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THE EFFECT OF FERTILISERS ON THE FLUX THROUGH A PERVAPORATIVE IRRIGATION TUBE

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Hannah Riordan, Dr Mike Templeton and Dr Lindsay Todman.

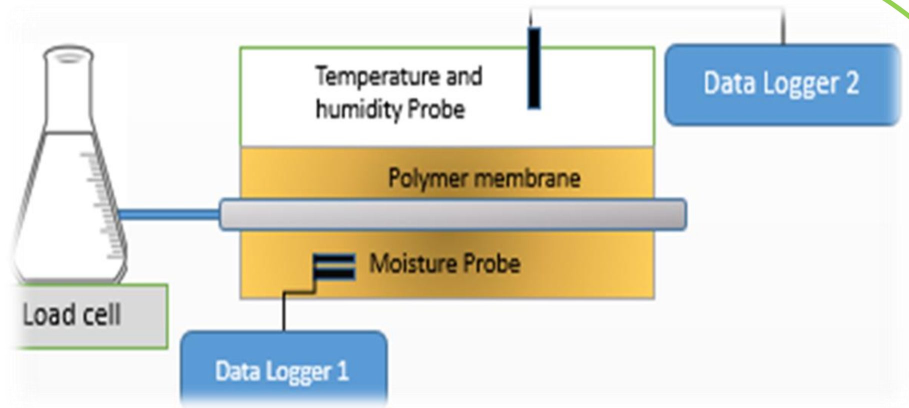
Civil and Environmental Engineering, EWRE Department, South Kensington Campus, Imperial College London.

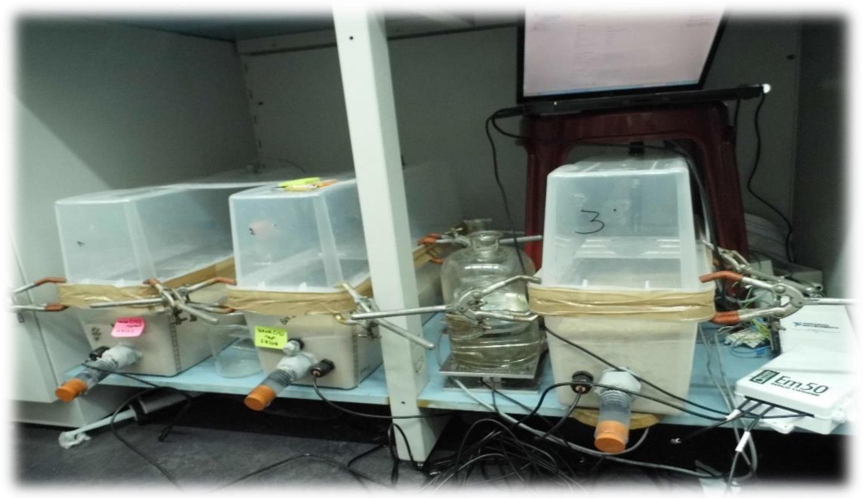
ABSTRACT

This study investigated the effect of nitrous fertilisers on the flux through a pervaporative irrigation tube. Pervaporation is a promising technology for desalination and irrigation purposes in arid environments. The project explored the influence of two concentration levels of urea ($CO(NH_2)_2$) and ammonium nitrate (NH_4NO_3) on the relative humidity (RH), soil moisture content and vapour flux in a dry silica sand. It also considered the effects of a 1:1 mass ratio of the two fertilisers. Desiccator experiments ran simultaneously and were used to construct soil moisture isotherms for the different nitrous fertiliser treatments. The experimental results were also used to validate and adapt a numerical model developed by Todman et al (2013).

METHODOLOGY

Flux experiments were set up for ten days in transparent plastic chambers, packed with sand at a density of 1600kg/m³. the solid granular fertiliser was manually distributed uniformly throughout the sand.





A polymer pervaporative membrane was set up to run through the centre with a glass reservoir feeding water through. The Reservoirs were placed on load cells to record the weight change. A soil moisture probe was positioned within the sand and a humidity and temperature probe recorded the relative humidity in the air in the chamber.

Water passed through the tube in the vapour phase and transported through the soil matrix. This transport also occurs in the vapour phase and is governed by Fickian kinetics as shown in Equation (1). Todman et al (2013):

$$q_v = -mD_e(\theta_s - \theta)\nabla c \qquad (1)$$

A range of five desiccators was set up. Supersaturated salt solutions were placed inside to maintain environments between 33% and 97% constant relative humidity. Samples of all fertiliser treatments were positioned inside for ten days in evaporation basins. The volumetric moisture contents were then measured gravimetrically for each sample to quantify the moisture sorption characteristics. This data was also used to assess the validity of an existing numerical model developed by Todman et al (2013).

ACKNOWLEDGEMENTS

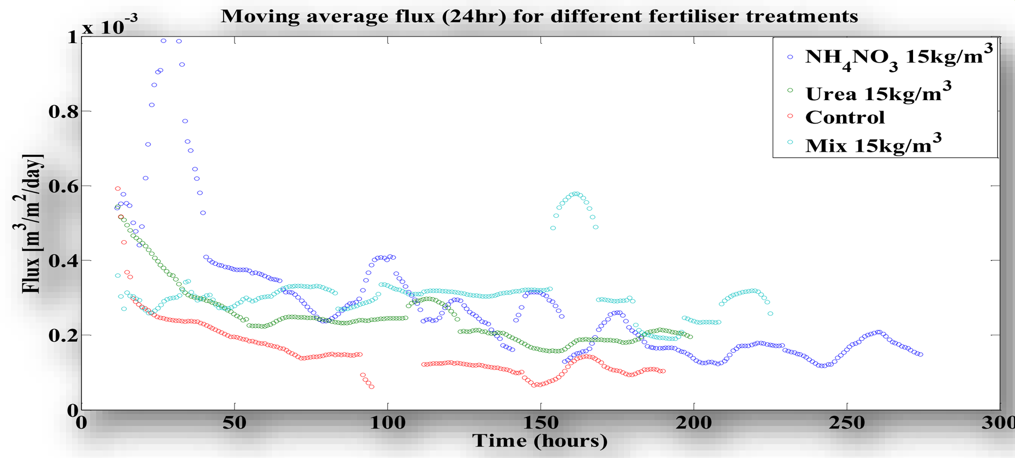
I would like to thank Dr Lindsay Todman and Dr Mike Templeton for excellent guidance and support throughout this project, as well as Dr Geoff Fowler and Carol Edwards for their assistance and patience in the lab.

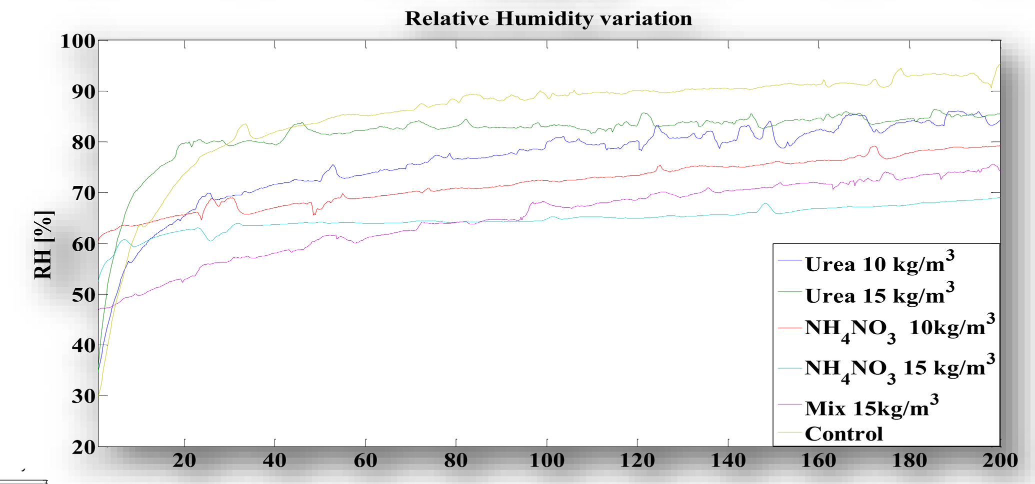
REFERENCES

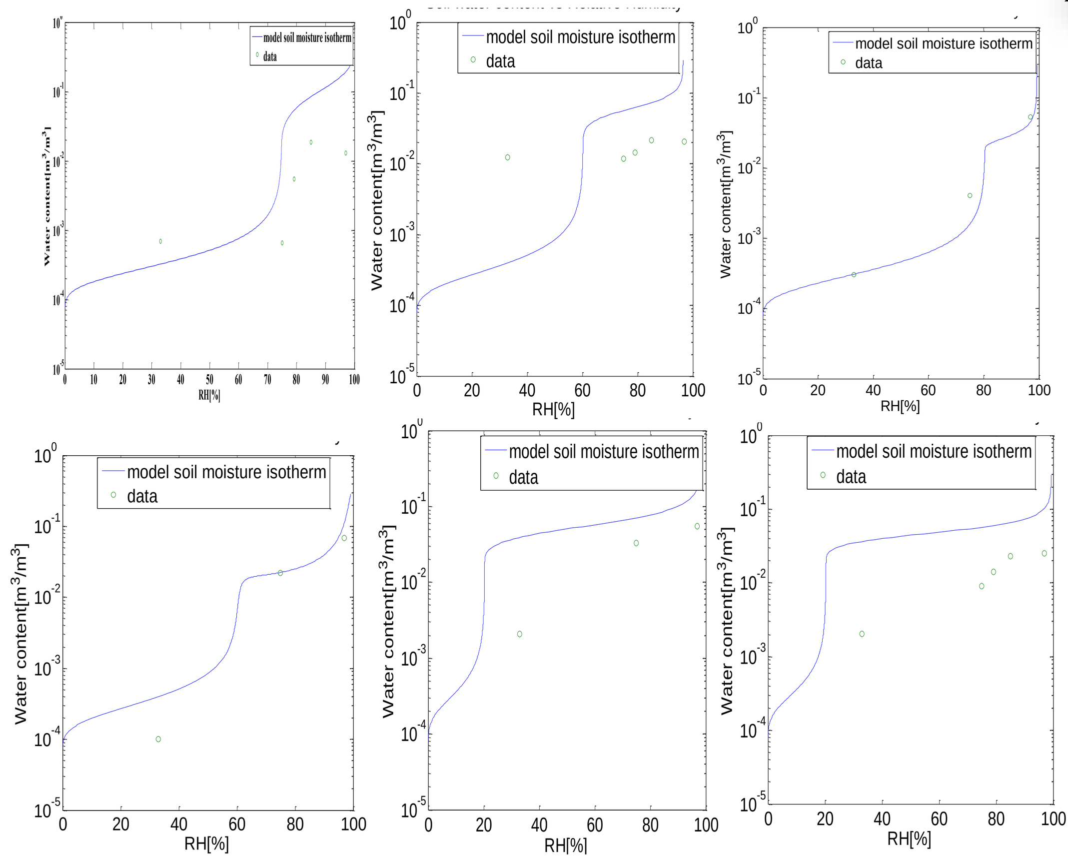
Brooks, D. (2014). London: Imperial College London, Todman, L., Ireson, A., Butler, A. and Templeton, M. (2013). Modeling Vapor Flow from a Pervaporative Irrigation System. Vadose Zone Journal, 12(4), p.0.

RESULTS AND DISCUSSION

The figures show both the measured flux and the humidity variations for all fertiliser treatments. It was observed that the highest average flux (3.05e-04m³/m²/day) and lowest RH coincided with a dosage of 15 kg/m³ of the mixture of ammonium nitrate and urea. This fertiliser has the lowest critical RH at 18%. A low critical RH coincides with a high hygroscopicity, and hence a strong tendency to absorb moisture. The flux results were therefore as expected. However it is expected that the reduced solubility also has an influence, as this value is reduced for the mixture.







Clockwise from top: Urea 15 kg/m3,Urea 45 kg/m3, ammonium nitrate 15 kg/m3, ,ammonium nitrate 45 kg/m³, Mix 15 kg/m³, Mix 45 kg/ m³

Soil moisture isotherms relate the volumetric moisture content of a soil to the relative humidity in the environment. The results from the desiccators were fitted to isotherms generated by the numerical model. Fitting parameters to account for the presence of fertiliser salts were estimated by inspection and the results are illustrated for the highest fertiliser concentrations. The best fit was observed for concentrations of 3g of fertiliser per 100g of sand for all fertiliser salts.

CONCLUSION

- Highest average vapour flux and lowest RH in the chamber coincided with the fertiliser with the lowest critical relative humidity: a 1:1 mixture of urea and ammonium nitrate at 15 kg/m³
- A lower solubility in water of a fertiliser has a reducing effect on the vapour flux in the soil
- The theoretical model is a reasonably good fit for samples with a high fertiliser concentration
- The experimental flux and moisture content results show that pervaporative irrigation could sustain crops when using a carefully engineered membrane