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Pesticides and violations of human rights to health and food sovereignty in Guarani Kaiowá communities in MS, Brazil

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Abstract *Brazil, one of the world's largest agricultural producers and consumers of pesticides, has expanded its agricultural area in the southern region of Mato Grosso do Sul, intensifying environmental contamination and increasing the vulnerability of indigenous populations. This research assessed the presence of pesticides in the waters of two indigenous communities in MS, Retomada Guyraroká and Aldeia Jaguapiru. Between 2021 and 2022, three sampling campaigns of surface, supply, and rainwater were conducted, considering the agricultural calendar. The study followed the LARP/UFSM protocol. In total of 22 active ingredients (AIs) were found, among these, 41% cause serious health effects, and 68% are banned in the European Union. Fipronil, 2,4-D, Atrazine are the among the most frequent IA found. Results show that these communities are exposed to pesticides, violating their rights to health and food sovereignty.*
Key words *Pesticide, Indigenous people, Public health, Water quality, Environmental pollution*

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Introduction

Globally, Brazil is one of the largest producers of agricultural commodities, dependent on pesticides for their production[1]. In 2021, the country was the world's largest exporter of soybeans, with 91 million tons[2].

According to Hess and Nodari[3], the cultivated area between 2010 and 2020 expanded 27.6%, while the number of pesticides sold increased 78.3%, evidencing a most significant growth in pesticide use. In 2020, the volume of pesticides sold in Brazil was 685,746 tons. From 2013 to 2020[4], the states with the most significant amounts of pesticides sold were MT (18.5%), SP (14.2%), RS (11.5%), PR (11.3%), GO (8.5%), MG (7.0%) and MS (6.2%).

Soybeans are the most widely cultivated commodity in Brazil, and according to the National Supply Company (CONAB) for the 2022/23 harvest, when the soybean planted area exceeded 43 million hectares. In this crop it is applied more than 63% of the total pesticide applied in the country, followed by corn (13%) and sugarcane (5%)[5]. In 2022, the total amount of pesticides sold in Mato Grosso do Sul was over 48 thousand tons[6]. The situation is even more critical with many cases of smuggling of pesticides, even those prohibited in Brazil[7] in the border areas with Paraguay and Bolivia.

The commodity production and deforestation growth are intensively pressuring Indigenous territories. The crops' proximity to Indigenous Lands (ILs) results in the exposure of communities, their rivers and streams, caused by drifting pesticides crossing the boundaries of large estates. These impacts violate human rights, land rights, health and sovereignty, and food and nutritional security. Furthermore, pesticide spraying has been used on Indigenous lands and bodies as an extermination mechanism, once they fight for the demarcation of their territories and prevent the expansion of agribusiness[9]. However, studies on pesticide contamination in Indigenous territories are scarce in the country[9].

According to Bombardi[10], MS is the third-highest state in number of cases (12) of Indigenous contamination by pesticides from 2007 to 2014. However, the toxicological surveillance in MS is poorly structured, with a high underreporting possibility. Mato Grosso do Sul is the third-largest Brazilian state in the Indigenous population, corresponding to 116,000 people in 2022[11]. Indigenous communities in the state have been surrounded by large-scale crops. Therefore, the Guarani and Kaiowá's routine have been historically and geographically marked by the deterritorialization and precariousness imposed by "internal colonialism"[8] on the agribusiness fronts. These people have been fighting for years to regain their life territories, the "*Tekoha*", and against pesticide contamination.

The pesticides' drift in the IL has already been reported in MS. In May 2019, according to the Indigenous Missionary Council (CIMI), a tractor applied poison to a soybean plantation adjacent to the Retomada Guyraroká, notably affecting the community, recorded by photos and videos[12]. Subsequently, children and young people reported symptoms of asthma, dry cough, shortness of breath, vomiting, and chest, stomach, and head pain[12].

In 2015, the Guyra Kambi'y (Dourados) reoccupation site with around 150 Guarani Kaiowá Indigenous people suffered a chemical attack from an airplane that sprayed a crop 15 meters away from the community. This practice is prohibited by the Ministry of Agriculture, Livestock and Food Supply (MAPA) at the Normative Instruction N° 02/2008[13], which prohibits the aerial application of pesticides in areas located at a minimum distance of 500 meters from towns, cities, villages, and districts, or a minimum distance of 250 meters from water sources, isolated homes, and groups of animals.

A Federal Police expert report attested that, in this case, the application violated legal parameters. After the incident, children and adults in the community had headaches and sore throats, diarrhea, fever, and skin and eye irritation[14]. Residents have been claiming that applications occurrs under the same circumstances since 2013[15].

Given the massive use of pesticides in commodity production and the Guarani Kaiowá people's vulnerable situation, this study assessed the presence and concentration of pesticides in surface, drinking, and rain water in two Indigenous communities surrounded by large crops in Mato Grosso do Sul. It is essential to monitor water quality in the affected communities and inform them about their rights to health and food sovereignty as a human right, promoting critical and participatory health surveillance.

Methods

The communities were chosen based on the criteria of having large farms in their surroundings. Retomada Guyraroká and Aldeia Jaguapiru are in this setting, in the southern region of MS (Figure 1), in the most significant agricultural production areas.

The Guyraroká Reclamation, in the municipality of Caarapó, occupies an area of 58 hectares, where approximately 100 Guarani Kaiowá Indigenous people live. The Jaguapiru Village is located in the Dourados Indigenous Reserve in Dourados. According to 2014 data from the Special Secretariat for Indigenous Health (SESAI)[16], approximately 15,000 people lived on the 3,539 hectares of the reserve. The ethnic groups that predominate in the villages are Kaiowá, Ñandeva, and Terena (Figure 1).

The two communities have similar realities: both survive on agriculture, using traditional techniques and without using industrialized inputs and are socially vulnerable. However, the Retomada Guyraroká is more fragile since its territory is not demarcated. Both have piped water for consumption from artesian wells, analyzed in this study. However, in Retomada Guyraroká, an elderly couple uses only water from the Ypytã spring, which was also analyzed in the study.

The study was conducted from 2021 to 2022, when surface water, supply water, and rainwater were collected in each community in three different periods, following the agricultural calendar for soybean cultivation. The first collection occurred in November/December 2021, at the beginning of planting, the second in February/March 2022, the harvest period, and the third in August 2022, the soybean sanitary break period, when planting the grain is not permitted in MS. Samples of water supply (tap), surface water (rivers and springs) and rainwater were collected to assess water exposure to pesticides. Rainwater collections were performed according to Beserra[17].

Samples were delivered to and analyzed by the Pesticide Residue Analysis Laboratory (LARP) of the Chemistry Department of the Federal University of Santa Maria (UFSM). The method developed by Donato *et al.*[18] was applied for the multi-residue determination of 70 pesticides with different properties. Glyphosate and its primary metabolite (aminomethylphosphonic acid, AMPA) were determined using a dedicated method by direct injection and a UHPLC-MS/MS system[18].

Results

According to our results, the studied populations are exposed to different Active Ingredients (AIs) of pesticides found in the three sources of water. Twenty-two different AIs were detected in all samples form the two communities over one year, with 16 AIs in surface water samples, 12 AIs in drinking water samples, and 17AIs in rainwater samples. The most frequent AIs were Fipronil, detected in 68.8% of the samples, followed by 2,4-D (62.5%), Clomazone (56.3%), Atrazine (50.0%), and Diuron and Simazine (43.8%).

Twenty different AIs were found in the results concerning the Retomada Guyraroká (Table 1). AIs were detected in 75% of the samples analyzed, and we measured the concentration in 45%. The most frequent AIs were 2,4-D and Fipronil, both detected in 50% of the samples, followed by Atrazine, Clomazone, and Tebuconazole (all found in 41.7% of the samples). All measured concentrations are below the Maximum Values listed in the CONAMA Resolution No. 357/2005[19].

According to Table 1, 14 different AIs were found in the surface water samples collected from the two springs whose water are frequently used by the community. The most frequent was Fipronil, detected in 50% of the samples, followed by the fungicide Propiconazole, detected in 33.3% of the samples.

Eleven AIs were detected in drinking water samples (Table 1), three of which (Azoxystrobin, Clomazone, and Propiconazole) are not included in Ordinance N° 888/2021 of the Ministry of Health[20], which governs the pollutants to be monitored by the VIGIÁGUA Program. Only 36.6% of the detections could be measured, and the concentrations are below the Maximum Permitted Values (MPV) established by the above ordinance.

The rainwater samples had the most significant number of different AIs (16), with six AIs in the first, 11 AIs in the second, and eight AIs in the third. Furthermore, according to Table 1, the highest amounts of AIs in drinking and surface water samples, were found in the third collection, referring to the sanitary break in August 2022. In surface water 11 AIs were detected in each sample collected from the springs, and in drinking water10 AIs were detected in a single sample, respectively.

Results found for the Aldeia Jaguapiru are shown in Table 2. Due to a new increase in COVID-19 cases affecting the territory during the second half of 2021, the team decided not to conduct the first campaign to avoid contagion situations for this community.

Twelve different AIs and pesticides were detected in all the samples collected in Aldeia Jag-

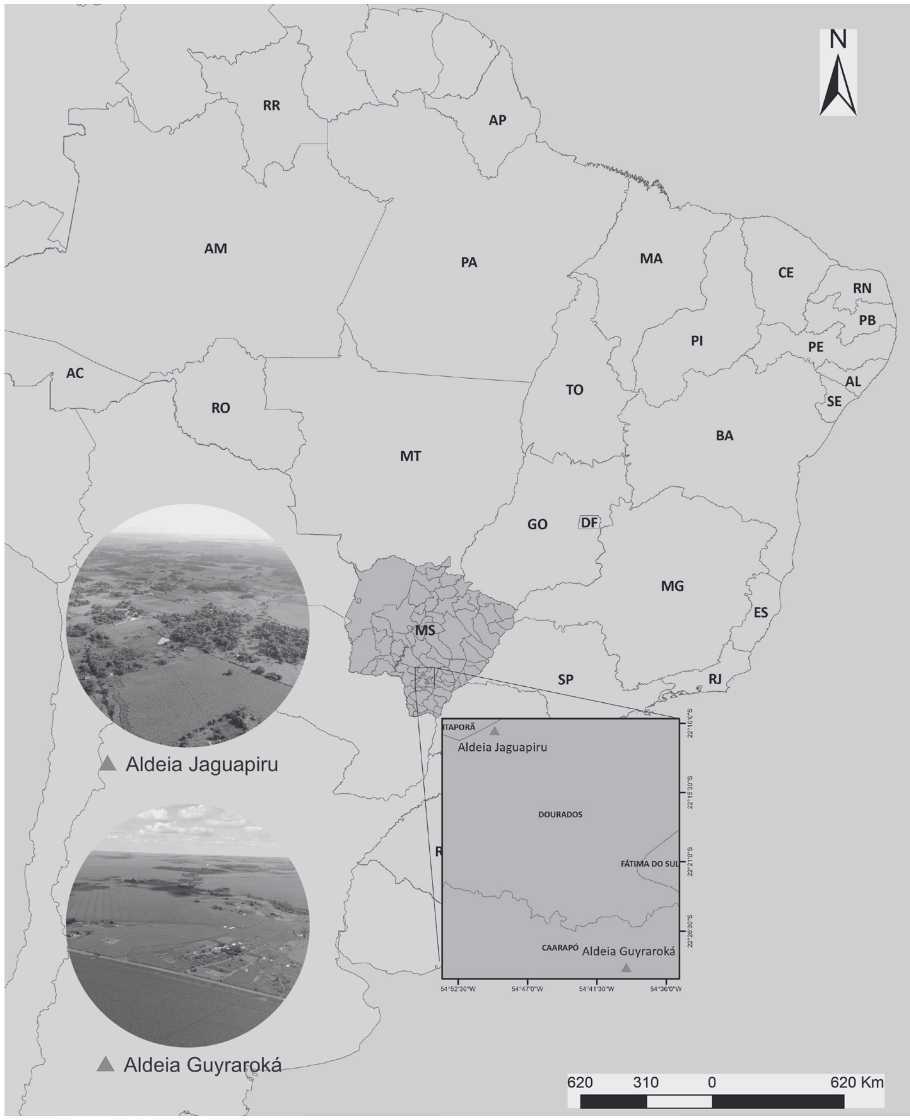

Figure 1. Location of the studied communities.

Source: Authors.

uapiru. The most frequent AIs were Fipronil, detected in 71.4% of the samples, followed by 2,4-D and Clomazone in 57.1% each; Atrazine, Diuron, and Simazine were found in 42.9% of samples.

The water source with the highest number of AIs was the rainwater, collected in February 2022, containing eight AIs, but only Atrazine was quantified. The AI analytic quantification was only possible in 17.2% of the samples; therefore, in 82.8% of samples, analyses was able only to detect the presence of the AI due to the low concentration.

Eight AIs were detected in t the surface water samples, of which the most frequent was Fipronil, identified in 75% of the samples. Only three AIs (2,4-D, Atrazine, and Simazine) are listed in Resolution N°357/2005 CONAMA[19], all with concentrations below the MPV. Eight different AIs were detected in drinking water samples and only two (Clomazone and Propiconazole) are not included in Ordinance N°888/2021 of the Ministry of Health[20]. Those included in the above mentioned ordinance did not show concentrations above the MPV. Other situations occurred

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Table 1. Active ingredients. concentrations. and collection dates of samples from Retomada Guyraroká.

Retomada GUYRAROKÁ	Active ingredient	Concentration (µg/L)	Collection date
Spring Water (Ypytã – red stream)	Glyphosate	4.316	nov/2021
	Fipronil	<LOQ	
	Propiconazole	0.038	feb/2022
	Fipronil	<LOQ	
	Atrazine	1.43	aug/2022
	Clomazone	0.10	
	Simazine	0.10	
	2.4-D	0.049	
	Ametrine. Azoxystrobin. Difenoconazole. Fipronil. Profenofos. Propiconazole. Tebuconazole	<LOQ	
Keili Spring Water	ND		nov/2021
	ND		feb/2022
	Atrazine	0.335	aug/2022
	Clomazone	0.096	
	Simazine	0.056	
	2.4-D	0.046	
	Propoxur	0.023	
	Ametrine. Difenoconazole. Fipronil. Diuron. Propiconazole. Tebuconazole	<LOQ	
Water supply	ND		nov/2021
	Fipronil	<LOQ	feb/2022
	Atrazine	1.71	aug/2022
	Clomazone	0.12	
	Simazine	0.12	
	2.4-D	0.06	
	Ametrine. Azoxystrobin. Difenoconazole. Diuron. Propiconazole. Tebuconazole	<LOQ	
Rainwater	2.4-D	0.123	nov/2021
	Imidacloprid	0.171	
	Cyproconazole	0.061	
	Methomyl. Methoxyfenozide. Thiamethoxam	<LOQ	
	Atrazine	0.917	feb/2022
	Fipronil	0.216	
	Imidacloprid	0.123	
	Propoxur	0.119	
	2.4-D	0.107	
	Clomazone	0.032	
	Diuron. Epoxiconazole. Profenofos. Tebuconazole. Thiamethoxam	<LOQ	
	Atrazine	0.23	aug/2022
	Clomazone	0.086	
	2.4-D	0.051	
	Simazine	0.03	
	Ametrine. Diuron. Tebuconazole. Thiamethoxam	<LOQ	

< LOQ: method's limit of quantification. ND: no active ingredient detected.

Source: Authors

Table 2. Active ingredients, concentrations, and collection dates of samples from Aldeia Jaguapiru.

Aldeia Jaguapiru Collection place	Active ingredient	Concentration (µg/L)	Collection date
Spring water Jaguapiru	Fipronil	0.045	02/2022
	2,4-D, Atrazine, Clomazone, Simazine	<LOQ	08/2022
Spring water Bororo	Fipronil	<LOQ	02/2022
	2,4-D	0.045	08/2022
	Carbendazim, Clomazone, Diuron, Fipronil, Propoxur, Simazine	<LOQ	
Water supply	Fipronil, Propiconazole	<LOQ	02/2022
	Atrazine	0.086	08/2022
	Simazine	0.022	
	2,4-D, Carbendazim, Clomazone, Diuron	<LOQ	
			02/2022
Rain water	Atrazine	1.47	
	2,4-D, Carbofuran, Clomazone, Diuron, Fipronil, Imidacloprid, Tebuconazole	<LOQ	

< LOQ: below the method's limit of quantification.

Source: Authors.

in Aldeia Jaguapiru besides COVID-19; thus, only rainwater could be collected.

Discussion

As verified in the results, the number of AIs found in the water samples was significant. At least one pesticide was detected in 82.2% of the analyzed samples. This means that communities are exposed to pesticides through several water access routes, whether from springs, public supply, or rainwater, contaminating vegetable gardens, water sources, aquatic ecossystems, animals, and people. Furthermore, the non-detection of a given pesticide does not mean it does not exist in the environment.

In Brazil, the regulation of Maximum Values in surface water is established by National Council of Environment – CONAMA's Resolution No. 357/2005[19] for natural water sources, as streams, rivers and lakes from Class I and II. The Maximum Permitted Values (MPV) in drinking water are established by Ordinance No. 888/2021 of the Ministry of Health[20]. Although the concentrations of all AIs measured in the two communities (36.2% of the samples) are below the values established in these two regulations, they have potential to cause chronic effects on all living beings.

The European Union (EU) pesticide legislation establishes that the MPV of any AI in water for human consumption is 0.1 µg/L, which is more restrictive than most Brazilian MPVs. One example is 2,4-D, one of the AIs that appeared most frequently in the samples, whose MPV in Brazil is 300 µg/L, 300 times higher than in the EU. If we consider the EU MPV in this study, 45.5% of all results would be above the maximum permitted limit.

Another troubling result is the large amount of active ingredients in per sample. EU legislation also regulates the sum of the concentrations of AIs found per sample, where the MPV is 0.5 µg/L. However, the sum of the AIs concentrations found in 56.6% of the samples from Retomada Guyraroká was higher than this value. A total of ten AIs were found in the water supply sample, and the sum of the concentrations was 2.0 µg/L, which is four times higher than that permitted by the EU, and represents a risk to human and environmental health.

Risk assessments of pesticides for the environment and living organisms are conducted with active ingredients in their purest form, and in controlled laboratory conditions. Studies on the synergistic effects of two or more AIs acting together in the environment are almost non-existent. However, the scientific evidences demonstrate that this mixture is more toxic than each pesticide separately.[21] Commercial products can be composed of AIs combinations, added to other inert chemicals. However, these can also be toxic when they interact with other substances or are released into the environment, and generally are not considered in the assessments.

Unfortunately, in Brazil, 36.8% (146 AIs) of the pesticides registered for use are not permitted in the EU. Fifteen of the 22 AIs found in the two communities have been prohibited in the EU (Ametryn, Atrazine, Carbendazim, Carbofuran, Cyproconazole, Diuron, Epoxiconazole, Fipronil, Imidacloprid, Methomyl, Profenofos, Propiconazole, Propoxur, Simazine, and Thiamethoxam). The reason for this prohibition is associated with the adverse effects on living beings exposed to the pesticides[3].

In the surface water samples (streams and springs) collected in the two communities, 16 AIs were detected, being nine prohibited in the EU, and only four are listed in the CONAMA Resolution[19]. Therefore, although the concentrations obtained in their water sources were not above MPV values, there are large amounts of pesticides with high toxicity in the springs and streams of these communities, which have caused severe chronic exposure. Springs are not only a water source for the Guarani Kaiowá People, they also have a cultural value as sacred sites, as well as for leisure, subsistence fishing, water supply for livestock and wild animals. Therefore, the impact of their exposure is much more significant.

Twelve AIs were found in samples of water supplied to communities, that is, the water used to drink, cook, and bath. Seven of these are prohibited in the EU, and three are not listed in the Ministry of Health Ordinance[21] and, thus, are not monitored: Azoxystrobin, Clomazone, and Propiconazole. The latter, one of the most frequent AIs, is a herbicide with mutagenic, teratogenic, and endocrine effects scientifically recognized[22].

This fact shows the urgency of reviewing legislation and procedures related to water and drinking water quality. Regulations that do not guarantee the health protection of the population regarding access to water need to be reviewed immediately. Besides it is necessary a periodic review of such regulations to consider the newly registered products, and more accurate detection methods and techniques , along with new information on the toxicological aspects of pesticides and regional agricultural specificities.

Another concern with this Ordinance related to the drinking water quality[20] is that the number of monitored pesticides (40 AIs) is tiny compared to the number of products used in Brazil, which totals more than 3,000 products authorized.

The most significant number of different AIs (16) was found in rainwater samples, of which 12 are banned in the EU. Carbofuran was also detected, which is banned in Brazil and, per National Agency of Sanitation Vigilance (Anvisa) criteria, is considered teratogenic, causing damage to the reproductive system, mutagenic, and is more dangerous to humans than laboratory tests have shown[23].

Rain with pesticides is a dire situation, as it indicates diffusive contamination and can reach places without direct application, especially in Mato Grosso do Sul, where biogeographic barriers are few and far between. Winds and rain flow freely in the region, increasing the dispersion of toxic rain. In addition, Atrazine and 2,4-D were detected, which have a high infiltration capacity and potential to reach groundwater[24,25].

Even if current regulations on pesticides application methods and barriers that mitigate drift are respected, there is no alternative to controlling this rainwater contamination. As a consequence, other water sources can be contaminated, affecting wildlife, causing loss of pollinators, compromising biodiversity, regeneration, and maintenance of preserved areas, crucial for the conservation of species. MPVs of pesticides in rainwater are not regulated in Brazil. Therefore, there are no monitoring programs for this exposure to human health or the environment.

The AIs found are classified in the toxicological classes with the most significant risks to human health. We should underscore the information found on the AIs that are proven or possibly carcinogenic or endocrine disruptors found in the samples. A wealth of recent scientific evidences[12,26,27] states that there is no safe dose for exposure to products that cause such illnesses. In other words, the slightest trace of AI that causes cancer or is an endocrine disruptor can expose the population to risks, even if they are below the MPV. This includes 2,4-D and Atrazine. The latter is already banned in the EU due to its endocrine disruptor status, responsible for changes in women's menstrual cycles and hypothyroidism, for example, and is considered carcinogenic in laboratory tests. The 2,4-D is not banned, but its use is subject to strict control, as it is also an endocrine disruptor and possibly carcinogenic for humans[28].

Some of the pesticides found in the water samples from both communities, such as Fipronil, which had the highest number of detections per sample (frequent in almost 70%), and neonicotinoids Imidacloprid and Thiamethoxam (detected in 18.8% of the samples) are considered to be slightly toxic from the perspective of human health. However, these are the leading causes of the disappearance of bees worldwide[29]. Therefore, our results indicate that there is a risk to food and nutritional sovereignty and security, as these AIs prevent the production of pesticide-free foods and the production of pollinator-dependent foods. This means a directly interference with the food culture, especially of Indigenous people, based on local biodiversity, including the honey resource, important both for self-consumption and income generation.

Some pesticides are stable in aquatic environments and can be incorporated into the ichthyofauna, according to their bioaccumulative capacity. TThese contaminants cross through trophic chain, causing biomagnification, and an exponential exposure until achieve a higher level in the food chain[30]. The main pesticides linked to this condition are organophosphate insecticides and pyrethroids[30]. When they biomagnify along the food chain, they become potential agents of acute and chronic poisoning for predators, such as humans. Fish is one of the primary animal protein sources for Indigenous populations, which is no different from the Guarani Kaiowá. The organophosphate Profenofos was also detected in surface and rainwater samples. It poses a high risk of dissemination because it is environmentally mobile.

In Guyraroká community, people report difficulties in producing food due to the drift of pesticides applied by tractor or via aerial spraying in the surrounding area. Some families no longer cultivate certain crops because they frequently lose their production, opting to produce only tubers and roots, therefore restricting significantly food and nutritional security and impacting the community's food culture.

We should emphasize that due to the insufficient capacity to determine the real risks of environmental exposure to various chemical classes and groups of pesticides on a permanent and increasing conditions, many of the AIs not yet characterized as bioaccumulative and biomagnifying will likely be classified as such as methods and assessment of exposure improve. The limitations of toxicology, which underpins assessments of health risks from pesticide exposure, are very well detailed in the article published by Friedrich *et al.*[21] and can support this reflection.

Another fundamental issue concerns water consumption itself. Even if communities can access drinking water from other sources, contact with contaminated water for personal hygiene, leisure, cleaning, and other uses continues to be a means of exposure and risk of acute and chronic poisoning, since the absorption route for all the pesticides described above is not exclusively oral. Pesticides are also absorbed through the skin, respiratory system, and eyes. The simple act of bathing is already a means of exposure.

The symptomatic manifestations of poisoning can be immediate, mixed, or delayed – acute, subacute, and chronic poisoning – in general. The main symptoms and signs of acute poisoning are skin and eye irritation, upper and lower respiratory tract irritation, allergic responses, gastrointestinal symptoms, and neurological manifestations. Acute poisonings can also be classified per their severity. These symptoms were reported by communities shortly after episodes of drift of pesticides applied to surrounding crops, as reported by Mondardo[31]. Residents of the Retomada Guyraroká reported general malaise and symptoms such as headaches, diarrhea, stomach pain, dizziness, and skin problems as itching. In the Jaguapiru village, 90% of families have felt unwell due to pesticides sprayed on adjacent crops and reported symptoms such as burning in the mouth, dizziness, diarrhea, vomiting, and headache. Guyraroká residents say they no longer enter some rivers due to the skin problems afterward. These situations corroborate the findings of Gonçalves *et al.*[32]

There is a need to perform assessments that correlate community health data with acute and chronic symptoms associated with the identified AIs to support the health teams of the Indigenous subsystem of the Brazilian Universal Health System (SUS and, thus, offer a much more effective health service, including for communities in non-demarcated areas and urban Indigenous people.

We should underscore that all information found on the action of AIs on human health refers to generalizations, usually based on parameters of the average, healthy adult population. However, when addressing different population categories, such as children and older adults, or specific population conditions, such as pregnant women, lactating women, people with comorbidities, and under nutritionally insecurity, among other factors, the impacts tend to be more diverse and severe.

Final considerations

This work is a small part of a broader research. Therefore, the data are not conclusive. However, the presented results serve as a warning and suggest how the impacts resulting from the excessive use of pesticides in commodities production make the health and food sovereignty of Indigenous populations vulnerable. This reality is very much present in the southern region of Mato Grosso do Sul and repeated in other Brazilian states.

The research is in its second year of data collection, and the results will provide further support for analyses to deepen discussions. This fact highlights the need for long-term research that considers activities to monitor the health of populations and the environment. Although it is possible to analyze the context with the results of only an agricultural year, it is essential to be able to compare a more robust database, monitor environmental changes and the health of exposed populations, and assertively collaborate with strategies to confront and mitigate damage, as well as propose appropriate public policies to guarantee the safeguarding of these populations.

Corroborating Lima *et al.*[9], this safeguard for native peoples exposed to pesticides will only occur if we have: a) Public surveillance policies based on territorial and participatory principles, which we have called, popular health and the environment surveillance[1]; b) An effective implementation of the Health Surveillance of Populations Exposed to Pesticides (VSPEA), a public policy already in force; c) actions to combat aerial spraying, and pesticide-free territories definition; d) demarcation of Indigenous lands and agrarian reform; e) An encouragement of autonomy and effective participation of Indigenous peoples in decision-making processes. All these actions must occur in an intersectoral and participatory fashion under the epistemological premise of Agroecology, a productive and technological matrix, and a guide for decision-making, formulation, management, and monitoring of public policies.

Collaborations

ADP Pinho (project coordinator) contributed to research design, data collection and analysis, discussion, writing, and review. DF Calheiros contributed to research design, data analysis, discussion, writing, and review. FS Almeida contributed to research design, data collection and analysis, discussion, writing, and review. PH Zerlotti contributed to research design, data collection and analysis, and discussion, writing, and review. M Cereali contributed to data collection and analysis, writing, and review. A Feiden contributed to research design, data collection and analysis, discussion, writing, and review. FF Machado contributed to data analysis and review. R Zanella contributed to data analysis and review.

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