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Pesticide contamination of water for human consumption in Sergipe, Brazil (2014-2022)

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ABSTRACT

The presence of pesticides in drinking water is a growing concern worldwide. In Brazil, and especially in Sergipe, few studies evaluate pesticide contamination in rivers. The study assessed the presence of pesticides in water intended for human consumption in municipalities in Sergipe between 2014 and 2022. Information on pesticides was extracted from the Water Quality Monitoring System for Human Consumption (SISAGUA). To carry out the analysis of pesticide contamination in each municipality, the concentrations, absolute and relative frequency of pesticide occurrence, and the number of times the maximum allowed values (MAV) established by Brazilian and European legislation were exceeded were considered. Contaminated samples were found in 60% of the municipalities, of which 8.8% exceeded the MAV for Brazil and 80% for Europe. In 41 municipalities, the most common pesticides are classified as Class I (extremely toxic). Among the pesticides most frequently found in the samples, "DDT+DDD+DDE" stands out with concentrations 3.6 times above the MAV for Brazilian legislation. For European legislation, the pesticides that presented values above the established limits were 2,4D + 2,4,5T, Chlorpyrifos, Carbendazin, Glyphosate, Manconzeb, Methamidophos, Profenophos and Tebuconazole, which presented values between 35 and 92 times. The results of this study provide a comprehensive overview of pesticide contamination in water intended for human consumption in Sergipe and highlight the urgency and importance of effective control and monitoring measures to reduce contamination and protect the health of Sergipe’s population.

Keywords: public health, water for public supply, water quality.

Contaminação por agrotóxicos em água para consumo humano no estado de Sergipe, Brasil (2014-2022)

RESUMO

A presença de agrotóxicos na água para consumo humano é uma preocupação crescente em todo o mundo. No Brasil e principalmente em Sergipe são escassos os estudos que avaliam a contaminação por agrotóxico em seus mananciais. O objetivo do estudo foi avaliar a presença de agrotóxicos em água destinada ao consumo humano nos municípios do estado de Sergipe, no período entre 2014-2022. As informações dos agrotóxicos foram extraídas do Sistema de Vigilância da Qualidade da Água para Consumo Humano (SISAGUA). Para realizar a análise de contaminação por agrotóxicos em cada município, foram consideradas as concentrações, frequência absoluta e relativa de ocorrência dos agrotóxicos bem como o número de vezes em que os valores máximos permissíveis (VMP), estabelecidos pela legislação brasileira e europeia foram ultrapassados. Em 60% dos municípios foram encontradas amostras contaminadas das quais 8,8% ultrapassaram o VMP do Brasil e 80% da Europa. Em 41 municípios os agrotóxicos mais presentes são classificados como classe I (extremamente tóxico). Entre os agrotóxicos mais frequentemente encontrados nas amostras destacam-se o "DDT+DDD+DDE" com concentrações 3,6 vezes acima do VMP para legislação brasileira. Para a legislação europeia, os agrotóxicos que apresentaram valores acima dos limites estabelecidos foram 2,4D + 2,4,5T, Clorpirifós, Carbendazin, Glifosato, Manconzebe, Metamidofós, Profenofós e Tebuconazol que apresentaram valores entre 35 e 92 vezes. Os resultados deste estudo fornecem uma visão abrangente da contaminação por agrotóxicos na água destinada ao consumo humano em Sergipe e destaca a urgência e a importância de medidas de controle e monitoramento efetivas para reduzir a contaminação e proteger a saúde da população sergipana.

Palavras-chave: água para abastecimento público, qualidade da água, saúde coletiva.

1. INTRODUCTION

In recent decades, agricultural production and the use of pesticides have increased worldwide (FAO, 2022), especially in Brazil, which has become one of the largest consumers to meet the commodities market. The considerable increase in the use of pesticides in search of greater agricultural productivity compromises the environment, and it is one of the main causes of contamination of potable water sources worldwide (Srivastav, 2020). This contamination can occur in two ways: direct contact either in preparation, application, or another form of handling along the production chain, and indirect contact through water, soil, atmosphere, and contaminated food (Frota and Siqueira, 2021; Ristow *et al.*, 2020).

The historical series of pesticide registrations in Brazil has been growing sharply, with 2,181 products released in the period from 2019 to 2022, with an average of 545 per year, according to the Ministry of Agriculture and Livestock. With the greater availability of active ingredients exposure to product residues increases (Brasil, 2022). It is also worth noting that of the total of these products registered in the period, 40% contained active ingredients that were not permitted for use in the European Union (Hess *et al.*, 2021).

In 2022, 800,652 tons of active ingredients (a.i.) were marketed, which represents an increase of approximately 11% compared to the previous year (2021), whose sales were 720,870 tons. In the same period, 576 new products were registered, with an increase of 194%, the ten most marketed active ingredients in the country being: glyphosate, 24-D, atrazine, mancozeb; acephate; chlorothalonil, diquat dibromide, glufosinate-ammonium salt, chlorpyrifos, and methomyl (IBAMA, 2024).

Pesticides widely used in agriculture contaminate water intended for public supply, which is used daily by the population for consumption, hygiene, and food preparation. Water quality analyses have found pesticide residues in raw water from springs and reservoirs in several Brazilian states (Kronbauer *et al.,* 2021; Do Carmo *et al.,* 2020; Montagner *et al.,* 2019), Souza *et al.* (2019), as well as in water intended for human consumption after conventional treatments, such as filtration and disinfection with chlorine (Vizioli *et al.*, 2023; Caldas *et al.*, 2019; Starling *et al.*, 2019).

In Sergipe, northeastern Brazil, contamination of water resources by pesticides has been reported in different studies (Soares *et al.*, 2020; Britto *et al.*, 2012; 2015; Silva Filho *et al.*, 2011). From this perspective, the state's favorable edaphoclimatic characteristics have contributed to agricultural expansion, which in 2020 grew 35.6% compared to 2019 (IBGE, 2020), associated with the growth in pesticide sales, increasing the risks of water contamination and human health (EMDAGRO, 2023).

The presence of pesticides in water sources can represent challenges for the treatment of water intended for human consumption since conventional treatments have low efficiency in eliminating organic contaminants (Vizioli *et al.*, 2023; Fernandes Neto and Sarcinelli, 2009). The use of more complex technologies such as reverse osmosis and activated carbon has shown the best results in removing pesticides from water sources, but these water purification methods are overpriced (Schreiber *et al.*, 2024).

Water quality control and surveillance in Brazilian territory must be carried out every 6 months to monitor physical, chemical, and biological parameters and maximum allowed values (MAV) for metabolites and pesticides that pose health risks (Brasil, 2021). A significant portion of Brazilian municipalities did not conduct pesticide tests in their supply networks between 2014 and 2022, totaling 2,931 municipalities out of 5,570. Highlighting that different pesticides were found in the water consumed in 25% of the cities in Brazil. Among the 1,396 municipalities that conducted tests, 27 pesticides were detected, of which 21 are banned in the European Union (EU) due to the health and environmental risks posed by these substances (Aranha and Rocha, 2019).

Continuous exposure to pesticides through water increases the risks of diseases and health complications (Zhang *et al.*, 2019). Furthermore, the consumption of contaminated food, rural work, and the drift of active ingredients to neighboring areas affect the population living close to producing areas and are also important sources of exposure to these contaminants (Gonzaga *et al.*, 2021; Marques and Silva, 2021; Souza *et al.*, 2019).

The harmful health outcomes of the population related to pesticides manIFSt as acute poisoning, with a prevalence of signs and symptoms such as headache, nausea, dizziness, weakness, and excessive fatigue (Lermen *et al.*, 2018) or result in neurodegenerative diseases, respiratory pathologies, metabolic disorders, reproductive dysfunctions, and cancer, due to chronic contacts (Vellingiri *et al.*, 2022; Fucic *et al.*, 2021).

The externalities related to the intensive use of pesticides go beyond environmental contamination, it also affects biotic systems, such as non-target species. The reduction of pollinators is increasing, due to the use of herbicides and fungicides and the cultivation of genetically modified plants, which, although considered harmless to bees, promote physiological and behavioral changes in these insects (Faita *et al.*, 2021).

Given this context, it becomes crucial to investigate the occurrence and frequency of pesticide contamination in water, especially in regions like Sergipe, which are susceptible to contamination due to the growth of agricultural activity and the wide range of chemical products used in the Region (Britto *et al.*, 2012).

The present study assesses whether the presence of pesticides in water intended for human consumption in Sergipe between 2014 and 2022 is above the limits established by Brazilian and European legislation (Brazil, 2021; União Europeia, 2019), and to identify possible gaps in contamination control in the region and assess the potential risk to public health. In addition, it seeks to identify the main pesticides found in public supply water in Sergipe from its capture, treatment, and distribution, and to classify them according to their toxicity based on the criteria established by the Ministry of Agriculture, Livestock, and Supply (MAPA).

2. MATERIAL AND METHODS

2.1. Study site

The State of Sergipe, in Northeast Brazil, is located in the western part of the region. Its geographic coordinates are 9°31’54” and 11°34’12” south latitude and 36°24’27” and 38°11’20” west longitude. Sergipe is the smallest state in Brazil in territorial terms, covering an area of 22,925.4 km^2. Its population is estimated at about 2,318,822 inhabitants distributed in 75 municipalities. Approximately 73.5% of these people live in urban areas, while the other 26.5% reside in rural areas (IBGE, 2020). Public supply water in the state of Sergipe is provided by the Sanitary Company of Sergipe (DESO). The capture is carried out in 29 surface sources (rivers, lakes, or dams) and 92 underground sources (formed by deep wells). Before reaching the final consumer, this raw water goes through a complex operation process that starts at the capture, passes through treatment stations, reservoirs, and a distribution network (DESO, 2024).

2.2. SISAGUA Database

SISAGUA 4, known as the Water Quality Surveillance Information System for Human Consumption, is an online tool made available by the Brazilian Ministry of Health to assist in controlling health risks related to the provision of potable water in the country. The information provided by this system is used to assess the health situation related to water supply for human consumption, aiming at reducing the dangers associated with the consumption of water that does not meet potability standards.

In SISAGUA, there are three main parts for data entry: Registration, Control, and Surveillance. The details are added according to the municipality and the supply method. Registration and Control information is collected from water supply service providers in the city and can be entered directly into the system or forwarded to the Health Department for entry (Oliveira *et al.*, 2019).

2.3. Analysis of Pesticide Data in Sergipe

All freely accessible public data from SISAGUA, made available by the Ministry of Health for the state of Sergipe, were used. The SISAGUA data set and variable dictionary were obtained through consultation and search on the Brazilian Open Data Portal (available at https://dados.gov.br/dados/busca?termo=SISAGUA). The data analyzed in this study come from samples collected at ETAs over the period from 2014 to 2022, covering the stages of capture (CP), treatment (TR), and distribution (DS) of water. The information provided in SISAGUA is sent by state and municipal authorities and supply companies as established by Brazilian legislation, which determines that water suppliers must conduct tests every six months and present the results to the Federal Government.

SISAGUA gathers test results for 27 pesticides (Table 1) analyzed in more than 40 water treatment stations (ETAs) of DESO located in sources distributed throughout the state of Sergipe. In SISAGUA, the data are structured as follows: Numeric Value (NV) is used when it is feasible to measure the concentration of the analyzed substance; less than the Detection Limit (< DL) represents the absence of the substance or concentration below the detectable limit by equipment and methodology, and less than the Quantification Limit (< QL) indicates identified presence but without information on the exact concentration. The collected samples are analyzed by the Institute of Technology and Research (ITR) using the multi-residue methodology using liquid-liquid extraction. Quantification was performed in a gas chromatograph, with electron capture detectors and liquid chromatograph. Of the 27 pesticides found in the ETAs of the State of Sergipe, they can be divided according to their toxicological classification into: 10 herbicides used to combat weeds and invasive plants; 14 insecticides that act directly on the lethality of insects; and 3 fungicides to combat fungi (Table 1).

Table 1. Main pesticides monitored with toxicological classification and maximum permissible values.

Active Ingredient	Toxicological Classification	Tipo	MAV μg L^{-1} (Brazil)	MAV μg L^{-1} (Europe)	Bra/Eur
2,4 D + 2,4,5 T	5	her	30	0.1	300
Alachlor	5	her	20	0.1	200
Aldicarb	1	ins, aca e nem	12	0.1	120
Aldrin + Dieldrin	1	Ins	0.03	0.1	0,3
Atrazine	3	her	2	0.1	20
Carbendazim + Benomyl	5	fun	120	0.1	1200
Carbofuran	1	Ins	7	0.1	70
Chlordane	1	Ins	0.2	0.1	2
Chlorpyrifos + Chlorpyrifos-oxon	3	Ins	30	0.1	300
DDT + DDD + DDE	1	Ins	1	0.1	10
Diuron	4	her	90	0.1	900
Endosulfan (α, β, and salts)	2	Ins	20	0.1	200
Endrin	1	Ins, roe	0.6	0.1	6
Glyphosate + AMPA	4	her	500	0.1	5000
Lindane (gamma HCH)	1	Ins	2	0.1	20
Mancozeb	5	fun	180	0.1	1800
Methamidophos	2	Ins	12	0.1	120
Metolachlor	4	her	10	0.1	100
Molinate	2	her	6,0	0.1	60
Methyl Parathion	1	Ins, aca	9	0.1	90
Pendimethalin	5	her	20	0.1	200
Permethrin	1	Ins	20	0.1	200
Profenofos	1	Ins	60	0.1	600
Simazine	5	her	2	0.1	20
Tebuconazole	3	fun	180	0.1	1800
Terbufos	2	Ins	1,2	0.1	12
Trifluralin	2	her	20	0.1	200

*MAV = Maximum allowed value, INS = Insecticide, HER = Herbicide, ACA = Acaricide, NEM = Nematicide, FUN = Fungicide, RAT = Rodenticide.

The toxicological classification of pesticides is done by categorizing the products according to their acute toxicity, considering the damage that occurs immediately after contact (Table 2). Classes I and II are considered extremely and highly toxic, meaning that the products can lead to death if ingested or come into contact with skin and eyes.

Pesticides that can cause intoxication without risk of death are classified as "moderately toxic," "low toxic," and finally the last classification of "unlikely to cause acute damage" comprise the new approved classification (ANVISA, 2024).

Table 2. Toxicological classification of pesticides found in the state of Sergipe.

Class	Degree	Band Color
I	Extremely Toxic Product	Red
II	Highly Toxic Product	Red
III	Moderately Toxic Product	Yellow
IV	Slightly Toxic Product	Blue
V	Unlikely to Cause Acute Harm	Blue
VI	Not Classified	Green

2.4. Statistical analysis

A non-parametric test was performed without significant results due to the data heterogeneity and insufficient number of observations. Thus, descriptive analyses were performed for the variables through calculations of absolute frequencies (N) and relative (%), as well as the number of times in which the maximum allowed values (MAV), established by Brazilian and European legislation, were exceeded. The graphical representations were generated using the ggplot2 package and basic functions of the R language (R Core Team, 2024), while the geographic maps were obtained using the geobr package (Pereira *et al.*, 2018). The statistical analysis of the data was performed using box plot diagrams. To accommodate the variation in the definitions of maximum permissible values (MAV) established by different legislations, the scales of the graphs were adjusted to accommodate this variation.

3. RESULTS AND DISCUSSION

3.1. Temporal trends in pesticide contamination.

In Sergipe, 621 water samples contaminated by pesticides were reported between 2014 and 2022, with up to 27 active ingredients identified per sample, totaling 1792 AI (Table 3). Monitoring of water intended for human consumption detected the presence of pesticides in 45 municipalities, according to data compiled by DESO water treatment plants (WTP) (Figure 1). This indicates that 60% of the monitored municipalities' water samples analyzed contained pesticide residues with VN, QL, or DL.

Table 3. Number of samples and presence of pesticides in the state of Sergipe from 2014 to 2022, along with MRLs (Maximum Residue Limits) according to Brazilian and European legislation.

Sergipe	No. Samples	Presence of Pesticide	Pesticides above MRL (Brazil)		Pesticides above MRL (Europe)	
			No.	%	No.	%
2014	25	113	9	8.0%	90	80%
2015	56	334	23	6.9%	273	82%
2016	29	156	13	8.3%	129	83%
2017	98	225	21	9.3%	181	80%
2018	80	356	34	9.6%	326	92%
2019	105	405	44	10.9%	32	8%
2020	102	44	2	4.5%	32	73%
2021	71	156	12	7.7%	118	76%
2022	55	3	0	0.0%	0	0%
Total	**621**	**1792**	**158**	**8.8%**	**1441**	**80%**

Note: Up to 27 different active ingredients can be identified in each sample.
Source: Brasil (2022).

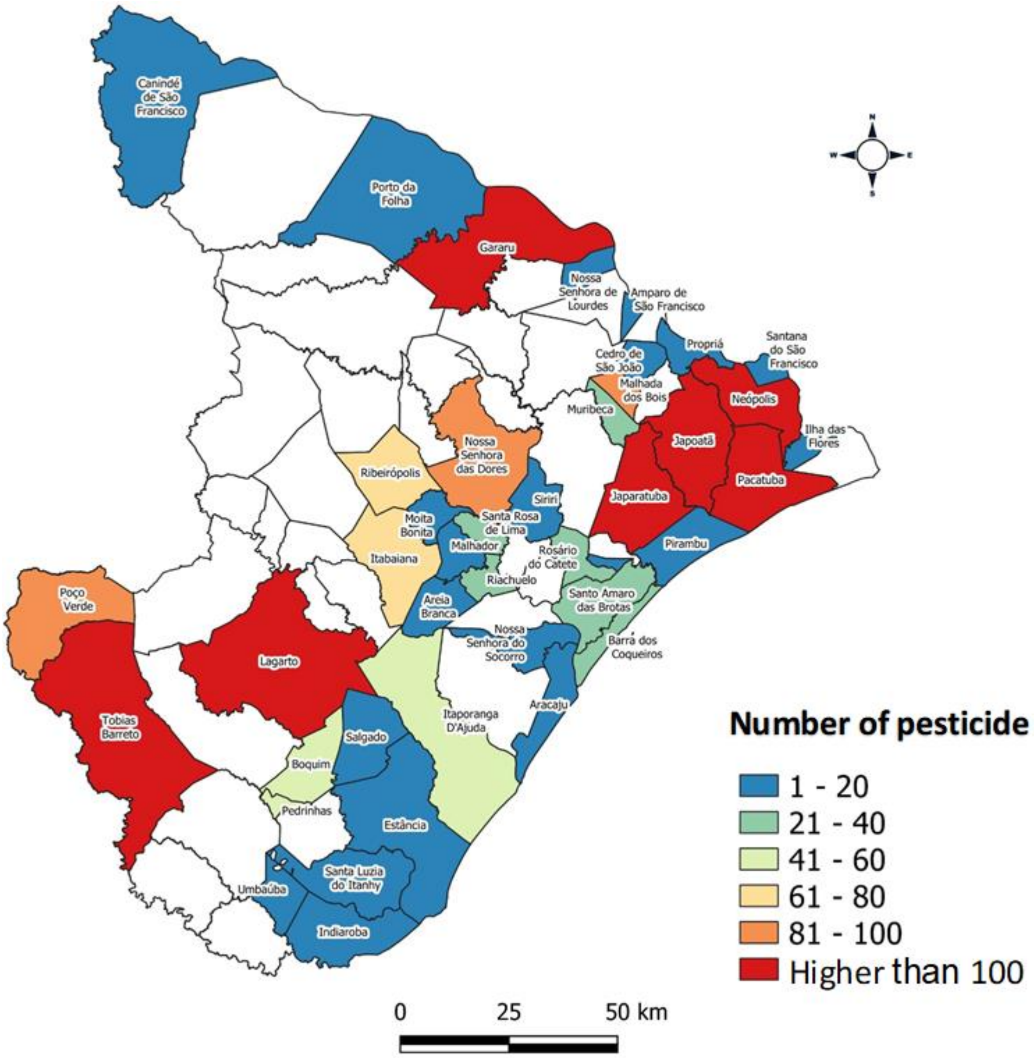

Figure 1. Map of Sergipe with the Number of Pesticides Found by Municipality from 2014 to 2022.

The water quality monitoring period in the municipalities of Sergipe registered in SISAGUA (2024) was characterized by fluctuations in the number of samples recorded, with a yearly average of 69 samples and approximately 200 annual contamination points in 9 years. This condition demonstrates irregularity in the control and monitoring of the quality of water intended for human consumption by the company providing water supply and sanitation services, which must carry out physical, chemical, and pesticide analyses with frequency and number of samples compatible with the sampling point, the population supplied and the type of source (Brasil, 2021; CONAMA, 2005).

Both the human consumption system (HCS) and the water supply system (WSS) of the States must promote annual monitoring of pesticide residues to analyze the level of contamination of water sources. The methodology must guarantee water quality control with a minimum number of samples, sampling frequency, and analysis of results compared with the MAV of existing legislation, thus having a monitoring history for pesticides (Brasil, 2021).

Irregular control and monitoring of water quality for public supply occur not only in Sergipe. Research carried out in Rio de Janeiro between 2015 and 2019 identified that the majority of municipalities did not carry out analyses or did not enter data into the Water Quality Surveillance Information System for Human Consumption (SISAGUA), totaling approximately 73% of municipalities without recorded information (Bastos *et al.*, 2022).

Of the total samples from Sergipe registered in SISAGUA, 2019 and 2020 stood out for the highest number of pesticide registrations, with 105 (17%) and 102 (16%), respectively. Furthermore, it was in 2019 that the greatest contamination of water was recorded in Sergipe, with 405 pesticides identified; however, the years 2015 (56 collections) and 2018 (80 collections), which had comparatively a smaller number of samples analyzed, resulted in more than 300 IA in each sampling unit (Table 3).

Water contamination by pesticides in Sergipe reflects the intense use of pesticides and the expansion of agriculture, which grew 35.6% in 2020 compared to 2019 and ensured that the three main crops of the 2020 harvest were corn with 52.6%, followed by oranges with 12% of production and sugar cane with 10.5%. The production follows the consumption of pesticides, and the State reached 461,280 kg in 2022 according to the marketing reports of the Sergipe Agricultural Development Company (EMDAGRO, 2023).

Growth in the commercialization of pesticides has been occurring in Brazil in recent years due to the great availability of active ingredients and agricultural expansion (IBAMA, 2023). An ecological time series study from 2000 to 2014 confirmed this trend in all regions of the country, with the highest record in the Southeast (4.88 kg ha^{-1} $year^{-1}$) and the greatest increase in the North and Northeast regions (Ribeiro *et al.*, 2022).

3.2. Spatial distribution of contamination.

Pesticide contamination in WTPs was identified in more than 40 municipalities in Sergipe. The spatial distribution of contaminated areas considered the frequency of AI identified in the samples on a color scale from 1 to more than 100 pesticides per municipal unit. A characteristic that strengthens the scenario of high and recurring contamination from 2014 to 2022 in these territories is the development of economic activities linked to agriculture and livestock (Figure 1).

Among these municipalities with the highest record of contamination, Neópolis, Pacatuba, and Japoatã belong to the Lower São Francisco region, whose previous studies in areas with rice and fish production have already identified contamination by pesticides. In the irrigated rice farming of Neópolis, chlorpyrifos, and the fungicides tetraconazole and tebuconazole were identified, which have the potential to be transported by sediments and water Britto *et al.* (2015), and analysis in tributaries of the São Francisco River and supply channels for fish farming indicated the presence of Deltamethrin, which causes physical and behavioral changes in fish (Dompieri *et al.*, 2020).

To compare the level of contamination of the group of 7 municipalities with the highest identification of pesticides, according to the red scale on the map, the non-parametric Kruskal-Wallis statistical test was performed using the Jamovi software (Jamovi, 2022). Descriptive statistics demonstrated an absence of normal distribution of the predictor variables (concentrations of 27 IA), verified by the Shapiro-Wilk test ($p<0.05$). The Kruskal-Wallis test result showed that there was no statistically significant difference in contamination between the municipalities with the highest presence of pesticides in the water samples analyzed ($p>0.05$).

3.3. Comparison of Brazilian and European standards

The active ingredients identified in ETAs in Sergipe above the MAV (Brazil) represented a frequency of contaminated points of 4.5% to 10.9% (average of 8.8%); however, the comparison with the MAV (Europe) revealed a much higher percentage of contamination, ranging from 73% to 92% (average of 80%) (Table 3).

When analyzing the relative concentration of pesticides in water samples, it was observed that some compounds significantly exceeded the established quantities when compared to water quality legislation. Concerning Brazilian legislation, the pesticides "DDT+DDD+DDE" and "Aldrin + Dieldrin" had values 3.6 times and 1.0 (one) times above the MAV, respectively.

According to the European legislation, most of the pesticides found presented values above the established limits, with emphasis on 2,4D + 2,4,5T, Chlorpyrifos, Carbendazin, Glyphosate, Manconzeb, Methamidophos, Profenophos and Tebuconazole, whose values were between 35 and 92 times above the maximum permitted concentration (Figure 2).

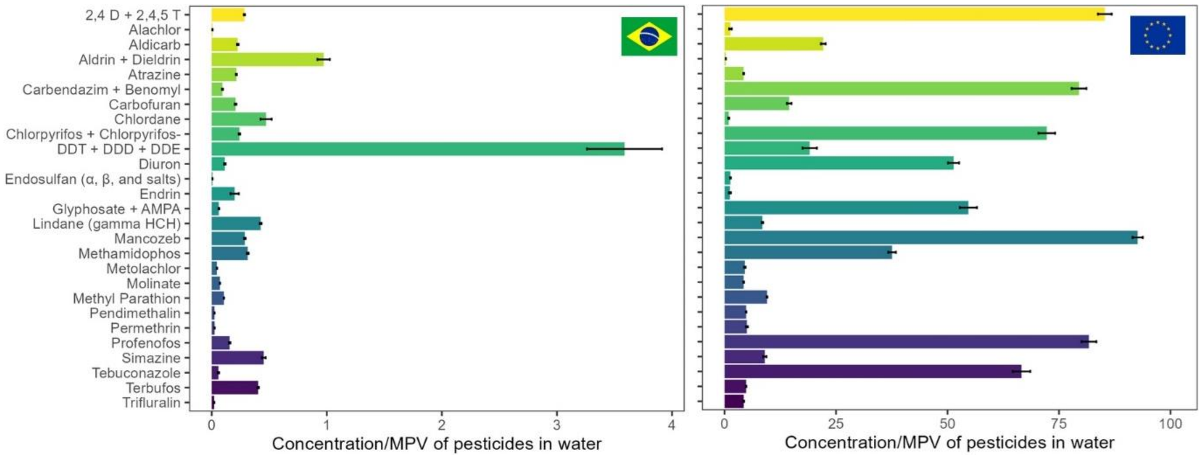

Figure 2. Relationship between concentration and maximum permissible value for different pesticides following Brazilian legislation (scale 0 to 4x) and European legislation (scale 0 to 100x).

This result confirms that most pesticides identified in water in Brazil are below the maximum permitted by Brazilian legislation, which has extremely high maximum allowed values, and above the European legislation, which establishes a stricter and single limit for pesticides in drinking water, set at 0.1 μg.L-1. An example of this discrepancy is glyphosate, which has a VPM/BR of 500 $\mu g.L^{-1}$ and exceeds the MAV/Europe by 5000 times (Table 1).

The fluctuations in the number of samples and identification of contaminants in Sergipe's WTPs in the years 2015 and the period from 2017 to 2019, as well as the percentages exceeded by the MAV (Brazil) and MAV (Europe), show a worrying panorama in the quality of water intended for human consumption (Table 3). Pesticide identification is necessary to assess the impacts on water resources, but monitoring and analysis actions are challenging due to the high number of AIs. Monitoring and analysis actions are made difficult by the high number of active ingredients used in agriculture and the costs related to their identification (Narenderan *et al.*, 2020).

3.4. Toxicological classes and repercussions of pesticides

The toxicological classification of pesticides groups the products into five categories, which warn of the risks and possible damage related to contact and ingestion (Table 2). Toxicity is an inherent characteristic of pesticides, whose effects arise from the agricultural production method, labor relations, chemical substance(s), and precarious health surveillance mechanisms.

The analysis of the monitoring results from 2014 to 2022, considering the toxicological classifications and calculating the relationship between the concentration of pesticides and the MAV of Brazil and Europe, identified contamination points for Class I, II, and III insecticides; Class IV and V herbicides and Class III and V fungicides (Figure 3).

It is worth noting that Class I insecticides presented concentrations up to 4 times above the MAV (Brazil), although when comparing these active ingredients with European legislation, the discrepant values in the data set involved Classes I, II, and III and reached values up to 100 times the maximum permitted. In the concentrations of Class IV and V herbicides, there was little variability in the results for the Brazilian MAV since the acceptable percentages for this chemical group are high and can reach up to 500μg L^{-1}, depending on the type of active ingredient. The fungicides of Classes III and V had similar behavior to the other chemical groups concerning the MAV (Brazil) but exceeded the maximum concentrations permitted in

Europe (Figure 4).

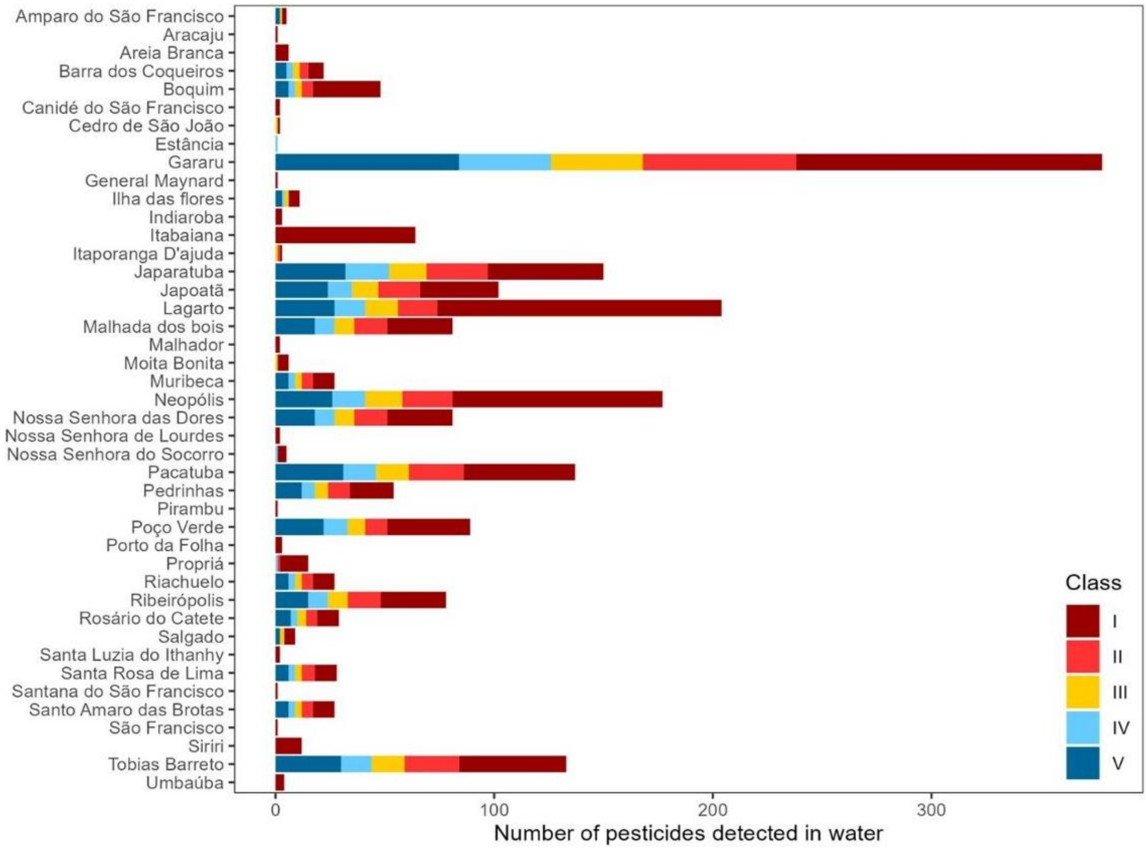

Figure 3. Toxicological Classification of Pesticides by Municipality in Sergipe from 2014 to 2022.

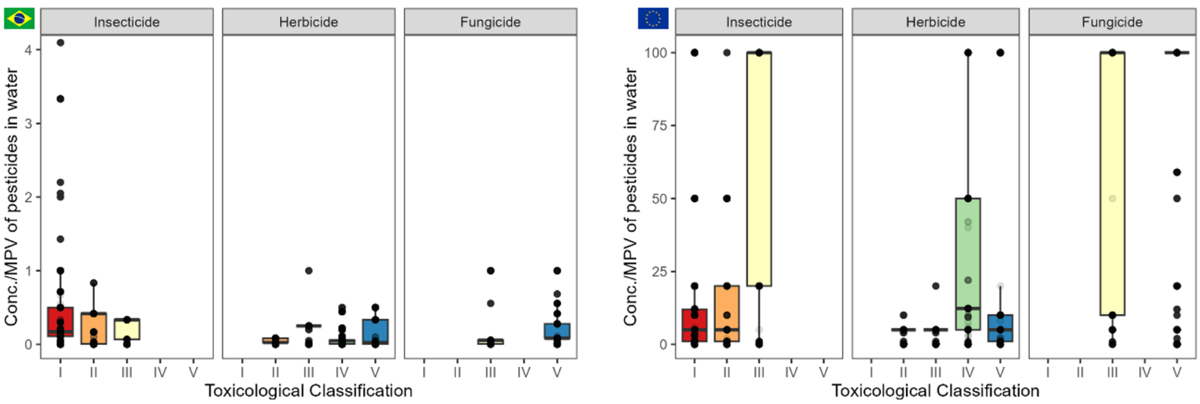

Figure 4. Relationship Between Concentration and Maximum Permissible Value for Different Classes of Pesticides According to Brazilian (0 to 4x scale) and European (0 to 100x scale) Legislation.

Unsafe exposure to pesticides for agricultural and domestic use can cause different symptoms depending on the time of exposure and the amount of absorption of the products, with nausea and dizziness being immediate conditions that characterize a case of exogenous poisoning, which in 2019 resulted in 7,309 records in Brazil (FIOCRUZ, 2019).

Rural workers represent a population that is highly vulnerable to the toxic effects of pesticides due to direct contact with different types of AI. Prolonged exposure to multiple pesticides due to work, unsafe product handling practices due to incorrect use of PPE, in addition to failure to respect re-entry and waiting periods for reapplication and harvesting can result in acute and chronic symptoms (Petarli *et al.*, 2019).

Young family farmers exposed to multiple active ingredients and who worked without technical and personal safety conditions had a high prevalence of acute and mental health symptoms, such as headaches, mucosal irritation, tachycardia, and depressive signs, according to (Buralli *et al.*, 2020).

Analyzing the municipalities with the highest contamination, all toxicological classes were found, with an emphasis on the most toxic products (Figure 3). In addition, it was found that agricultural activities are part of the economy of municipalities with high levels of pesticides. In Gararu, in the outback of Sergipe, where corn and bean crops predominate, 210 contaminated spots were identified, and more than 300 pesticides, mainly Class I, were identified. In the municipality of Lagarto, 148 contamination points were listed, with emphasis on cassava and orange production, and at Neópolis, which produces sugar cane and coconut, there were 119 spots contaminated by pesticides (EMDAGRO, 2023).

Still, on the distribution of contamination in the ETAs of Sergipe, the municipalities of Nossa Senhora das Dores and Itabaiana, members of the groups with the frequency of identification of pesticides between 61 - 80 and 81 - 100 respectively, (Figure 1), led the commercialization of pesticides between 2020 and 2022 in Sergipe, demonstrating that high consumption can be reflected in environmental contamination (EMDAGRO, 2023).

Among the most sold pesticides in Sergipe in the period between 2020-2022, Glyphosate (Herbicide), Cypermethrin (Insecticide), and Atrazine (Herbicide) stood out with more than 40% of sales, being classified in toxicological Classes IV, IV, and III respectively. Numerous studies show that the increasing consumption of herbicides, fungicides, and insecticides means that these substances can accumulate in the environment, especially in aquatic systems and reservoirs used for drinking water production (Mas *et al.*, 2020; Caldas *et al.*, 2019).

Once in the environment, pesticides can reach the human body through daily ingestion of contaminated food and drinking water. Water quality analyses carried out in municipalities in Rio Grande do Sul (RS) found pesticide residues in untreated water even after conventional treatment (Kronbauer *et al.*, 2021; Lucas *et al.*, 2020). In two drinking water treatment plants in Campinas (São Paulo, Brazil), there was also no removal of pesticide residues with the same type of treatment for drinking water Vizioli *et al.* (2023), contaminants that, if they persist in the water, can be ingested daily, exposing the health of the population. Environmental and dietary exposures can harm humans, as pesticides are associated with the development of neurodegenerative diseases, respiratory pathologies, metabolic disorders, reproductive dysfunctions and cancer (Vellingiri *et al.*, 2022; Fucic *et al.*, 2021; Zhang *et al.*, 2019).

4. CONCLUSION

This study provides important information about the significant presence of pesticides in supply water in various municipalities of Sergipe, highlighting the need for greater attention and control in this area.

The results revealed that 60% of the municipalities in Sergipe were monitored for pesticides through ETAs, and among these, almost half presented contaminated samples, representing a risk to the population's health. Furthermore, it was found that positive samples were mainly concentrated in the water distribution and treatment sectors.

It is concerning to observe the irregularity in conducting analyses and entering data into SISAGUA. This failure compromises the effectiveness of monitoring and taking appropriate preventive measures. The low frequency of sampling in certain years and the lack of data entered into the system by municipalities are alarming issues, as the legislation establishes clear guidelines for water quality control, but its effective implementation and enforcement are still challenges to be faced.

The results indicated a predominance of the insecticides Endosulfan, Profenofos, Methamidophos, and Methyl Parathion, classified as highly toxic and harmful to human health, with the last two being banned by ANVISA from being marketed in Brazil. The concentrations of herbicides Classes IV and V found in the ETAs showed little variability in the results for the Brazilian MAV, as the acceptable percentages for this chemical group are high and can reach up to 500µg/L, depending on the type of active ingredient. While the fungicides of Classes III and V had similar behavior to other chemical groups concerning the Brazilian MAV, they exceeded the maximum permissible concentrations in Europe.

When comparing the maximum permissible values (MAV) between Brazil and Europe, it is evident that the effects of pesticides on the ecosystem can be significantly different considering the high MAV value for some substances established in Brazil, in contrast to the value established in Europe set at 01µg/L, which contributes to a contradictory idea of a low level of environmental contamination. It is worth noting that the main active ingredients that exceeded the Brazilian MAV the most were DDT+DDD+DDE and Aldrin + Dieldrin, while for the European MAV, Mancozeb, 24 D + 245 T, and Profenofos stood out. The presence of pesticides in the water in the treatment and distribution sector raises an alert about the conventional treatment process that does not filter these contaminants.

Given this finding, consumers should use more technological systems that can ensure the reduction or elimination of these pollutants, even without real guarantees. It would be recommended that public policies encourage the development of residential equipment that can use studies developed in the laboratory among the existing treatment methods: reverse osmosis, activated carbon, ion exchange resins, ultraviolet radiation, membrane filters, or a combination of these methods so that the final consumer can have guarantees regarding water decontamination.

Finally, the data found for pesticides in the SISAGUA information system of Sergipe could be extracted, cataloged, and analyzed, providing a statistical treatment comparing them with existing legislation and MAV, classifying them according to their toxicity, and thus characterizing the possible effects on the environment and harmfulness to humans. Given this scenario, it is essential that the competent authorities strengthen the inspection and regulation of water quality standards, as well as the implementation of effective measures to reduce the presence of pesticides in water sources.

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