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ABSTRACT

Despite a changing world in terms of data sharing, availability, and transparency there are still major resource issues associated with collating datasets that will satisfy the requirements of comprehensive pesticide risk assessments especially those undertaken at regional or national scale. In 1996 a long-term project was initiated to begin collating and formatting pesticide data to eventually create a free-to-all repository of data which would provide a comprehensive transparent, harmonised and managed extensive dataset for all types of pesticide risk assessments. Over the last 20 years this database has been keeping pace with improving risk assessments, their associated data requirements, and the needs and expectations of database end users. In 2007 the Pesticides Properties DataBase (PPDB) was launched as a free-to-access website. Currently, the PPDB holds data for almost 2300 pesticide active substances and over 700 metabolites. For each substance around 300 parameters are stored covering human health, environmental quality and biodiversity risk assessments. Approaching the twentieth anniversary of the database this paper seeks to elucidate the current data model, data sources, its validation and quality control processes and describes a number of existing risk assessment applications that depend upon it.

Key Words: pesticides, risk assessments, database; data model, environmental fate, environmental impact

INTRODUCTION AND BACKGROUND

Pesticides have an important role to play in ensuring that there is an abundant supply of safe and healthy food as well as delivering other benefits such as reducing the labour, fuel and machinery required for crop protection activities (Gardner et al. 2009; Cooper et al. 2007). Without pesticides it has been estimated that global food production could fall by as much as 35-40% (Oerke 2006), increasing the cost of food and threatening food security. However, their use does involve potential risks to human health (Frantke et al. 2012; Mostafalu and Abdollahi 2013) and the environment (Skinner et al. 1997; Tilman 1999; Van der Werf et al. 2007) and so pesticide policies, particularly those of the developed world, advocate the sustainable use of these chemicals to minimise the risks and maximise the benefits. For example, within the European Union this is delivered primarily via its Thematic Strategy on the Sustainable Use of Pesticides, which includes EC Regulation 1107/2009 concerning the placing of plant protection products on the market. The United States has a similar regulatory approach delivered via the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and the Food Quality Protection Act (FQPA). Whilst in Australia the National Registration Scheme for Agricultural and Veterinary Chemicals was established under Commonwealth, state and territory legislation and has a clear mandate, via the Agricultural and Veterinary Chemicals (Administration) Act 1992 and the Agricultural and Veterinary Chemicals Code Act 1994, to ensure that, prior to registration, the risks associated with the use of the pesticide are considered acceptable when used according to label instructions.

Evidence-based risk assessment is fundamental to protecting human health and ecosystems from the possible adverse effects arising from exposure to pesticides. Within the regulatory context of most developed countries, establishing that any potential risks to humans and the environment are acceptable requires a suite of complex risk assessments to be undertaken. These consider the potential for that substance to pollute the environment, harm biodiversity and endanger consumers, the general public or agricultural workers. Simply put, and where science and data allow, regulatory risk assessments use sophisticated mathematical models and calculators (e.g. PRZM – Carsel et al. 1985; GLEAMS – Leonard et al. 1987; EUROPOEM – Van Hemmen 2001; MACRO – Larsbol et al. 2005, Jarvis and Larsbo 2012) to predict levels of exposure or environmental concentrations, which are then compared with regulatory thresholds of acceptability, toxicology/ecotoxicology and biological responses.

Pesticide environmental fate and human / biodiversity exposure depends on a number of factors. Firstly, the physico-chemical properties of the pesticide which govern its potential for leaching, sorption, volatilisation, photodegradation, microbial or chemical degradation etc. Secondly, the environmental conditions at the application site (e.g. soil and air temperature; wind direction and speed; air humidity; soil pH, organic matter and water content; microbial activity, etc.) affect environmental fate and degradation. Fate and exposure are also influenced by the choices and decision making at the site of application e.g. farm, amenity site such as the pesticide application method, machinery use, pesticide product formulation and use of protective clothing and equipment. In recent years there have been considerable scientific advances in the way in which regulatory pesticide risk assessments are conducted. For example, in 2013, following rising concerns over the global decline in pollinator populations, the European Food Safety Authority (EFSA) published guidance for undertaking risk assessments for honey bees, bumble bees and solitary bees (EFSA 2013). This introduced a new procedure that sought to provide greater protection to honey bee colonies situated on the edge of fields treated with pesticides. In 2014, EFSA published guidance and a calculator for the assessment of exposure of operators, workers, residents and bystanders in risk assessments for plant protection products (EFSA 2014). This was designed to improve and harmonise the EU approach to estimating exposure levels and to provide assistance to industry applicants seeking pesticide registration, researchers and other risk assessors.

The need to undertake pesticide risk assessments is, however, much broader than just the regulatory arena. They are extensively used, for example, by national and local governments to help define national, regional and catchment pollution mitigation and management plans, as well as to develop and monitor policies and interventions. They are also used by water companies to help establish risks to drinking water supplies and by multi-national grocery retailers to reduce risk to consumers and drive forward the sustainable farming agenda. However, for non-regulatory applications, it is not unusual for techniques to be used that are less complex than the regulatory approachess and these often rely only on the physico-chemical properties of the pesticide to calculate risk indices disregarding environmental, landscape or application effects. These types of approaches are also very common in the developing world as their relative simplicity is often more appropriate under conditions of limited data availability and resources (Feola et al. 2011).

Regardless of the adopted risk assessment approach, its development and validation rely on quality data and these systems are often highly demanding in terms of the input data they require. Indeed, the more sophisticated the

underpinning scientific approach the more data hungry it is likely to be. Although it is difficult to be precise, there are probably more than a thousand different pesticide active substances available globally with many, many more used historically. It is not unusual for an individual country to have around 300 or more pesticides registered for use at any given time. Depending on the type and purpose of the risk assessment a wide range of parameters are required (USEPA 1992). It would not be unreasonable to suggest that 6-10 parameters are necessary to calculate predicted environmental concentrations. Acute and chronic ecotoxicological threshold values are needed for mammals, birds, earthworms, pollinators and aquatic species (e.g. fish, invertebrates, lower and higher aquatic plants). Additional data **are** also required for estimating human exposure, e.g. acute and chronic endpoints for oral, dermal and inhalation toxicity plus information on biological responses such as if the pesticide is a carcinogen, mutagen or reproduction toxin. Therefore, one might need up to 30 parameters for each pesticide studied, 9000 or more for all registered pesticides within one country and potentially many more if the assessment is to be undertaken at a larger spatial or temporal scale.

Identifying reliable data has long been a problem particularly for interested parties outside of the manufacturer-regulatory world. Looking back twenty years or so, the data generated by manufacturers and by regulatory processes was regarded as commercial-in-confidence. Data that were published in a variety of scientific journals were as hardcopy, access was expensive and identifying a specific parameter was a time consuming and frustrating experience. Those days are long gone, due to a more transparent regulatory process, greater access to data, freedom of information and, of course, the internet. Nevertheless, problems still exist and whilst data are more accessible it is sparsely distributed and managed by organisations with their own specific aims and objectives (Caracciola *et al*., 2013). Some government departments publish on-line systems containing useful data but these are often limited to just the substances approved for use in that country, they rarely cover all parameters needed for comprehensive risk assessments, and management and updating of the system is often poorly resourced. The DESC chemical database was designed to manage data arising from the EC 1907/2006 REACH (Registration, Evaluation, Authorisation of Chemicals) Regulation (Caracciola et al. 2013) and this database does have similarities to those required for pesticide risk assessments in terms of stored parameters. However, DESC contains data for very few pesticides as substances which are adequately controlled under existing sector-specific EU legislation are largely exempt from REACH. There are a few exceptions but not enough to satisfy the demands of a pesticide risk

assessment. On-line, free-to-access databases with a restricted focus are also available, for example those relating to chemical identify (e.g. IPCS INCHEM database - Keita-Ouane et al. 2001), ecotoxicology (e.g. ECOTOX - USEPA 1996) or chemicals that are carcinogenic or mutagenic (e.g. IARC 2015; EC 2002). Many regulatory authorities do publish their regulatory documents and organisations, such as the FAO, also publish chemical reviews. However, these are usually in monograph format and it is up to the individual to search through them for the required data. This means multiple databases and documents may need to be consulted in order to collate data for the risk assessment. Consequently, collating data becomes a resource intensive activity and researchers / risk assessors have a tendency to develop their own unique databases. This is far from satisfactory. Not only does this represent a significant overlap in research effort and thus a waste of resources but pesticide data are inherently variable and different databases will inevitably have different data and, thus, will give different risk assessment outcomes. There are also questions relating to data quality that need to be considered. This undoubtedly reduces the transparency of analyses and judgments, decreasing the utility of risk assessment for decision-makers (Dann et al. 2006).

Recognising the problem, in 1996 a long-term project was initiated, as a secondary activity associated with a related research project (Lewis and Bardon 1998; Lewis et al. 2003, Hart et al. 2003; Brown et al. 2003), to begin collating and formatting pesticide data. The motivation was to eventually create a free-to-all repository of data to provide a comprehensive, transparent, harmonised and managed extensive dataset for all types of pesticide risk assessments. Over the last 20 years this database has been restructured, expanded to keep pace with improving risk assessments and their associated data needs, and has been validated/peer reviewed. In 2007 the database was launched as a free-to-access website and has continued to expand. Currently, this database (the Pesticides Properties DataBase – PPDB) holds data for almost 2300 pesticide active substances (synthetic and natural including those with veterinary applications) and over 700 records for associated metabolites. Despite the fact that this database has been available for a long time and is now used extensively throughout the world, endorsed by IUPAC and promoted by several major organisations including the FAO it has never been fully and formally described. Therefore, to provide transparency to those systems and researchers that rely on it this paper seeks to elucidate the data model, the data sources, its preparation and validation together with a number of existing risk assessment applications that depend upon it.

THE PESTCIDE PROPERTIES DATABASE (PPDB) DESIGN AND DEVELOPMENT

The PPDB (sometimes referred to as the FOOTPRINT database due to some work on the database being undertaken as part of the FOOTPRINT EU FP-6 project) builds upon existing chemical databases, bringing together data on pesticides, used both past and present, into one comprehensive system, capturing data from a wide variety of sources to satisfy the needs of a full range of potential end-users. The database was designed to be flexible such that new data sets could be incorporated as they became available and new parameters added such that the system could keep up with risk assessment requirements. In addition, it was important to capture information on data quality as this adds transparency to risk assessments and ensures that data are informative for risk managers.

The current structure of the database is given in Figure 1 and examples of the types of parameters stored are presented in Table 1. For each chemical, data for over 300 different parameters are stored relating to the substances uses, chemistry, environmental fate, ecotoxicology, human health, regulation and application. Most parameters (excluding information on, for example, application and regulation) are described using three fields (i) its value, quantitative or qualitative, (ii) a quality barometer code and (iii) a flexible free-text notes field to provide information clarifying the data.

One of the key objectives of the database was to present information in a manner suitable for a range of different end-users. Thus it needed to be a presented in a format usable and understandable by lay persons as well as providing the detail and accuracy required by risk assessors. It also needed to be in a format that would allow it to be used as direct input into third-party models and decision support systems. This was achieved by developing the core database in MS Access and managing this with an off-line software system which provided a number of functions including (i) more efficient database population (ii) various database validation and checking tasks and (iii) export routines to firstly allow data (entire system or just selected parameters) to be exported into various database or spreadsheet formats to suit the needs of third party models and decision support systems and, secondly, to generate html datasheets for each chemical to be uploaded onto the database website.

This approach satisfied the needs of the different potential end users and also provided the opportunity for the on-line datasheets to be given added value. As well as the scientific data, general information on how the data might be interpreted is presented using, where available, regulatory thresholds used to identify which pesticides require detailed (higher tier) risk assessments (Hart et al. 2003) and general ‘rules of thumb’ widely used for interpretation. In addition, a number of simple, environmental risk indices are also calculated from the data to aid

risk communication. These indices are based purely on the pesticides properties and do not take into account local environmental condition or landscape factors but nevertheless are frequently used and provide an indication of the potential for human or environmental harm. These include the GUS index (Groundwater Ubiquity Score) which is a very simple indicator of a chemical's potential for leaching into groundwater (Gustafson 1989); the SCI-Grow indicator, which is used by the USEPA, to crudely estimate pesticide concentrations in vulnerable groundwater (Barrett 1999); the particle-bound transport index used to estimate the run-off potential of a pesticide (Goss and Wauchope 1990) and the Threshold of Toxicological Concern which uses the Cramer Classification Scheme to evaluate health risks based on chemical structure (Patlewicz et al. 2008).

The database website allows completely free access and includes a number of user-orientated facilities including an A-Z index, search facility using a full range of substance identifiers, short help videos, support documentation and information on the dedicated help email and telephone line.

DATA SOURCES AND QUALITY MANAGEMENT

Data are extracted from a wide variety of sources including regulatory dossiers (such as the EFSA risk assessment conclusion documents and the US Reregistration Eligibility Decision (RED) documents), peer reviewed publications and manufacturer datasheets. This is supplemented with data from various priority lists published by organisations such as the World Health Organisation, Food and Agriculture Organisation and EC working groups etc. Various on-line databases are also consulted including the European Chemical Substances Information System (ESIS) for chemical identification data, the US National Institutes of Health databases for chemical identification and toxicology and the International Uniform Chemical, Information Database (IUCLID) for information on chemical hazards (Heidorn et al. 1996). The US ECOTOX database is used as a source for ecotoxicity data (USEPA 1996). Table 1 provides information on the types and extent of data collated.

Quality is given considerable attention. Data are selected according to some basic rules used to add transparency and provide an indication of the data quality. A simple scoring system is applied that is based on the data publishing source, data traceability and its consistency with other data (bearing in mind that some pesticide data is inherently variable and the presumed quality of the other data). Peer reviewed regulatory data, are given the highest ranking [#5], whereas miscellaneous unreferenced internet sources or qualitative information would be given the

lowest ranking [#1]. Data with the highest quality ranking are selected first. Low ranking data will only be used in the absence of anything better and is replaced with higher quality data as they are identified or become available. Where data is inherently variable, the mean value is given as well as the data range. For complex, highly variable data sets such as those relating to soil degradation or sorption (data depending on, for example, temperature, soil type, pH and organic carbon content) the mean value and data range is reported in the Environmental Fate Table along with details of the number of relevant samples in the data set but the detailed dataset is also stored in a separate Soil Degradation Table (Figure 1).

In-house data management procedures and checks embedded into the management software help ensure data **are** entered into the core system correctly. On an 'as-needed' basis the core system is used with the bespoke software to generate datasheets for the on-line system. In addition to the on-line version copies of the core MS Access version are also available, under license, for direct linking to third party external applications such as models and risk assessment decision support systems.

The PPDB is frequently peer reviewed both internally and externally especially prior to its use with main-stream and major applications. This has included cross checking with other databases and industry peer-review consultations, end users are also encouraged to report erroneous data. Data is subject to an internal rolling review programme whereby each record is checked at least once per year for correctness in terms of data such as its regulatory and availability status, and spot checks are also conducted against the original core data source. During this review new searches are undertaken to plug gaps in data or upgrade poor quality data.

One of the more popular definitions of 'big data' refers to the three 'Vs' of data management: volume, velocity, and variety (Laney 2001). Whilst the database is not in the same league as 'big data' sets many of its characteristics are comparable. These reflect the difficulties experienced in populating the PPDB. The sheer volume of data to be collated for database input and assessed for quality meant that developing the database was, and still is, a resource intensive activity. New data are published on an ongoing basis for new pesticides, as new experimental studies determine new data and as emerging environmental or health issues gain public and regulatory attention. In addition, regulatory authorities have continuous programmes of assessment and re-assessment where data are often upgraded. Consequently, the pace (velocity) at which data are generated is increasing year on year. In addition, as

risk assessments have become more complex, in an attempt to represent more aspects of reality, the need for an increased variety of parameters stored has become apparent. There is also a considerable variety in terms of numbers and types of data sources to be considered which use a broad array of different reporting formats.

PPDB USAGE

Since being launched on-line, usage and demand for the PPDB has increased annually with some levelling off in 2014. However, data accumulated to date for 2015 predicts a modest increase of around 3-5% for 2015. Figure 2 shows the year on year use of the on-line system by individual users since its launch. In Figure 2 'Page Loads' refers to the total number of webpages on the PPDB website visited in the year. 'Unique Visits' refers to the sum of 'Returning Visits and 'First Time Visits' where a 'Return Visit' refers to a visit by the same user over an hour later than their previous visit. Page Loads are the most accurate statistic as the other three rely purely on the use of computer cookies and so the reliability of these data is dependent on an individual's 'cookie' management.

Now established, the database is widely supporting risk assessment and risk management applications globally. A 'quick and dirty' exploration of the Google Scholar database for published papers citing the PPDB during the period 2007-2014 returned well over 1300 manuscripts. Figure 3a shows the growth since 2007. Those identified have been classified into five broad categories: (i) Comprehensive, (ii) Environment, (iii) Biodiversity, (iv) Health and (v) Non-risk assessments. The first category refers to studies that cover all three risk assessment areas: environment, biodiversity and health. Categories 2 to 4 refer to studies where the objective lies within one specific area. The fifth category refers to studies that are not strictly risk assessments but concerned with, for example, methodological development or data analysis. Figure 3b presents the data and shows that environmental studies are by far the most common.

Perhaps one of its most prominent applications (that fall into Group 1) is the use of the PPDB to support the Danish pesticide tax. Prior to 2012 the retail price of pesticide products in Denmark was taxed at a rate of 33.3% for fungicides and herbicides, and 53.85% for insecticides. There was no differentiation according to toxicity or potential for environmental damage (Bichel 1998). This situation was addressed in 2012 with the introduction of a new taxation system (translated as 'Act no. 592 June 2012 Act amending the Act on Tax on Pest Controllers') based on a 'pesticide load' indicator linked to a tax band. The indicator is based on three core data sets: (i) the pesticide

products classification, labelling and packaging risk phrases (according to Regulation (EC) No. 1272/2008), which is used as a surrogate for human health impacts, (ii) its physico-chemical properties which represents the chemicals potential for causing environmental damage, and (iii) its ecotoxicity to a range of fauna and flora. The latter two data sets are taken from the PPDB (Miljøstyrelsen 2012). Using a very similar approach to that taken with the Danish tax the authors developed a pesticide loading indicator for Waitrose Foods which is now used to inform and improve the company's policy in relation to the safe and sustainable use of crop protection chemicals by its growers worldwide. Waitrose is not the only major food company to use the PPDB, for example, Unilever also use a sub-set of PPDB data in their own pesticide risk system. Both the Waitrose indicator and that of Unilever can be classified as Group 1 studies.

Mathematical modelling and decision support systems are vital tools for pesticide risk assessments and risk management. There are numerous examples of such systems where the PPDB has helped the model development, its validation and those where data from the database is used directly as input to drive the model assessment. For example, Leach et al. (2011) used toxicity and environmental behaviour data extracted from the PPDB to aid the development of an environmental accounting tool to provide a monetary estimate of the environmental and health impacts of pesticide use. The International Centre for Pesticides and Health Risks (ICPS) in Italy use the PPDB database to support their on-line ASTERisk (ASsess The pEsticide RISK) tool (ICPS 2015). ASTERisk is used for risk assessments that consider the exposure to pesticides of the general population and farm workers in the Lombardy Region and to identify environmental 'hot spots' in agricultural areas. Whilst Elsaesser and Schulz (2010) used the database to support the development process of the ArtWet tool which was built to model pesticide pollution in surface waters following rainfall runoff events at the European scale. Nowell et al. (2014) present an ecological risk index based tool for assessing potential toxicity of pesticide mixtures to fresh water organisms. Calliera et al. (2008) reported the development of the PARDIS (Prediction of Agrochemical Residue Data using an Informatic System) model which uses a simplified procedure for calculating pesticide residue levels on fruit at harvest by considering the application of the compound and the relevant exposure route. Risk is estimated using Acceptable Daily Intake (ADI) data taken from the PPDB.

The PPDB has frequently, been used in conjunction with several regulatory risk assessment models and methodologies. MACRO 5.2 is a one-dimensional physically based model of water flow and solute transport in soil

based on a dual-permeability approach. It is widely used in European regulatory pesticide risk assessments as part of the registration process (Larsbo et al. 2055; Jarvis and Larsbo 2012). A spatial version specific to Sweden (MACRO-SE) has recently been developed and has been used to assess the direct and indirect effects of climate change on herbicide leaching to groundwater in Scania, major crop production areas of the country (Steffens et al. 2015). A sub-set of PPDB data relating to the environmental fate properties of herbicides is integrated into the MACRO-SE model. PPDB environmental fate data is similarly used to support the groundwater VULnerability to PESticide software system (VULPES), which is user-friendly, GIS-based and client–server software working with the PELMO model, developed to identify vulnerable areas to pesticides at regional level (Di Guardo and Finizio 2015). Recently the WHO/IPCS presented a methodology (Meek et al. 2011) for evaluating the risk of chemical mixtures to human health which is a rapidly emerging risk assessment topic, as there is growing concern that a chemical-by-chemical risk assessment approach may underestimate the combined effects. Using the proposed approach Evans et al. (2015) presented a case study showing the strengths and weaknesses of the approach using data for 67 pesticides, much of which was extracted from the PPDB.

There are also many examples where the PPDB has supported specific risk assessment studies. For example, it has supported studies to consider the pesticide pressure on fish farming in northeastern France (Lazartigues et al. 2013); to monitor the occurrence of polar pesticides in the groundwater of Catalonia in Spain (Köck-Schulmeyer et al. 2014); to determine leaching of pesticide residues in Swedish topsoils (Larsbo et al. 2013) and to determine the combined ecological risks from multiple pesticides in Norway (Petersen et al. 2013). In the USA the database has been used to, for example, assess the impact of pesticides on honey bees (Frazier et al. 2015; Tuell and Isaacs 2010) and on surface and groundwater quality (Reilly et al. 2012; Nowell et al. 2014, Zhan and Zhang, 2014). There are many examples where the database has been used to consider pesticide risks in areas subject to high pesticide pressure but have limited environmental and health protection measures in place. This is often the situation in developing countries; countries which can find accessing scientific data difficult. Brazil is the largest consumer of pesticides in the world and there is evidence of significant effects on both human health and the environment (Rigotto et al, 2014, Carbo et al. 2008). There are several examples where the PPDB has been used to support studies relating to the contamination in surface and ground waters in Brazil (e.g. Milhome et al. 2015; Nogueira et al. 2012; Gustavo et al. 2011) and those that undertake an ecological risk assessment (e.g. Oliveira et al., 2015; Miranda et al., 2011).

There are also many examples of the database supporting risk assessments in other developing countries (e.g. Ahouangninou et al. 2012; Carrasco-Letelier et al. 2012; Malherbe et al. 2013; La et al. 2014).

DISCUSSION AND CONCLUSIONS

Despite a changing world in terms of data sharing, availability, and transparency there are still major resource issues associated with collating datasets, such as that described here, that will satisfy the requirements of comprehensive risk assessments, especially those undertaken at regional or national scale where data for many chemicals is required. The PPDB has been developed to help address such issues.

The development of the PPDB can be tracked over 20 years and it is expected to continue to evolve in line with the development of risk assessment methodologies and the awareness of emerging environmental and ecological issues in the future. Up until 2012 the vast majority of end users were from Europe, the USA, Australia and Canada. However, recently collated data suggests new users are predominately from the developing world; and in particular from those countries with rapidly growing economies such as Brazil, sub-Saharan Africa and India. Developing countries are generally seeking to intensify their agricultural production to meet increased consumer demand and to increase exports. Consequently, there is an increased pesticide use and, potentially, increased risk. This view is supported by **a** United Nations report (UNEP 2012) which concluded that between 2005 and 2020 the accumulated cost of illness and injury linked to pesticides in small scale farming in sub-Saharan Africa could reach USD $90 billion. There is, however, evidence of the introduction of more stringent pesticide regulation in the developing world to try and address the issue. Brazil, for example, is developing a pesticide regulation system akin to that of industrialised nations (Rigotto et al. 2014). Similarly, acknowledging the lack of pesticide safety in India, the Government of Jammu and Kashmir has decided to establish a State Pesticide Regulatory Authority (The Hindu 2015) which will have the remit of developing a risk-based regulatory system for pesticide approvals. Increased usage of the PPDB can also be seen in China. Whilst this may be explained, in part, by an expansion of the PPDB in late 2014 to accommodate many pesticides that are predominately used by China, particularly in paddy fields, China has also tightened up its pesticide regulation in recent years. According to the Chinese State Council completing the revision of pesticide regulation has been a priority during 2015 (Chemlinked, 2015). There is no way

of knowing if the increased awareness of pesticide risks and the subsequent increased regulation in these countries is in any way leading to the increasing use of the PPDB, but it does present one explanation and it also highlights a possible growth area for future demand.

There are also pointers that indicate that the database itself may need to expand in the near future in terms of the parameters it stores, particular with respect to human toxicology. Currently, the regulatory system for pesticides found in foods does not routinely address the toxic effects of different substances in combination. Similarly, there are not yet generally accepted methods for assessing the risks to individuals (i.e. operators, field workers, bystanders and residents) that may be exposed to more than one pesticide. Whilst there is uncertainty regarding the best approaches to handling these 'cocktail' effects, it is highly likely that the demand for quality data will be enhanced and the PPDB will require expansion to accommodate these. For example, there are currently data gaps regarding the toxicological sensitivity and the sensitivity variance of different population sub-groups (particularly pregnant and nursing mothers, children, infants and embryos) to pesticides. It also looks likely that pesticides may need classifying into common groups regarding their toxicological mode of action which may require a greater understanding of the toxicokinetic, toxicodynamic and mechanistic behaviour of pesticides. In addition, some of the proposed techniques for assessing cocktail effects rely on data such as the pesticides Benchmark Dose (i.e. BMD -. the dose associated with a pre-specified response level) and the Tolerable Daily Intake (i.e. TDI -. the daily amount of a chemical that has been assessed safe for human being on long-term basis) and so the PPDB may need to include these types of parameters in the future.

Since its on-line release usage of the PPDB has grown considerably year on year. Alongside standard usage data provided by website traffic monitoring, the sheer volume of citations within peer reviewed scientific literature provides additional evidence of its success. The example applications highlighted here also show that its use is global. As well as continued growth in usage the database itself has also grown in terms of both the number of substances covered, and the depth and breadth of parameters stored. Looking to the future it seems that both demand and the scope of the database will increase still further.

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Table 1: Examples of the stored / generated parameters

Table name	Description
Background	General information on the type of substance, example uses and date introduced.
Commercial	Examples of brands, manufacturers, formulations, availability status (e.g. obsolete, banned, current).
Regulatory	Information on the regulatory status in European member states and other countries.
Application	Information on pests controlled, crops it can be used on, application methods, resistance classes and information.
Chemical identity	Includes for example, common names and synonyms; CAS and IUPAC chemical names; Identity numbers, codes; Canonical SMILES, InChl descriptors; structural diagram; chemical formula, molecular mass, purity level and impurities. Active substances are directly linked to their metabolites. This table contains data only relevant to substances that have veterinary applications and include conditions managed, animals pertinent to, ATCVet code, etc.
Physico-chemical properties	Includes for example, physical state, solubilities; pH, density, dissociation constant; vapour pressure, Henry's constant, octanol/water partition coefficient; melting point, boiling point, degradation point, flashpoint, UV-Vis spectrum, surface tension, refractive index.
Environmental Fate plus three secondary tables	Mean values and data ranges for soil, water, sediment, foliar hydrolysis, photolysis, degradation (DT_{50}, DT_{90}), soil absorption / desorption (e.g. linear and Freundlich sorption coefficients)
	Soil degradation: detailed degradation data by soil types, clay content, OM content, pH
	Sorption data: detailed absorption & desorption data by soil types, clay content, OM content, pH
Human toxicology	Mammalia toxicity thresholds (e.g. acute oral, dermal, inhalation), ADI, AOEL, ARfD, hazard class for carcinogens, mutagens, endocrine disrupters, cholinesterase inhibition, irritancy, sensitisers etc.)
Environmental toxicology	Acute and chronic toxicity to terrestrial and aquatic fauna and flora including pollinators and non-target soil macro organisms; bioaccumulation, details of mesocom studies.
Handling & safety	CPL risk and safety codes, UN number, IDMG Transport codes, packaging group and details relating to chemical and material incompatibilities, explosivity and oxidising potential.
Interpretation	Automatic calculations of common risk assessment indicators including GUS, SciGrow and Potential for Particle Bound Transport, Threshold of Toxicological Concern and use of regulatory & other thresholds for risk banding (e.g. high, medium, low),
Admin	Used for internal management for managing updates, references and version control.

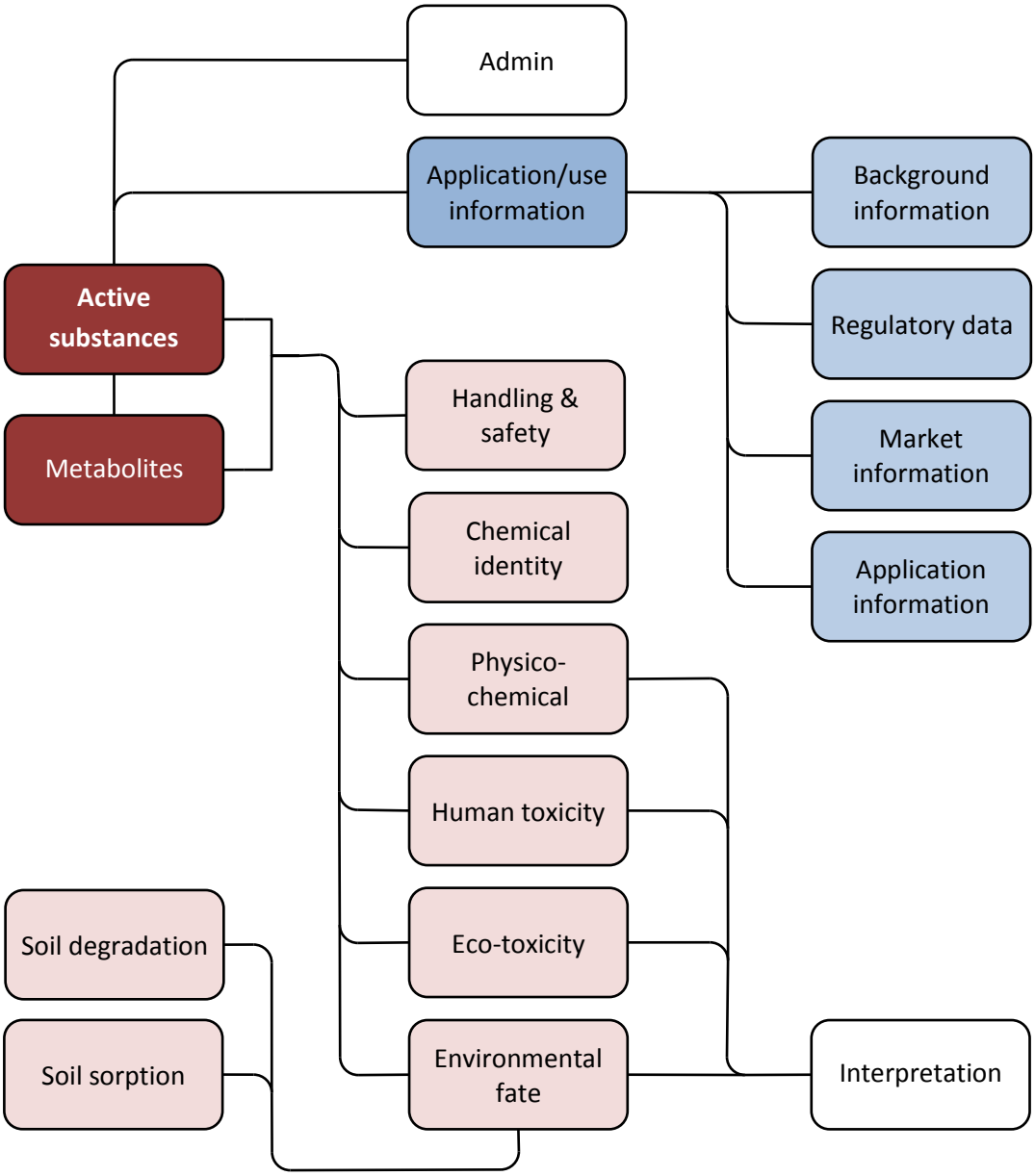

Figure 1: Data structure

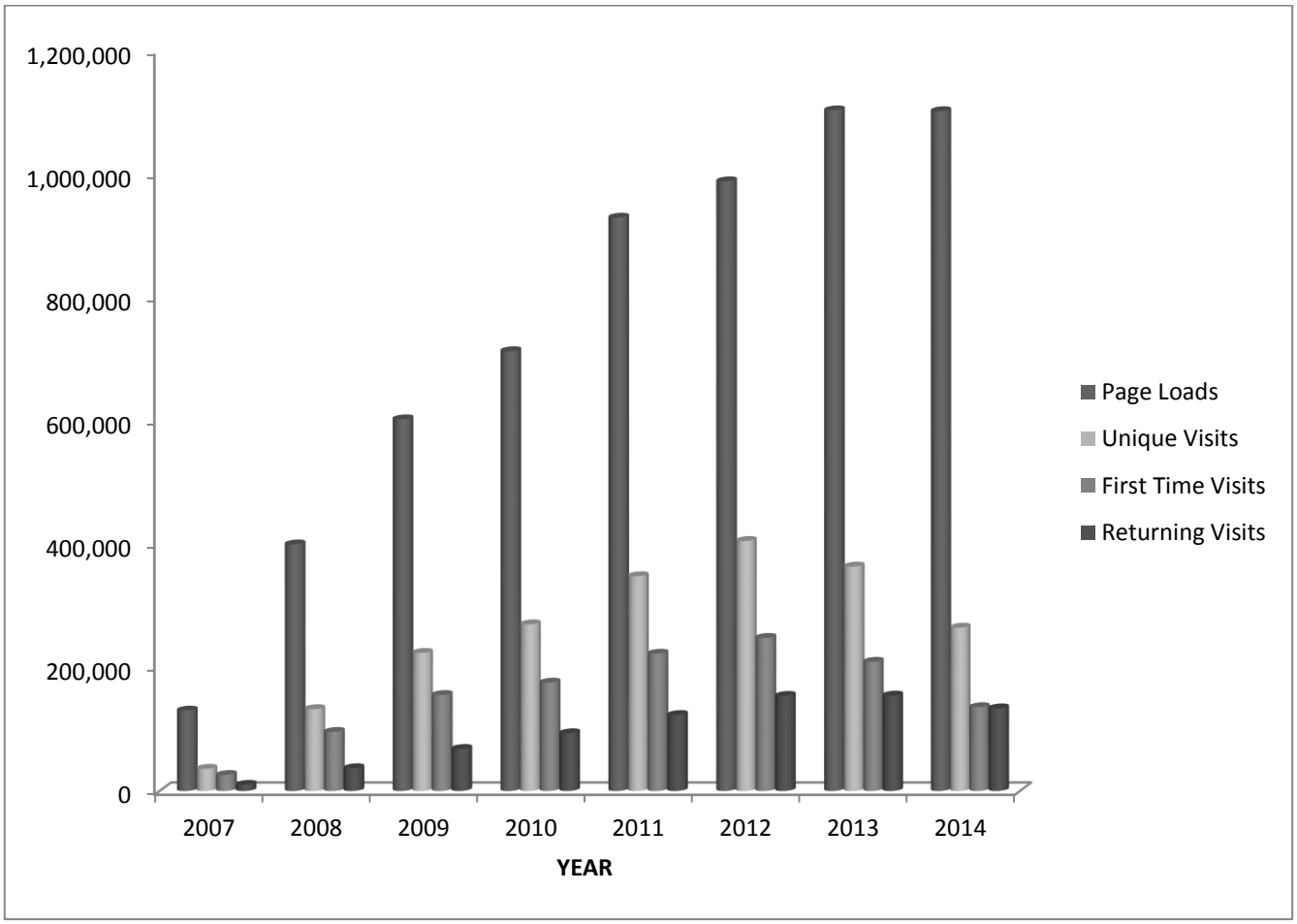

Figure 2: Use of the on-line system

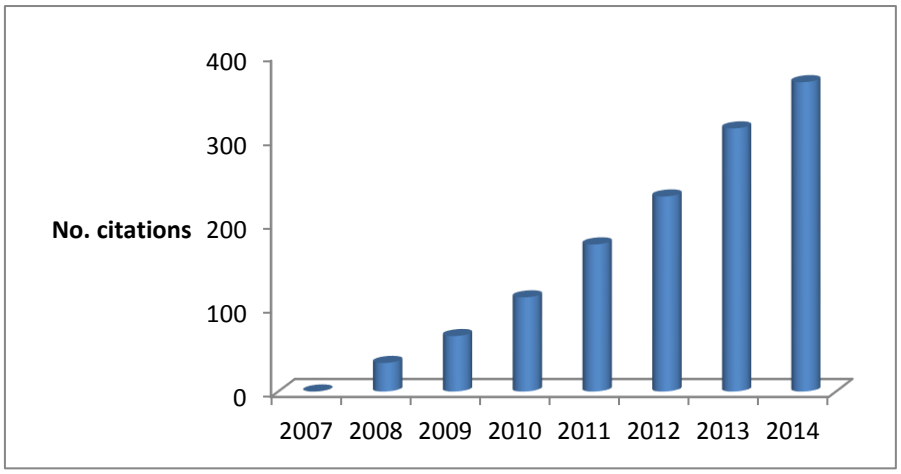

Figure 3a: Number of citations per year

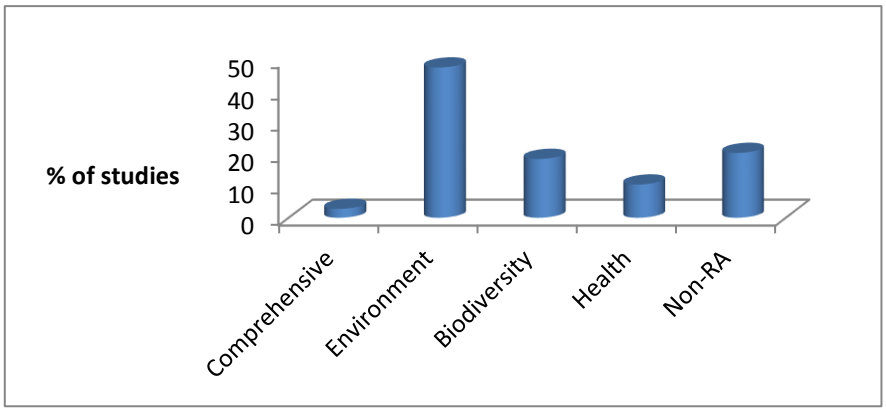

Figure 3b: Classifications by broad study type

Figure legends

Figure 1: Data structure
Figure 2: Use of the on-line system
Figure 3a: Number of citations per year
Figure 3b: Classifications by broad study type
Table 1: Examples of the stored / generated parameters