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Research article

Comparison of the drinking water standard for pesticides of the Brazil with other countries

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A R T I C L E I N F O

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A B S T R A C T

The objective was to compare the types and concentrations of pesticides allowed in the water potability standard for human supply in Brazil with other countries considered to be the largest consumers of pesticides in dollars invested in purchase/trade. This is a descriptive and documentary study, with data collection in regulations available in official government websites in Brazil, USA, China, Japan, France, Germany, Canada, Argentina, India, Italy, and World Health Organization (WHO). Since Germany, France and Italy are part of the European Union (EU), the legislative resolution of the European Parliament was adopted. Pesticides number and maximum permitted values (MPV) differ between the countries and WHO. In the Brazilian ordinance there are forty pesticides, a number like the USA, Canada, China, and WHO, but that represents only 8% of the total pesticides registered for agricultural use in Brazil. When comparing the ordinance of Brazil with EU the values are only the same for Aldrin + Dieldrin. For other, amounts between 2 and 5000 times more are allowed in Brazil. Brazilian regulations do not establish a total value for the mixture of pesticides in water, only individual limits, which together can reach 1677.13 μg/L, while in EU standards it is only 0.5 μg/L. The study showed discrepancies of the pesticides allowed in water potability standard of the Brazil with other countries, but features 12 pesticides with the same concentrations as WHO guidelines, thus, a worldwide standardization in water potability regulations is necessary to promote health and reducing risk of exposure.

1. Introduction

Countless contaminants generated by anthropogenic activities reach surface and ground waters, which has compromised water quality and caused adverse effects on population health. Among the contaminants of aquatic ecosystems, pesticides for agricultural use stand out [1].

In 2018, approximately 4.1 million tons of pesticides were used in the world, which represented an increase of 33.4% in the last 20 years [2]. Among the countries that consume the most pesticides in terms of dollars invested in purchases and trade are Brazil, in first place since 2008, followed by the United States, China, Japan, France, Germany, Canada, Argentina, India, and Italy [3–5]. Currently, the United States and the European Commission list about 500 active ingredients approved for use in the country, covering 18 classes of pesticides, the main ones being herbicides, insecticides, and fungicides [6]. In Brazil until 2021, there were 499 registered active ingredients [7] and in 2020 a total of 493 formulated products were registered, with 10 new active ingredients [8]. In 2019 alone, 620, 537.98 tons of pesticide active ingredients were sold in Brazil, and glyphosate and its salts were the most sold, surpassing 217,000

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tons/year, followed by 2,4-D (52 thousand tons/year) and mancozeb (49 thousand tons/year) [9].

When pesticide is applied even following good agricultural practices a part may still be dispersed in the atmosphere and have the ability to infiltrate into the soil, surface waters, groundwater and aquifers, what can contaminate the water for human use with pesticides [3,10–15].

High concentrations of herbicide, fungicide, and insecticide have been quantified in surface and groundwater worldwide [14, 16–18]. A study carried out between 2012 and 2019 in various parts of the world showed high concentrations in surface water of the herbicide diuron, the insecticide dimethoate, and the fungicide carbendazim [14]. The study by Pietrzak et al. [19] found that the insecticides (imidacloprid, acetamiprid and thiamethoxam) were the most frequently found in surface water, groundwater, and in effluents from sewage treatment plants, and are associated with their widespread use in agriculture in 21 countries.

In watersheds in Asian countries, where rice cultivation is common, the presence of pesticides has been observed in human drinking water [20] and water resources in China [21–23], and in northern India [24,25]. Water contamination by pesticides is also a problem in European countries, and have been found in Germany [26], France [17, [27], [28],18], and Italy [29,30].

Studies have also registered pesticides in drinking water in countries in North and South America, such as the USA [31], Argentina [32,33] and Brazil [16,32,34–37].

Prolonged exposure to pesticides, even at low doses, can cause negative effects on human health, such as depression [12], it can cause endocrine and oxidative dysfunction, kidney disease, stress, problems in the immune and neurological systems, chromosomal alterations, among other effects that can be more serious in pregnant women and children [14,38], it can damage human DNA by influencing the immune system [39], and increase the risk of developing diabetes mellitus type 2 [25,40].

The World Health Organization (WHO) and each country establish recommendations and guidelines on the minimum water quality parameters (including maximum allowed value of the pesticides) for the consumption of its human population, based on advances in technical-scientific knowledge and international experiences [41–48]. The WHO guidelines have a list of pesticides with values considered acceptable in human drinking water [48]. In addition, improving water quality by reducing pollution, through the elimination of sewage discharge and reduction in pesticides and hazardous materials is among the 17 Sustainable Development goals of the UN 2030 Agenda [49]. Despite the prerogatives in national and international legislation, the excessive use of pesticides in agriculture is a concern, as it is a risk factor to human, animal, and environmental health in its different compartments such as soil, air, and water [3,50]. Thus, this study objective was to compare the types and concentrations of pesticides allowed in the water potability standards for human supply in Brazil with other countries considered to be the largest consumers of pesticides in dollars invested in purchase/trade.

2. Material and methods

This is a descriptive study using documents. We use a quantitative approach, where data were collected on the active ingredients of pesticides found in the regulations of drinking water for human consumption in countries that consume the most pesticides in terms of the value invested in the commerce of these chemicals. Thus, Brazil, United States, China, Japan, France, Germany, Canada, Argentina, India, and Italy were selected for this study [3–5].

For the inclusion of the 10 countries in the study, the following criteria were used: countries that have laws/ordinances for regulating the potability of water for human consumption, with official documents published on the internet for free and with free access.

From August 2019 to December 2020, using the internet, we found government ordinances and official documents that regulate the potability of water for human consumption. For this, we used the descriptors "drinking water and ordinance" followed by the name of the country.

Laws, ordinances, and guidelines that regulate the potability of water for human consumption were found on government websites

Table 1
Ordinance on water potability in countries that consume the most (in value invested in trade) pesticides in the world.

Ranking in the use of pesticides	Countries	Current Ordinance	Year of Publication	Author
1	Brazil	Ordinance no. 888	2021	BRASIL, 2021
2	USA	National Primary Drinking Water Regulations	2009	USEPA, 2009
3	China	National Drinking Water Quality Standard of the People's Republic of China GB 5749	2006	CHINA, 2006
4	Japan	Ministry Ordinance on Water Quality Standards	2003	JAPAN, 2003
5	France	European Parliament Legislative Resolution	2019	UE, 2020
6	Germany	European Parliament Legislative Resolution	2019	UE, 2020
7	Canada	Guidelines for Drinking Water Quality in Canada	2020	CANADA, 2020
8	Argentina	Joint Resolution SRYGR and SAB No. 34/2019	2019	ARGENTINA, 2019
9	India	Indian Standard Drinking Water - Specification (Second revision)	2012	INDIA, 2012
10	Italy	European Parliament Legislative Resolution	2019	UE, 2020
11	WHO	Guidelines for Drinking Water Quality - 4th ed.	2011	WHO, 2011

Source: Prepared by the authors.

(ministry/department of health and environment) of the selected countries and the World Health Organization (Table 1), which are the primary sources of data. Among them, Germany, France, and Italy are part of the European Union and have a single legislation that guides the minimum quality parameters of water for human consumption, with some specifications belonging to each country (Table 1).

Subsequently, information was extracted from official documents regarding the year of publication and validity of regulatory documents, number of active ingredients included in the legislation, and the maximum permitted value/concentrations (MPV) of the pesticides, among other variables.

Among the official documents, the Japanese ordinance was the only one that did not have an English version, so the online tool Google Translate was used to translate the documents into English.

After surveying the regulatory documents on water potability, the data on the active ingredients of pesticides were tabulated and organized in a spreadsheet in the Microsoft Excel Program. The results were presented in figures and tables.

3. Results

When comparing the number of pesticides in the documents on the potability of water for human consumption, we observed that the number of active ingredients differed between the countries and in relation regulations established by the World Health Organization (WHO) (Fig. 1). Germany, France, and Italy are part of the European Union, thus the European Parliament Legislative Resolution for the three countries was adopted in this study. This resolution establishes maximum values allowed for organic pesticides and total pesticide values, not naming the respective active ingredients, except for aldrin, dieldrin, heptachlor epoxide, and heptachlor, as a result, it was not possible to make some comparisons regarding the number of pesticides listed in the EU with the other countries (Fig. 1).

Japan is the country that lists the highest number of pesticides (114) that must be monitored in the drinking water distributed to the population, and the lowest number of pesticides are found in the potability standards of India (18 active ingredients) and Argentina (19) (Fig. 1). In addition, Brazil lists 40 pesticides in the standards of potability of water for human consumption, the USA 38, Canada 36, China 34, and the WHO lists 31 pesticides (Fig. 1).

When comparing pesticides established in the WHO standards and in the countries studied, we found that Brazil, with a new water potability ordinance in place since 2021, is the country that has the largest number of pesticides in common with the WHO, totaling 12 (Table 2), followed by the USA and Japan with 10 pesticides. It is not possible to make comparisons to the European Union (Germany, France, and Italy), since there is no list of active ingredients; however, they have established maximum values for organic pesticides and for the total amount of pesticides.

Among the advances of the current ordinance in Brazil is the increase from 27 to 40 pesticides that must be evaluated by water supply companies, the reduction of the maximum permitted values of diuron from 90 μg/l to 20 μg/oil, the change of mancozeb (180 μg/l) to mancozeb + ETU (8 μg/l), and methamidophos (12 μg/l) to methamidophos + acephate (7 μg/l).

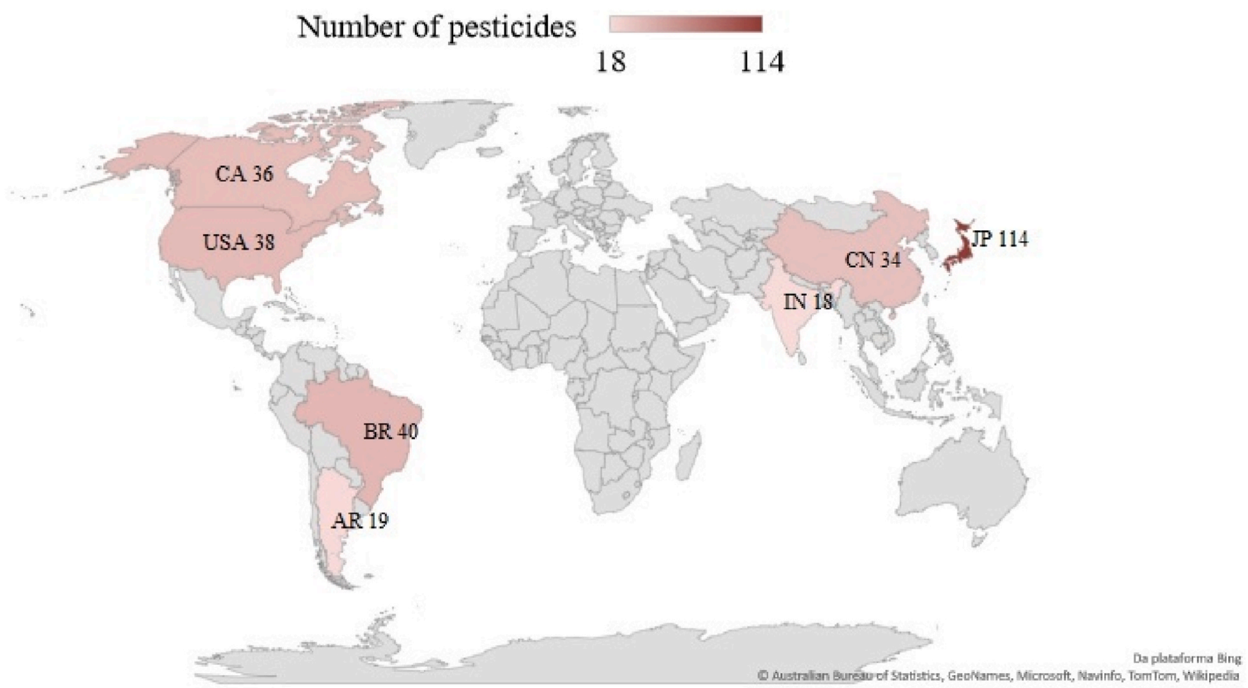

Fig. 1. Number of pesticides present in the drinking water ordinances of the countries that consume most pesticides.

Table 2
Maximum Permitted Values (MPV) of Pesticide Active Ingredients (μg/L) in drinking water in selected countries.

Active Ingredients	Brazil	WHO	Argentina	Canada	China	USA	India	Japan	Germany, France e Italy (EU)[a]
2,4 D	30	30	100	100	30	70	30	20	
Alachlor	20	20				2	20	30	
Aldicarb+ Aldicarbesulfone+ Aldicarbesulfoxide	10								
Aldrin									0.03
Aldrin + Dieldrin	0.03	0.03	0.03				0.03		
Ametrine	60								
Atrazine				5	2	3	2	10	
Atrazine + chloro-S-triazine	2	100							
Carbendazim	120								
Carbofuran	7	7		90	7	40		5	
Cyproconazole	30								
Chlordane	0.2	0.2	0,3			2			
Chlorothalonil	45				10			50	
Chlorpyrifos + chlorpyrifos-oxon	30								
DDT			1		1		1		
DDT + DDD + DDE	1								
Difenoconazole	30								
Dimethoate + omethoate	1.2								
Diuron	20			150				20	
Epoxiconazole	60								
Fipronil	1.2							0.5	
Flutriafol	30								
Glyphosate + AMPA	500								
Glyphosate				280	700	700		2000	
Hydroxy-Atrazine	120	200							
Lindane	2	2	3		2	0.2	2		
Malathion	60		35	190	250		190	700	
Mancozeb + ETU	8								
Methamidophos + acephate	7								
Metolachlor	10	10		50					
Metribuzim	25			80				30	
Molinate	6	6						5	
Paraquate	13			7				5	
Picloram	60			190		500			
Profenophos	0.3								
Propargito	30								
Prothioconazole + ProticonazoleDestio	3								
Simazine	2	2		10		4		3	
Tebuconazole	180								
Terbufos	1.2			1					
Thiamethoxam	36								
Thiodicarb	90							80	
Tiram	6							20	
Trifluralin	20	20		45				60	

[a] The European Union adopted 0.1 μg/l for organic pesticides and 0.5 μg/l for total pesticide values.
Source: Prepared by the authors.

Of the 12 pesticides in the Brazilian ordinance in common with those recommended in the WHO guidelines for water quality for human consumption, all pesticides have the same maximum permitted values (MPV), except for atrazine + chloro-S-triazine metabolites and hydroxy-atrazine, which Brazil set a value 50 times lower than the WHO (Table 2).

Brazil and Argentina only have five pesticides in common listed in the drinking water standards for human consumption, they are: 2,4-D, aldrin + dieldrin, chlordane, lindane, and malathion (Table 2). Aldrin + dieldrin (0.03 μg/L) are the only pesticides with the same maximum permitted value (MPV) in drinking water in both countries. Argentina has established MPV for 2,4-D (100 μg/L), chlordane (0.3 μg/L), and lindane (3 μg/L) that are higher than those recommended by the WHO and the values adopted in the Brazilian ordinance. The malathion MPV in Brazil (60 μg/L) is higher than that established by Argentinian regulations (35 μg/L).

Brazil and Canada have 11 pesticides in common in the standards of drinking water for human consumption, namely: 2,4-D, carbofuran, diuron, malathion, metolachlor, metribuzin, paraquat, picloram, simazine, terbufos, and trifluralin (Table 2). However, the two countries do not have the same MPV for these pesticides. The Canadian guideline has higher maximum permitted values than those established by the Brazilian ordinance (Table 2). Only the pesticides paraquat and terbufos have higher MPV in the Brazilian ordinance than the Canadian guideline.

The drinking water standards in Brazil and China have only five pesticides in common, they are: 2,4-D, carbofuran, chlorothalonil, lindane, and malathion (Table 2). For the pesticides chlorothalonil and malathion, different MPV are adopted in drinking water in these countries.

The USA and Brazil have only seven pesticides in common in their standards of drinking water for human consumption, they are: 2,4-D, alachlor, carbofuran, chlordane, lindane, picloram, and simazine (Table 2). The MPV of these pesticides differ in the standards between the USA and Brazil, where the MPV of alachlor and lindane are higher in Brazil (Table 2). On the other hand, the US standards for 2,4-D pesticides, carbofuran, chlordane, and simazine have a higher MPV than that established by the WHO and by the current ordinance in Brazil. Regarding picloram, which is not included in the WHO guidelines, the USA and Brazil have a MPV of 500 μg/L and 60 μg/L, respectively.

Brazil and India have five pesticides in common in standards of drinking water for human consumption, they are: 2,4-D, alachlor, aldrin + dieldrin, lindane, and malathion (Table 2). Both countries have the same MPV for these pesticides, except for malathion, where 190 μg/L (VMP) is allowed in India, while 60 μg/L (VMP) is allowed in Brazil.

Japan and Brazil regulate 14 pesticides in common in standards of drinking water for human consumption, they are: 2,4-D, alachlor, carbofuran, chlorothalonil, diuron, fipronil, malathion, metribuzin, molinate, paraquat, simazine, thiodicarb, thiram, and trifluralin (Table 2). The two countries do not have the same MPV for these pesticides. The MPV in Japan are higher when compared to the Brazilian ordinance, with the exception of the pesticides 2,4-D, carbofuran, fipronil, molinate, paraquat, and thiodicarb (Table 2). The pesticide diuron (20 μg/L) has the same MPV established in the standards of drinking water for human consumption in Japan and Brazil.

The European Parliament Legislative Resolution establishes that the maximum limit for any pesticide is 0.1 μg/L. In addition, it establishes that the sum total of pesticides in water does not exceed 0.5 μg/L, and in the case of aldrin, dieldrin, heptachlor, and heptachlor epoxide the value is 0.03 μg/L. In Brazil, the MPV of pesticides in water varies between 0.03 μg/L and 500 μg/L. Aldrin + Dieldrin are the only pesticides with the same values as the EU, for other active ingredients amounts between 2 and 5000 times more are allowed in the water consumed by Brazilians. Table 3 shows the MPV values of the Brazilian Drinking Ordinance and those for pesticides monitored in drinking water in the countries in the European Union.

Comparisons of the maximum permitted values (MPV) of the most common pesticides between the water potability standards of the

Table 3
Standards for the maximum permitted values of pesticides (μg/l) in the drinking water for human consumption in Brazil and the European Union.

Active Ingredients	Brazil	EU	Number of times more than Brazil
2,4 D	30	0.1	300
Alachlor	20	0.1	200
Aldicarb + Aldicarbsulfone + AldicarbSulfoxide	10	0.1	100
Aldrin + Dieldrin	0.03	0.03	0
Ametrine	60	0.1	600
Atrazine + chloro-S-triazine	2	0.1	20
Carbendazim	120	0.1	**1200**
Carbofuran	7	0.1	70
Cyproconazole	30	0.1	300
Chlordane	0.2	0.1	2
Chlorothalonil	45	0.1	450
Chlorpyrifos + chlorpyrifos-oxon	30	0.1	300
DDT + DDD + DDE	1	0.1	10
Difenoconazole	30	0.1	300
Dimethoate + omethoate	1.2	0.1	12
Diuron	20	0.1	200
Epoxiconazole	60	0.1	600
Fipronil	1.2	0.1	12
Flutriafol	30	0.1	300
Glyphosate + AMPA	500	0.1	**5000**
Hydroxy-Atrazine	120	0.1	**1200**
Lindane	2	0.1	20
Malathion	60	0.1	600
Mancozeb + ETU	8	0.1	80
Methamidophos + Acephate	7	0.1	70
Metolachlor	10	0.1	100
Metribuzim	25	0.1	250
Molinate	6	0.1	60
Paraquat	13	0.1	130
Picloram	60	0.1	600
Profenophos	0.3	0.1	3
Propargito	30	0.1	300
Prothioconazole + ProticonazoleDestio	3	0.1	30
Simazine	2	0.1	20
Tebuconazole	180	0.1	**1800**
Terbufos	1.2	0.1	12
Thiamethoxam	36	0.1	360
Thiodicarb	90	0.1	900
Tiram	6	0.1	60
Trifluralin	20	0.1	200

Source: Prepared by the authors.

studied countries and the WHO can be seen in Fig. 2. The highest MPV of glyphosate is allowed in the water potability standards of Japan (2000 μg/l), followed by China (700 μg/l), USA (700 μg/l), and Brazil (500 μg/l) (Fig. 2A).

The pesticide 2,4 D is included in all standards of drinking water for human consumption in the investigated countries and the WHO. However, the maximum permitted values are different between countries and WHO, with the highest values found in Argentina (100 μg/l) and Canada (100 μg/l), followed by the USA (70 μg/l) (Fig. 2B).

The highest MPV of the herbicide atrazine were found for Japan (10 μg/l) and Canada (5 μg/l) (Fig. 2C).

Other pesticides present in most standards of drinking water for human consumption in the countries analyzed are carbofuran, lindane, and malathion. Carbofuran is an insecticide found in the drinking water standards of Brazil, Canada, China, USA, Japan, and WHO, with the highest MPV in Canada (90 μg/l) and USA (40 μg/l) (Fig. 2 D). The insecticide lindane has much lower values in the US (0.2 μg/l) (Fig. 2 E). Regarding the malathion acaricide/insecticide, the highest MPV is found in Japan (700 μg/l) (Fig. 2 F). The standards of drinking water for human consumption in selected countries of the European Union have a MPV of active pesticide ingredients of 0.1 μg/L, that is, they are the lowest values observed among all the analyzed standards.

4. Discussion

The Brazilian ordinance for drinking water for human consumption was updated in 2021, increasing the monitored pesticides in

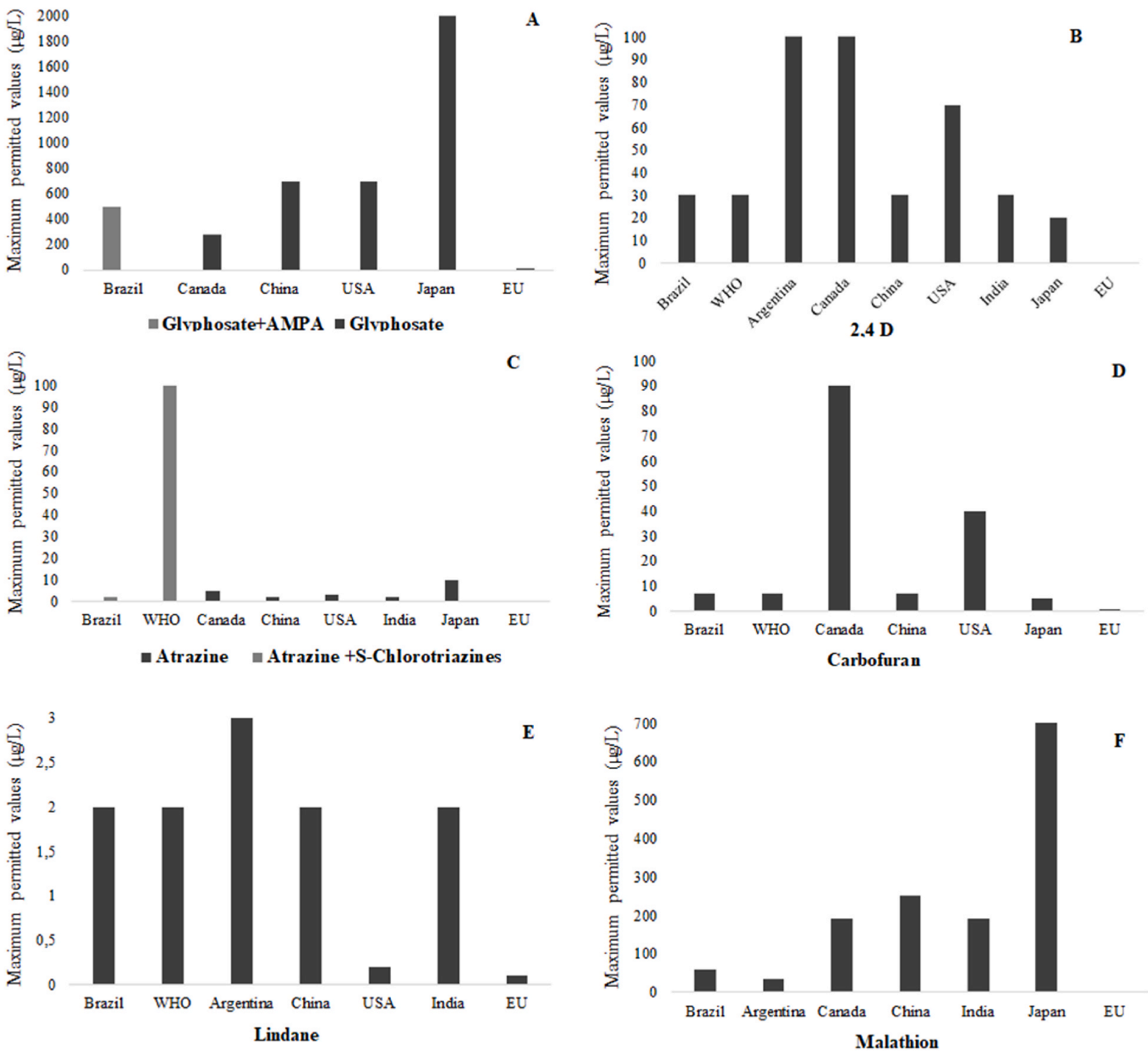

Fig. 2. Maximum permitted values of the main pesticides used in Brazil, which are present in the standards of drinking water for human consumption in the countries selected for the study and the World Health Organization.

drinking water from 27 to 40. Brazil had not made changes since the Ordinance n. 2.914/2011, because the Consolidation n. May 2017 kept the same pesticides and maximum permitted values from the 2011 ordinance. During these 10 years, the ordinance remained the same in terms of the number of monitored active ingredients; however, between 2011 and November 2021, 33 new active ingredients were registered for use in agricultural activities in Brazil [8].

The new ordinance requires water supply companies to monitor 19 new active ingredients; however, it omits the obligation to monitor the pesticides endosulfan, endrin, methyl parathion, pendimethalin, and permethrin, the latter two of which are still authorized for use in agricultural activities in Brazil, and the others have already been banned in the country. Despite the current ordinance's increase in number of monitored pesticides, which now monitors similar numbers of pesticides to those of the WHO, USA, Canada, and China, they represent only 8% of pesticides (499 active ingredients) registered for agricultural use in Brazil. In 2020 alone, there were a total of 493 registrations of new formulated products granted in the country, of which 10 are new active ingredients [8].

The pesticides methamidophos and paraquat, despite being banned by the National Health Surveillance Agency (ANVISA), remained in the current drinking water ordinance, since they are molecules that persist in the environment and can accumulate in soil and water. Methamidophos is associated with neurotoxic and immunotoxic diseases and causes toxicity on the endocrine, reproductive, and embryo-fetal system [3,51–53]. Paraquat has been banned from use due to scientific evidence regarding its mutagenic potential and Parkinson's disease [54–59]. The pesticides acephate, paraquat dichloride, and sulfur are not included in the current Brazilian ordinance for drinking water, despite being among the 10 most used pesticides in agricultural activities in Brazil. The pesticides, acephate and paraquat dichloride, were banned in the European Union in 2003 and 2009, respectively [60].

The comparisons showed that the maximum permitted values of pesticides differ greatly between the documents that regulate the drinking water standards of the analyzed countries and the WHO guidelines. In 2010, the researcher Neto, when comparing the values of pesticides in the Brazilian ordinance with other countries, found great variability in the criteria used to establish the maximum allowed value and the active ingredients included in drinking water potability standards [61]. For example, the values for pesticides established by the European Union Directive where the maximum allowed concentration is 0.10 μg/L for any pesticide (except for aldrin, dieldrin, heptachlor and heptachlor epoxide whose MPV is 0.03 μg/L) and that the sum of the concentrations of all pesticides detected in the water must have a maximum concentration of 0.50 μg/L was established due to the analytical detection limit available and due to the premise that these substances should not be present in the supply water public [61]. The Guidelines for Drinking-water Quality of the WHO play an overall significant role setting of parameters, limits, values, etc, for drinking-water quality, besides encourage countries and territories to set their own water-quality standards to ensure they are locally relevant. In report that summarized information from 104 countries and territories showed that many of the documentation received not includes a full explanation on why parameters are included and how are determined their values [62]. The Brazilian standard seems to follow WHO guidelines in part, as it contains 12 pesticides with the same concentrations. The Brazilian standard also mentions that the analytical methodologies for determining the parameters must comply with the most recent national or international standards, such as: United States Environmental Protection Agency (USEPA); Standards published by the International Standardization Organization (ISO); methodologies proposed by the WHO [42]. However, the Brazilian standard does not present in its content the theoretical bases that underlie the definition of pesticides included in standard and their maximum permitted value [61,63]. According to Barbosa et al. (2015) [63] defining a drinking water standard is not an easy task and in addition to scientific data it also includes economic, technological and political factors.

In order to reduce the population's prolonged exposure to pesticides in drinking water, it would be important to reduce the maximum permitted values allowed by current legislations, following the example of the EU, in addition to promoting more severe penalties for irregular use and marketing in agriculture [1,64], as well as promoting sustainable agriculture without depending on pesticides.

The Brazilian ordinance does not set a maximum permitted value for the total amount of pesticides in drinking water. Thus, when adding the values of the 40 pesticides in the ordinance, a total of 1677.13 (μg/L) of pesticides is legally allowed in the drinking water by Brazilians. In addition to the residues of other pesticides used in agricultural activities that may be present in the water and are not monitored.

The mixture of pesticides in water can be more toxic than individual compounds, both in drinking water for human consumption and in bodies of water, given that humans, in addition to consuming water contaminated by pesticides, can also consume aquatic animals [14]. When evaluating individual and synergistic toxic effects of pesticides performed with zebrafish and Nile tilapia, the researchers showed that there is a synergistic effect in the combination of pesticides [65,66]. From these synergistic mixtures, cholinesterase inhibitor insecticides (organophosphates), triazole fungicides, triazine herbicides, and pyrethroid insecticides, which are toxic and affect human health, have been detected in water [67]. The individual components of a mixture influence the toxicity of each other and the sum of the individual components compromises the metabolic and molecular processes of the individual pesticides, causing their biotransformation [67].

In the state of Santa Catarina, southern Brazil, the presence of various pesticides in public water supply for human consumption has been reported in 22 municipalities, including atrazine, simazine, bromopropylate, metalachlor, permethrin, propargite, propiconazole, which are banned in the European Union because they are considered harmful to human health [16,68]. However, all active ingredients were within the maximum permitted limits from the Consolidation n. May 2017 [16]. In the study carried out by Hess [16], seven different substances were registered in the water in the city of Rio do Sul, SC, and another 13 cities had more than one active ingredient simultaneously.

When comparing the maximum permitted values of pesticides in the Brazilian drinking water ordinance with the EU regulations, we observed an amount 5000 times greater of glyphosate in Brazil than is allowed in water for human consumption in EU regulations [60]. Glyphosate, one of the most popular pesticides in agricultural activities in the world and in Brazil. It is listed in the drinking water standards of Brazil, Japan, and the USA at high values, even considering the health risks arising from the respective regulations of the countries, consumption of glyphosate-contaminated water may lead to kidney problems, reproductive difficulties, and may be related to increases in body weight [47,69]. Additionally, in its March 2015 assessment, the International Agency for Cancer Research concluded that glyphosate is likely to be carcinogenic to humans [70]. It is essential for the WHO to include glyphosate in its guidelines for drinking water quality and establish maximum permitted values to guide the internal legislation of countries.

Despite advances in Brazilian legislation, the potability ordinance should include all pesticides used in Brazilian agriculture that have the potential to be detected in drinking water. A strategy that could be used, is for each state or region to identify the active ingredients primarily used in agricultural and livestock activities developed in the watershed catchment area and include them in programs for diagnosing and monitoring pesticide active ingredients even before reaching water treatment plants [63]. This was already established by the EU directive (2021) which mandates Member States to identify relevant and dangerous pesticides that must be monitored in drinking water, whose presence is likely in a given water supply basin or reservoir [46].

In Brazil, the ordinance requires a semiannual analysis of pesticides at the capture point in surface and groundwater sources, in addition to an assessment of pesticides used in agriculture in the watershed area [42]. However, the ordinance does not provide a methodological strategy to determine the pesticides used in the areas surrounding the water sources, and pesticides should be measured and monitored in the catchment areas. Moreover, there is no wide dissemination of the database with the results of pesticide monitoring. On the other hand, the EU Commission, based on data communicated by Member States, feeds a database of pesticides and their relevant metabolites considering their possible presence in water intended for human consumption [46].

5. Conclusion

In short, this study shows that the maximum permitted values for pesticides in water for human consumption differ greatly between Brazil and the other countries analyzed; therefore, it is essential to standardize these values between countries, with the establishment of clear criteria to determine the VMP and with lower values, similar to those of the European Union. Despite the advances made by current ordinance in Brazil, which now monitors similar numbers of pesticides to those of the WHO, USA, Canada, and China, they represent only 8% of pesticides registered for agricultural use in Brazil. Nonetheless, Brazil is the country that comes closest to the World Health Organization in terms of the number and maximum permitted allowed of monitored pesticides. However, the Brazilian ordinance did not reduce the maximum permitted limit of pesticides with quantities considered elevated for water, as is the case of glyphosate. It also does not establish a total value for the mixture of pesticides in water, only individual limits, which can reach about 3500 times more than the EU directive.

Author contribution statement

Dinoraide Mota de Oliveira: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed materials, analysis tools or data; Wrote the paper. Lenita Agostinetto: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed materials, analysis tools or data; Wrote the paper. Ana Emilia Siegloch: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed materials, analysis tools or data; Wrote the paper.

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Data availability statement

Data associated with this study has been deposited at http://biblioteca.uniplaclages.edu.br/biblioteca/index.php?resolution2=1024_1&tipo_pesquisa=&filtro_bibliotecas=&filtro_obras=&termo=&tipo_obra_selecionados=

Declaration of interest's statement

The authors declare no competing interests.

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