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Application of a health risk assessment model for cattle exposed to pesticides in contaminated drinking waters: A study case from the Pampas region, Argentina

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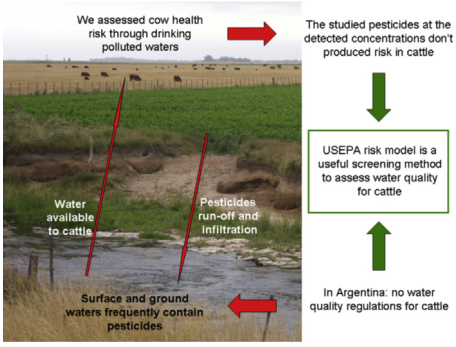
HIGHLIGHTS

- Surface and ground waters in the Pampean plain frequently contain pesticides.
- We assessed the health risk for cows through drinking pesticides polluted waters.
- The studied pesticides at the detected concentrations don't produced risk in cows.
- USEPA risk model is a practical screening method to assess the cattle water quality.

GRAPHICAL ABSTRACT



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ABSTRACT

Using the USEPA methodology we estimated the probabilistic chronic risks for calves and adult cows due to pesticide exposure through oral intake of contaminated surface and ground waters in Tres Arroyos County (Argentina). Because published data on pesticide toxicity endpoints for cows are scarce, we used threshold levels based on interspecies extrapolation methods. The studied waters showed acceptable quality for cattle production since none of the pesticides were present at high-enough concentrations to potentially affect cow health. Moreover, ground waters had better quality than surface waters, with dieldrin and deltamethrin being the pesticides associated with the highest risk values in the former and the latter water compartments, respectively. Our study presents a novel use of the USEPA risk methodology proving it is useful for water quality evaluation in terms of pesticide toxicity for cattle production. This approach represents an alternative tool for water quality management in the absence of specific cattle pesticide regulatory limits.

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1. Introduction

Pesticide use in agriculture has become a common practice for preventing or reducing losses due to infectious plant diseases or plagues and improving the yield and quality of agricultural crops (Damalas and Eleftherohorinos, 2011; Bozdogan, 2014). The use of these chemicals can cause dispersion to multiple environmental compartments (e.g., soil, surface and ground waters, etc.) by means of drift, surface run-off and infiltration (Hildebrandt et al., 2008; Papadakis et al., 2015). Studies conducted in the last decade revealed the occurrence of pesticides in several groundwater aquifers worldwide (Hildebrandt et al., 2008; Melo et al., 2012; Shashavari et al., 2012) as well as in surface waters (Carriger and Rand, 2008; Centofanti et al., 2008; Loewy et al., 2011; Belenguer et al., 2014). In Argentina, several studies evidenced the presence of pesticides in the environment (Jergentz et al., 2005; Marino and Ronco, 2005; Silva et al., 2005; Peruzzo et al., 2008; Loewy et al., 2011; Bonansea et al., 2013; Miglioranza et al., 2013; De Gerónimo et al., 2014), including organochlorine pesticides which have been prohibited since 1990 (Di Marzio et al., 2010; Isla et al., 2010; Miglioranza et al., 2013; Ballesteros et al., 2014; Grondona et al., 2014). As pesticides residues in water and plants may be ingested by herbivores, cow meat and milk represent potential pesticide sources for humans, as reported in several studies (Ahmad et al., 2010; Bayat et al., 2010; Bulut et al., 2011; Fromberg et al., 2011; Nag and Raikwar, 2011; Avancini et al., 2013). Indeed, some studies conducted in Argentina revealed the occurrence of pesticides in agricultural or stockbreeding products (Villaamil Lepori et al., 2006, 2013; Ruíz et al., 2008) raising the awareness of what we consume.

Quality of surface and ground waters is an important aspect to consider for animal production to ensure good animal health and productivity however this aspect is often disregarded (Morgan, 2011). Among the established regulatory criteria promoted by the National Research Council (NRC) for assessing water quality for livestock production are odor, taste, pH, hardness, concentration of total dissolved solids, total dissolved oxygen, heavy metals, toxic minerals, organophosphates, hydrocarbons, nitrates, sodium, sulphates, iron and bacterial load (NASEM, 2016). In Argentina, water quality requirements for animal production have also been established (Bavera et al., 2001; Fernández Cirelli et al., 2010). However, the pyrethroids and organochlorine pesticides are not among the compounds for which regulations ensuring proper water quality for cattle have been set.

Studies conducted by Peluso et al. (2007) in Tres Arroyos County, Argentina, showed that surface and ground waters from a vast area of the county are polluted with organochlorine (α-Hexachlorocyclohexane –HCH–, γ-HCH, δ-HCH, aldrin, γ-chlordane, dichlorodiphenyldichloroethane –DDD–, dieldrin, endosulfan, endosulfan sulphate, heptachlor), and pyrethroid (deltamethrin and cypermethrin) pesticides. Because these waters are used for livestock production, the aim of this study was to apply a health risk model based on cattle chronic exposure to the pesticides through water intake. Thus, health risk assessment was performed for calves and adult cows destined for meat production using the USEPA risk model, in order to evaluate the suitability of this method as an alternative tool for water quality evaluation in cattle farming. The USEPA risk model allows characterizing the nature and magnitude of health risks due the exposure to stressors that may be present in the environment. This model is an estimate of the likelihood that a chemical agent of concern generates a toxicological effects in exposed people (USEPA, 1989). Although this model is widely used for human health risk estimation (Peluso et al., 2012, 2014; Chica-Olmo et al., 2017) there is a lack of studies on risk assessment applied on non-human animals. Thus, we consider that the cattle risk exposure to pesticides in drinking water is a novel use of the USEPA risk model with a potential utility in water quality management serving as an alternative tool to determine harmfulness when regulatory limits are absent.

2. Study area

Most of the province of Buenos Aires surface belongs to the Pampean plain region, including the study area. Major grain crops such as wheat, corn, soybean and sunflower are produced within this region; secondary crops are represented by sorghum, barley and linen. An important annual consumption of pesticides has been observed for the whole country, mainly related to the agricultural expansion in the last years: the amount (kg) of pesticides sales switched from 151.3 million in 2002 to 225 million in 2008 (Pórfido et al., 2014). Among the organochlorine pesticides mentioned in this study, HCH, aldrin, chlordane, DDD, dieldrin, and heptachlor were banned by Argentine law in 1990, and endosulfan and endosulfan sulphate are currently under a progressive elimination program (INTA, 2017a). Contrarily, pesticides based on deltamethrin and/or cypermethrin are freely commercialized.

The study area is located in the Tres Arroyos County (5962.88 km^2), southeast of Buenos Aires province (38°22′46″S – 60°16′38″W). This county plays an important role in the economy of the province due to the large extensions of land devoted to intensive agriculture and cattle-ranching (Carbone and Pícollo, 2002; Carbone, 2004). According to the 2013–2014 census carried out by the Ministry of Agriculture, Livestock and Fisheries of Argentina, 70.4% of the land in the county is used for agriculture whereas 23.1% is used for livestock production. The census showed that the main crops are soybean (237,170 ha), wheat (129,000 ha), sunflower (29,100 ha) and corn (26,700 ha) (SIIA, 2017). In the Pampean region, where our study took place, British cows and their crosses are the main cow breeds, with a predominance of Aberdeen Angus (INTA, 2007). In 2014, there were a total of 216,709 cattle heads in Tres Arroyos County, from which 91,240 were adult cows and 37,660 were calves (SENASA, 2017).

The Tres Arroyos basin has a surface area of 3017 km^2. Considering the 2000–2013 period, the average annual temperature is 14.5 °C, with an average annual minimum of 1.7 °C (in July) and an average annual maximum of 30 °C (in December); the average annual rain for this period is 765.6 mm (INTA, 2017b). The basin (Fig. 1) is formed by three shallow tributaries (first, second and third branches of the Tres Arroyos creek system) flowing through the city of Tres Arroyos, capital of the County. Downstream from the city, these three watercourses meet forming a single one: the Claromecó creek (A in Fig. 1). The latter runs throughout the rest of county and finally opens into the Argentine Sea. Two other watercourses flow in the same direction: the Quequén Salado River (B) and the Cristiano Muerto creek (C) (García Martínez et al., 2008). Due to the potential runoff of pollutants from the agricultural land into these watercourses, the water quality of the basin has been periodically monitored for pesticides (Peluso et al., 2011, 2014). Likewise, ground water wells (Figs. 2 and 3) were also tested for the presence of these substances (Othax et al., 2013). The Pampeano Aquifer System is the name of the ground water aquifer sitting below the Pampean plain from which water is extracted for drinking (Zabala et al., 2015).

3. Methodology

3.1. Cattle probabilistic risk assessment

To calculate the cow risk for the oral intake pathway, different pesticide daily exposure doses were estimated based on the USEPA