Training Report INSPIRATION ITN

1st November 2016- 15th December 2017

Work Package 4

Mitigation of soil and groundwater impacts from agriculture

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This report has been prepared within the INSPIRATION (Managing soil and groundwater impacts from agriculture for sustainable intensification) Marie Skłodowska-Curie Innovative Training Network (Grant agreement no. 675120).

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1 Introduction

As part of INSPIRATION ITN project, we, Early Stage Researchers ESR11 Golnaz and ESR13 Julia are working together within Work Package 4 (WP). This WP investigates intensive dairy systems and how they affect nutrient and gaseous losses to the environment. In addition it seeks to identify natural attenuation areas thereby mitigating losses where this protection is lacking along open ditch drainage networks.

Training helps us to achieve our project objectives of the INSPIRATION ITN study, providing us with new skills and collaborative opportunities.

In this document which will be the first of a series of training reports across the entire ITN network, we will summarise our training activities and outcomes/or knowledge that may be of interest to you the reader.

We (Figure 1) are both conducting our experiments on a dairy and beef farm in Johnstown Castle, Wexford, SE, Ireland, which is a high rainfall area with heterogeneous soils covering all drainage classes. The abolition of EU milk quota has allowed dairy farmers in Ireland to expand and become more intensive. Indeed many farmers spread across the SW and S of the country have applied successfully for derogation. This means they can carry a higher stocking density of cows on their land (Figure 2). Therefore, both our studies will help inform the concept of sustainable intensification and provide tools to assess and improve such a concept.

Figure 1. left: EST 11 (Golnaz); right: ESR 13 (Julia)

2 Joint Training

Out study site is the intensive dairy farm in Teagasc, Johnstown Castle. This site has been characterised in terms of reactive nitrogen over the past 10 years and has an extensive monitoring network already installed. Less is known in terms of phosphorus concentrations across the monitoring network. We both work on this site for different reasons i.e. Julia will focus on gaseous emissions from the unsaturated zone, whereas Golnaz will focus on N/P characterisation in water and soil and mitigating losses along the open drainage ditch network. Therefore our training activities have focused on obtaining the relevant skills to enable us both to carry out our field work and interpret the data we gather.

Figure2. Johnstown Castle Mini-Catchment boundary in SE Ireland.
Artificial lakes are shown in blue. Green dotted lines and light green lines represent subsurface and surface drainage systems, respectively. The black dots across the map shows water sampling points e.g. multi-level wells, surface sampling points, and end of pipes.

Step 1 in this process was to consult previously gathered data pertaining to the site. The next step was a combined field site campaign, where we were shown how to take water samples, setup in-situ flow-through cells to obtain biogeochemical parameters, develop piezometers and boreholes, take flow measurements on flow weirs and preserve field samples before analysis. Fellows also presented different techniques they had already learned previously to each other. The next section outlines in more detail this field site training activity.

2.1 Field training onsite at Johnstown Castle, Ireland

We focused on the Johnstown Castle dairy farm which has an extensive monitoring network built up over many years. The components are:

- A multi-level groundwater component
- An open ditch network
- End of pipe sample locations with an associated land drainage map (10 km of piped drains on site)
- Surface water sampling locations to assess the receiving water body and a nearby lake system

Interpretation of this excel based dataset allows us to spatially and temporally characterise water in terms of its nutrient concentration (e.g. nitrate, ammonium, dissolved reactive phosphorus) and its biogeochemistry (e.g. pH, temperature, dissolved oxygen, electrical conductivity, redox potential). This information can then be coupled with weather (e.g. daily rainfall) and farm management (e.g. fertilizer inputs, grazing days and silage areas) data as well as soil physical (e.g. soil texture, bulk density) and chemical (e.g. Fe, Al, Ca, organic matter%, sorption isotherm parameters) characterisation to get a bigger picture of nutrient fluxes within the delineated catchment. Potential areas with nutrient surplus and/or low natural attenuation capacity could thereby be identified and vice versa. Such characterisation will identify where the leaks are in the system (point and diffuse) and this will enable us to come up with clear mitigation strategies to minimise losses. Some of these will be management driven whereas others will focus on engineered alternatives e.g. intercept high nutrient drainage water before it discharges from the farm.

We developed our knowledge on: how to collect water samples; how to properly store samples and transport them from the field to the water laboratory. To complete this sampling event we did an extensive water sampling campaign to collect ~60 different water samples from all possible water bodies on the farms. This included deep groundwater wells (<20 m), shallow piezometers (<7 m) and surface drainage water. Here we got familiar with methods used by the other. The data gathered provide a comprehensive and detailed look into water quality.

2.1.1 Water sampling from surface and groundwater

Field work included making decisions on suitable sampling times and storage equipment. Special high density polyethylene (HDPE) storage bottles were used to store the water at suitable temperatures depending on future analysis. For analysis of nitrate isotopes for example water should be stored frozen, while for water isotopes it should be stored at 20°C.

We used a peristaltic pump to pump water into an *in situ* probe (Figure 3 & 4) which is a multi-cell probe that measures rugged oxygen, pH, temperature, turbidity, redox potential and electric conductivity in the field. Those parameters give an overview with respect to the water chemistry. Further laboratory analysis included general water chemistry as well as specific nutrient concentrations and isotopic signatures of nitrogen. For dissolved reactive phosphorus (DRP) and nitrogen (ammonium (NH^{4+}), nitrate(NO_{3-}) we filtered water samples through a 0.45 µm filter in the field. Other non-filtered samples are used for total N and P.

According to the EPA, the maximum allowable concentration (MAC) of dissolved reactive phosphorus, ammonium-N and nitrate-N in surface water is 0.035, 0.23, and 5.65 mg/l. For groundwater (drinking water) the nitrate-N standard is 11.3 mg/l.

The results of those water samples give deeper insight into water quality in Johnstown Castle. Water samples are monthly collected from all sampling points across the dairy farm, plus water samples collected from open ditch network in the farm, combined with soil analysis results (discussed further) helps to define an appropriate in-field remediation structure and mitigation measure that suits the field site.

Figure 3. Water sampling equipment: Peristaltic Pumps, Tubing, Battery, *In situ* Probe, Dipper (groundwater depth measuring tool)

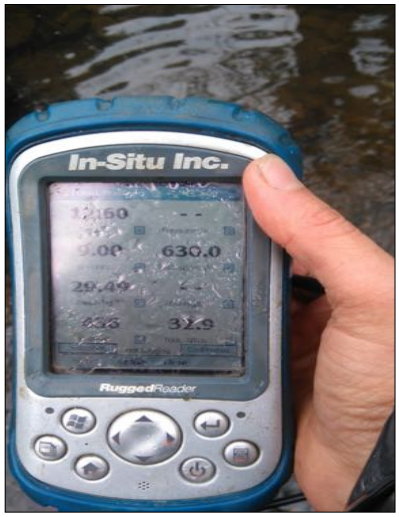


Figure 4. Reading chemical data from *in situ* probe handheld

2.1.2 Discharge measurements using divers

Divers or water loggers are devices used for measuring the height of the water table. They can be installed in boreholes, piezometers or even in flow-weirs. During this period of work we have deployed divers in piezometers that have been installed in the open ditch to measure the height of water flowing through the weirs (Figure 5 & 6). This data is then converted to flows using a flow rating equation provided by the concrete weir manufacturer. To measure the height of water we needed to install a piezometer with a pressure transducer inside. This transducer is set up to coincide with the concrete base and measures the height of water above this point. This data is downloaded and inserted into the equation and the flow is calculated. With these data we can define the appropriate design of a potential mitigation technique required on this farm.

High resolution flow data is then combined with nutrient data at that sampling point to calculate loads passing through the open ditch network. Therefore, a weir has been installed up-gradient of the farmyard (potential point source) and at the discharge point on the farm.

Figure 5. Installation of divers into piezometer in front of a weir

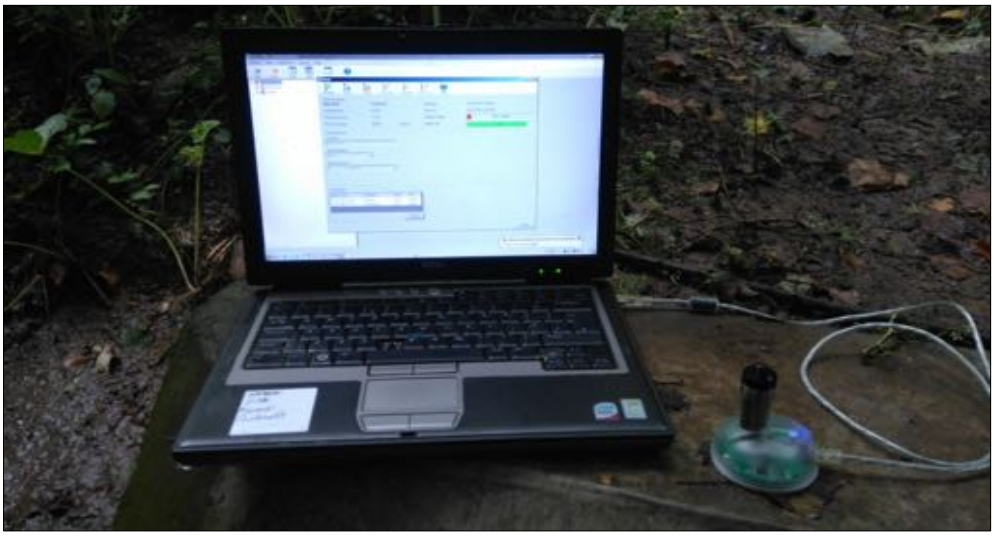


Figure 6. Downloading diver data onsite to elucidate the height of water flowing through the weir. This helps with calculating the load of nutrients flowing through the weir throughout the year.

2.1.3 Soil gas sampling

Concentrations and composition of soil gases provide vital information about microbiological driven soil processes. Through the characterisation of the oxygen concentration in soil pores one can derive which microorganisms are likely to be active, since some of them require oxygen for their metabolism and some do not. Nutrient cycling, especially nitrogen cycling depends on microbial activity, therefore soil gases such as nitrous oxide (N_2O) a potent greenhouse gas can be monitored.

This method was demonstrated in the field with colleagues from UFZ. For this an air lance for soil gas sampling was used (Figure 8). The procedure is quite novel and straight forward. First you put a rivet on the tip of the lance to avoid the hole getting blocked with soil; you then hammer it into the soil until you reach the depth you want to sample. By pulling the lance out only for a few cm the rivet remains in the soil, uncovers the lance hole and creates a small headspace. With a vacuum pump and gas bags you can sample ~1 litre of soil gas. This is then analysed later in the laboratory and a dataset is gained. Carrying out this procedure across different soil types or drainage classes could provide information on gaseous losses within the unsaturated zone. Currently this unsaturated zone is poorly understood in terms of pore water concentration, and gaseous losses.

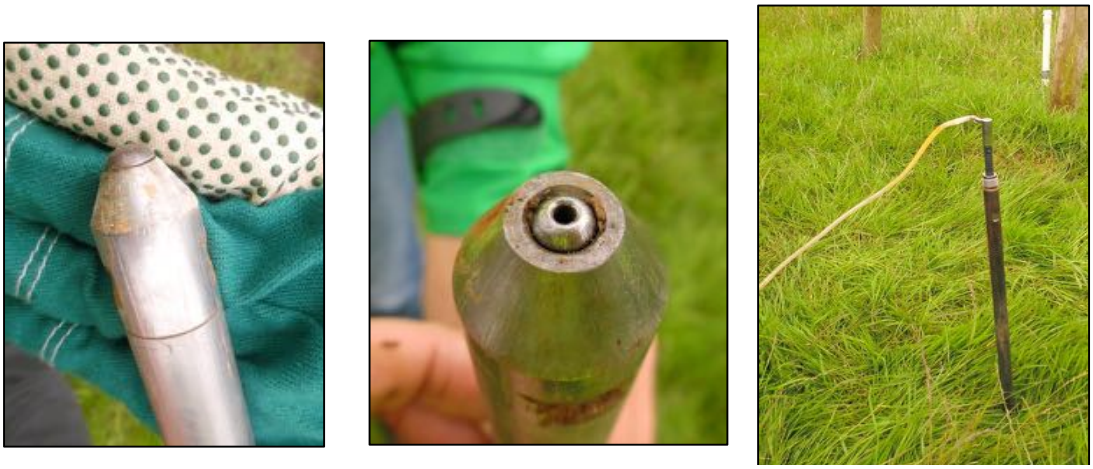


Figure 7. soil gas sampling using an air lance

2.1.4 Automatic water sampling

It is obviously impossible to be in the field 24/7. Therefore automatic samplers were installed to sample water on a regular basis e.g. every 2 hours sampling 500 ml water each time based on flow. In this way we are able to collect samples at high resolution, which provides more detailed information during rainfall events (rising limb, peak and falling limb of the event could produce different types of signals) compared to one time sampling. This is very useful in characterising a field site in terms of water quality over different periods of time and seasons. Those devices can theoretically be set up for all kinds of water sampling. We use them for sampling of drainage water and surface runoff water.

Figure 8. Automatic water sampler

2.1.5 Passive sampler deployment [collaboration with Tellab]

Passive samplers are membranes which collect composite water quality data. These were also deployed at the study site to compare with grab sample data. The samplers can be either deployed in surface water, drains or wells. Before implementing passive sampler into waters it is important to handle them with care to avoid any contamination of the highly reactive surface. According to project needs, passive samplers can remain in water for days, weeks up to months and accumulate nutrients on this highly reactive surface.

2.2 Workshop and summer schools

Developing science into practice &
Project and time management skills with a focus on academic and industry
[20-22 March 2017, Manchester, UK]

The workshop and seasonal school were very helpful and we learned about what it means to be a researcher, what our role as a researcher and how to interact with stakeholders and transfer knowledge gained to a wider audience. Additional modules focused on project management skills and how to best organise research outreach activities using the Inspiration ITN conference as an example. The participants also had to form groups and present an end product from their respective working group within the ITN. A presentation was then made to a "Dragons Den" type panel composed of ESR supervisors and the ITN co-ordination team. The panel asked the group questions. This exercise made us think about the end goal and likely outputs of our project work at a very early stage in the project. It also forged a team spirit within the ITN and prepared us for keeping our research objective relevant to the overall project objectives and goals. It also made us think about how a scientific endeavour should be communicated to other types of stakeholders.

Novel monitoring techniques to assess contaminant sources, natural processes and remediation performance with focus on nutrient and carbon cycles
[11-14 September 2017, Athens, Greece]

The aim of this 3-day summer school, which was a combination of academic training as well as field visit, was to explore the role of nutrient and carbon cycles in the natural environment, in particular their relevance in groundwater, soil and agricultural processes, assessment and management approaches.

All ESRs of the entire INSPIRATION network participated at this great workshop.

Lectures received centred around using isotopes to charactreise landscapes, radon as a tracer tool, denitrification, high resolution monitoring.

Take home message that could be transferred to the sustainbale intensification concept:

- Isotopic techniques can be used to elucidate N source, transformation and fate.
- High resolution data and additional parameters can open up the interpretation of water science and the landscape imposed.
- Radon tracers could be used to investigate the storage time and time lag concepts in the unsaturated zone. This would be useful when trying to correlate nutrients losses from a farm to water quality in pore water, drainage water and disentangle water quality data from different storage components e.g. groundwater versus infiltrating water.

- Field visit show cased a real life story of how conflict may arise between a city and an agricultural area. Both need water but for conflicting reasons.

The project also visited another EU project which introduced high resolution sensors, management databases (FREEWAT) and tutorials were received.

Figure 9. Demonstration of field monitoring equipment

3 Individual training

3.1 ESR 11- Golnaz Ezzati

Research topic

Sustainable treatment technologies using mixed media to mitigate agricultural contaminants in land drainage

I have been developing my field work and laboratory research skills parallel to academic and analytical skills . All my training has either been onsite in Johnstown Castle; in Ireland; as well as overseas workshops/seasonal schools and conferences. I have divided my training into three sections including Field training, Laboratory Training, and Academic Training. Each training is then further divided into two subfields of Onsite and Abroad.

The figure numbering is based on a group of figures representing a single but multi-stage activity.

3.1.1 Field training

On-site

- Water sampling (discussed earlier in detail)

- Charactreisation of P soil chemistry and P dynamics interacting with the open drainage ditch network and potential point source pollution hotspots:

This part of my training showed me how to divide a field site into sampling areas, how to then subdivide open ditch banksides into horizons or sampling depths, how to take soil samples and transfer to the laboratory. Samples were also taken from the base of the open ditch and augering enabled samples to be taken down to 1 m between the farmyard and the open ditch network (Figure 10).

Figure 10. Bankside soil sampling (left) and augering (right)

This open ditch area is a high resolution water sampling hub, which is sampled frequently. Water samples focus on pipes, open ditch and boreholes in the adjacent area. Water chemistry and biogeochemical parameters, which I learned in the group field work campaign will be used here and then the soil chemistry and water quality will be correlated and written up as a manuscript and submitted to a journal.

3.1.2 Laboratory training

After receiving laboratory induction training at Teagasc Johnstown Castle, which showed me how to conduct myself in a laboratory environment and follow laboratory protocols, which include the provision of standard operating procedures and risk assessment documentation before any laboratory experiment is conducted. It also showed me where different parts of my experimental work could be conducted. A similar exercise was undertaken at the Teagasc Growth Room facility.

- **Adsorption test (water/media)**

I learnt how to conduct batch laboratory test to study the adsorption potential of various media (that I have figured out from my literature review and already submitted in my ITN progress report) known to be good in taking up nutrients such as nitrogen, phosphorus, etc. This batch test consisted of several steps: Sieving, solution preparation, equal weighting of media into tubes, shaking, centrifuging, filtering, chemistry analysis. This batch test helped me to rank the most useful media to be used as filter media in adsorbing nutrients. Then I use the adsorption isotherm of top media for designing the column study. The combination of the two will then help me to develop best field-scale water structure in coming months.

Figure 11. Adsorption test: media preparation, sieving, solution preparation, shaking, centrifuging, filtering

Characterisation of my field site requires characterisation of water quality as well as soil chemistry and its properties. For understanding the source and fate of Phosphorus pollution in water, I have learnt how to carry out the following soil tests for my samples along the open drainage network:

Mehlich 3 Extraction (Figure 12), *P-Isotherm Extraction* (Figure 13), *Organic matter test* (Figure 14)

For getting the tests done, the collected soil samples needed to be dried in oven until there is no moisture left, then they were sieved to 2 mm, packed, and recorded in details. Specific amount of each soil sample is required for different soil test. Also, solutions such as Mehlich extracting and various concentrations of P solutions had to be prepared before starting any procedures.

Figure 12 Automatic soil sieving machine (left); Phosphorus isotherm extraction (middle and right)

Figure 13. Mehlich 3 extraction

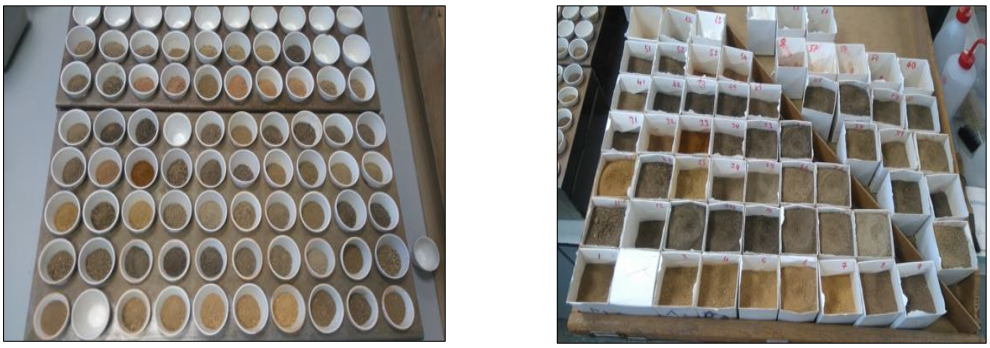


Figure 14. Organic Matter test (left) and soil sample preparation (right)

Adding to all above, Soil-P-extraction Isotherm was carried out as a collaboration between Johnstown Castle Teagasc and China Agricultural Univerisy, Beijing. This teamwork opened doors of new opportunities for further collaboration and insight into how water and soil pollution is regarded and treated in different countries.

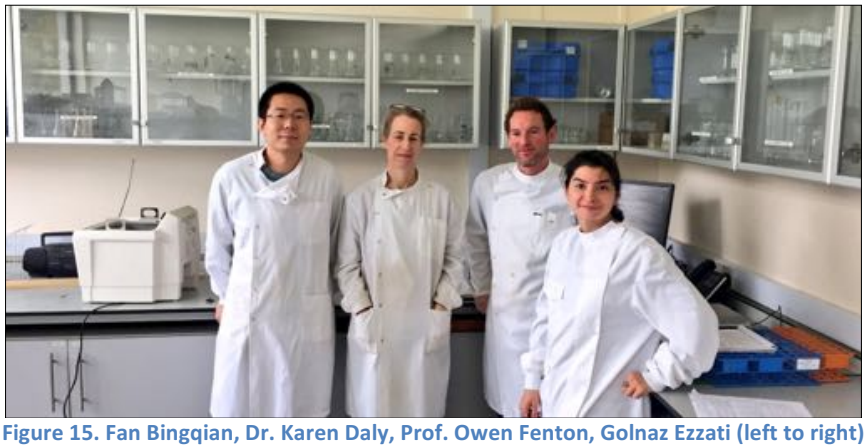


Figure 15. Fan Bingqian, Dr. Karen Daly, Prof. Owen Fenton, Golnaz Ezzati (left to right)

Column study structure and setup

Following to Laboratory Batch studies on adsorption potential of various media, I am going to study the media's efficiency in removing contamination without producing further pollution in controlled column study in designated growth rooms (isolated chambers in which the humidity and temperature are controlled by the user) (Figure 16). This study requires complicated and long (timewise) preparation and careful set up. I learnt how to develop the detailed multi-part structure required for this study including tubing, water pumps, etc through continues discussion and workshop. (Figure 17)

Figure 16. Column setup in growth rooms

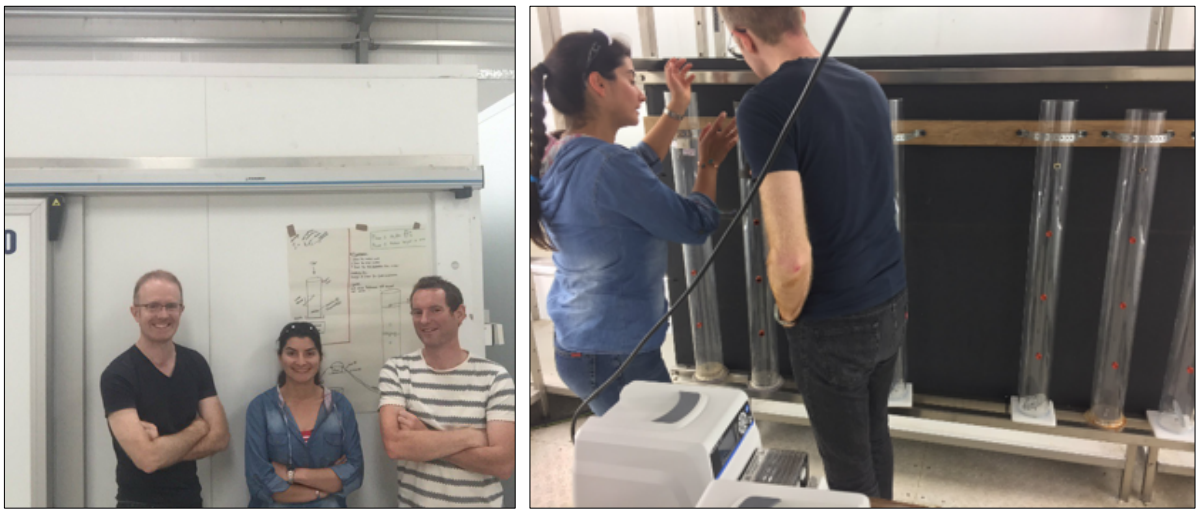


Figure 17. Left: Column study workshop with Prof. Owen Fenton (right) and Dr. Mark Healy (left)

3.1.3 Academic Trainings/Conferences

Ireland

- Laboratory Safety fundamentals & Chemical Safety Awareness Course

This course provided me with required knowledge of how to safely work in the laboratory. It highlighted the importance of the responsibility of the laboratory-user for taking care of its safety as well as others.

- Problems and Solution in numeric modelling of Karst Aquifers using Modflow-USG with Connected Linear Networks (CLNs) in Groundwater Vistas [28th Feb- 1st March, 2017; Trinitiy College Dublin, Ireland]

This groundwater modelling intensive course was very good at explaining how different factors affect the time lag and how water flow rate, and thus contamination load, is affected by various factors. It was very good in teaching how to use software by lead author of Modflow-USG.

- Research integrity, Scientific writing and Presentation [31th May-2nd June 2017, University College Dublin, Ireland]

This course which was sponsored by Department of Agriculture (DAFM) and the Minister of Agriculture paid us a visit as well, was fantastic in teaching how to make presentation, how to talk to people, how to get out of your comfort zone and speak to public and deliver your main message with no hassle. It was also very good in understanding how to make valuable publication and how the author(s) are responsible toward research integrity and should make sure of the accuracy and precision of the paper.

- Manual Handling training

This course was invaluable to understand how to handle everyday work in a safe healthy manner. I was surprised to know how simple but repetitive actions could actually harm the physical health.

- Statists- Using R [17th August 2017, Johnstown Castle, Wexford, Ireland]

This course was a refresher one for me. I will need statistic for modelling various parameters in my column study such as required water flow, depth of filter media, etc. Then I will get into modelling field-scale bioreactor/engineered structure to be installed in Johnstown Castle dairy farm. Statistics help me to design the most appropriate dimension and criteria which is specific to field conditions.

- RAMIRAN International Conference, [4-5th Sep 2017, Wexford Co., Ireland]

RAMIRAM International conference was a great opportunity to meet people from different countries and to hear how their novel research is contributing to agriculture, environmental health and ecosystem vulnerability. I learnt a lot from presentations along with meeting new people, scientists and students thus it was a very great platform for transferring knowledge and research outreach.

Abroad

- Big Phosphorus Conference and Exhibition- Removal and Recovery organized by AquaEnviro [4-5th July 2017 Manchester, UK]

This conference was really helpful in knowing what kind of projects other scientists are running which would help capture excess phosphorus from waste water of different industry. It was a great chance to hear state of the art technologies being used to capture and use Phosphorus with their pros and cons. Moreover, what was very interesting for me was to see how column-studies in different European countries were carried out in terms of Phosphorus removal and what kind of material (synthetic or natural) was showing good removal efficiency.

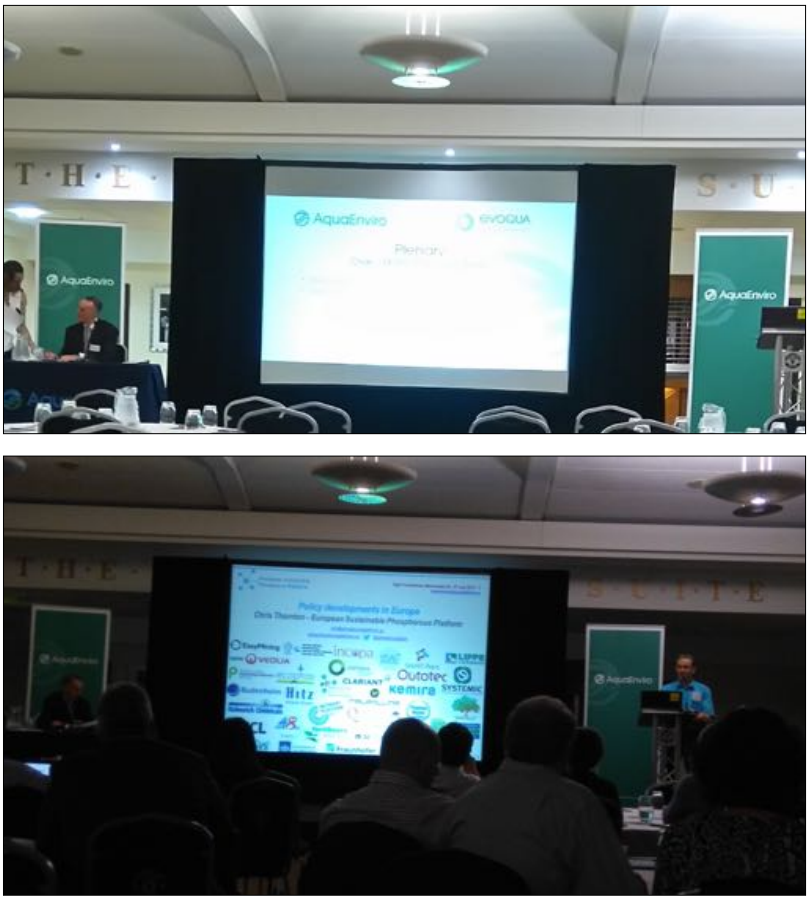


Figure 18. Phosphorus Conference- Removal and Recovery Organised by AquaEnviro and sponsored by evoQUA

3.2 ESR 13 – Julia von Chamier

Field of interest

Biologically driven nitrogen attenuation in the unsaturated zone and the use of stable isotopes of nitrogen and oxygen as proxies for transformation.

3.2.1 Field training

01. – 18. Aug. 2017: Secondment Teagasc, Co. Wexford Ireland

The overall aim of the secondment was to install sampling equipment in the field. This included ceramic cups and temperature probes in the unsaturated soil zone as well as two test probes for soil gas sampling.

I was able to apply my knowledge about soil classification and learned about the differences between international, German and Irish soil classification systems. I refreshed my field and lab knowledge about bulk density and grain size sampling techniques. I was shown how automatic surface water sampling operates using a Sigma 900 max sampler incl. a pressure transducer for discharge measurements. For groundwater table monitoring I programmed and installed electronic divers into piezometers. Samplers will take weekly drainage and surface runoff samples as well as discharge measurements. Combining those data enables to visualise discharge and nutrient loads as well as isotopic signatures of nutrients along a hydrograph.

Figure 19. left: automatic samplers; right: field site with open soil pits

3.2.2 Laboratory training

5. – 6. Oct. 2017: molecular lab work training at BTU, Cottbus GER

At the "Brandenburg University of Technology Cottbus – Senftenberg (BTU)" I did a training in the molecular lab, learning how to isolate microbial DNA from soil samples. This is of interest since the linkage of nutrient intermediate concentrations as a result of microbial transformation and actual responsible encoding genes is a very promising approach to enhance understanding of nutrient fluxes and cycling.

Figure 20. DNA isolation of soil microbes

3.2.3 Conference/workshop

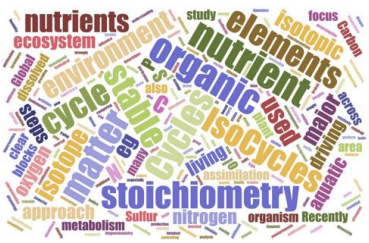
31. Jan. 2017: MOBICOS workshop, Magdeburg GER

The internal UFZ "Mobile Aquatic Mesocosms (MOBICOS)" workshop aimed to introduce the so called MOBICOS experimental container as a unique research platform. It enables the analysis of ecological processes in running waters as natural as field studies and as controllable as laboratory experiments. Besides group discussion and an afternoon of brainstorming how to combine different fields of research using the MOBICOS I found a short field trip very enriching. There I got the chance to see one version of how to equip and use such a container. Although MOBICOS does not have a direct relevance to my project I am convinced that it offers a great opportunity for long term monitoring studies. In this respect they may be suitable for success monitoring of agricultural management adaption strategies.

Figure 21. A MOBICOS container at the River Elbe in Magdeburg

15. – 20.Oct. 2017: ISOCYCLE conference, Ascona CH

Stable isotopes are powerful tools to trace sources, track transfers, and understand abiotic and biological processes and transformations of nutrients in the environment. The conference is a joint effort of an international team of researchers from different fields, but all working with stable isotopes. This diverse audience enabled presentations and discussion to be multifarious and interdisciplinary. By giving a lot of room for group discussions in relaxed atmosphere the development of potential future research agenda using coupled isotopic analysis was encouraged. I introduced my poster via short oral presentation followed by a long poster



session which I found vital and scientifically helpful, whether to explain my field of interest to someone working in a very different scientific field or to discuss critically my methodological approach.

Poster reference:
von Chamier, J.; Fenton, O.; Knöller, K.; Martienssen, M. (10/2017): Nitrogen transformation in the unsaturated zone on intensive grassland farms, ISOCYCLE 2017, Ascona Switzerland

3.2.4 Academic courses

07. – 08., & 14. Feb. 2017: HIGRADE "Environmental Risk Assessment", Leipzig GER

Although I am focusing on nutrients in my project I find it important to know about risk assessment of different contaminants. The course was separated into environmental risk assessment (ERA) of chemicals and human exposure assessment. Besides a historical overview of different chemical regulations worldwide the course predominately focussed on the European Chemicals Regulation REACH. The 3 days were well balance between theory and practice. Thus every participant could run an own ERA for one pollutant, followed by a presentation and discussion. Particularly interesting was the topic on RA of pesticides and biocides and their differences to industrial chemicals. I found that course very helpful to get a deeper understanding on how chemicals are evaluated and where regulations are still week.

3.2.5 Soft skills

04. – 05. April 2017: HIGRADE "Media training for scientists", Leipzig GER

A fantastic workshop on media training and soft skills. Due to only 10 attendants, group discussions on target audience, appropriate media choice, language used and content were vital and fruitful. Attending researchers from different backgrounds and in different stages of their career enhanced the horizon of discussions. The radio interview and the video recorded interview were the highlights of the 2 days. It gave me the chance to get a feedback from peers on my professional (and personal) appearance.

18. – 20. April 2017: HIGRADE "Critical reasoning and logic", Leipzig GER

As an environmental researcher I find it particularly important to try closing the gap between environmental science and public. Therefore, I believe that soft skills such as critical reasoning and argumentation are important for my personnel development. This includes theoretical training to raise awareness of the importance of different validity's and soundness's of arguments. I learnt that scientists predominantly use inductive arguments which are less comprehensible for the public compared to deductive arguments. This course helped me a lot to question my own argumentation structures (written and oral) and to improve my understanding for argumentation patterns.