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USE OF AGROCHEMICALS IN BRAZIL AND THEIR CORRELATION WITH INTOXICATIONS

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ABSTRACT

This work investigates the historical series of pesticide consumption in Brazil and the types of illnesses related to their exposure to workers' health, statistically analyzing the hypothesis of a relationship between pesticide consumption and the appearance of symptoms. The results evidenced in the investigation confirm the hypothesis and point to the need for improvements in guidance on the safe use of agrochemicals and in public policies on prevention and health, which ensure safer work for people, in addition to more active inspection, especially in the states of the Southeast Region.

Keywords: Agrochemicals, Worker's Health, Statistics.

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1. INTRODUCTION

The topic of pesticides has been discussed on the national scene through Bill no. 6,299/2002, which aims to amend Law no. 7,802/1989. Several renowned entities are making statements on the subject, including the National Cancer Institute (INCA, 2018), which published a public note, which in part says the following:

> "In the current world scenario, Brazil is the largest consumer of agrochemicals and, in ten years, the Brazilian market for agrochemicals has grown 190%. However, it is noteworthy in national and international scientific literature that the current model of cultivation, with the intensive use of agrochemicals, generates food insecurity and other harmful effects, such as environmental pollution, contamination of springs, soil, air, and intoxication of rural workers and the population in general. Among the effects on human health associated with exposure to agrochemicals, the most worrying are chronic intoxications, characterized by infertility, impotence, abortions, malformations, and neurotoxicity, manifested through cognitive and behavioral disorders and neuropathy and hormonal deregulation, also occurring in adolescents, causing negative impact on their growth and development among other outcomes during this period".

By Law No. 7 802 of July 11, 1989 and Decree No. 4074 of January 4, 2002, which regulated it, we have the definition of agrochemicals and alike in Article 1, item IV.

> "...IV - agrochemicals and alike - products and agents of physical, chemical or biological processes, intended for use in the production sectors, in the storage and processing of agricultural products, in pastures, in the protection of forests, native or planted, and other ecosystems and urban, water and industrial environments, whose purpose is to alter the composition of flora or fauna in order to preserve them from the harmful action of living beings considered noxious, as well as substances and products used as defoliants, desiccants, stimulators and growth inhibitors...".

Pesticides are substances whose main purpose is to protect agricultural products from the action of harmful living beings and, often, by being used incorrectly, they end up creating health risks. The inadequate use of these substances, the high toxicity of certain products, the lack of use of protective equipment and the precariousness of surveillance mechanisms are the major causes of diseases and intoxications caused by pesticides.

Table 1 below shows the classification of agrochemicals according to their effects on human health, according to the precepts of the National Health Surveillance Agency (*Agência Nacional de Vigilância Sanitária* – ANVISA).

Table 1. Toxicological classes and their respective range colors

CLASS	TOXICITY	LABEL STRIP COLOR AND INSTRUCTIONS PACKAGE INSERT	PANTONE MATCHING SYSTEM - PMS
I	Extremely toxic	Red band	PMS Red 199 C
II	Highly toxic product	Yellow band	PMS Yellow C
III	Moderately toxic product	Blue band	PMS Blue 293 C
IV	Low toxic product	Green band	PMS Green 347 C

Source: ANVISA, 2018, p. 10

The Brazilian Institute of Environment and Renewable Natural Resources (*Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis* – IBAMA) carries out the assessment of the potential dangerousness in relation to the environment, as illustrated in Table 2.

Table 2. Assessment of the potential for environmental hazards

Class I	**HIGHLY DANGEROUS** product to the environment
Class II	**VERY DANGEROUS** product to the environment
Class III	Product **DANGEROUS** to the environment
Class IV	Product **LITTLE DANGEROUS** to the environment

Source: IBAMA, 2018

There are numerous studies that discuss the use of pesticides in Brazil. It can be said that a reference work was presented by Bombardi (2017), who prepared the Atlas of the Geography of the Use of Agrochemicals in Brazil and Connections with the European Union. The work constitutes an exhaustive survey of data on the subject of pesticides in Brazil, drawing a parallel with what happens in the European Union.

Gomes et al. (2018), in a review of the literature that identifies the main health problems of rural workers who use agrochemicals in agricultural production, highlighted acute exogenous intoxication, which causes nausea, vomiting, headache, dizziness, disorientation, hyperexcitability, skin and mucous membrane irritation, respiratory difficulty, he-

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morrhage, convulsions, coma, and even death. And among the many chronic effects of pesticides on human health, they describe immunological changes, genetic disorders, congenital malformations, and cancer.

In turn, Vieiro et al. (2016) sought to learn the perceptions of rural workers about the risks posed by the use of agrochemicals to their health, and observed that they deny direct association between the use of agrochemicals and health problems, highlighting the lack of proper use of personal protective equipment (PPE).

Abreu and Alonzo (2014) present a critical review of the “safe use” approach to pesticides in scientific articles published in the last 15 years in Brazil. The authors conclude that the studies do not address, simultaneously, all work activities involving exposure and risk of intoxication (acquisition, transport, storage, preparation and application, final destination of empty containers, and washing of contaminated clothes/EPI), nor do they comprehensively address the various “safe use” measures described in the safety manuals, which are mandatory for each activity.

It should be noted that despite numerous studies on the use of agrochemicals and their consequences for the health of farm workers, there is a scarcity of statistical studies that seek to correlate the use of agrochemicals and the health of people who handle or come into contact with the toxic agent, which characterizes a gap in the national literature.

2. OBJECTIVES

This work aims to study the historical series of agrochemical consumption for agricultural, domestic or public health use in Brazil from 2007 to 2017. In addition, it focuses on the types of illnesses related to exposure to agrochemicals in people’s health, especially workers, by statistically analyzing (correlation and regression tests) the hypothesis that there is a relationship between the consumption of pesticides and the appearance of the first signs of intoxication.

3. METHODOLOGY

The methodology of bibliographic research was applied, followed by the application of statistical modeling techniques. The bibliographic research was performed through articles, journals, books, catalogs and websites in order to compile as many specific works as possible in this study area. The data applied in the statistical modeling study were taken from the sites of IBAMA, ANVISA and the Ministry of Health. Excel and Minitab programs were used to confirm possible relationships between pesticide consumption and intoxication rates in workers. To perform the analyses, a time cut was applied and a geographic criterion was established for the period from 2007 to 2017 within the 26 Brazilian states and the Federal District. Descriptive statistical analyses and studies of the variables were carried out, considering the marketing of pesticides by active principle. Subsequently, several hypotheses were tested, always seeking correlations. It should be noted that in this text the terms marketing or sales will be used indistinctly and have the same meaning.

The data source for the historical series of sales of agrochemicals and related products by active ingredients and by unit of the Federation was taken from the IBAMA website, based on data provided by companies that registered technical products, agrochemicals and related products for the period from 2007 to 2017. The IBAMA website states in a note that the data for 2007 and 2008 were not systematized; however, with the data available before 2007 and after 2008 these years were estimated without losing coherence. The raw data were taken from the IBAMA website, through the consultation of the “Annual Bulletins of Production, Importation, Exportation and Sales of Agrochemicals in Brazil - Total Sales of Agrochemicals and Related Products in Brazilian Regions and States Year by Year”. The data was arranged in a set that related year, state and consumption.

As for the historical series of poisoning due to agrochemical use, a portrait of the effects of pesticide intoxication on society was sought in Brazilian databases. Since there is no specific database of sources consistent with the intoxication data, the Ministry of Health and its Aggravated Notification Information System (*Sistema de Informações de Agravos de Notificação* – SINAN Net) were chosen, which, according to the Ministry, aims to collect, transmit and disseminate data routinely generated by the Epidemiological Surveillance System of the three spheres of government, through a computerized network, to support the investigation process and provide support for the analysis of epidemiological surveillance information on compulsorily notifiable diseases.

The data was accessed by the Department of Information Technology of the Unified Health System (*Departamento de Informática do Sistema* Único *de Saúde* – DATASUS), which was created in 1991 by the National Health Foundation (*Fundação Nacional de Saúde* – FUNASA) to, among other objectives, support information systems. Its structure allows the storage of health information of the entire Brazilian population, and it is present in all regions of the country, which makes it easier to collect information. Within the universe of available information, the desired period (2007 - 2017) was entered for the following filters: number of notifications of the first symptoms of diseases associated with pesticides (agricultural, domestic or public health); deaths and sequelae; notifications by age group; sex; Brazilian state; and country region. The data were organized and “cleaned” so that they could be read by the analysis tools.

4. RESULTS AND DISCUSSION

Analysis of the historical series of pesticide marketing in Brazil – 10-year period: from 2007 to 2017

In Brazil, the commercialization of agrochemicals had an accelerated growth until the year 2013, losing its strength from 2014 in the face of the economic crisis experienced in the country. Between 2007 and 2017, the commercialization of agrochemicals passed the mark of 500 thousand tons per year. Figure 1 below shows the evolution of pesticide sales in tons up to the year 2017.

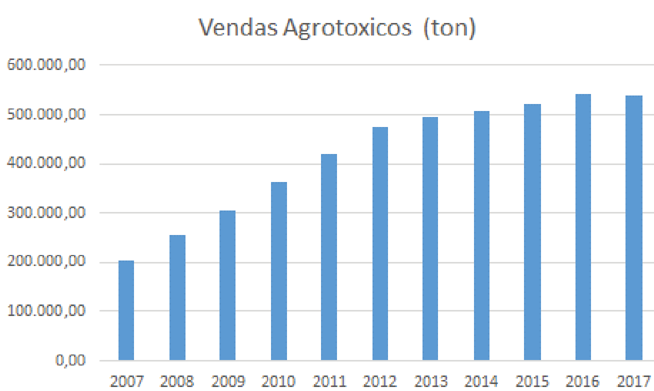

Figure 1. Sales of agrochemicals (active ingredient)
Source: Authors; IBAMA, 2018

As can be seen in Table 3, the states of Mato Grosso, São Paulo, Rio Grande do Sul, Paraná, Goiás, Minas Gerais, Mato Grosso, Bahia and Santa Catarina represent 90% of all pesticide sales in Brazil, when we look at the average consumption in 2016 and 2017. In 2017, the states of Mato Grosso and São Paulo traded 100,638 and 77,232 tons, respectively. In total, 518,564 tons were sold in 2017.

In Figure 2, all Brazilian regions have shown an increase in the commercialization of agrochemicals with an outstanding participation of the Center-West and South regions. The expansion of agricultural production in these regions is largely justified by the intensive use of agrochemicals and the levels of commercialization observed in the southern region.

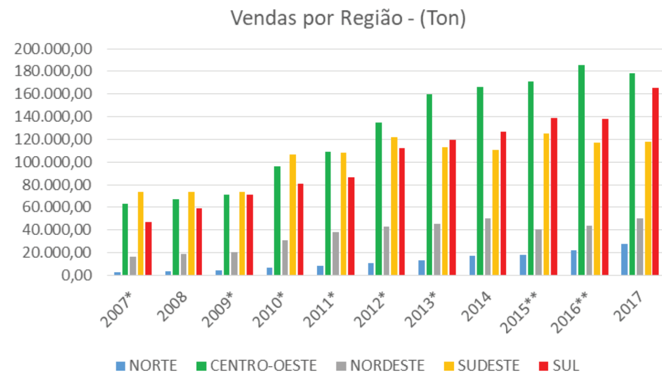

Figure 2. Sales of Agrochemicals (Active Principle) by Region
Source: Authors; IBAMA, 2018
Regions, in that order: North, MidWest, Northeast, Southeast, South

It is important to point out that as of 2008, Brazil became the largest consumer market for agrochemicals in the world. Sales of the product totaled US$7.125 billion, compared to US$6.6 billion for the second place, the United States, according to the National Union of the Industry of Products for Agricultural Defense (*Sindicato Nacional da Indústria de Produtos para Defesa Agrícola* – SINDAG). The use of pesticides has been a fundamental part of an agricultural model that seeks high levels of productivity. However, the social and environmental impact demands constant concern on the part of society, as we can see from cases of exogenous poisoning in Brazil, whether by pesticides in agricultural, domestic or public health use.

Analysis of the historical series of intoxication due to the use of pesticides in Brazil - 10-year period: from 2007 to 2017

Until 2006, the records of the first symptoms were few. In 2007 the occurrences started to be reported. In the period between 2007 and 2012, the data on the first symptoms practically doubled, reaching the mark of 5,283 cases in 2012. Five years later, in 2017, the number of 7,199 cases was exceeded. As can be seen in Table 4, in the period between 2007 and 2017, the trend was increasing, whether due to greater use of agrochemicals and their inappropriate use, or even due to the appearance of effects arising from chronic exposure, often taking longer to appear.

Table 3. Participation of the first 11 states in the marketing of agrochemicals

States	MT	SP	RS	PR	GO	MG	MS	BA	SC	MA	PA
Partic (%)	20	15,0	13,0	12,1	8,8	7,2	6,5	4,8	2,4	1,9	1,9
Acum (%)	20	35	48	60	69	76	83	87	90	92	94

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Table 4. Number of first symptom cases per year

Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
1st symptom	2726	3043	3635	4020	4744	5283	6787	6722	6299	6334	7199

Table 5. Number of first symptom cases every 1000 tons, 2016 and 2017

States	CE	AM	PE	ES	RJ	PB	DF	AL	RR	RN	SC	SE	RO	TO
1st symptom per 1000 tons	33,7	302,7	245,8	147,0	134,3	108,2	99,8	87,0	78,8	71,4	34,9	25,1	23,4	22,4
States	**MG**	**AC**	**PR**	**SP**	**BR**	**PI**	**PA**	**AP**	**BA**	**GO**	**RS**	**MA**	**MS**	**MT**
1st symptom per 1000 tons	21,2	17,7	13,5	13,4	13,2	11,8	9,9	9,9	9,8	8,2	6,3	4,8	3,6	1,3

In the evolution chart of the first symptoms by region (Figure 3), we observe the same growth trend of the country as a whole. It is worth mentioning that the Southeast Region has the highest number of occurrences followed by the South and Northeast Regions. It is possible to infer that in more distant and remote regions there is underreporting and that, therefore, the records may not reflect the real situation involving intoxications.

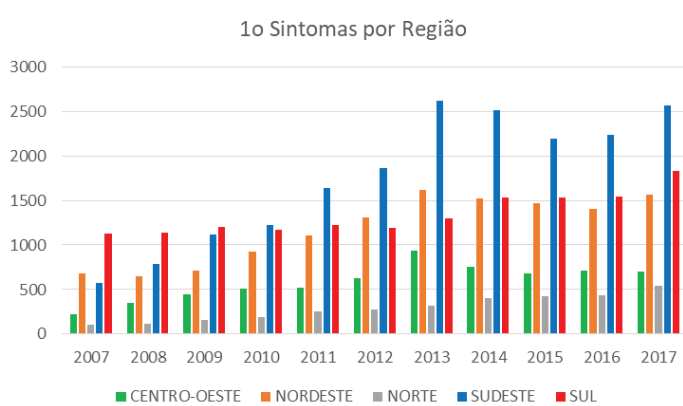

Figure 3. First symptoms by region

Source: Authors; DATASUS, 2019

Regions, in that order: MidWest, Northeast, North, Southeast, South

It would be unreasonable to analyze in an absolute way the number of cases of the first symptoms of pesticide intoxication for each state, since different states have quite unequal levels of consumption. In order to characterize each state, the rate of cases per thousand tons traded between the years 2016 and 2017 was calculated, as can be seen in Table 5. Ceará, Amazonas, Pernambuco, Espírito Santo, Rio de Janeiro, and Paraíba presented rates above 100 cases per thousand tons traded. States such as Mato Grosso, Mato Grosso do Sul, Maranhão, Rio Grande do Sul and Goiás had the lowest rates. In Brazil, as a whole, the index is 13.2 cases of the first symptoms every thousand tons. Thus, of the 27 states, nine are below the national average, Ceará and Amazonas being the worst cases, and Mato Grosso and Mato Grosso do Sul being the states with the lowest rates of occurrence.

When observing the number of the first symptoms by age group and sex (Figure 4), it can be seen that the number of cases is more expressive in the 15 to 39 age group, followed by the 40 to 69 age group, which are the most predominant groups in the productive force. Symptoms decrease after the age of 70 due to less contact with agrochemicals.

Figure 4. First symptoms by age group and sex

Source: Authors; DATASUS, 2019

Sex: In that order, male and female

With regard to gender, it is possible to observe that the female sex has a participation of 30% to 40% in the number of cases. This shows that intoxications reach a significant

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percentage of women, compatible with work divisions, especially in the agricultural context.

Relations between marketing and symptoms

This study aimed to correlate the association between the marketing of pesticides and notifications of intoxication. To do this, a statistical correlation analysis and a regression study were performed. Correlation analysis is devoted to statistical inferences of the measures of linear association between two variables, from the calculation of the Pearson correlation coefficient (r). Values of (r) close to -1.0 or 1.0 indicate strong association, while values close to zero indicate absence of correlation. One can obtain a p-value to test whether there is sufficient evidence that the correlation coefficient is not zero.

On the other hand, the regression study analyses the relationship between a dependent variable and one or more independent variables. This relationship is represented by a mathematical model, that is, by an equation that associates the dependent variable with the independent variables. The determination coefficient (R^2) is an adjustment measure of a linear statistical model in relation to the observed values. The (R^2) varies between 0 and 1, indicating, in percentage, how much the model can explain the observed values. The larger the (R^2), the more explanatory the model is, i.e. the better it adjusts the sampling.

Looking at the graph in Figure 5, which portrays the historical series of pesticide marketing and intoxication notifications, it can be seen that at the national level both show quite similar behavior over time. The calculation of Pearson's coefficient reveals the following:

Correlation: Marketing x 10 Symptoms

Pearson correlation 0,972

Value – P 0,000

As the value is positive and very close to 1.0 and the p-value is lower than alpha=0.05, it can be stated that there is a good correlation between consumption data and the records of the first symptoms for the country between the years 2007 and 2017.

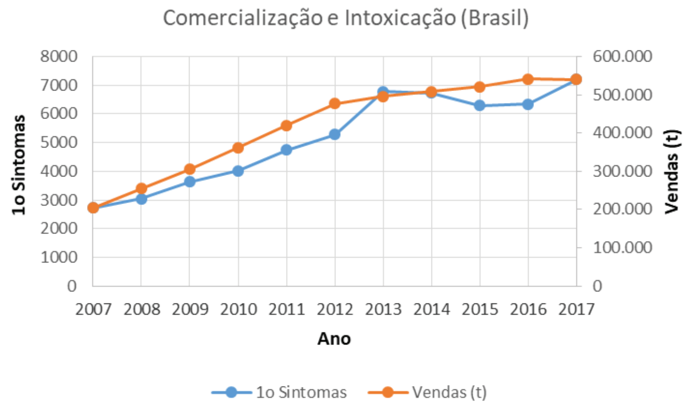

Figure 5. Time series of pesticide sales and intoxication records

Source: Authors; DATASUS, 2019

The correlation observed between pesticide sales and intoxications at the national level may not necessarily imply correlations at local levels, since scales, handling methods, and use intensity, among others, may be quite different from state to state or region of the country. In order to verify this same association within states, the calculation of correlations was extended to each unit of the Federation and within the same period of analysis.

To synthesize these numbers, a Table was constructed to present the correlation coefficient for each state and region, as can be seen in Table 6. Pearson's correlation values above 0.7 were highlighted in order to identify states with high correlation values.

Of the 27 states of the Federation, including the Federal District, 13 showed a positive correlation between marketing and first symptoms of intoxication. In two states, Acre and Amapá, it was not possible to determine the correlation. In 12 states, no significant association was found between the variables. It is worth noting that of the 6 states that most commercialize pesticides, representing 76% of the total, three of these, Rio Grande do Sul, Goiás and Minas Gerais presented a positive correlation above or equal to 0.90. Mato Grosso, São Paulo, and Paraná, which are three of the four largest states in Brazil for pesticide sales, presented little evidence of association between the analyzed variables. It can also be observed that the Northern and Northeastern regions presented the highest correlation rates.

When we look at the regression perspective, we can see that the independent variable "marketing" has an explanatory power of 94.41% of the independent variable "first symptoms", as can be seen in Figure 6.

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Table 6. Correlation between marketing (t) and first symptoms, 2007-2017

Region	North							MidWest				Northeast		
State	AC	AM	AP	PA	RO	RR	TO	DF	GO	MS	MT	AL	BA	CE
Pearson's correlation	ND	0,54	nd	0,96	0,91	0,80	0,89	0,44	0,90	0,49	0,28	0,36	0,88	0,43
Region	Northeast						Southeast				South			Brazil
State	MA	PB	PE	PI	RN	SE	ES	MG	RJ	SP	PR	RS	SC	BR
Pearson's correlation	0,73	0,92	0,52	0,86	0,36	0,55	0,87	0,93	0,02	0,59	0,12	0,92	0,76	0,97

Source: Authors; DATASUS, 2019

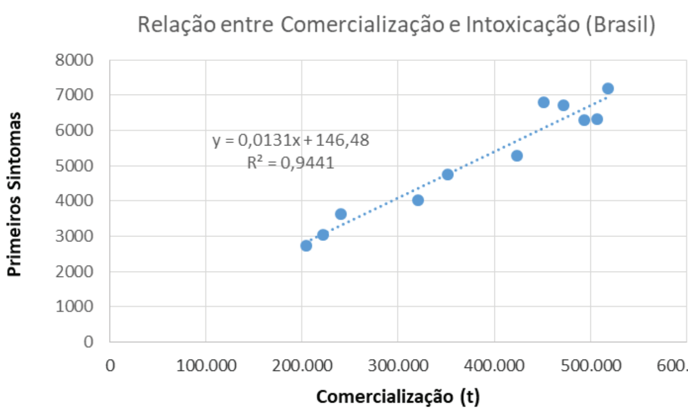

Figure 6. Correlation between marketing of agrochemicals and intoxications

Source: Authors; DATASUS, 2019

From the elaboration of Table 7, of Analysis of Variance, relative to the regression model, it is possible to demonstrate that the predictor variable "Marketing (ton)" presents a p-value lower than an alpha significance level of 0.05, meaning that the predictor variable has a statistically significant relation with the variable "first symptoms".

Table 7. Variance analysis

Fonte	GL	SQ (Aj.)	QM (Aj.)	Valor F	Valor-P
Regression	1	317871603	317871603	2148,10	0,000
Marketing (ton)	1	317871603	317871603	2148,10	0,000
Erro	10	1479783	147978		
Total	11	319351386			

Statistically, it can be said that as more tons of agrochemicals are marketed more cases of intoxication will occur. From equation 1, below, we can estimate the number of new cases for each thousand tons marketed. Assuming an annual commercialization of 500 thousand tons in Brazil, one can expect around 6,696 new cases of intoxication caused by pesticides per year.

Equation 1

First Symptoms (Cases) = 0.0131 x (Tonnes Marketed) +146

However, it is curious to note that although it can be observed in Brazil a close connection between pesticide sales and the generation of first symptoms due to intoxication, the states of Mato Grosso, São Paulo and Paraná, which are among the four largest pesticide traders, have low R^2, analyzed at 0.08, 0.0143 and 0.35, respectively, and consequently low correlation between sales and first symptoms (Figure 7).

In this context, it is important to highlight that the state of Mato Grosso has one of the lowest rates of intoxication in ten years, of 129 cases per year, even though it has the highest volume of sales.

The state of São Paulo has had the highest number of intoxications in the last ten years, totaling over 8,000 cases. It should also be noted that there is an increasing trend in the number of occurrences, and in the last three years, São Paulo has registered an average of 1,000 cases per year.

The state of Paraná, the fourth largest in commercialization, maintains a persistent average of approximately 830 cases per year over ten years, which varies little according to the quantity sold.

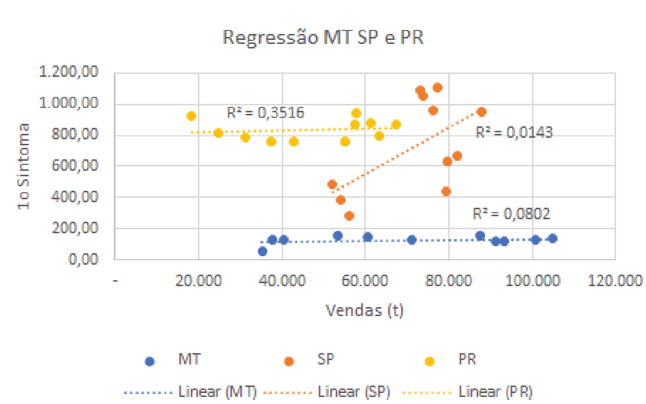

Figure 7. Linear regression: sales x first symptoms in the states of Mato Grosso - MT, São Paulo - SP, and Paraná - PR

Source: Authors; DATASUS, 2019

Rio Grande do Sul, the third state in pesticide commercialization, shows a high correlation between sales and first symptoms (r = 0.92), and sales explain R^2 = 85.3% of symptoms. In this state, the cases are half of those of Minas Gerais, although marketing is double in the latter. Minas Gerais, with an average of nearly 21 cases for each thousand tons sold, presents R^2 = 85.59%, adding a persistent amount of 900 cases per year in the last three years.

The state of Goiás, sixth in commercialization, despite the good correlation between sales and intoxications (R^2 = 81.1%), appears among those states that have the lowest rate of symptoms per thousand tons sold, and maintains an average of eight cases for each thousand tons sold.

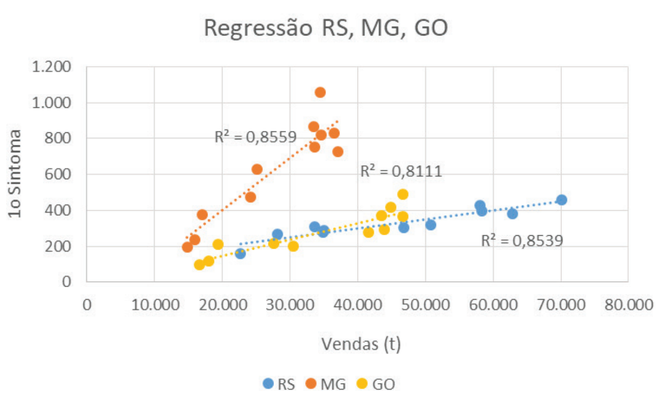

Figure 8. Linear regression: sales x first symptoms in the states of Rio Grande do Sul - RS, Minas Gerais - MG, and Goiás - GO
Source: Authors; DATASUS, 2019

It would not be satisfactory to develop several statistics involving intoxication with agrochemicals if we could not establish the number of people who die or have sequelae from contact and intoxication with agrochemicals. Figure 9 shows that the rate of deaths and sequelae due to agricultural, domestic, or public health pesticides in the period 2007-2017 is around 5.3% in relation to the annual intoxication notification totals. Considering 6,700 annual notifications, it is expected that approximately 355 people will die or have sequelae due to contact and handling of agrochemicals. The Northeast and Southeast regions present the highest mortality rates, with 37.3% and 26%, respectively, and Pernambuco and São Paulo being the states with the highest number of deaths during the period observed.

It is good to remember that longer-term effects that cannot be earned are not accounted for in the study because the notifications are specifically associated with the most visible and understood effects in the short term. In situations of death involving pesticides, there is a need to prove that it was in fact the intoxication that caused the death, a situation that is not always easy to prove, especially in situations where the poisoning occurred in more distant agricultural regions and lacked the best technical resources to investigate the causal nexus that may have led to death.

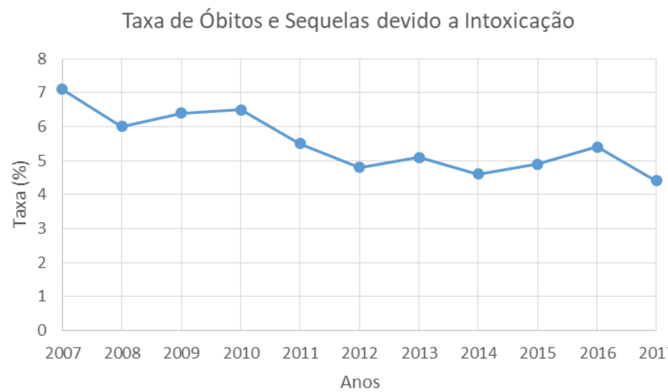

Figure 9. Rate of deaths and sequelae due to intoxication
Source: Authors; DATASUS, 2019

Thus, by analyzing the sources of SINAN data and the deaths caused by these diseases, it is possible to believe that many cases are undernotified or have irregular notification of deaths. This fact ends up hampering not only the more accurate research and quantification of these events, but also hinders judicial notifications against pesticide producing companies.

5. CONCLUSION

The intention of the study was to test the hypothesis that there is a relationship between the consumption of agrochemicals and the appearance of symptoms related to them, which may even be the reason for a causal connection regarding work diseases. This hypothesis was confirmed if we observed the country as a whole (R2=94%), as well as in 13 Brazilian states, with R2 above 75%. Therefore, it is fundamental to deepen these issues in order to avoid the illness of the Brazilian population, especially the rural worker in the country.

In this sense, it is up to each Brazilian state to evaluate in depth the evolution, distribution and incidence of intoxication cases, especially in those states that have high rates of intoxication cases per thousand tons sold, such as Ceará, Amazonas, Pernambuco, Espírito Santo, and Rio de Janeiro. Even those states that have not shown evidence of correlation between pesticide sales and intoxications, such as São Paulo and Paraná, deserve attention because they persistently present a high number of cases.

Another relevant aspect is the mortality indicator. The study identified that the highest rate of fatalities occurs in the Northeastern Region, despite occupying the 4th position in pesticide consumption among the regions of Brazil. This

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fact demands attention to worker guidance programs on the correct handling and application of the product, especially in Pernambuco, which concentrates 18% of all deaths observed between 2007 and 2017.

The indication that women have high rates (30% to 40%) of intoxication from the use of agrochemicals also requires further study. INCA's public note (2018) on Bill no. 6,299/2002 reports that among the effects of chronic intoxication, the most worrying are: infertility; abortions; malformations; neurotoxicity; manifestations through cognitive and behavioral disorders; neuropathy and hormonal deregulation.

Among other aspects that deserve attention, there is also underreporting, i.e. not issuing the Work Accident Communications (CAT), necessary when there is a causal link between the illness and the activities performed at work. It is interesting to note that agrochemical poisoning is not considered a compulsory notification in Brazil, although it is considered of national interest and is notified by the health units in SINAN, according to Ordinance No. 777/GM, 04/28/2014. The Ministry of Health itself estimates that underreporting means that for each pesticide intoxication event notified, there are 50 others not notified.

All these elements together should ignite an alert for the large number of rural workers who may be unassisted, and suggest inefficiency of public policies that support a significant group of citizens responsible for agricultural production in Brazil.

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