3	5	7	2	5	8	9
16	2	4	4	7	7	4	6	11	11
17	2	3	3	6	6	5	5	9	11
18	3	5	3	7	8	5	8	10	13
19	3	6	3	7	8	4	9	10	12
20	3	5	3	6	8	4	8	9	12
21	4	5	4	6	8	4	9	10	12
22	4	7	4	8	7	6	11	12	13
23	4	7	4	7	8	5	11	11	13
24	4	8	5	7	8	6	12	12	14
25	4	8	4	10	7	6	12	14	13

Appendix L – Drip irrigation brochures

A full PDF version of the brochure can be downloaded in either Nepali or English on *www.eawag.ch/stun*.

Dosing: When fertigate?

Irrigation:

Use water in your drip system as often as your plants need water.

Fertigation:

Use the urine & water mix (1 part urine per 3 parts of water) three times during one cropping season, i.e. from the planting until the harvest. As a general rule of thumb, use 0.7 L/m² of urine at every fertigation stage:

1. One week after planting
2. Half-time between planting and flowering
3. When the crops are flowering

For crop-specific urine dosing, refer to the publications indicated to the right (Further readings).

Calculation example:

Field size:
12 m length by 3.5 m width = 42 m2 area
Urine volume (per fertigation stage):
42 m2 · 0.7 L/m2 = 29 L
The urine volume may be applied in three runs of 10 litres of urine mixed with 30 litres of water. Spread the runs over two days. Repeat the runs at every fertigation stage (1, 2, 3, as described above).

Suppliers of drip systems

In Nepal:

Thapa Mould and Die
Gwarkho
Lalitpur
+977 1 52 03 688

Outside Nepal:

Check the IDE website for contacts:
www.ideorg.org/OurTechnologies/DripIrrigation.aspx

Further readings

• Zandee, M. (2011): Basic urine use guidelines for Nepal. Eawag: Swiss Federal Institute of Aquatic Science and Technology, Dübendorf, Switzerland.

• Zandee, M., Etter, B., Udert, K.M. (2011): Clogging of drip-line emitters during urine fertilisation through drip irrigation equipment. Project report. Eawag: Swiss Federal Institute of Aquatic Science and Technology, Dübendorf, Switzerland.

• Richert, A., Gensch, R., Jönsson, H., Stenström, T.A., Dagerskog, L. (2010): Practical guidance on the use of urine in crop production. EcoSanRes Programme, Stocholm Environment Institute, Sweden.

Palada. M., Bhattarai, S., Wu, D., Roberts, M., Bhattarai, M., Kimsan, R., Midmore, D. (2011): More crop per drop: Using simple drip irrigation systems for small-scale vegetable production. The World Vegetable Center, Shanhua, Taiwan.

> Download the publications from www.eawag.ch/stun

Internet resources

• www.eawag.ch/stun
• www.ideorg.org/OurTechnologies/DripIrrigation.aspx
• www.kdf.org.np
• www.ecosanres.org
• www.sswm.info

Contact information

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www.kdf.org.np, khotangdev@gmail.com

How to use urine in drip irrigation

Urine contains valuable nutrients; it is an excellent fertilizer if applied to crops.

With a **drip irrigation system**, a maximum of water reaches the crops directly: you save time and water used for irrigation.

From time to time, you may add urine to your irrigation system to provide your crops with a **balanced nutrient supply**.

Eawag: Swiss Federal Institute of Aquatic Science and Technology
KDF: Khotang Development Forum

Water: Irrigation

With drip irrigation:

• you **use less water**, because the water reaches the plants directly through a hose and does not evaporate.

• you **save time** used for irrigation, because you only have to fill the tank and open the tap, once the system is installed.

Drip **irrigation** & urine **fertilization** =

Fertigation

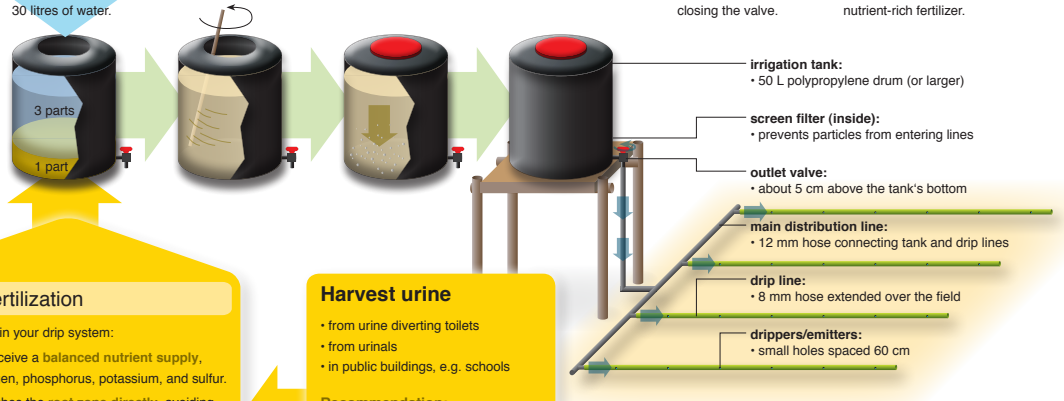
Maintenance

Once a week:

• remove and clean the **cloth filter** at the tank outlet.

• while running your drip irrigation kit, check if any emitters have become blocked. If so, remove the precipitates with a ballpoint pen to **unblock** the emitters.

1. In a 50 litre tank add: 10 litres of urine + 30 litres of water.
2. Mix urine & water briefly with a stick.
3. Let the sediments settle during 30 min.
4. Open the the irrigation outlet.
5. Let the tank drain completely before closing the valve.
6. Invert the tank to remove the sediments – use them as a nutrient-rich fertilizer.



Urine: Fertilization

By using urine in your drip system:

• your crops receive a **balanced nutrient supply**, including nitrogen, phosphorus, potassium, and sulfur.

• the urine reaches the **root zone directly**, avoiding leave contact, which might damage the plants.

• **nitrogen does not evaporate** as ammonia, which would cause bad smell and nutrient losses.

Harvest urine

• from urine diverting toilets
• from urinals
• in public buildings, e.g. schools

Recommendation:

• Store the urine for 1 month.
• Use gloves and a face mask when handling urine.

Risk of clogging of drip-line emitters during urine fertilization through drip irrigation equipment

www.eawag.ch/stun

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