



Research Programme
- Short Calls, Final Report -

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Host Organisation name	Trinity College Dublin
Project Title	Fluorescence-based tracking of particles from domestic wastewater treatment system plumes discharging to springs in Karst aquifer systems.
Contract Number	2017-sc-007

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This report covers the period November 1st 2017 to October 31st 2018

1. (a) Project information:

Final project report (max **2500** words, excluding figures and headings):

- (i) Progress of objectives and scientific/engineering targets beyond the state of the art & methods used

Significant progress has been made since the beginning of the project in terms of main objectives and scientific targets. Water samples were collected monthly at Ballindine and Cregduff springs (Co. Mayo) in addition to Drumcliff and Elmvale spring (Co. Clare) for analysis as stated in the project proposal. It was not suitable or possible to install the In-situ UV spectrometers and/or particle counter at all springs due to budget constraints and/or practical/safety reasons. Hence, Elmvale spring, which is one of the largest springs in county Clare was focused on in terms of temporal fluorescence and particulate dynamics.

Sediment traps were deployed and particles recovered at Elmvale, Cregduff and Ballindine spring on a monthly basis. It was not possible to install sediment traps at Drumcliff spring for practical reasons. Cregduff spring has a significant particle discharge, while Ballindine has not. However, there was significant algal growth at Ballindine spring which would affect the fluorescence meter measurements; to avoid this would have required cleaning of the instrument every couple of days, which was not practically possible. Since microorganisms are considered particles, as proposed, flow cytometry was used for determining the microbiological status of groundwater on a monthly basis from all four springs (two originally proposed springs and two springs additionally included in the study). With this method it is possible to determine the total number of



microorganisms in the form of particles and the number (percentage) of those which are alive and those which are damaged or dead

On a monthly basis, samples are being collected and analysed or preserved for analysis for faecal sterol analysis using GC-MS. It is an expensive and time-consuming technique, but very powerful in terms of distinguishing pollutant sources. A Chromatogram for Ballindine spring sample taken in November 2017 is given as an example in Figure 5:

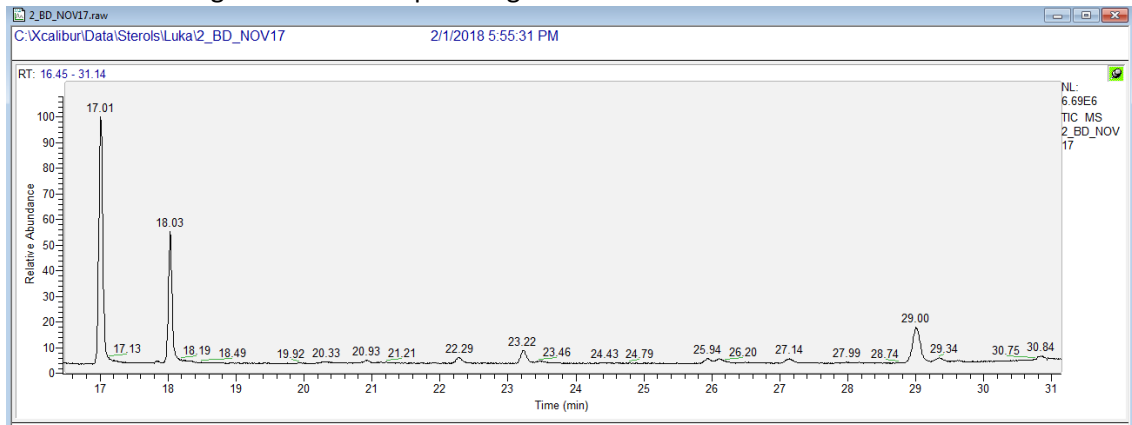
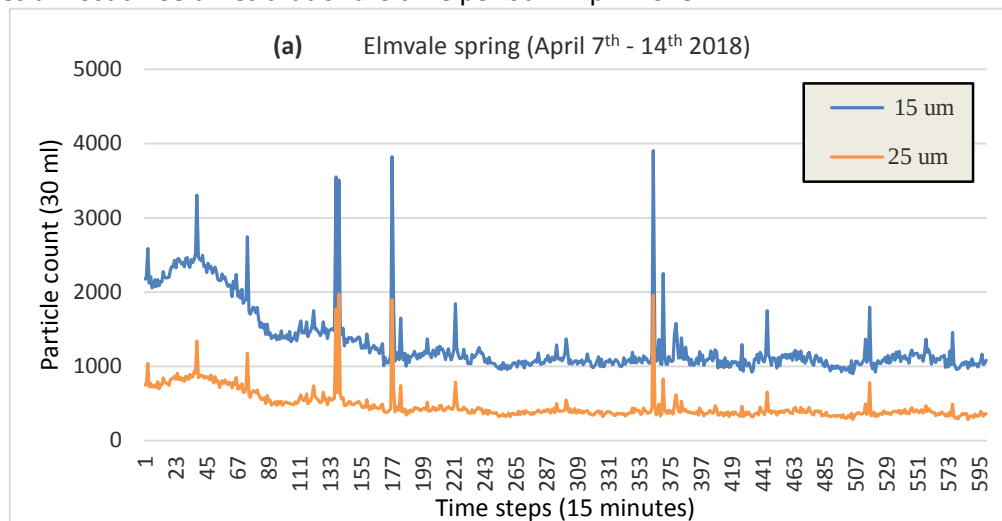


Figure 5: Analysis of faecal sterols in groundwater in Ballindine spring

Figure 6.(a) below shows results from the in-situ particle counter and increased discharge of particles (15 and 25 μm) during high precipitation last April (7th -14th 2018). By Comparison, Figure 6.(b) shows a rain event in early August 2018 which highlighted a concentrated flushing of particles almost three times that of the time period in April 2018.



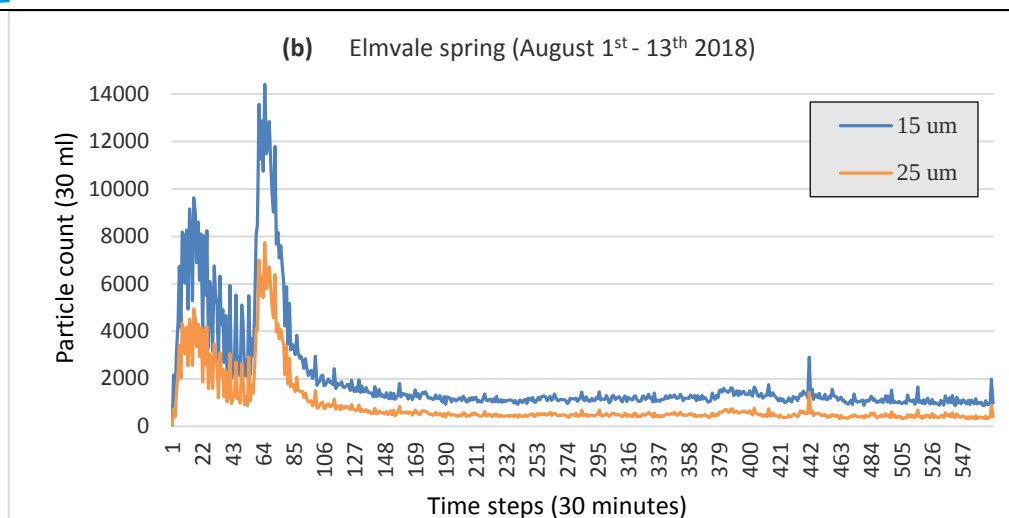


Figure.6 (a) Particle count numbers for particle size 15 µm and 20µm during the period of April 7th – 14th 2018 and (b) particle count numbers for particle size 15 µm and 20µm during the period of August 1th – 13th 2018.

Samples for EEMs were collected and processed with a focus on Elmvale spring on a monthly basis and for storm events in April and August 2018. Figure.7 (a) shows EEMS for the April 2018 high flow event (April 7th -14th 2018) within Elmvale spring discharge water with a mild septic tank influence possibly due to significant prior flushing due to the high discharge winter conditions and a stronger dilution of the septic tank influence fluorescence signals at Elmvale spring. In comparison (b), shows EEMS for the low flow period event (August 1st-13th 2018) within Elmvale spring discharge waters which

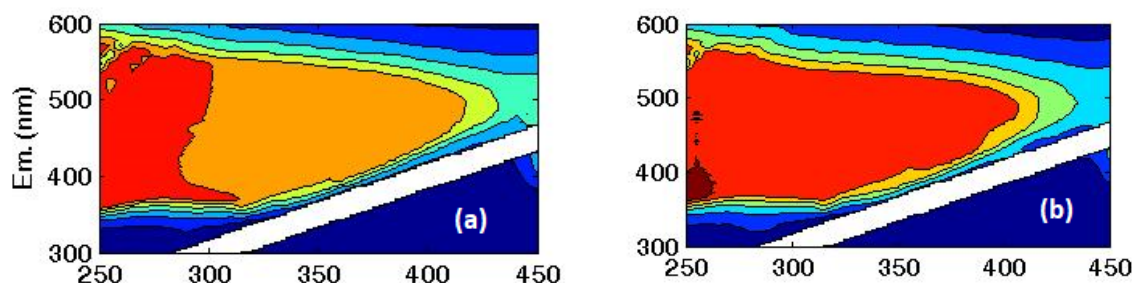


Figure.7 (a) illustrates EEMS for the April 2018 high flow event (April 7th -14th 2018) within Elmvale spring discharge water. In comparison (b), shows EEMS for the low flow period event (August 1st-13th 2018) within Elmvale spring discharge waters.

Illustrates a strong septic tank influence as indicated by elevated protein-like fluorescence (Excitation at 250-300 nm, Emission at 300-350 nm) potentially due to a flushing effect after a very dry 2018 summer in the locality. Our fluorescence EEMS analysis suggests that Elmvale spring is impacted perennially by septic tank leachate from its catchment, with fluctuations in its extent affected by groundwater flow conditions and associated variable dilution of the signal within the karst conduit network. This data will be further analysed by PARAFAC modelling of the obtained fluorescence spectra. Moreover, we aim to calibrate the in-situ UV-VIS probe to model organic matter optical properties by partial least squares regression of UV-VIS spectra and thus to identify potential septic tank influence on high temporal resolution during flushing events.

- (ii) Implementation (please include any issues with timelines, milestones, management etc. or deviations from the original implementation plan)



There are 7 main stages to this project. Each builds on the previous stage and there were natural overlaps of tasks. As part of the project we have:

- Installed an in-situ turbidity/UV-vis probe at two spring locations (Elmvale spring, Co. Clare and Creggduff spring, Co. Mayo) during March 2018.
- Deployed in-stream sediment traps for preliminary analysis occurred at Ballindine and Creggduff spring, Co. Mayo and at Elmvale spring, Co. Clare.
- During December 2017/January 2018 the majority of analytical techniques were tested in the lab using actual spring waters and draw up protocols for analysis for field campaigns.
- Fluorescence EEMS were processed to detect changes caused by natural organic matter variation from septic tank effluent above any background levels at Elmvale spring during a high flow period in April 2018.
- In April 2018, the 1st Particle monitoring campaign commenced during high flow events (Winter/spring): use of portable particle size analyzer during a high flow event and couple this to turbidity. Samples were also taken for fluorescence excitation emission matrix (EEMS) analysis which suggest a septic tank leachate influence but not very strong.
- A storm event during low flow conditions was monitored using a particle counter and continuous in-situ UV-vis was recorded for later adjustment to EEMS analysis over this period.
- In August 2018, the 2nd particle monitoring campaign commenced for 2 weeks to catch the impact of storms on particle discharge from the springs following a significant summer 2018 drought period. Use of a portable particle size analyzer following a high flow event was coupled fluorescence excitation emission matrix (EEMS) show a definite septic tank leachate influence.

(iii) **Outputs** (please provide a short description and complete the table below)

- Showed correlations between seasonal fluctuations in particles and fluorescence EEMS associated with potential associated contaminants from DWTs at a karst spring during high flow events.
- The project fills gaps in knowledge, which may inform and influence future policy and governance on domestic wastewater treatment systems within karst aquifer systems both in Ireland and internationally.
- Results have formed the basis of a poster presentation at an international conference (European Geoscience Union Assembly) and lay foundations for a future peer reviewed publication in a leading international academic journal (e.g. Journal of Hydrology or Hydrological processes), a contribution in a national journal/newsletter

Task	Deliverable description	Planned delivery	Date of delivery
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No.		(as per proposal)	
1	Establish temporal variations of sediment particles/turbidity in response to recharge events (i.e. rain) and also contaminant transport variation.	3 months	Delivered June 2018 with temporal change in flow cytometry at Elmvale spring and other springs.
2	Characterise and differentiate two principle components, storage and infiltrated water and relationship between sediment particles/turbidity and mobilization of particles associated with DWTSS through their component EEMs analysis.	10 months	Delivered EEMS for April 2018 storm event at spring. Future isotope results will help differentiate infiltrating water from storage water.
3	Confirm (or refute) the use of particles as the basis for an indirect cost effective early warning contaminant detection technique based on PARAFAC for DTWSS contamination to potable water supply springs.	10 months	Delivered November 2018. Elevated particles coincided with changes in EEMs indicating a Wastewater influence during April 2018 and August 2018 storm event.
4	Proof of seasonal dynamics in influence of particulates from DWTSS effluent composition.	10 months	Delivered November 2018. Correlation between high particle counts and EEMS suggesting septic systems influence in spring discharge waters.
5	Disseminate findings at international conferences and represent TCD and the GSI. Vienna 2018 EGU conference, Poster presentation.	6 months	Delivered poster presentation in April 2018 at EGU and in November 2018 at Geoscience Ireland.
6	Preparation of the final report to lay basis for future research publication, with the following themes: (i) A novel indicator technique for contaminant detection at springs from DWTSS in low land karst systems (iii) Assessment of the potential importance of particulates in contaminant transport from DWTSS to potable water supply springs in an Irish context enabling development of better conceptual models and future water supply policy.	10 – 12 months	Delivered final report November 2018. Results lay foundations for future research article (2019) to a leading international journal, (i.e. <i>Hydrogeology Journal</i> or <i>Hydrological processes</i>) in 2019.



Publications to date:

[Conference Publication] Vucinic, L., O'Connell, D.W., Knörr, K, Coxon, C., Gill, L.W (2018) Fluorescence-based tracking of particles from domestic wastewater treatment system plumes discharging to springs in Karst aquifer systems. Geophysical Research Abstracts Vol. 20, EGU General Assembly April 2018.

4. Data/outputs submitted with final report

(redacted)

c. Figures of particle number fluctuations (15 and 25µm size) using a particle counter during a storm event in April 2018 and August 2018 at Elmvale spring.

d. Figure showing GC-MS chromatogram of faecal sterol analysis at Ballindine spring for November 2017.

e. Figures showing EEMs of Elmvale spring water during a low flow period pre-storm event (August 2018) and during a high flow storm event (April 2018) with varying degrees of septic tank influence evident.

SUPPLEMENTARY MATERIAL

(This section will be included in your published report unless otherwise instructed. If you have a published report, publication, etc. you may include it here).

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