Institution: University of Hertfordshire		
Unit of Assessment: 6 – Agriculture, Food and Veterinary Sciences		
Title of case study: Improving worldwide pesticide risk assessments for more effective international regulation and stronger protection of human and environmental health.		
Period when the underpinning research was undertaken: 2000 – 2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	**Role(s) (e.g. job title):**	**Period(s) employed by submitting HEI:**
Kathy Lewis	Professor of Agricultural Chemistry	1994-present
John Tzilivakis	Reader in Agriculture and Environmental Systems	1995-present
Doug Warner	Associate Professor (Research)	2001-present
Andrew Green	Senior Research Fellow	2000-present
Period when the claimed impact occurred: 1 August 2013 – 31 December 2020		
Is this case study continued from a case study submitted in 2014? N		

1. Summary of the impact (indicative maximum 100 words)

Combining agri-environmental science and software development, research at the University of Hertfordshire (UH) Agriculture and Environment Research Unit (AERU) has developed one of the most comprehensive pesticide resources in the world, significantly improving risk assessments. The Pesticide Properties Database (PPDB), which received 2.6 million page views in 2020, has strengthened intergovernmental and EU regulation. It has provided evidence to underpin United Nations treaties that ban the sale of damaging pesticides, supported developing countries to better evaluate risk and has strengthened how the EU measures the 'Environmental Footprint' of farm products sold in the Single Market. It has enabled several governments to introduce policy changes reducing the use of harmful pesticides in agriculture and increased water quality protection. It has supported industry and advocacy groups, including Waitrose and Greenpeace, to reduce the negative impact of pesticides through changes to supply chains and greater awareness raising. Consequently, the PPDB has helped improve the safety of pesticides and has ensured those most harmful to human health and the environment are no longer available.

2. Underpinning research (indicative maximum 500 words)

Safe pesticide use relies on effectively assessing the risks they pose in order to identify appropriate mitigation measures. Risk depends upon many factors including the unique properties of each pesticide, but a comprehensive assessment is 'data hungry', requiring tens of parameters per pesticide. Identifying quality data can be challenging as it is scattered across different resources and managed by organisations with their own aims and objectives. Data are inherently variable depending on experimental protocols, test conditions, climate and soil type. Previously, risk assessors developed their own databases that held different data and thus produced different risk assessment outcomes. Thus, studies were not easily comparable or transparent, leading to inconsistencies in decision making.

AERU research has created a comprehensive, harmonised and independently verified database for pesticide risk assessments [**3.1**]. Having been continuously improved through further UH studies since its launch in 2007, the PPDB now holds data for almost 2,500 pesticide active substances and over 850 metabolites. For each substance around 320 parameters covering human health, environmental fate and ecotoxicology are stored. The PPDB is underpinned by over two decades of research. AERU had developed the Environmental Management for Agriculture (EMA) software, one of the first computerised decision-support systems for on-farm use. This included a pesticide risk model and supporting pesticide database. Data was collated from regulatory and peer-reviewed literature, and the extracted data manipulated according to prescribed protocols to ensure a standardised dataset. AERU used regulatory thresholds to band data within the database into risk categories. EMA system outputs were designed to provide clear and meaningful information for users at various levels of detail, from an individual pesticide application to an overall farm assessment [**3.2**]. As a consequence, farmers were, for the first time, able to consider the environmental impact of their pesticide strategies. To help users understand data limitations a unique data quality barometer was also developed, using a scoring system that

considered the data source (e.g. regulatory, peer-reviewed, industry), its age (modern protocols usually generate better data) and whether the data could be independently verified [**3.3**].

In 2006 the database was expanded and validated during the EU FOOTPRINT project [**G1**]. A year later it was relaunched as the PPDB, a comprehensive relational database of pesticide physicochemical, human health and ecotoxicological data. It was made freely available online (UH website); an offline database, with greater data detail, was offered under licence. A systematic programme of expansion, updating, data quality assessment, along with external peer review by the Danish Environmental Protection Agency, was introduced to maintain its integrity and enhance its usefulness for regulators and policymakers; this process is ongoing. A second PPDB portal was launched by the International Union of Pure and Applied Chemistry in 2011.

AERU research has evolved in response to the rapid development of risk assessment processes in recent years. Risk assessments now use data on the degradation rate of pesticides on plant matrices (e.g. leaves, stems, fruits) to identify how long access to sprayed areas must be restricted to protect workers. An AERU study in 2016 for the European Food Safety Authority (EFSA) [**G2**] used systematic reviews to produce a robust dataset that could calculate the risk to those exposed to pesticides through their work or physical proximity [**3.4**]. This allowed EFSA to develop a database to support non-dietary exposure assessments for regulatory purposes. This work fed into the development of a comprehensive dataset, based on data from 400 pesticides and 200 crops, for the rate at which pesticide active substances dissipate on or within various plant matrices [**3.5**]; this was subsequently incorporated into the PPDB [**3.1**]. Regulatory risk assessments have also been expanded to protect wild bees due to concern over declining populations. However, toxicity data for these species is scarce. AERU created a new dataset covering the toxicity of 120 pesticides to wild bee species and incorporated it in the PPDB [**3.6**].

3. References to the research (indicative maximum of six references)

3.1 Lewis K, Tzilivakis J, Warner D, Green A. An international database for pesticide risk assessments and management. Human and Ecological Risk Assessment. 2016 May 18;22(4):1050-1064. BHER-2015-0308. https://doi.org/10.1080/10807039.2015.1133242
3.2 Hart A, Brown CD, Lewis K, Tzilivakis J. p-EMA (II): evaluating ecological risks of pesticides for a farm-level risk assessment system. Agronomie. 2003;23(1):75-84. https://doi.org/c46wzb
3.3 Lewis K, Brown CD, Hart A, Tzilivakis J. p-EMA (III): overview and application of a software system designed to assess the environmental risk of agricultural pesticides. Agronomie. 2003 Feb 28;23(1):85-96. https://doi.org/10.1051/agro:2002076
3.4 Lewis K, Tzilivakis J. Review of the published exposure data to pesticides for residents and bystanders, and for environmental risk assessment: Final report. 5 ed. European Food Safety Authority (EFSA), 2017. https://doi.org/f26j (*Contract awarded via tender*)
3.5 Lewis K, Tzilivakis J. Development of a data set of pesticide dissipation rates in/on various plant matrices for the Pesticide Properties Database. Data. 2017 Aug 29;2(3). Data-221231. https://doi.org/10.3390/data2030028
3.6 Lewis K, Tzilivakis J. Wild bee toxicity data for pesticide risk assessments. Data. 2019 Jul 11;4(3). 98. https://doi.org/10.3390/data4030098

Key underpinning grants
G1 EU FP6: FOOTPRINT – Functional tools for pesticide risk assessment and management; Dates: 2005 – 2009; Value: £57,000 to UH.
G2 European Food Safety Authority (EFSA): Data on the Exposure of Pesticides for Residents and Bystanders; Dates: 2015 – 2016. Value: £131,000.

4. Details of the impact (indicative maximum 750 words)

The PPDB, continuously shaped and enhanced by ongoing AERU research, has provided regulators, policymakers, industry and advocacy groups worldwide with high quality data to ensure greater consistency and accuracy in pesticide risk assessments. Funded by government and private sector organisations including Syngenta and Bayer, PPDB usage has grown significantly

over the impact period, increasing from 1.1m annual page views in 2014 to 2.6m in 2020 [**5.1**]. Web analytics show that on a typical day the PPDB is accessed by national government agencies and users in 20-40 different countries [**5.1**]. Whilst access is global, the majority of users are in Europe, North and South America and East Asia.

Government policy changes reduce use of harmful pesticides in agriculture

The human health and environmental impacts of pesticide use are directly connected to government policy and regulation as these define what chemicals can be used, in what situations. The PPDB has influenced both policy and regulation across Europe and beyond.

EU Regulation 1107/2009 governs the authorisation of commercial plant protection products; pesticides with undesirable properties are highlighted and listed as 'candidates for substitution (CfS)' to drive them to obsolescence. Companies seeking regulatory approval to market new products must show that these are safer than those labelled as a CfS, however, no standard comparative process exists. In 2015 the German Environment Federal Office (Umwelt Bundesamt) used the PPDB in the development of a comparative process to satisfy EU regulatory requirements. It relied upon the PPDB as a key data source, citing it 17 times in the resulting 2017 report [**5.5**]. It is now an established part of the German pesticide authorisation process.

In 2012, the Danish Government introduced a pesticide tax based on environmental indicators that were developed using PPDB data [**5.6a**]. The tax is enshrined in Danish law and the statute specifically names the PPDB as a major data source. The tax aims to reduce demand for the most damaging substances by taxing them at the highest rates. This legislation has been in place throughout the impact period, and the benefits in this timeframe have been demonstrated. An evaluation carried out for the *Danish National Action Plan on Pesticides 2017-2021* showed that pesticide load, measured in terms of sales, had declined by 40% since 2011 [**5.6b**]. The same scientific approach formed the basis of Denmark's new Pesticide Load Indicator (PLI), a key part of its national strategy, providing the Danish Government with detailed information that allows them to single out 'hot spots' and target pesticide monitoring activities [**5.6c**].

The success of the Danish PLI has led to the development of a UK PLI based on a similar approach. The UK PLI combines pesticide usage data collated by FERA Science with environmental fate and toxicity data from the PPDB (Defra funded AERU to develop it, see [**5.7a**]). The Environment Agency envisages the UK PLI as contributing to the development of metrics on the exposure and effects of pesticides on wildlife under the Government's flagship 25-Year Environment Plan [**5.7b**]. Elsewhere, the US Agricultural Research Service, the research agency for the US Department of Agriculture, discontinued its own pesticide database in 2017 and recommended the PPDB as the key alternative data source [**5.8**].

The PPDB was used at EU level to advance the flagship Single Market for Green Products policy initiative in which the measurement of a product's 'Environmental Footprint' (EP) is harmonised across member states. This initiative uses USETox, a model for characterising human and ecotoxicological impacts of chemicals in lifecycle impact assessments. Whilst USETox is a valuable tool, pesticides were not adequately addressed so the EP for products that used pesticides in their production (food, fibres, natural products etc.) were not sufficiently robust. In a major study the EC's Joint Research Centre (JRC) used the PPDB to strengthen the model by calculating new, more accurate ecotoxicity characterisation factors for pesticides thus enhancing EP determinations. In the 2020 report, the PPDB was cited 55 times, with the JRC stating: 'PPDB brought a significant benefit especially when dealing with pesticides not used or banned in Europe, as those chemicals are out of European legislations and agencies competence [**5.4**].'

Improving pesticide governance in the developing world

The PPDB has played a significant role in facilitating better pesticide governance in the developing world. The UN's Food and Agriculture Organization (FAO) recommends the PPDB as a key data source for its Pesticide Registration Toolkit [**5.2**]. This is a decision support system for pesticide registrars who decide whether a pesticide can be sold or used in developing countries. It is designed to address issues of insufficient staff and limited technical expertise. The FAO notes that

the PPDB is '*more comprehensive'* than the EU's pesticide database and highlights the relative limitations of the US Government's ECOTOXicology database [**5.2a**]. FAO cited ecotoxicity data from the PPDB in its 2014 field manual *Pollinator Safety in Agriculture*, which supports farmers and land managers to mitigate the impacts of agricultural pesticides on key pollinators [**5.2b**].

The UN's Rotterdam Convention is a multilateral treaty covering pesticides and chemicals that have been banned or severely restricted for health or environmental reasons (there are currently 35 pesticides on the Convention's 'Annex III' list). A key provision of the Convention is the Prior Informed Consent (PIC) procedure. Under the legally binding procedure, importing countries must decide whether or not they consent to receiving shipments of PIC-listed pesticides. The decisions, known as import responses, are published every six months as 'PIC Circulars'; they include 'notifications of final regulatory actions', where countries announce bans or severe restrictions on specific pesticides. PPDB data has been used as evidence to support these regulatory actions. In 2018 the EU and ten African countries – Burkina Faso, Cabo Verde, Chad, the Gambia, Guinea-Bissau, Mali, Mauritania, the Niger, Senegal and Togo – issued a final regulatory action for acetochlor, a maize herbicide, due to its '*unacceptable risk to human health and the environment*' [**5.3a**]. PPDB data was cited in a document published by the Convention's Chemical Review Committee confirming acetochlor's inclusion in Annex III. The ban was '*expected to lead to a … significant reduction of the exposure of humans and the environment*' [**5.3a**]. A PIC circular in 2015 announced a ban on four pesticides – Atrazine, Carbosulfan, Fipronil and Triazophos – in seven of the African countries above; PPDB data was cited 64 times [**5.3b**]. It was used for these conclusions: Carbosulfan is '*highly toxic*' to birds, fish, aquatic invertebrates and bees; Fipronil is '*highly toxic*' to northern bobwhites and pheasants and '*extremely dangerous*' to sea and freshwater fish; Triazophos is '*highly acutely toxic to human beings and mammals*' [**5.3b**]. Therefore, the PPDB has made a major contribution towards reducing the human and environmental impact of some of the most harmful pesticides in developing countries.

Better protection for water quality from pesticide pollution

Monitoring the quality of water bodies is an important process for protecting human health and the environment. The process requires sound scientific data to enable the prioritisation of pesticides for monitoring and to predict concentrations to facilitate mitigation activities and potentially policy changes to manage impact. The EU Water Framework Directive requires water bodies to have a good ecological status; many government agencies use the PPDB for their monitoring programmes including Sweden, Turkey and Germany [**5.9**]. As a particular example, the Luxembourgish Water Administration uses the PPDB for groundwater monitoring: '*We rely on the PPDB to calculate leaching concentrations to groundwater of both parent compounds and their metabolites from which we establish a list of priority substances. That list forms the basis for monitoring and for targeted efforts to reduce total doses in water protection zones.* [**5.9**].

Water catchment management aims to improve the quality of waterbodies that supply drinking water. MACRO-SE is a regulatory groundwater pollution model and a spatial version of this model was developed using PPDB data to identify high-risk areas in Sweden [**5.10**]. The developers state: '*A practical example on how we use data from PPDB is within our model MACRODB. The model is a decision support tool used by water protection boards all around Sweden to grant, or deny, applications by farmers for a licence to apply pesticide* [**5.10**].' In Italy, the International Centre for Pesticides and Health Risk Prevention (ICPS) developed a tool (ASTERisk), using PPDB data, to identify pesticide risk hotspots in agricultural areas [**5.9**]. The Californian Government uses the PPDB to prioritise pesticides for surface water monitoring [**5.11**].

Supporting industry and advocacy organisations to reduce the impact of pesticides

AERU worked with Waitrose Foods to develop a bespoke pesticide risk assessment scoring system based on the approach used for the Danish pesticide tax. The Waitrose indicator, launched in 2014, has enabled Waitrose growers worldwide to develop more benign crop protection programmes. A Waitrose representative stated in 2019: '*It has made our job infinitely easier and it has been an invaluable tool in informing our decisions when reviewing our policy and evaluating usage [of pesticides] across our worldwide grower base* [**5.12**].'

In 2018 AERU worked with advocacy group Bee.Watch to develop and launch a mobile phone app to communicate the risk of pesticides to pollinators. As Bee.Watch explains: '*All pesticide information notified by Bee.Watch to its users, is extracted from the PPDB'* [**5.13**]. This app sends early warning alerts to beekeepers and farmers. Red Tractor, a leading farm assurance scheme, require their crops and fresh produce members to give local beekeepers a minimum of 48 hours' notice of their intention to apply a pesticide product that is hazardous to bees. *Red Tractor can confirm that using Bee.Watch would be one such acceptable way a farmer could demonstrate they meet the Red Tractor requirement* [**5.13**]. Greenpeace used the PPDB to '*identify intrinsic properties and hazards*' of pesticides used in European apple production to identify potential health impacts [**5.14a**]. It also formed the basis of Greenpeace's EU Pesticide Blacklist in 2016, which blacklisted 40% of all authorised pesticides in the EU due to their high toxicity [**5.14b**].

5. Sources to corroborate the impact (indicative maximum of 10 references)

5.1 Analytics report based on data from the PPDB's online web tracker system.
5.2 (a) FAO Pesticide Registration Toolkit – cites the PPDB as a key data source (first on page): http://www.fao.org/pesticide-registration-toolkit/information-sources/pesticide-properties/en/ **(b)** FAO's Pollinator Safety in Agriculture field manual: http://www.fao.org/3/a-i3800e.pdf (p121)
5.3 (a) Rotterdam Convention on PIC: Chemical Review Committee decision document, 2018. https://undocs.org/pdf?symbol=en/UNEP/FAO/RC/CRC.14/3 (PPDB cited p14) **(b)** PIC Circular XLI June 2015 http://www.fao.org/3/a-i4735e.pdf (PPDB cited throughout)
5.4 JRC Technical Report, 2020. Environmental Footprint: Update of LCIA Methods: Ecotoxicity freshwater, human toxicity cancer, and non-cancer. (PPDB cited throughout) https://eplca.jrc.ec.europa.eu/permalink/JRC114227__FINAL_online.pdf.
5.5 Establishment of a concept for comparative risk assessment of plant protection products with special focus on the risks to the environment (2017), Umweltbundesamt, Germany. https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2017-06-07_texte_47-2017_umweltrisiken-pflanzenschutzmittel.pdf (PPDB cited throughout)
5.6 (**a)** Danish EPA, 2012. The Agricultural Pesticide Load in Denmark. https://www2.mst.dk/Udgiv/publikationer/2012/03/978-87-92779-96-0.pdf (p 13, 48) **(b)** Danish National Action Plan on Pesticides 2017-2021, Ministry of Environment, Denmark. https://ec.europa.eu/food/sites/food/files/plant/docs/pesticides_sup_nap_dan-rev_en.pdf (page 27) **(c)** Kudsk, P., Jørgensen, L.N. & Ørum, J.E. 2018. Pesticide load – a new Danish pesticide risk indicator with multiple applications. *Land Use Policy*, **70**, 384-393. (see abstract)
5.7 (a) Defra Science and Research Projects: Develop a new UK pesticide risk indicator http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=2&ProjectID=20383 **(b)** UK Expert Committee on Pesticides, minutes of 28/01/2020 meeting. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/883054/ecp-200128-fullminutes.pdf
5.8 Webpage of the Agricultural Research Service, US Department of Agriculture. https://www.ars.usda.gov/northeast-area/beltsville-md-barc/beltsville-agricultural-research-center/adaptive-cropping-systems-laboratory/docs/ppd/pesticide-properties-database/
5.9 File of corroborating emails on the role of PPDB from Luxembourgish Water Administration, Helmholtz Centre for Environmental Research and ICPS, and peer-reviewed papers relating to government water quality monitoring programmes using PPDB in Sweden and Turkey.
5.10 Corroborating statement from the Swedish University of Agricultural Sciences.
5.11 Methodology for Prioritizing Pesticides for Surface Water Monitoring in Agricultural and Urban Areas III: Watershed-Based Prioritization (pages 9 and 13) https://www.cdpr.ca.gov/docs/emon/pubs/ehapreps/analysis_memos/luo_prioritization_3.pdf
5.12 Corroborating email from Waitrose Foods.
5.13 Bee.Watch user guide.
5.14 (a) Greenpeace. 2015. Pesticide applications as routine in EU apple production p 3, 10, 15-16) https://www.greenpeace.de/sites/www.greenpeace.de/files/publications/apple_testing_19-10_2.pdf **(b)** Greenpeace. 2016. The EU Pesticide Blacklist (PPDB cited throughout) https://www.greenpeace.de/sites/www.greenpeace.de/files/publications/20160727_schwarze_liste_pestizide_greenpeace_final.pdf