Integrated Environmental
Assessment and Management

Aquatic Risk Assessment of Pesticides in Latin America: Current Status and Future Needs

Journal:	*Integrated Environmental Assessment and Management*
Manuscript ID:	IEAM-2014-043-OA
Wiley - Manuscript type:	Original Article
Date Submitted by the Author:	07-Apr-2014
Complete List of Authors:	Carriquiriborde, Pedro; National University of la Plata, Faculty of Exacts Sciences Mirabella, Paula; Syngenta Agro S.A., Waichman, Andrea; Universidade Federal do Amazonas, Solomon, Keith; University of Guelph, School of Environmental Sciences Van den Brink, Paul; Alterra and Wageningen University, Environmental Risk Assessment Subdivision Maund, Steve; Syngenta Crop Protection, Global Regulatory Policy and Stewardship
Keywords:	

Abstract:	Latin America is anticipated to be a major growth market for agriculture and production is increasing with use of technologies such as pesticides. Reports of contamination of aquatic ecosystems by pesticides in Latin America have raised concerns about potential for adverse ecological effects. In the registration process of pesticides, all countries require significant data packages on aquatic toxicology and environmental fate. However there are usually no specific requirements to conduct an aquatic risk assessment. To address this issue, the Society of Environmental Toxicology and Chemistry organized a workshop that brought together scientists from academia, government, and industry to review and elaborate on aquatic risk assessment frameworks that can be implemented into regulation of pesticides in Latin America. The workshop concluded that the international framework for risk assessments (protection goals, effects, and exposure assessments, risk characterization and risk mitigation) is broadly applicable in Latin America, but needs further refinement for the use in the region. Some of the challenges associated with these refinements are discussed in the paper. It was recognized that there is potential for data sharing both within and outside of the region where conditions are similar. However there is a need for research to compare local species and environmental conditions to those in other jurisdictions to be able to evaluate the applicability of data used in other countries. Development should also focus on human resources as there is a need to build local capacity and capability, and scientific collaboration and exchange between stakeholders in industry, government, and academia is also important. The meeting also emphasized that, although establishing risk assessment is important, this also needs to be accompanied by

	enforcement of developed regulations and good management practices to help protect aquatic habitats. To achieve this education, training, and communication efforts are needed.

Running Header: Aquatic Risk Assessment of Pesticides in Latin America

Title: Aquatic Risk Assessment of Pesticides in Latin America: Current Status and Future Needs

Authors: Pedro Carriquiriborde[*,†], Paula Mirabella[‡], Andrea Waichman[§], Keith Solomon[‖], Paul J. Van den Brink[#,††] and Steve Maund[§§]

[†] Facultad de Ciencias Exactas, Universidad Nacional de la Plata, Calle 47 y 115, La Plata, Buenos Aires, 1900 Argentina; Tel/Fax: +542214229329, Email: pcarriqu@quimica.unlp.edu.ar

[‡] Syngenta Agro S.A., Av. del Libertador 1855, Vicente Lopez, Buenos Aires, B1638BGE Argentina, Email: paula.mirabella@syngenta.com

[§] Universidade Federal do Amazonas, Instituto de Ciências, Biológicas, Av. Rodrigo Otávio Jordão Ramos 3000, Manaus, Amazonas, 69077-000 Brazil, Email: awaichman@gmail.com

[‖] Centre for Toxicology, School of Environmental Sciences, University of Guelph, 50 Stone Road East, Guelph, ON, N1G 2W1, Canada, Email: ksolomon@uoguelph.ca

[#] Alterra, Wageningen University and Research centre, PO Box 47, 6700 AA Wageningen, The Netherlands, Email: paul.vandenbrink@wur.nl

[††] Department of Aquatic Ecology and Water Quality Management, Wageningen University, Wageningen University and Research centre, PO Box 47, 6700 AA Wageningen, The Netherlands, Email: paul.vandenbrink@wur.nl

[§§] Syngenta Crop Protection AG, Schwarzwaldallee 215, Basel, 4002 Switzerland, Email: steve.maund@syngenta.com

* To whom correspondence may be addressed.

ABSTRACT

Latin America is anticipated to be a major growth market for agriculture and production is increasing with use of technologies such as pesticides. Reports of contamination of aquatic ecosystems by pesticides in Latin America have raised concerns about potential for adverse ecological effects. In the registration process of pesticides, all countries require significant data packages on aquatic toxicology and environmental fate. However there are usually no specific requirements to conduct an aquatic risk assessment. To address this issue, the Society of Environmental Toxicology and Chemistry organised a workshop that brought together scientists from academia, government, and industry to review and elaborate on aquatic risk assessment frameworks that can be implemented into regulation of pesticides in Latin America. The workshop concluded that the international framework for risk assessments (protection goals, effects, and exposure assessments, risk characterization and risk mitigation) is broadly applicable in Latin America, but needs further refinement for the use in the region. Some of the challenges associated with these refinements are discussed in the paper. It was recognized that there is potential for data sharing both within and outside of the region where conditions are similar. However there is a need for research to compare local species and environmental conditions to those in other jurisdictions to be able to evaluate the applicability of data used in other countries. Development should also focus on human resources as there is a need to build local capacity and capability, and scientific collaboration and exchange between stakeholders in industry, government, and academia is also important. The meeting also emphasised that, although establishing risk assessment is important, this also needs to be accompanied by enforcement of developed regulations and good management practices to help protect aquatic habitats. To achieve this education, training, and communication efforts are needed.

Key words: Aquatic risk assessment Pesticides Latin America

INTRODUCTION

Over the coming decades, the world faces significant challenges in producing sufficient food, feed, and fibre to support a burgeoning global population, while sustainably using agricultural land and freshwater supplies. Much of the growth in agricultural production will come from the southern hemisphere, and Latin America is anticipated to be a major growth area for agriculture. In order to support this growth, one option is to intensify production through improved agricultural technology. Simply just using more land is not a viable option; there is a limited amount of additional land that is suitable for agriculture and further conversion of natural habitats to agricultural uses is considered by many as undesirable. Intensification of agriculture and expansion of agricultural frontiers with concomitant increases in pesticide use have been evident in Latin America since the late 1990s (Brannstrom, 2009; Richards et al., 2012; Schreinemachers and Tipraqsa, 2012). This has led to concerns about the possible effects of pesticides in the environment.

Pesticides play a key role in enabling agricultural intensification by protecting crops from damage by insect pests and pathogenic diseases, and by reducing competition from weed plants. Without pesticides, almost twice the area of land would be needed to achieve the same levels of production that are attainable with them. However, since pesticides are designed to be biologically active, they may also be hazardous to certain non-target organisms. They are also typically introduced into the agroecosystem in large quantities. Consequently, it is necessary to assess whether the use of pesticides might pose potential risks to non-target organisms, including those in off-target habitats, such as surface water. Reports of contamination of aquatic ecosystems by pesticides in Latin America and have raised concerns about their potential for adverse ecological effects (Palma et al., 2004; Marino and Ronco, 2005; Carriquiriborde et al., 2007; Dores et al., 2008). Since local data are often lacking, risk assessments are also often based on data from other regions that, depending on the protection goals, can raise additional uncertainties and concerns as to whether this yields appropriate assessments. Only few studies on risk assessment of pesticides for Latin America aquatic ecosystems are reported in the literature (Barra et al., 2000; Waichman et al., 2002; Resgalla Jr et al., 2007; Venturino et al., 2007; Ronco et al., 2008; Waichman, 2008; Tosi et al., 2009; Di Marzio et al., 2010; Rico et al., 2011; Chelinho et al., 2012; Martini et al., 2012; Schiesari et al., 2013).

To discuss the issues raised above, the Society of Environmental Toxicology and Chemistry (www.setac.org) organised a workshop which took place between 10th and 13th of October 2012 which was hosted by the Instituto Nacional de Technología Agropecuaria (INTA), Buenos Aires, Argentina. The format of the workshop was to bring together scientists from academia, government and industry to review and elaborate on aquatic risk assessment frameworks that can be implemented into regulation of pesticides in Latin America. The

workshop considered protection goals, effects and exposure assessments (and the experimental studies and modelling activities required to support those), risk characterization (exposure: effect), and risk mitigation.

CURRENT STATUS OF AQUATIC RISK ASSESSMENT IN LATIN AMERICA

In order to assess the current status of the risk assessment in a sample of Latin American countries a small survey was conducted among regulators of Argentina, Brazil, Bolivia, Chile, Colombia, Peru, Paraguay and Uruguay (SI Table 1). The results showed a variable year of introduction for pesticide legislation. Whereas Uruguay had already introduced pesticide legislation in 1977, Colombia only did so in 2008. Brazil was also among the early adopters (1989) and Paraguay among the later (2006), while other countries introduced pesticide legislation around the turn of the millennium (SI Table 1). Brazil and Peru were the only countries surveyed with a framework for environmental risk assessment included in the legislation and only the legislation in Peru includes specific protection goals.

Despite the general absence of protection goals, all countries require acute and chronic toxicity information for algae, daphnids, and fish for the active ingredient and also sometimes for the formulation (SI Table 1). To evaluate environmental fate, studies on abiotic and biotic degradation are usually requested as well as soil adsorption/desorption studies. Most countries do not currently have an aquatic exposure modelling framework, with the exception of Brazil and Peru where environmental risk assessments are conducted. Both of these countries use the GENEEC (GENeric Estimated Exposure Concentration) model (USEPA, 2001) which is a USEPA surface water model that is used to assess exposure of pesticides to aquatic organisms and the environment. Output from this model is compared to the toxicity-values using a risk quotient approach. Buffer zones are used most often to refine and mitigate the risks, and Brazil and Peru also manage potential risks through the use of drift-reducing technology, minimising use rates, restricting uses to certain crops, and not permitting aerial applications for certain uses.

FRAMEWORK FOR RISK ASSESSMENT

The participants agreed that the overall international framework for risk assessment of pesticides in aquatic systems is applicable (e.g. http://www.oecd.org/env/ehs/risk-assessment/, USEPA, 1992, EC, 2009), but that it needs to be made specific for Latin American uses of pesticides. In particular there is a need to establish protection goals for Latin American ecosystems and to use a tiered approach moving from conservative to more realistic tiers. Guidance is needed to develop exposure scenarios and procedures for modelling fate of pesticides in aquatic systems that account for geographic variability of climate, hydrogeology

across Latin America. In this context it was recognized that, where environmental conditions and crops are similar, it will be possible to combine scenarios across countries as well as hemispheres. In addition, it was recognized that a process is needed for systematic re-evaluation of existing compounds to ensure a consistent approach with new and existing substances, and ensure that the current state of the science is applied. Harmonization of frameworks for risk assessment was discussed with the obvious benefits in terms of sharing data and approaches as well as maximizing the usefulness of limited resources.

PROTECTION GOALS

The participants agreed that the protection goals should ultimately ensure integrity and sustainability of ecosystems. This could include protecting against mortality of vertebrates (e.g., to prevent fish kills) and ensuring the protection of ecosystem function and that the long-term viability for other biological endpoints (e.g., invertebrates, algae and macrophytes) is maintained. In addition, it was recognized that the protection goals need to be part of a wider framework that considers good agricultural practices, integrated pest management, and good landscape management practices. While this was outside the specific mandate of the workshop, this latter point was recognized as very important and it was agreed that establishing landscape management goals could contribute significantly to improving the status of aquatic ecosystems in Latin American agriculture.

TESTING OF EFFECTS

In terms of characterizing toxicity, the participants recommended that the Tier-1 effects studies should initially include the standard OECD test species and protocols. It was agreed that the use of local species could be considered in the higher tiers. It was recognized that there are data on the toxicity of pesticides to species from Latin America but that these data are dispersed and not readily accessible. The participants recommended that a Latin American database of toxicity information for local species be developed but that it was important that these data should be assessed for quality. In order to validate the use of results from experiments with standard test species for a Latin American risk assessment, it is important to compare the sensitivity of the local species with those of standard test species. It was suggested that, for local species, the OECD (or any other appropriately standardized) testing protocols could form the basis for characterizing effects, but that these may need to be modified to consider the specific conditions required by these species (e.g., temperature and water-quality). It was acknowledged that there was probably no physiological or biochemical reason why species in Latin America should be, in general, more or less sensitive from species from other regions. This has to some extent been addressed in the literature (e.g. Maltby et al.,

2005; Bernal et al., 2009; Daam and Van den Brink, 2010) but there are relatively few studies specifically addressing Latin America and some additional research was suggested to test the null hypothesis.

There was much interesting debate concerning the use of standard OECD or local species for assessment of toxicity. The lack of good-quality data and sometimes appropriate methods for local species together with the absence of evidence for differences in sensitivity, tend to argue for the use of data from OECD standard species. However, developing test methods for local species could also bring indirect benefits such as enhancing local testing infrastructure, increasing knowledge of local species and ecosystems (e.g. by identifying sensitive and tolerant species within local ecosystems), and avoiding the introduction of non-native species for testing.

It was agreed that experimental data should be generated in a way that is quality controlled and reproducible (e.g., consistency, data recording, standard protocols, etc.), and that microcosms may be useful in this context as they would allow testing of assemblages of local species under locally relevant conditions.

EXPOSURE ASSESSMENTS

The participants agreed that estimation of exposures to pesticides in surface waters should consider specific conditions found in regions of Latin America. In the first instance, a simple, conservative and reliable Tier-1 model is needed to implement characterization of aquatic exposures for the first step in assessing risks. It was agreed that the currently available models from other jurisdictions for estimating exposures should be reviewed to establish which are suitable and applicable for use in Latin America. These models need to be assessed in terms of the appropriate level of complexity, which tiers they are most applicable to, and how they will take into account hydro-geochemical factors (e.g., adsorption to soil, degradation, water quality, etc.). There is a wide range of aquatic ecosystem types in Latin America and often little physico-chemical data are available with which to characterize the water bodies. Further research is needed to gather and evaluate such information.

It was also noted that monitoring data can be useful for the ground-truthing of models and assessing responses to mitigation. Monitoring is a post-registration process that can be used for retrospective assessments and for calibrating prospective risk assessments. The participants recognized that refining assessments of exposure will be a major challenge, especially in the higher tiers where extensive resources (both data and modelling capabilities) are needed. Where these resources will come from is an important question. In the first instance, efforts should probably be focused on developing robust lower tier models.

RISK CHARACTERIZATION

At the outset, it was recognized that it would be helpful to summarize the current registration, risk assessment and re-registration processes for pesticides in the different Latin American countries. The participants agreed that the Tier-1 risk characterization is best conducted by comparing predicted environmental concentrations (PEC) with predicted no effect concentrations (PNEC) for the main groups of organism (i.e., algae, macrophytes, invertebrates, and fish). This is an appropriate approach for all organism groups but needs to consider potential differences in sensitivity by the use of standard uncertainty factors; however, these factors need to be assessed for applicability in the environment and frameworks of risk assessment in Latin America. Tier-1 risk assessments should be specific to exposures resulting for the local use scenarios (application rates, use patterns, etc.) and should be conducted for the active ingredient and formulation(s). It was recognized that probabilistic risk assessment techniques are more appropriate for higher-tier approaches. In terms of conduct of the assessments, it was suggested that the submitting companies should do the risk assessment as part of the dossier submission. Authorities should then carefully review and check the assessments (using internal and/or external experts as appropriate).

REFINEMENT AND MITIGATION OF RISKS

It was agreed that refinement of risk assessments and mitigation are closely linked and that refinement is an iterative process that should be tiered. Refinement of the risk assessment can include experiments or modelling to improve the realism of lower tier characterization of toxicity and exposures. A range of tools are available that can be adapted for use in Latin America (additional species testing, modified exposure studies, semi-field and field fate and effects studies, higher-tier models, etc.).

Risk mitigation includes changes to how the product is used, most often to reduce exposures. These strategies include changes to the use pattern, buffer zones, and application technology to reduce exposure (e.g., low drift nozzles, shrouded booms). It was suggested that mitigation measures need to be realistic, feasible, enforceable, and consistent with good agricultural and landscape management practices, such as riparian buffer zones. These landscape management practices protect surface waters from physical stressors such as sediments and temperature as well as reducing inputs of nutrients and pesticides, and are important for maintaining viability of aquatic ecosystems. It was agreed that even small riparian buffers of 5-10 m can improve the ecological quality of surface water.

GENERAL RECOMMENDATIONS AND RESEARCH NEEDS

The following general recommendations and needs for research were identified:

- Harmonization of risk assessment approaches, collaboration, and data sharing between countries (also outside Latin America where conditions are comparable) will lead to more efficiency;
- Education, training, and communication of best practices for pesticides is needed;
- Risk assessment of pesticides is important but there also needs to be a focus on good management practices to protect aquatic habitats;
- Research is needed to compare local species and environmental conditions to evaluate applicability of data generated in other jurisdictions;
- There is a need to characterize pesticide use in each country.
- Building human resources capacity and capability is a key need
- SETAC has an important role to play in building the scientific collaboration and exchange between stakeholders in industry, government and academia
- SETAC could play an important role in gathering existing data, establishing databases and developing suitable risk assessment methodologies
- The workshop recommended that a SETAC Latin America Pesticide Risk Assessment Advisory Group be established to take forward the recommendations and actions of the workshop.

ACKNOWLEDGEMENT

The authors wish to thank the following workshop participants for their invaluable input: Karina de Oliveira Cham de Moraes, Guillermo Mentruyt, Maria Elena Zaccagnini, Julie Brodeur, Luis Gelosi, Alicia Ronco, Karina Miglioranza, Fabiana Lo Nostro, Leónidas Carrasco-Letelier, Bernardo Bocking, Gabriela Eguren, María Consuelo Díaz Baez, Cilia Leonor Fuentes and Ruth Carhuallanqui. SETAC is thanked for their support, while INTA kindly provided the venue for the workshop. The workshop was financially supported by CropLife International.

REFERENCES

Barra R, Vighi M, Maffioli G, Di Guardo A, Ferrario P. 2000. Coupling SoilFug model and GIS for predicting pesticide pollution of surface water at watershed level. *Environ Sci Technol* 34: 4425-4433.

Bernal MH, Solomon KR, Carrasquilla G. 2009. Toxicity of formulated glyphosate (Glyphos®) and Cosmo-Flux® to larval Colombian frogs 1. Laboratory acute toxicity. *Journal of Toxicology and Environmental Health A* 72: 961-965.

Brannstrom C. 2009. South America's neoliberal agricultural frontiers: Places of environmental sacrifice or conservation opportunity? *Ambio* 38: 141-149.

Carriquiriborde P, Díaz J, Mugni H, Bonetto C, Ronco AE. 2007. Impact of cypermethrin on stream fish populations under field-use in biotech-soybean production. *Chemosphere* 68; 613-621.

Chelinho S, Lopes I, Natal-da-Luz T, Domene X, Tenorio Nunes ME, Espíndola ELG, Ribeiro R, Sousa JP. 2012. Integrated ecological risk assessment of pesticides in tropical ecosystems: A case study with carbofuran in Brazil. *Environ Toxicol Chem* 31: 437-445.

Daam MA, Van den Brink PJ. 2010. Implications of differences between temperate and tropical freshwater ecosystems for the ecological risk assessment of pesticides. *Ecotoxicology* 19: 24-37.

Di Marzio WD, Sáenz ME, Alberdi JL, Fortunato N, Cappello V, Montivero C, Ambrini G. 2010. Environmental impact of insecticides applied on biotech soybean crops in relation to the distance from aquatic ecosystems. *Environ Toxicol Chem* 29: 1907-1917.

Dores EFGC, Carbo L, Ribeiro ML, De-Lamonica-Freire EM. 2008. Pesticide levels in ground and surface waters of primavera do Leste Region, Mato Grosso, Brazil. *Journal of Chromatographic Science* 46: 585-590.

EC European Commission. 2009. Regulation (EC) No 1107/2009 of the European Parliament and of the Council of 21 October 2009 concerning the placing of plant protection products on the market and repealing Council Directives 79/117/EEC and 91/414/EEC. *Off J Eur Comm L* 309: 1–50

Maltby L, Blake NN, Brock TCM, Van den Brink PJ. 2005. Insecticide species sensitivity distributions: The importance of test species selection and relevance to aquatic ecosystems. *Environ Toxicol Chem* 24: 379-388.

Marino D, Ronco A. 2005. Cypermethrin and chlorpyrifos concentration levels in surface water bodies of the Pampa Ondulada, Argentina. *Bull Environ Contam Toxicol* 75: 820-826.

Martini LFD, Caldas SS, Bolzan CM, Bundt AC, Primel EG, de Avila LA. 2012. Risk assessment of surface and groundwater contamination by the rice pesticides. Risco de contaminação das águas de superfície e subterrâneas por agrotóxicos recomendados para a cultura do arroz irrigado. *Ciência Rural, Santa Maria* 42: 1715-1721.

Palma G, Śnchez A, Olave Y, Encina F, Palma R, Barra R. 2004. Pesticide levels in surface waters in an agricultural-forestry basin in Southern Chile. *Chemosphere* 57: 763-770.

Resgalla Jr C, Noldin JA, Tamanaha MS, Deschamps FC, Eberhardt DS, Rörig LR. 2007. Risk analysis of herbicide quinclorac residues in irrigated rice areas, Santa Catarina, Brazil. *Ecotoxicology* 16: 565-571.

Richards PD, Myers RJ, Swinton SM, Walker RT. 2012. Exchange rates, soybean supply response, and deforestation in South America. *Global Environmental Change* 22: 454-462.

Rico A, Waichman AV, Geber-Corrêa R, Van Den Brink PJ. 2011. Effects of malathion and carbendazim on Amazonian freshwater organisms: Comparison of tropical and temperate species sensitivity distributions. *Ecotoxicology* 20: 625-634.

Ronco AE, Carriquiriborde P, Natale G, Martin ML, Mugni H, Bonetto C. 2008. Integrated approach for the assessment of biotech soybean pesticides impact on low order stream ecosystems of the Pampasic Region. In: Columbus, F. (Ed.). Ecosystem Ecology Research Developments. NOVA Publishers, New York, pp. 209-239.

Schiesari L, Waichman A, Brock T, Adams C, Grillitsch B. 2013. Pesticide use and biodiversity conservation in the Amazonian agricultural frontier. *Philosophical Transactions of the Royal Society B: Biological Sciences* 368.

Schreinemachers P, Tipraqsa P. 2012. Agricultural pesticides and land use intensification in high, middle and low income countries. *Food Policy* 37: 616-626.

Tosi AP, Pechen de D'Angelo AM, Savini MC, Loewy RM. 2009. Evaluación de riesgo por plaguicidas sobre aguas superficiales de la Región Norpatagónica argentina. *Acta toxicológica argentina* 17: 1-6.

USEPA U.S. Environmental Protection Agency. 1992. Framework for Ecological Risk Assessment. EPA/630/R-92/001.

USEPA U.S. Environmental Protection Agency 2001. (GEN)eric (E)stimated (E)nvironmental (C)oncentration model User's manual. 2001. http://www.epa.gov/oppefed1/models/water/geneec2_users_manual.htm

Venturino A, Montagna CM, de D'Angelo AMP. 2007. Risk assessment of Magnacide® H herbicide at Río Colorado irrigation channels (Argentina). Tier 3: Studies on native species. *Environ Toxicol Chem* 26: 177-182.

Waichman AV. 2008. A proposal for integrated risk assessment of pesticide use in Amazon State, Brasil. Uma proposta de avaliação integrada de risco do uso de agrotóxicos no estado do Amazonas, Brasil. *Acta Amaz* 38: 45-50.

Waichman AV, Römbke J, Ribeiro MOA, Nina NCS. 2002. Use and fate of pesticides in the Amazon State, Brazil: Risk to human health and the environment. *Environmental Science and Pollution Research* 9: 423-428.