Department of Agriculture, Food and the Marine
An Roinn Talmhaíochta, Bia agus Mara

Research Stimulus Fund

Final Report

Assessment of the vulnerability of groundwater to pesticide inputs from Irish Agriculture

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Please tick below the appropriate area on the research continuum where you feel this project fits

BASIC/FUNDMENTAL ⟶ APPLIED/PRE COMMERCIAL

X		

Key words: *(max 4)*
Pesticide, groundwater, vulnerability

NDP NATIONAL DEVELOPMENT PLAN

1. Rationale for Undertaking the Research

The widespread use of agricultural pesticide compounds has been of growing concern in the area of groundwater protection. The Drinking Water Directive (CEC, 1998) has imposed an upper limit of 0.1 µg/l for concentrations of individual pesticides in drinking water. Recent EPA reports highlighted the presence of pesticides in water samples at levels greater than 0.1 µg/l, which may have negative implications for human health. An assessment of factors influencing groundwater contamination with pesticides in Ireland was therefore urgently required. Such an assessment needed to assess the influence of pesticide mobility, adsorption, absorption and preferential flow characteristics, all of which may vary according pesticide characteristics and site-specific conditions. The need for data which are specific to Irish agricultural conditions and can be used in a risk assessment framework to help inform policy makers of high risk compounds and regions was evident. The key objective of this research was to provide knowledge to assist in the development and implementation of policy actions to reduce the impact of pesticide usage on the environment, and in particular on groundwater quality.

2. Research Approach

The research work for this project was spilt into 5 technical scientific tasks, as per the approved project proposal:

1) Risk ranking – An initial literature review was conducted to evaluate state of the art in relation to pesticide risk ranking tools. A probabilistic risk ranking model was subsequently developed for Ireland to compare several active substances and their metabolites according to the risk of groundwater contamination and the possible threat to human health. The model was developed using the @Risk risk assessment software package. The leached quantity was coupled with likely exposure and the NOAEL in order to generate a human health risk based model. The method used Monte Carlo simulation techniques to take account of parameter uncertainty and varibility.
2) Pesticide mobility – The researh used state-of-the-art techniques in the quantification and characterisation of pesticides in water samples. Two analytical pesticide methods were developed (1. Quantitative DI-SPME & GC/MS-SIS analysis and 2. SPE and UHPLC-MS/MS) for the project which have been drafted as papers. Due to the complexity and volume of samples analysised some sample analysis was outsourced (March and April 2010, samples were sent to the UK for analysis of phenoxyacid herbicides and in March 2012 samples were sent to the UK for analysis of organophosphorus herbicides). Facilities and methods already in place at the NIEA, Lisburn were used to quantify c.200 samples for pheonoxacid herbicides. All other samples were quantified for organochlorine herbicides and phenoxy acid herbicides. These methods were used to quantify for pesticides in seven study areas across the Republic of Ireland which were selected using national datasets of physical characteristics.
3) Adsorption/Desorption of pesticides - The adsorption and desorption data of contrasting plant protection product's active substances were measured using a worldwide recognised batch equilibrium method (OECD, 2000) and have been published in *chemosphere* and *Water, Air and Soil Pollution*. Three substances were examined: a non-polar fungicide chlorothalonil and two polar herbicides MCPA and Mecoprop-p. Four common Irish soils were selected under two contrasting management practices, grassland and tillage. This allowed the relationship between the selected chemicals and a broader spectrum of soil properties to be examined as well as any effects of soil management practices. The soil column study was setup and conducted at Backweston Laboratory facilities and examined the herbicides breakthrough in selected soil types of contrasting management (grassland and tillage).
4) EU-FOUCS scenario – This task used approved EU-FOCUS modelling tools (e.g. Macro, PELMO). Based on data available for the model parameterisation and validation, four Irish sites (i.e. Oakpark, Clonroche, Rathangan and Elton) were selected for the model parameterisation by using the site specific parameters. Before the model was used to simulate solute leaching to groundwater the model was validated to ensure hydrological processes are being captured within the model. A two stage validation was carried out 1) the daily percolate observations

from lysimeters for four Irish grassland soils (i.e. Oakpark, Clonroche, Rathangan and Elton) were used to validate the hydrology. The predicted cumulative daily percolate values showed the general pattern of the observed cumulative percolate for Oakpark, Clonroche, Rathangan and Elton. 2) Soil tension measurements were obtained at the OakPark Research Centre, Co. Carlow in well drained sites and the details of the experimental conditions were described in Premrov et al. 2010. The results showed an inverse relationship between the percolate predictions and observed soil tension at 0.3 and 0.6 m depth. The peak values of the percolate predictions highlighted the potential occurrence of leaching events. This stage also acted as a validation of the model as periods of high percolate are expected to correspond to periods of low soil tension (and vice versa). After the model validation, a number of simulations were carried out to model the monitoring sites selected (by taking into account the site specific data generated in task 4 in relation to pesticide adsorption/desorption).

5) Vulnerablity mapping – The first part of the project was concerned with reviewing and comparing the most important vulnerability assessment methods that have been used in catchment/regional scale studies. Based on the review, data availability and the Irish environmental setting a vulnerability model was developed (based on the COST-620 pan-European approach) named CORE, the acronym for 'Concentrated water flow, Overlying layers, Recharge and Extreme rainfall events'. The model employs extensive data sets including spatial data (land use, topographic DEM, soil, subsoil, karts features) and attribute data (non-spatial data such as meteorological and pesticide presence data). All the necessary data to develop the method were collected and stored in the ArcGIS geo-database framework. The CORE method evaluates the protectiveness of the overlying layers (topsoil and subsoil), the reduction of protection due to concentrated flow through surface karst features (e.g. swallow holes, rock outcrops) and the effect of precipitation due to groundwater recharge and extreme rainfall events. The output is a composite index that classifies vulnerability into five categories (Very High, High, Moderate, Low, and Very Low). A sensitivity analysis based on Monte Carlo simulation showed that two parameters were more significant in the model, namely the topsoil and subsoil. The result is in agreement with the conceptual model of groundwater vulnerability and the current knowledge concerning the parameters that influence groundwater vulnerability.

3. Research Achievements

Key results from the work include:

- A risk ranking model was developed. The highest risk ranking was obtained by MCPA (Risk ratio = 1.2 × 10-5) as this compound is highly toxic coupled with a high leaching potential. This was followed by desethly-terbuthylazine and deethylatrazine. A sensitivity analysis indicated that soil organic carbon (Soc) and soil sorption (Koc) were the key parameters in reducing the risk associated with use of active substances. The scenarios analysis highlights the usefulness of the model in evaluating the potential risk from past or proposed plant protection products.
- A monitoring network was implemented and completed in October 2009. Monitoring took place monthly between March 2010 to March 2012 and the data used to create a pesticide occurrence database. Pesticides detected in groundwater at the monitoring network sites rarely exceeded the EU DWS (European Union Drinking Water Standard) for drinking water which is 0.1µg/L for individual compounds. Exceedances of the EU DWS were notable for transformation products – particularly DBA, PAC, and 4C2MP which are potentially metabolites of the PPP dichlobenil, 2,4-D, and MCPA, respectively. Commonly used herbicides such as fluroxypyr, triclopyr, bentazone and bromoxynil were rarely detected in Irish groundwaters.
- Adsorption desorption isoterms were calculated for a number of pesticides for a range of Irish soils. Adsorption-desorption isotherms of MCPA in four grassland soils were completed. Adsorption-desorption isotherms of Mecoprop-p in Oakpark tillage and grassland soil were completed. Adsorption isotherms for the simultaneous presence of MCPA and Mecoprop-p in Oakpark tillage and grassland soil were completed. A mix of MCPA and Mecoprop-p was assessed for transport through Oakpark tillage and grassland soil using laboratory columns. The

resulting data were useful for modelling and risk assessment purposes. The soil cores were undisturbed and this allowed transport simulation similar to natural conditions, thus helping to understand the transport of these phenoxyalkanoic acid herbicides in the first 20 cm topsoil. The data are the first empirical data of this kind available for Ireland.

- PELMO was parameterised and validated for four Irish soils (Oakpark, Clonroche, Rathangan and Elton). The model validation (a two stage approach based on monitored percolate and soil tension data) showed that PELMO can simulate hydrological processes under Irish conditions. Several pesticide flow simulations were conducted and the results showed a similar trend to the pesticide monitoring results from Oakpark, Ballycanew and Casteldockrell. While caution needs to be advocated in comparing absolute values, the model may be more useful in highlighting likely "at risk periods" and "at risk sites", which can assist in guiding monitoring regimes. The EU FOCUS scenarios Okehampton and Hamburg were parameterised and compared to site specific scenarios for Oakpak, Clonroche, Rathangan and Elton series soils. MCPA, Mecoprop-p and Chlorothalonil were simulated. Chlorthanil showed no leaching potential for all scenarios. MCPA exhibited the highest leaching potential. A comparison of the Irish site specific scenarios with the Okehampton and Hamburg scenarios revealed showed that the EU FOCUS scenarios overestimated the leaching potential with a difference ranging from 42 to 99%. For the four Irish soils evaluated, Rathangan had the highest leaching potential followed by Elton, Oakpark and Clonroche, respectively. This also highlights the potential of the modelling tool to rank sites in terms of leaching potential. In addition, results showed that crop management practices affected the leaching potential of pesticides differently, hence the need to group the impact of pesticides based on their physical properties. This study represents a first attempt to compare EU FOCUS scenarios with Irish site specific simulations.
- A review and evaluation of vulnerability modelling tools used worldwide was carried out. The evaluation showed that the COP and PI index-based methods and the MACRO and PRZM process-based methods represent the most advanced tools currently available for large scale applications. An index based model (CORE) was dveloped. The CORE method's output was verified in karst areas using the total organic carbon (TOC) concentration in groundwater. TOC is a relevant indicator of vulnerability and its usefulness was verified using data from 17 springs from a Dinantian pure bedded limestone (DPBL) rock unit. First using the principal components analysis (PCA) multivariate method the relationship between various hydrochemical and hydrogeochemical data (e.g. magnesium, TOC, nitrate, calcium) was investigated. PCA showed that TOC was positively related to shorter transit time, i.e. greater concentration of TOC would indicate shorter transit time of water through the overburden and hence greater vulnerability. In addition, multiple correspondence analysis (MCA) showed TOC concentration in groundwater also depending on the land use in a spring's zone of contribution (ZOC). Nevertheless, performing a multiple regression analysis it was possible to show that even though TOC depends on land use, the degree of karstification and type of recharge (both indicators of vulnerability) were significantly related to TOC and hence it is possible to use TOC as an indicator of groundwater vulnerability if the effect of land use is considered in the analysis. Based on these results TOC was used to verify the CORE method in karst areas. Multiple regression analysis showed that all the classes of estimated groundwater vulnerability from the CORE method were significantly related to TOC and hence the CORE method could efficiently distinguish between vulnerable and less vulnerable springs in karst areas. In non-karst areas visual indicators related to the vegetation, topography and overburden permeability were used to verify the CORE method. The method's output was shown to be significantly related to the field data, indicating a good overall performance and reliable results at the regional – national scale.

4. Impact of the Research

The project made significant advancements in knowledge of the risks to groundwater from pesticides in Ireland. This is evidenced by:

1) The risk ranking model can be used as an initial screening tool to highlight pesticides of environmental and human health concern and which may require a detailed risk assessment,

while also directing future research needs by identifying parameters requiring further investigation. The model will be of interest to risk managers in providing a ranking of pesticides where vigilance may be required and helping to focus monitoring programmes on potentially harmful compounds (as opposed to the traditional approach of focusing on ones that are likely to leach).

2) A risk based ranking approach as developed in this project and has been recognized as an alternative to traditional hazard based chemical screening methods as this can include the likely level of exposure and the subsequent effect of active substances on non target organisms. In addition, water monitoring programmes are usually selective in terms of the compounds tested for. Hence, to facilitate a comparison of chemicals where vigilance may be required from a monitoring point of view, the focus of this study is on end-user risk (i.e. leachability and consumer exposure risk). This study ranks pesticides, and their degradation products, used in Irish agriculture and identifies those posing the greatest risk to groundwater and to human health, as opposed to the traditional leachibility approach. From a risk management perspective, the study will also facilitate identification of compounds for targeted monitoring in the groundwater system.
3) The mobility and monitoring studies represent the first analysis of pesticide groundwater quality under Irish specific conditions and can be used to assist the government in responding to EU protocols.
4) New analytical methods were established for pesticides at the research laboratories at Teagasc Johnstown Castle, Wexford and Teagasc Food Research Centre, Ashtown. These may be used for future projects.
5) The Pesticide Control Service in DAFM can use the results to help identify compounds which pose a risk to groundwater in an Irish context.
6) New transformation products DBA and PAC were widely detected in Irish groundwater monitored at the seven study sites. These compounds are relatively unknown and little is known about their toxicity or persistence in the environment in Ireland, Europe or globally.
7) The seven sites selected and used across Ireland are now fully instrumented and could be used in the future to gain further insight into groundwater contamination.
8) From the seven sites selected and monitored monthly, few parent compounds from pesticide products exceeded the EU DWS in groundwater, but those detections that did exceed the EU DWS were mainly transformation products.
9) The outcomes from the adsorption-desorption study are vital for compliance with emerging EU pesticide regulations since such data have never been available for Irish soil/pesticide combinations before. Adsorption-desorption parameters are now available for use in various ground- or surface water models, i.e. EU Focus models, to quantify and predict possible concentrations and potential harm in various environmental compartments. The adsorption-desorption parameters contribute to international pesticide research since this study was done in soils of a temperate climate.
10) The adsorption-desorption study is the first ever completed for combinations of pesticides and Irish soils, the results are crucial for national pesticide research. They have helped develop our understanding of the interactions between selected pesticides and soils. The findings may now form the basis for future pesticide studies related to pesticide soil sorption, pesticide leaching, pesticide run-off, pesticide risk assessment or pesticide environmental modelling. Further work is required to create a national pesticide data base. These data also support international research by providing additional information for the current international parameter databases.
11) The extraction methods developed for this study were novel and may now be used elsewhere. They are detailed in the peer-review paper and reports
12) The comparison between tillage and grassland soils was interesting in the national and international context because they provide quantified evidence of pesticide sorption in soils under contrasting management. However, the use of undisturbed soil columns helped to understand what factors other than pesticide/soil interaction are responsible for pesticide transport and leaching in the soil profile.

13) The pesticide mix study data were a novel addition to international research since very few studies have been conducted of this kind.
14) The pesticide transport study using the soil column laboratory facility was unique. Such apparatus may now be constructed elsewhere in order to study pesticide transport processes in various soils. The design also allows pesticides transport under unsaturated conditions to be studied.
15) For the registration of pesticides in Ireland, the approval procedure is based on the EU Focus scenarios of Okehampton and Hamburg. However, these scenarios may not accurately represent Irish specific conditions, especially in terms of soil and climatic conditions used in the scenarios. Pesticide fate depends on environmental conditions hence the need to model the leaching potential of pesticides based on Irish site specific scenarios. This work is a unique pesticide modelling study for Ireland which includes Irish specific soil and climatic conditions and pesticide fate parameters based on Irish conditions. This study represents a first attempt to compare EU FOCUS scenarios with site specific simulations and highlights the conservative nature of the EU Focus scenarios for Irish conditions.
16) This site specific modelling work is an initial attempt to simulate Irish site specific conditions coupled with adsorption/desorption data specific to Irish soils, climatic conditions, management practices and pesticides. Hence, it represents the first study to bring all these site specific elements together. The study represents a modelling approach in comparing EU FOCUS Scenarios with Irish site specific scenarios and highlights the conservative nature of current EU FOCUS scenarios as applied to Ireland.
17) The methodology used for the vulnerability assessment in this study is based on the COST620 pan-European framework for the assessment of groundwater vulnerability. Hence, it is comparable to other studies that have been conducted in various countries in Europe (e.g. Spain, Italy). However, the method developed in this study provides a process-based way to consider the external stress due to rainfall (based on recharge) while it is the first study that developed and verified the estimated vulnerability at the national scale. It should also be noted that the method provided an objective consideration of the effect of dilution on the attenuation of pollutants and that it is the first application of the COST620 methodology that provides an assessment of the specific vulnerability of pesticide pollution. In addition, it provides evidence for the feasibility of verifying a method at the regional scale with readily available data.

The combined outputs of the project will support groundwater pollution research and the objectives of the Plant Protection Products Directive (91/414/EEC) and ultimately the development of targeted and effective catchment management plans and sustainable use of pesticides to meet the needs of the Water Framework Directive (WFD).

5. Exploitation of the Research

The research carried out in this project has largely been fundamental. The research has resulted in several analytical protocols, techniques and tools which can be used by other users. The expertise and facilities established through this project can be used to attract other national and international funding.

6. Summary of Research Outputs

(a) Intellectual Property applications/licences/patents
1.
2.

(b) Innovations adopted by industry
1.
2.

(c) Number of companies in receipt of information

(d) Outcomes with economic potential

1.

2.

(e) Outcomes with national/ policy/social/environmental potential

1. Risk ranking tool developed to prioritise pesticides of human health concern
2. Monitoring network set up
3. Pesticide characterisation data specific to Irish conditions available
4. Vulnerability map developed

(f) Peer-reviewed publications, International Journal/Book chapters.

1. Pavlis M., Cummins E., McDonnell K. (2010). Groundwater Vulnerability Assessment of Plant Protection Products. *Human and Ecological Risk Assessment* **16**(3), 621 – 650.

2. Labite H, Butler F, and Cummins E. (2011). A Review and Evaluation of Plant Protection Product Ranking Tools Used in Agriculture. *Human and Ecological Risk Assessment* **17**, 300–327.

3. Labite H and Cummins E (2012). A quantitative approach for ranking risks from pesticides used in Irish agriculture. *Human and Ecological Risk Assessment*, in press. Available online, DOI: 10.1080/10807039.2012.722797

4. Piwowarczyk A and Holden. N (2012). Adsorption and Desorption Isotherms of the Nonpolar Fungicide Chlorothalonil in a Range of Temperate Maritime Agricultural Soils. *Water, Air & Soil Pollution*, **223**: 3975-3985

5. Piwowarczyk A and Holden. N. (2012). Phenoxyalkanoic acid herbicide sorption and the effect of co-application in a Haplic Cambisol with contrasting management. *Chemosphere* online: http://dx.doi.org/10.1016/j.chemosphere.2012.08.023.

6. Piwowarczyk A. and Holden N. (2012). Adsorption-desorption processes and mobility of (4-chloro-2-methylophenoxy) acetic acid in Irish grassland soils. Penultimate draft completed. Will be submitted to Journal of Environmental Science and Health, Part B

7. McManus S.L., Richards K., Grant J., Mannix A., and Coxon C. (2012). Pesticide occurrence in Ground Water and the factors contributing to these detections in Ireland. *Journal of Environmental Quality*, Under review.

8. McManus S.L., Coxon C., Richards K. and Danaher, M (2012). Quantitative DI-SPME & GC/MS-SIS analysis of the pesticides lindane, heptachlor and two heptachlor transformation products in groundwater. *Journal of Chromatography B* , Under review.

9. McManus S., Moloney M., Coxon C., Richards K. and Danaher M (2012). Rapid determination & application of 10 pesticides and 8 transformation products in groundwater using SPE and UHPLC-MS/MS, (in advanced stage preparation).

10. McManus, S. Coxon C. and Richards K. (2012) Diffuse herbicide leaching to groundwater across six locations within Ireland (In preparation, incorporated into thesis).

11. Pavlis M. and Cummins E. (2012). Identification of hydrochemical indicators for the assessment of groundwater vulnerability in karstic regions. *Journal of hydrology*, Under review.

12. Pavlis M. and Cummins E. (2012) Assessing the intrinsic vulnerability of groundwater to pollution in Ireland based on the COST-620 pan-European approach. Under internal review.

(g) Scientific abstracts or articles including those presented at conferences

1. Piwowarezk A. Richards, K, and Holden N. (2008). A laboratory study of pesticide adsorption/desorption processes in five Irish soils. 2nd Research day of the UCD School of Agriculture, Food Science and Veterinary Medicine, 4th December 2008. Book of abstracts p26.

2. Pavlis, P., Cummins, E., and McDonnell, K., (2008). Conceptual model for the assessment of the vulnerability of groundwater to pesticide inputs from Irish agriculture. 2nd Research day of the UCD School of Agriculture, Food Science and Veterinary Medicine, 4th December 2008. Book of abstracts p26.

3. McManus, S., Coxon, C. and Richards, K. (2009) Pesticide loss to groundwater in Ireland. Environ'09, 9th-11th February 2009, Waterford Institute of Technology, Book of abstracts, C14.

4. Pavlis, P., Cummins, E. and McDonnell, K. (2009). Conceptual model for the assessment of the vulnerability of ground water to pesticide inputs from Irish agriculture. Environ'09, 9th-11th February 2009, Waterford Institute of Technology, Book of abstracts C16.

5. Labite H., Cummins, E. and Butler, F. (2009). A stochastic risk ranking tool for pesticides based on the leached quantity. UCD School of Agriculture Food Science and Veterinary Medicine-Seminar day, 8th December 2009, Book of abstracts, No. 53

6. Piwowarczyk A., Peng X., Richards K. and Holden N. (2009). A laboratory lysimeter for pesticide transport with controlled boundary conditions. UCD School of Agriculture, Food Science and Veterinary Medicine, Research Day, 8th December 2009, Book of abstract, No. 61.

7. Pavlis M., Cummins E. and McDonnell K. (2009). Assessing the intrinsic vulnerability of groundwater to pollution in Ireland. UCD School of Agriculture, Food Science and Veterinary Medicine, Research Day, 8th December 2009, Book of abstracts, No. 67.

8. McManus, S-L., Coxon, C.E & Richards, K.G (2009) Case studies of Pesticide loss to groundwater in Ireland. York Pesticides '09, 14th – 16th September, Food and Environment Research Agency, book of abstracts, A33.

9. Pavlis M., Cummins E., McDonnell K. 2010. Modelling the potential of groundwater pollution using GIS. Environ Conference, book of abstracts pp115. 17 – 19 February 2010, Limerick Institute of Technology, Limerick, Ireland.

10. Labite, H. and Cummins, E. (2010) Probabilistic risk ranking of pesticides used Irish agriculture. Environ'10, 17th-19th February, Limerick Institute of Technology, Book of abstract PD16.

11. Piwowarczyk, K. Richards and N.M. Holden. 2010. Optimization of extraction method for the non-polar fungicide Chlorothalonil. Biosystems Research Review. P176-179

12. Pavlis, M., Cummins E., and McDonnell K. (2010) A GIS model for the assessment of groundwater vulnerability to pollution. Biosystems Research Review. P89-92

13. Labite,H., and Cummins, E. and Butler F. (2010) Probabilistic risk ranking of pesticides used Irish agriculture. Biosystems engineering research review, 85-88

14. Labite, H. and Cummins, E. (2010). A quantitative approach for ranking risks from pesticides used in the Irish agricultural sector (Poster). SEGH 2010 International Conference and Workshops of the Society for Environmental Geochemistry and Health on Environmental Quality and Human Health. June 27th – July 2th, National University of Ireland. Book of page abstract 152, Galway, Ireland. Available at: www.nuigalway.ie/segh2010

15. Labite, H. and Cummins, E. (2010). Development of a risk based model for ranking pesticide use Irish agriculture. UCD School of Agriculture Food Science and Veterinary Medicine. Research and innovation seminar day, 7thDecember. Book of abstract, abstract Number no 53.

16. Pavlis M., Cummins E. (2010). National Environmental Planning - Assessing the Vulnerability of Groundwater using GIS. UCD School of Agriculture, Food Science and Veterinary Medicine. Research and innovation seminar day, 7th December, Book of abstract, abstract no 56.

17. Piwowarczyk A., Richards K. and Holden N.M. (2010). Determination of distribution coefficients of chlorothalonil in Irish soils using a batch technique. UCD School of Agriculture, Food Science and Veterinary Medicine. Research and innovation seminar day, 7th December, Book of abstract, abstract no 44.

18. Piwowarczyk A., Peng X., Richards K. and Holden, N. (2010). A laboratory lysimeter for pesticide transport with controlled boundary conditions. 19th World Congress of Soil Science, Soil Solutions for a Changing World. 1-6 August, Brisbane, Australia. Paper No 0170. Available at : http://www.iuss.org/19th%20WCSS/symposium/pdf/0170.pdf

19. Piwowarczyk A., Peng X., Richards K. and Holden, N. (2010) A laboratory lysimeter for pesticide transport with controlled boundary conditions. 19th World Congress of Soil Science, Soil Solution for a Changing World. 3.2.2. Improved water and soil management using lysimeters, Poster symposium, P-0659, 1-6 August, Brisbane, Australia.

20. Labite H and Cummins E. (2011). Ranking the risks from pesticides used in Irish agriculture. Biosystems Research Review, 16, P82-85

21. Labite H, Butler F and Cummins E. (2011). A review and evaluation of plant protection products. 2nd Young Environmental Scientists Meeting-SETAC. Feb 28th -02nd March. RWTH Aachen University, Aachen, Germany . Book of abstract p88

22. Labite H and Cummins E. (2011). Risk ranking of pesticides used in Irish agriculture. Environ 2011. 6-8th April. UCC Cork , Ireland. Book of abstracts p124.

23. Pavlis M and Cummins E. (2011). Assessing the vulnerability of groundwater to pollution using hydrochemical data and multivariate statistical methods. Biosystems Research Review, 16, P86-89.

24. Pavlis M., Cummins E. (2011). Assessment of groundwater vulnerability to pollution in Ireland based on the COST-620 pan-European approach. 21st Irish Environmental Researchers' Colloquim, Cork 6th – 8th April 2011. Book of abstracts page 48.

25. Piwowarczkk A., Richards K. and Holden N. (2011) Adsorption isoterms of fungicide chlorothalonil in selected Irish soils. Environ 2011. 6-8th April. UCC Cork , Ireland. Book of abstracts p125.

26. Piwowarczkk A, Richards K and Holden N. (2011) Adsorption isoterms of chlorothalonil in selected Irish soils. Biosystems Research Review, 16, P168-171

27. Piwowarczkk A, Richards K and Holden N. (2011). Adsorption isotherms of the non-polar fungicide chlorothalonil in a range of Irish soils using a batch equilibration method. Soil Science Society of Ireland Spring Meeting, March 2011, UCD, Dublin, Ireland, poster presentation and abstract available on http://www.ucd.ie/sssi/Spring_Meeting_2011.html

28. McManus, S-L., Richards, K.G., Grant, J., Mannix, A. and Coxon, C.E. (2011) Physical characteristics & pesticides in groundwater across Ireland: results of the EPA groundwater survey 2007-2008. International Association of Hydrogeologists – Irish Group conference proceedings Tullamore, Co. Offaly, 12th & 13th April.

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30. McManus,S-L., Richards, K.G., Grant, J. Mannix, A and Coxon,C.E (2011) Which physical site characteristics are associated with pesticide detections in groundwater across Ireland? Agricultural Research Forum, 14th & 15th March, Tullamore, Co. Offaly.

31. Labite, H. and Cummins, E. (2011). A quantitative approach for ranking risks from pesticides used in Irish agriculture. XIV Symposium in Pesticide Chemistry. August 28th – September 1st, Universita Cattolica del Sacro Cuore. available at: http://convegni.unicatt.it/meetings_3667.html. Accessed: 20 january 2012

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33. McManus S-L, Mellander P-E, Coxon C, Richards K, (2011) Pesticide Leaching to Groundwater in an Agricultural Catchment. In proceedings of Catchment Science 2011, 14th-16th September 2011, The Mansion House, Dublin, Ireland, p. 42.

34. McManus S-L, Mellander P-E, Coxon C, Richards K, (2011) Pesticide leaching from diffuse agricultural sources to groundwater in the Republic of Ireland. In proceedings of the XIV Symposium in Pesticide Chemistry: Pesticides in the Environment: fate, modelling and risk mitigation. 30th August - 1st September 2011, Universita Cattolica del Sacro Cuore, Piacenza, Italy.

35. Pavlis M. and Cummins E. 2012. Assessing the intrinsic vulnerability of grondwater to pollution in Ireland based on the COST-620 pan-European approach. Oral and poster presentation at the 32nd IAH Annual Conference, p3, 24 – 25 April 2012, Tullamore, Ireland.

36. Pavlis M. and Cummins E. 2012. Assessment of the intrinsic vulnerability of groundwater in karst aquifers using TOC. Poster presentation at the IWA World Congress on Water, Climate and Energy, Dublin p80, 13 – 18 May 2012, National Conference Centre, Dublin, Ireland.

37. Piwowarczyk A. and N. M. Holden. 2012. Adsorption-desorption processes and mobility of different pesticides in agricultural Irish soils. Environ 2012. 7-9th March. University College Dublin. Book of abstract, page 99. Abstract 51.

38. Piwowarczyk A. Richards K. and Holden N. 2012. Phenoxyalkanoic acid herbicide sorption processes in a Haplic Cambisol under contrasting management. P151-154, 17 Biosystems Research Review, University College Dublin. ISSN 1649-475X

39. Labite, H. and Cummins E. (2012). Assessing the use of EU focus groundwater vulnerability scenarios for Irish specific conditions (Oral presentation). Environ 2012. 7-9th March. University College Dublin. Book of abstract, page 91. Abstract 43.

40. Labite, H. and Cummins E. (2012).Evaluation of pesticide guideline values in drinking water using a probabilistic approach p79-82. 17 Biosystems Research Review, University College Dublin. ISSN 1649-475X

(h) National Report

None

(i) Popular non-scientific publications

1. McManus, S-L., Richards, K.G & Coxon, C.E (2009) Pesticide occurrence in Irish groundwaters. GSI groundwater newsletter, December 2009.

2. McManus, S-L., Richards, K.G & Coxon, C.E (2009) Investigating pesticide occurrence in groundwater in Ireland. Ireland's rural Environment: Research Highlights from Johnstown Castle, August 2009, Teagasc, Wexford.

(j) Workshops/seminars/ open days at which results were presented (excluding those in (g))

1. Cummins, E, Butler, F., Holden, N., McDonnell, K., Richards, K., Coxon, C., Piwowarczyk, A., Pavlis M., Labite H., Mcmanus S., (2009) Risk Management Forum, Assessment of the vulnerability of ground water to pesticide inputs from Irish Agriculture, Agriculture and Food Science Centre, 27th January 2009.

2. Cummins, E, Butler, F., Holden, N., McDonnell, K., Richards, K., Coxon, C., Piwowarczyk, A., Pavlis M., Labite H., Mcmanus S., (2012) Risk Management Forum, Assessment of the vulnerability of ground water to pesticide inputs from Irish Agriculture, Agriculture and Food Science Centre, 30th April 2012.

3. Piwowarczyk A. 2012. Assessment of the vulnerability of groundwater to pesticide inputs from Irish Agriculture - Adsorption-desorption isotherms of key pesticides in Irish soils. Pesticide Control Laboratory, Department of Agriculture, Fisheries and Food, Backweston, 5th June 2012.

7. Permanent Researchers

Institution Name	Number of Permanent staff contributing to project	Total Time contribution (months)	Average time contribution per permanent staff member
UCD	4	13.14	3.285
Teagasc	2	6.18	3.09
TCD	1	4.8	4.8
Total	**7**	**24.12**	**3.44**

8. Researchers Funded by RSF

Type of Researcher	Number	Total Time contribution (months)	Average time
Post Doctorates			
Contract Researchers			
PhD postgraduates	4	188.98	47.25
Masters postgraduates			
Temporary researcher			
Other			
Total	**4**	**188.98**	**47.25**

9. Postgraduate Research

Total Number of PhD theses: 4

1. Piwowarczyk A. (2012) Sorption processes of pesticides in Irish soils, PhD Thesis, University College Dublin, To be submitted: December 2012.

2. Labite, H. (2012).Risk assessment of pesticides in Irish Agriculture, PhD Thesis, University College Dublin, To be submitted: December 2012.

3. Pavlis M.(2012). Assessment of the vulnerability of groundwater to pesticides from Irish Agriculture, PhD Thesis, University College Dublin, To be submitted: December 2012.

4. McManus, S-L. (2012). Pesticide leaching from diffuse agricultural sources to groundwater and the analytical methods to quantify for these compounds., PhD Thesis, Trinity College Dublin, To be submitted: October 2012.

10. Project Expenditure

Total expenditure of the project: €645,728.02

Total Award by RSF €616,004.02

Other sources of funding (specify) €

1.

2.

Breakdown of Total Expenditure

Category	UCD Institution 1	TCD Institution 2	Teagasc Institution 3	Name Institution 4	Total
Contract staff					
Temporary staff					
Post doctorates					
Post graduates	256,120.79	76,500.08			332620.87
Consumables	28,859.24	12,276.05	67,507.71		108,643.00
Travel and subsistence	7,943.94	8,050.89	1,970.11		17,964.94
Sub total	292,923.97	96,827.02	69,477.82		459,228.81
Durable equipment	7,287.02		21,388.72		28,675.74
Other	1,653.48	4,815.58	13,089.75		19,558.81
Overheads	88,373.22	29,048.19	20,843.35		138,264.66
Total	**390,237.69**	**130,690.70**	**124,799.64**		**645,728.02**

11. Future Strategies

(1) Dissemination: there are a large number of papers currently under review from the project. Completing the scientific publication of the work is a key short-term priority as this will underpin the long-term value of the data and methods developed. The results will also be highlighted at future conferences.

(2) Further funding:
   a. National: There are many drivers that will lead to pesticide pollution in the Irish agri-environment, for example, on-going crop protection strategies used for existing and emerging crops. The SSAPRI report assign *Rank A* priority for pesticide resistance and *Rank B* on understanding the perceived negative impacts of intensive farming on biodiversity. The project consortium is now well placed to be able to address these priority areas in environmental risk assessment, building on the foundations of analytical methods and risk procedures developed in this project.
   b. European: The project has provided the participant with the necessary capacity to now compete for further EU funding on pesticides and their management in agri-environments.

12. Industry Collaboration

Given the fundamental nature of the project collaboration in this project was predominantly scientific. There was an active role played by many through the risk managers forum. Its input made the project possible. In particular, the role of the pesticide surveillance centre (Dr. Aidan Moody and his team) was critical to assist with pesticide analysis task and in providing guidance and advice for all the other tasks when called upon. The participation of Teagasc (Dr. Martin Danaher residues analysis) was critical also for perfecting some pesticide techniques. The input from EPA (Dr. Matthew Craig and Dr. Anthony Mannix) and GSI (Dr. Caoimhe Hickey) was acknowledged for useful suggestions and in providing data sets used in the project. There was however no formal commercial companies involved with the project.