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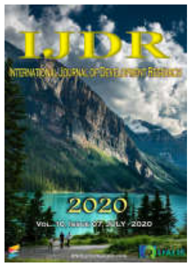

RESEARCH ARTICLE

OPEN ACCESS

MORTALITY RATE AND WATER CONTAMINATION BY ATRAZINE IN RIO GRANDE DO SUL STATE: AN ECOLOGICAL STUDY

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ABSTRACT

Objective: to identify the relation between mortality rate by specific cause and atrazine concentration in drinkable water, pointing the crops that use this pesticide in the state of Rio Grande do Sul (RS). **Method:** ecological study. Were selected 19 RS cities that had atrazine concentration in the drinkable water in the period of 2016 and 2017 and in this way it was performed a search of the crops related to atrazine use. The data search occurred through the following databases: DATASUS, SISAGUA, SIGA and FEE. Spearman bivariate correlations were performed to evaluate the relation between mortality rate and water concentration of atrazine. **Results:** The search shows three cities with atrazine contamination in the drinkable water which have values equal or higher than the allowed at Brazil (≥ 2 μg/L). The mortality rate of the genitourinary system was positively related ($r=0{,}419$; $p=0{,}047$) to the atrazine levels in the drinkable water. About the crops, corn was the prevailing. **Conclusion:** deaths related to the genitourinary system are possibly related to the excess of atrazine in the drinkable water from agriculture use.

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INTRODUCTION

The Brazilian agricultural production model is more dependent of the pesticides use and chemical fertilizers than ever, being this fact justified by the need to increase food production in Brazil and in the world (Pignati et al, 2017). Those several chemical inputs used in the agricultural production show different actions in the environment because of their structures, properties and distinct chemical characteristics (Spadotto, 2006). The National Report of Health Surveillance of Agrochemical Exposed Population, published in 2018, presents data from the Phytosanitary Agrochemical Sistem (Agrofit) from the Agriculture Ministry, Livestock and Supplying (MAPA), which demonstrates that agrochemical commercialization at Brazil between 2007 and 2014 increased 149,14% (IBGE, 2015). At this same period, the Brazilian Institute of Geography and Statistics (IBGE) registered an increasing of 22,31% of planted area (IBGE, 2014). Also according to IBGE, the country commercialized around 500 tonnes of active ingredients in 2014 and around 550 tons in 2018, showing constant increase in the poison used in brazilian agricultural production (IBAMA, 2018). Among the commercialized agrochemicals in the country, the chlorotriazines class (atrazine, simazine, propazine and terbuthylazine) easily reach superficial and underground water, through drift during the application, empty package with atrazine residues, equipment cleaning or industrial effluents of biocides (Breckenridge, 2016). Atrazine is a synthetic herbicide introduced in the market in the sixties and mainly used to the pre-planting of crops as corn, sorghum and sugarcane, as in the early post-planting, controlling broadleaf weed and others grass-plot. Atrazine is a III class chemical substances, considered dangerous to the environment (ANVISA, 2018), and it was the fourth active ingredient more commercialized in the country in 2018, representing 5,2% of the sales (IBAMA, 2018). The substances present in atrazine are confirmed or potential harmful to human health, proven by many national and international scientific researches (Winston et al, 2016; Chan et al, 2007; Faria et al, 2014; Martins et al, 2015; Silva et al, 2016; Lin et al, 2016; Georgiadis et al, 2018). In Brazil it remains the use of active ingredients forbidden abroad (Georgiadis et al, 2018). In 2019, brazilian Agriculture Ministry released 474 new agrochemicals, between generics and new compounds (Bombardi, 2017). In the United States, atrazine is one of the most used agricultural herbicides in the last fifty years, whose effects on the human health are related to endocrine system deregulation, cardiovascular diseases and genitourinary malformations (Winston et al, 2016; Chan et al, 2007). The harmful impacts to human health because of agrochemicals intensive use is concerning, since the intrinsic toxicity may change according to the active principle, the absorbed dose and the exposure time. This harm may arise from different metabolic routes, ways and simultaneously by more than one type of agrochemical, exposing workers and consumers through the residues of those poisons in the final products (Brasil, 2006). Agricultural work is one of the mainly human exposure routes to agrochemicals. However, water for human consumption is one of the mainly ways of contamination (Brasil, 2011). Atrazine is a percolate compound in the system water-soil, so the monitoring of its residues in superficial and underground water is necessary, mostly because of the contamination risk in the water distribution network to human consumption (Carmo et al, 2013). Despite the thematic, quality of the water for human consumption, being of world interest, more studies need to point the relation between environmental contamination and human health in Brazil, so policies of health protection, with measures to reduce agrochemical use, may be implemented. From the presented problem, this work had as goal to identify the relation between mortality by specific cause and atrazine concentration in potable water, specifying the crops produced in the state of Rio Grande do Sul (RS) that use this agrochemical.

METHODS

It's a descriptive study, ecological type, characterized by using data from population groups (Medronho et al, 2009). The information about water monitoring in Rio Grande do Sul is from the State Centre of Health Surveillance (CEVS) of the State Health Secretary from Rio Grande do Sul (SES-RS) and was collected through the Surveillance Information System of Water Quality for Human Consumption (SISAGUA) in the period of 2016 to 2017. The amount of atrazine commercialized in Rio Grande do Sul was obtained through the Integrated System of Agrochemicals Management (SISAGUA). The characterization of the agricultural production at the cities searched was obtained through the Economics and Statistics Foundation of Rio Grande do Sul (FEE-RS) in the year of 2017. Rio Grande do Sul Water Supply System (SAA) covers almost all cities and thus, many kinds of agrochemicals were analyzed, and atrazine stands out, since it was found in human consumption water in 19 cities: Ametista do Sul, Áurea, Bom Jesus, Cândido Godói, Canguçu, Dona Francisca, Erechim, Frederico Westphalen, Ijuí, Lagoa Vermelha, Marau, Planalto, São Borja, Seberi, Três de Maio, Vacaria, Venâncio Aires, Maximiliano de Almeida and Salto do Jacuí. According to the current legislation, in the period from 2016 to 2017,[13] the Maximum Acceptable Value (MAV) of atrazine in drinkable water is 2,0 µg/L, being considered, from this value, the presence of water contamination by the agrochemical. The residues level of atrazine found in the water of the cities were analyzed according to parameters from CEVS, SES-RS. In the data collection instruments (laboratory reports and SISAGUA) was the result of the analyzed parameter and the Method Detection Limit (MDL) and Quantification Limit (QL) values. This information is important when measures of low levels of a substance are made, according to the trace level. It's important to know the lowest concentration value of this substance that can be detected by the equipment method.

The Detection Limit (DL) and the Quantification Limit (QL) used in the results of atrazine found are following:

a) Ametista do Sul, Bom Jesus, Ijuí, Marau, Planalto, São Borja, Seberi e Três de Maio (DL: 0,02; QL: 0,06);
b) Áurea, Cândido Godói, Canguçu, Dona Francisca, Erechim, Frederico Westphalen, Lagoa Vermelha, Vacaria, Venâncio Aires, Maximiliano de Almeida, e Salto do Jacuí (DL: 0,043; QL: 0,172).

The population mortality data was extracted from the Information System of the United Health System (DATASUS) between 2016 and 2017, organized according to the 10ª International Classification of Diseases (CID-10) through the codes: 066-072 (circulatory system diseases); 078-082 (digestive system diseases); 085-087 (genitourinary system diseases); 055-057 (endocrine, nutritional and metabolic diseases); 032-052 (neoplasms); 109 (intentionally self made injuries). Although the most prevalent death causes in the selected cities had been from circulatory system diseases and neoplasms, the inclusion of the other causes were defined by bibliographic search, that relates their occurence to agrochemical exposure.[8,9,10] The statistical analysis was made through Statistical Package for the Social Sciences (SPSS), 2.0 version. The Shapiro-Wilk normality test was performed, asymmetry and kurtosis values to verify the variables distribution. Bivariate Spearman correlations were performed (to asymmetric variables), to evaluate the relation between mortality rate by the above-mentioned diseases and atrazine concentration in the water consumed by the population. To the mortality coefficient by diseases calculation, the total death ratio (numerator), by every city population in the period of 2016 (denominator) was performed, multiplied by 100. The present study wasn't submitted to the Ethics Research Committee because it used public and available on the internet data.

Figure 3. Total sum of the crops corn, sugarcane and sorghum (agricultural products that use atrazine in its productive system) as a percentage of the total cultivated in Rio Grande do Sul counties in quantity produced in the year 2017. The counties selected in the study were highlighted.

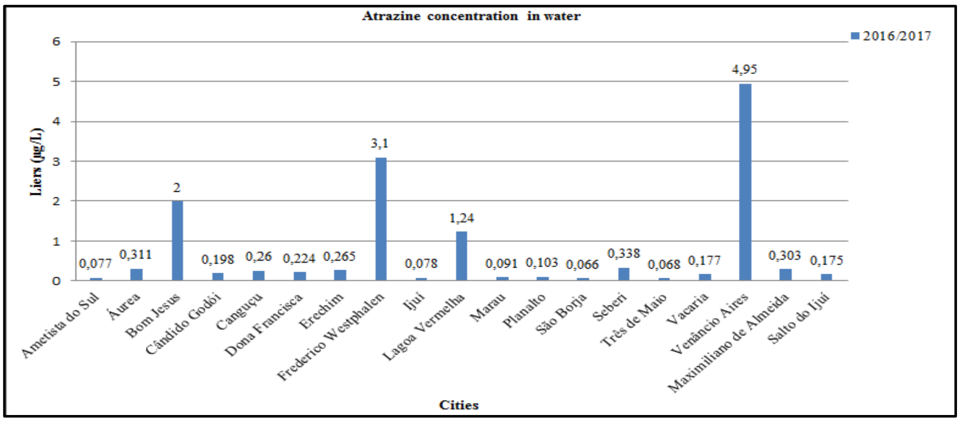
Source: Economics and Statistics Foundation of Rio Grande do Sul (FEE-RS) in 2017.

Atrazine concentration in water, in the period from 2016 to 2017, at the 19 RS cities according to CEVS/SES-RS is shown in the Figure 1. The cities with atrazine potable water contamination that have values higher or equal the MAV were: Bom Jesus with 2 (µg/L), Frederico Westphalen with 3,1 (µg/L) and Venâncio Aires with 4,95 (µg/L). Besides, all the cities showed residual values, being 0,066 (µg/L) the minimum detected at São Borja city. The quantity of atrazine commercialized in the cities of the present study, in liters, from 2017 to 2018 is shown in Figure 2.

The genitourinary system mortality rate showed positive relation (r=0,419; p=0,047) to the atrazine concentration in water. There was no relation between digestive and circulatory system, endocrine diseases, neoplasm or self made injuries ($p<0,05$). The crops survey in the cities where atrazine was identified showed the production of corn, sorghum and sugarcane, where atrazine is used (Figure 3). According to data from FEE-RS, in 2017, corn was the third most cultivated product in the State, producing 6,05 million tons.

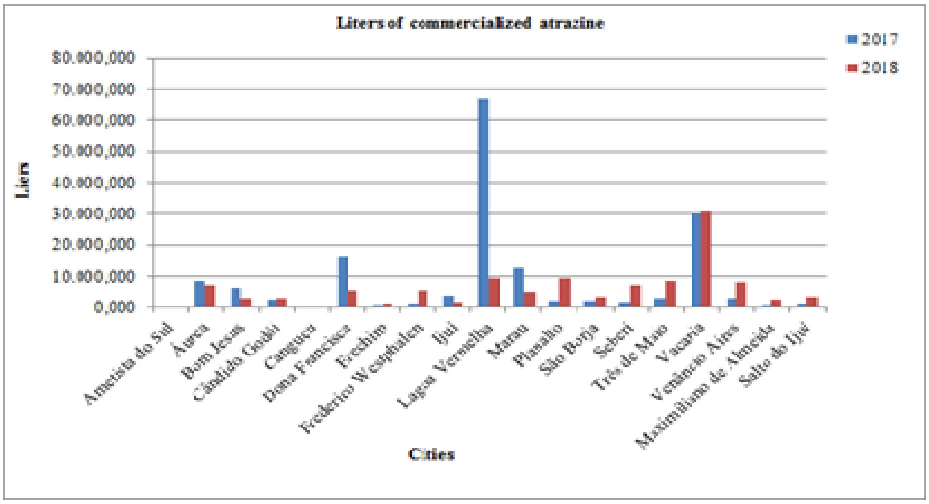
DISCUSSION

According to the brazilian legislation, the maximum acceptable value of atrazine in potable water is 2 µg/L



Source: Centre of Health Surveillance of the State of Rio Grande do Sul, Brazil, 2016 to 2017.

Figure 1. Quantity (µg/L) of atrazine contamination in the water from the cities of Rio Grande do Sul state, 2016 to 2017



Source: Integrated Agrochemical Management System (SIGA) from the Agriculture, Livestock and Irrigation Secretary of Rio Grande do Sul State, 2017.

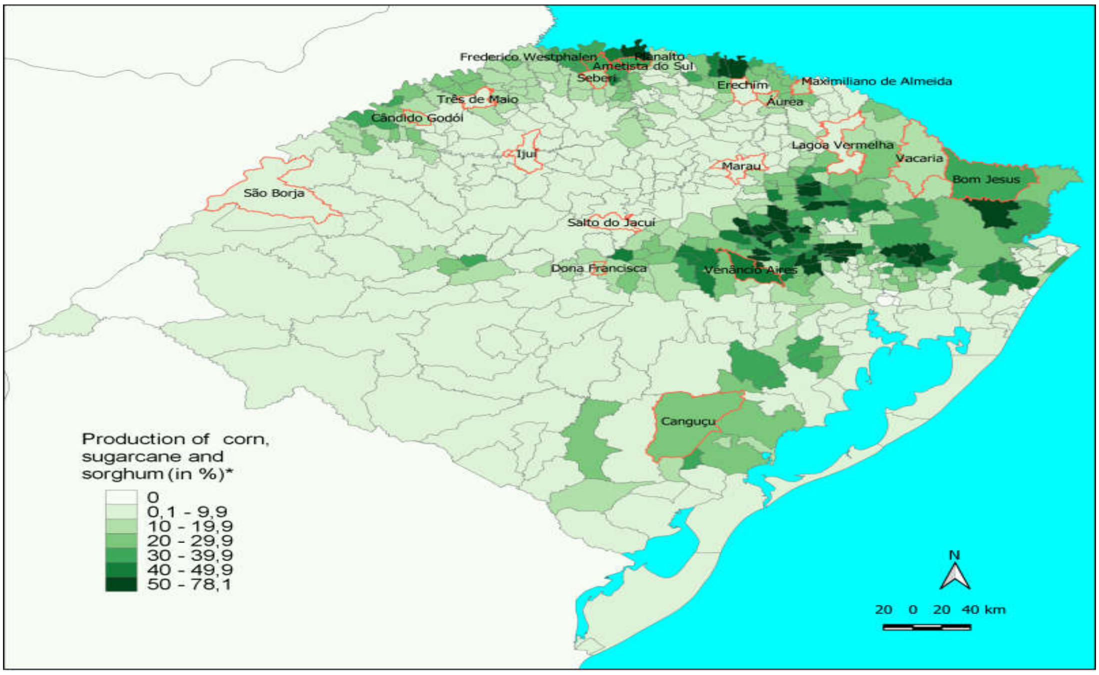
Figure 2. Quantity of atrazine commercialized in the counties of Rio Grande do Sul state in liters, Brazil, in the period from 2017 to 2018

Table 1. Correlations coefficient between mortality rates by circulatory and genitourinary system, endocrine diseases, neoplasm and self made injuries, and atrazine concentrations in water in Rio Grande do Sul cities, 2016

Atrazine (µg/L)	Circulatory System	Genitourinary System	Digestive System	Endocrine, metabolic and nutritional diseases	Neoplasm	Intentionally self made injuries
	0,192	0,419	0,062	0,365	0,399	0,090
	p= 0,380	p= 0,047	p=0,779	p= 0,087	p=0,59	p=683

The city Lagoa Vermelha showed commercialization of approximately 66.975,250 liters of atrazine in the year of 2017 and the city of Vacaria approximately 30.004,500 liters in 2017 and 30.896,750 in the year of 2018. The correlation results between mortality rates by disease and atrazine concentration in the water are described in Table 1.

(Winston et al, 2016), and this value is high above the acceptable value by the European Union (EU), which is 0,1 µg/L. In countries as Germany, atrazine was banished, as it remains in high concentration in potable water (Sass and Colangelo, 2006; Vonberg et al, 2014). This argument corroborated the study performed in Ceará state, where the



Source: Economics and Statistics Foundation of Rio Grande do Sul (FEE-RS) in 2017.

Figure 3. Total sum of the crops corn, sugarcane and sorghum (agricultural products that use atrazine in its productive system) as a percentage of the total cultivated in Rio Grande do Sul counties in quantity produced in the year 2017. The counties selected in the study were highlighted

researches verified that atrazine, and other chemical compounds, showed high contamination potential because of its dissolution in water (Pinheiro et al, 2017). Therefor, in the period from 2016 to 2017, among the cities that belong to Subterranean Water Supply System of RS state, atrazine was detected in 19 cities. Three of them had atrazine concentration in drinkable water higher or equal the MAV, beyond this, other five showed lower residual values than 0,1 µg/L, as 11 cities showed concentrations between 0,103 – 1,24 µg/L, considered unsafe to health in many countries. This data corroborate the quantity of atrazine commercialized at Brazil in 2017, 24.730,9 t, being the 6º most commercialized agrochemical in the country and yet, this number is growing. In 2018, 28.799,34 t of atrazine were commercialized, going to 4º place between all commercialized agrochemicals. In RS, the sales of this active ingredient went from 721,62 t in 2017 to 744,45 t in 2018 (IBAMA, 2018). It is worth noticing the abusive use of atrazine in the cities of Bom Jesus, Erechim, Lagoa Vermelha, Marau, Cândido Godói, Ijuí e Vacaria (0,17 – 1,31 L/t), where the values found between the quantity of commercialized atrazine (L) and the agricultural production (t) is up to 1000 times the value of the used quantities in other cities (0,0036 – 0,070 L/t).

In order to relate the agricultural production and the quantity of atrazine found in the potable water, it was observed that there is no direct relation between the commercialization and the use of atrazine, suggesting that the contamination in potable water can come from another cities, as the hydraulic system, being superficial or underground, is dynamic and in constant moving, transpassing geographic boundaries. The rural population collects and consumes water from artesian wells, where atrazine can equally be found. Researchers as Fan et al. (2018) analysed consumption water from the rural population in a region producer of tobacco, and found in some properties up to four different types of agrochemicals in the water from the artesian wells used by the families. In Lucas do Rio Verde, city with large agricultural production in the Mato Grosso State, it was observed that 83% of the samples from artesian wells of urban distribution had agrochemical residues, atrazine among them (Moreira et al, 2012). Another important aspect, besides the commercialization and water contamination, is that agrochemical residues, mainly atrazine, in water and soil can modify the endocrine system as the hypothalamic-pituitary axis, thyroid, parathyroid and sexual organs. In human beings, deformation in sexual organs, increase of breast, vagina, testicules and prostate cancer, occurence of polycystic ovaries, endometriosis and decrease in sperm production and even infertility (Martins et al, 2015). A study which analysed socioeconomic profile of rural workers showed that the most affected were male, with zero to four years of education, older than 60 years and predominantly workers from corn crops, reporting agrochemicals use, and non-use of personal protective equipment (Silva et al, 2016). The most common neoplasms in this population were in the digestive and urinary systems, respectively. There was association between mortality rate by diseases of the genitourinary system and the cities with higher concentrations of atrazine in water for human consumption. Besides the fact that the water analysis referred to the years of 2016 and 2017, this data serves as an indicator of ambiental contamination to which the population is exposed. Atrazine is an old herbicide but it is still used because of its low cost and its sinergy when used together with other herbicides (Correia et al, 2006). It is largely used in Brazil and worldwide, being frequently detected as mainly organic pollutant in underground and superficial water in many countries, including the United States of America (Dorfler et al, 1997).

Although the present study did not find relation between atrazine concentration in water for human consumption to the mortality rate in other systems as digestive or circulatory, endocrine diseases, neoplasms and selfmade injuries, other studies observed damage because of the exposure to agrochemical, mainly in reproductive organs as: deformity of sexual organs, infertility, hormonal alterations, congenital malformations and abortions (Martins et al, 2015; Rodrigues et al, 2018). Through many researches, it was observed that intoxication by atrazine may cause reproductive problems, endocrine disturbances, cardiac diseases and cancer (Lin et al, 2016; Georgiadis et al, 2018; Hu et al, 2015). Agrochemical exposure can occur from different ways of contamination, as food source, water consumption or even damage of rivers and lakes (Machado et al, 2018). The contaminants present in soil can be carried by the water from the rain, rivers, weirs and lakes, causing risks to animal and human health (Fan et al, 2018). Thus, the contamination of superficial water might cause partial or total pollution, generating interferences in human health through the frequent consumption of agrochemical residues (Pinheiro et al, 2017).

Conclusion

The present study identified the presence of atrazine in 19 counties of Rio Grande do Sul state, and three of them presented MAV equal or higher according to brazilian legislation, as well as significative statistic association to the genitourinary system with drinkable water contamination by atrazine. About the crops, corn was the third most produced in RS. The values between the quantity of commercialized atrazine and the agricultural production revealed excessive use of this agrochemical, which may cause harm to human and environmental health. It is considered relevant to give visibility to a public health topic that involves the relation between production-work-health-environment. Although a greater level of detail was not possible, future studies may point the relation between the mainly harms to health in the population of the cities with atrazine water contamination.

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