

Presence of pesticides in atmosphere and risk to human health: a discussion for the Environmental Surveillance

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Abstract *Brazil is the main consumer of pesticides in the world. Large-scale use of these products is likely to contaminate major environmental compartments and expose more people to their toxic effects. Therefore, this literature review was carried out to seek supporting elements for a qualified discussion about the performance of Environmental Surveillance (HS) within the Brazilian Unified Health System (SUS) related to air contamination by pesticides and health risks. Twelve papers were selected and analyzed in this literature review. Of these, only one was published in a specialized public health journal. Notwithstanding this, two epidemiological studies published in the field of environmental sciences investigated the association between air contaminated by pesticides and specific outcomes such as non-Hodgkin's lymphoma (NHL) and amyotrophic lateral sclerosis (ALS). Our findings reflect the lack of studies addressing such issue by public health. The discussion on air contamination by pesticides and potential risks to human health should be expanded by Brazilian science in order to further increase knowledge on the subject and support the HS performance capacity.*

Key words *Pesticides, Air pollution, Environmental health, Public Health Surveillance*

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Introduction

Increased productivity, strong monoculture presence, field mechanization, export agribusiness and pesticides consumption are characteristics of the so-called Brazilian “agricultural modernization” begun in the 1960s and 1970s¹. However, the development of this agricultural model to current times has been responsible for impacts and damages to the environment and public health².

The National Program of Agricultural Pesticides (PNDA) launched in 1975 and based on an official government policy to encourage the consumption of pesticides contributed to the intensified use of these products in the country. The policy thus fostered the adoption of measures such as exemption from levies and import taxes, in addition to expanded subsidized agricultural credit³.

In the 1990s, the Brazilian market-oriented and profit-driven Brazilian agricultural industry increased the consumption of pesticides. In 2008, Brazil became the world’s leading consumer of pesticides. This fact, combined with the poor management and control of consumption by the environmental agencies resulted in a worrisome national setting both from the environmental viewpoint and from public health, which is the focus of this review.

When used, pesticides can easily divert their primary purpose of fighting target species, also known as “pests”. The toxicity of these products is directly related to the undesirable effects observed in other living organisms, communities, ecosystems and to the contamination of the main environmental compartments: water, soil and air⁴⁻⁷.

Pesticides easily spread in the environment and can reach the atmosphere and contaminate the surroundings of the place of application thanks to its volatilization potential from soil, water and vegetal surface (physicochemical property inherent to pesticides, which varies according to the active principle)^{5,8}. Other physicochemical attributes and mechanisms that include the incineration of contaminated waste, temperature, weather conditions and type of management of these products may also be related to air contamination by pesticides⁹.

In 2000, the National Health Foundation (Funasa), an agency of the Ministry of Health, through Decree No. 3,450/2000, officially launched in Brazil the process of implementation of Environmental Surveillance (ES) in the SUS, focused on the refurbishment of Zoonosis

Control Centers and structuring of the Drinking Water Quality Information System (SISAGUA). From that point on, some institutional restructuring was implemented and new normative instruments appeared to adjust the configuration of EHS to the model that is currently in force and that includes the surveillance of pesticide-exposed populations¹⁰.

Based on Normative Instruction N° 1 of the Health Surveillance Secretariat (SVS) of the Ministry of Health, established in 2005, the General Coordination Office of Environmental Surveillance (CGVAM), previously exercised within FUNASA, was reorganized and assumed a technical structure based on risk management: (i) Drinking Water Quality Surveillance (VIGIAGUA); (ii) Health Surveillance of Populations Exposed to Chemical Contaminants (VIGIPEQ), focused on priority chemical substances (pesticides, benzene, lead, asbestos and mercury), currently also involving VIGISOLO activities (contaminated areas); (iii) Air-exposed populations surveillance (VIGIAR), today unlinked from VIGIPEQ; and (iv) Environmental Surveillance of Risks Associated with Disasters (VIGIDESASTRES), encompassing VIGIFIS (related to physical factors) and also VIGIAPP (related to accidents with dangerous products)¹¹.

The development and application of methods to detect the presence of pesticides in the air is not a new subject in the field of environmental sciences. The risk to the environment and to human health due to the contamination by pesticides has also been investigated over the years and is therefore not an unprecedented agenda for science.

However, the problem of pesticides in the context of Health Surveillance has traditionally focused on worker’s health, soil and water. Thus, it is necessary to start the discussion on the matter in order to promote the improvement of Environmental Surveillance measures for population groups exposed to air contaminated by pesticides.

Thus, the dispersion of pesticides in the air consists of a transversal matter that requires permanent dialogue between VIGIPEQ and VIGIAR technical areas for the development of technical-scientific material that subsidizes the construction of adequate public policies to strengthen the EHS at the federal level. Therefore, the EHS’ primary scope is related to the instrumentalization of the SUS for the planning and execution of actions aimed at health promotion, prevention and control of damages associated

with environmental factors, from the viewpoint of integrality.

Despite the relevance of this issue to Environmental Surveillance with regard to the risk to human health, environmental monitoring and entry routes of such substances into the body of exposed individuals, especially those belonging to more vulnerable population groups (children, the elderly and workers), we note a lack of Brazilian studies on this issue.

The scope of this review is not limited to exploring studies whose air contamination by pesticides has occurred by means of spraying processes and resulting drifts, nor does it intend to seek specific health outcomes potentially associated with pesticide contamination. The reason of this study is to expand the understanding of contamination mechanisms of the environmental matrix “air” and its effects on human health in the scope of Environmental Surveillance.

Therefore, the purpose of this bibliographic review is to gather and analyze the scientific publications of the last five years on air contamination by pesticides, the effects on human health and possible impacts on public health, in order to further reflect on the formulation of Environmental Surveillance strategies in the country on the subject, as well as the capacity to promote a qualified action supported by scientific evidence.

Methods

This is a systematic review of literature based on the online search in databases for the dissemination of scientific and technical knowledge in health sciences: PubMed – developed and maintained by the National Center for Biotechnology Information (NCBI) of the United States – and by the Virtual Health Library (BVS) / Regional Library of Medicine (Bireme) – specialized center of the Pan American Health Organization / World Health Organization (PAHO/WHO).

A preliminary search was conducted for subject descriptors that could result in a research with little noise and that satisfied the primary objective of the study. Thus, descriptors “pesticides”, “air pollutants”, “public health”, “risk” and their English correspondents were used in this study.

The research used the relationship of terms and identified 28 publications in the last five years exclusively from PubMed. From these, we resorted to reading the abstracts and titles to guide the selection of papers to be carefully analyzed and included in the review.

At this stage, the authors agreed, after extensive discussion, to exclude studies that were devoted to assessing exposure in work environments, given the specificity of certain occupational groups, whose nature of work presupposes a greater exposure than that observed in the general population, such as with farmers and workers in agrochemical industries, for example.

Of the 12 papers previously eligible for review, one could not be accessed, remaining 11 papers. On the other hand, we noticed that the bibliographic search was not able to capture one of three papers published in series, probably due to the specificity of the subject. Then, an independent search for that paper was carried out. After a preliminary review of the paper, authors agreed to include it in this review by completing the three-part series. Thus, the review was performed from 12 papers ($n = 12$), since that relevant paper was added in isolation to the 11 papers included in advance.

Finally, we performed a critical reading of the 12 papers included in the study, which were individually analyzed, according to the criteria of originality, relevance and adequacy to the purpose of this study (Figure 1).

In the analysis of the included studies, comparisons of the information available in each of them were made. The presentation and discussion of the results obtained focused on the following perspectives: potential health effects, exposure assessment and environmental monitoring of air contaminated by pesticides.

Results

The electronic search identified 28 studies. Of these, 12 papers were previously selected, and one was eliminated because it was in Chinese and was not published in Portuguese or English. In addition, this article was not available in the databases that we accessed in the conduction of this study. In contrast, a paper previously excluded by search engines and related to the other two of this review was added last.

Finally, of the 12 papers included in the review, six originated from the United States¹²⁻¹⁷, one each from Australia¹⁸, France¹⁹, Armenia²⁰ and Portugal²¹ and two in Pakistan^{22,23}. These were published in specialized journals in the areas of environmental sciences ($n = 9$), health ($n = 1$) and toxicology ($n = 2$) (Chart 1).

We observed that the only published work in the health area included a literature review

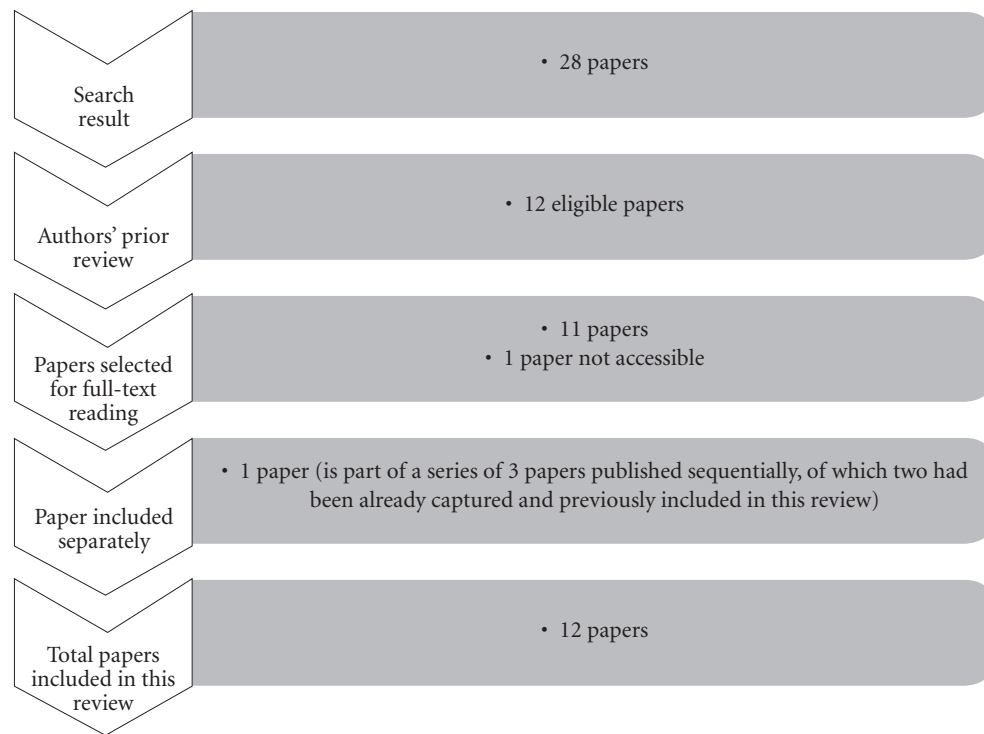


Figure 1. Flowchart showing criteria and decisions taken at each stage of selection of the studies in this review.

Source: the authors.

addressing general concepts in environmental health and the possible environmental risk factors for the development of cancer, among them air pollution, pointed by the author as an example of causal association well established in literature¹⁸.

Interestingly, two epidemiological case-control studies that sought to associate exposure of air contaminated with pesticides were not published in public health journals, commonly observed in investigations with this objective and approach^{17,19}.

One of them¹⁹ sought association between organochlorines (OC) from an incineration plant in Besançon, France, and development of non-Hodgkin's lymphoma (NHL). Of the OCs evaluated, Beta-hexachlorocyclohexane [OR = 1.05; 95% CI: 1.00-1.2] and DDT (OR = 1.20, 95% CI: 1.01-1.45) were associated with NHL.

However, another study with the same approach conducted by Malek *et al.*¹⁷ found no association between pesticides and the development of amyotrophic lateral sclerosis (ALS).

Much in the same way as these, seven other papers^{12,13,15,20-23} addressed the issue of air contamination by pesticides from the perspective of environmental sciences (environmental monitoring and risk analysis and assessment), while the methodology for assessing the impact and risk of exposure frequently observed in these studies includes, somehow, analyses of public health interest, such as the estimation of risk or carcinogenic potential related to exposure to pesticides, according to risk assessment methodologies proposed by international agencies of the environmental or health sector, such as the U.S. Environmental Protection Agency (US EPA) and the World Health Organization (WHO).

Chart 1. Main characteristics of the studies included in this literature review.

Authors (year) / country	Paper title	Journal	Study type	Objective	Main results
Stewart BW (2012) / Australia ¹⁸	Priorities for cancer prevention: lifestyle choices versus unavoidable exposures	Lancet Oncol	Literature review (Author's considerations)	To elucidate by scientific means, environmental risk factors and "unavoidable exposures" associated or not with the development of cancer in order to discuss the need to implement preventive measures.	There is a well-established relationship in the literature between air pollution and the risk of developing lung cancer. Therefore, reduced releases of pollutants in the air is an urgent measure of cancer control in developing countries, and a problem for developed countries. As for pesticides, the potential to cause cancer as well as carcinogenicity are not well established for all chemical classes. However, it is of relevant interest to public health, especially for the occupationally exposed population, and not through the intake of food contaminated by pesticides, as society in general assumes. Nevertheless, based on a precautionary principle, monitoring and adopting possible measures for the reduction of residues in food should be a public health concern.
Batterman et al. (2012) / USA ¹²	Sources, concentrations, and risks of naphthalene in indoor and outdoor air	Indoor Air	Environmental monitoring: assessing exposure	To describe the distribution and sources of naphthalene concentration in the gas phase in four communities in Southeast Michigan, USA.	Outdoor: the median concentration found in the external environment was 0.15 µg / m ³ , with a slight increase observed in the period of intense traffic; Indoor: the median concentration observed in the long term was 0.89 µg / m ³ , with some asymmetry in the values found. Some 14% of the households evaluated had concentrations of naphthalene above 3 µg / m ³ , a reference value for chronic non-carcinogenic effects. Some 8% exceeded 10 µg / m ³ , but values reached up to 200 µg / m ³ . The estimated cancer risk was approximately in the range of 1 to 10,000, but reached 1 in 100 in some households. The main pollutant sources observed are the use of naphthalene as an insect repellent, room flavoring agent and from garages attached to houses.

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Chart 1. continuation

Authors (year) / country	Paper title	Journal	Study type	Objective	Main results
Viel et al. (2011) / France ¹⁹	Increased risk of non-Hodgkin Lymphoma and serum organochlorine concentrations among neighbors of a municipal solid waste incinerator	Environmental International	Case control	To assess the risk of developing NHL in the population exposed to types of organochlorines released into the air through the incineration of solid waste in a municipality of France using the serum concentration of the pesticide to assess the exposure.	Organochlorines associated with the risk of developing NHL: Beta-hexachlorocyclohexane ([OR] = 1.05; [CI] 95% = 1.00-1.2); DDT ([OR] = 1.20; [CI] 95% = 1.01-1.45); Other chemical species associated with increased risk for NHL: Dioxins, Furans and PCBs
Segawa et al. (2014)/ USA ¹³	Community air monitoring for pesticides. Part 1: selecting pesticides and a community	Environ Monit Assess	Development and application of specific methods of air environmental monitoring	To select pesticides relevant to human health, as well as a community in the state of California / USA to receive an airborne pesticide monitoring station, based on society participation and objective and transparent choice criteria	The study of the California Department of Pesticide Regulation (CDPR) has resulted in a list of the 40 most important pesticides and the products of their degradation, from the Public Health perspective and feasibility of monitoring, as well as a community: Parlier, located in the Valley of San Joaquin/California , to receive the monitoring of pesticides in the air for one year.
Hengel & Lee (2014) / USA ¹⁴	Community air monitoring for pesticides. Part 2: multiresidue determination of pesticides in air by gas chromatography - mass spectrometry, and liquid chromatography - mass spectrometry	Environ Monit Assess	Description of the development process and validation of an analytical method for the determination of multiple pesticides in the air	To develop methods for determining multiple pesticides in the air	The two methodologies developed are comparable and appropriate for the determination of residual pesticides in the air

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Chart 1. continuation

Authors (year) / country	Paper title	Journal	Study type	Objective	Main results
Wofford et al. (2014) / USA ¹⁵	Community air monitoring for pesticides. Part 3: using health-based screening levels to evaluate results collected for a year	Environ Monit Assess	Environmental monitoring of air potentially contaminated by pesticides and their by-products	To assess the potential exposure of the resident population of Parlier / California to pesticides and the products of their degradation in the air	Parlier residents were exposed for one year of monitoring to 19 types of pesticides, with peaks of daily concentration varying from 16 to 23.6 µg/m ³ . Diazinon exceeded the Screening Level (SL), a measure used by the study to estimate exposure levels based on the likelihood of the non-occurrence of non-cancer adverse health effects. – 1,3-Dichloropene exceeded the values assigned to its Cancer Potency Value, a measure used to estimate the carcinogenic potential based on the Intra-Risk Information System proposed by the US EPA.
Dvorská et al. (2012)/ Armenia ²⁰	Obsolete pesticide storage sites and their POP release into the environment - na Armenian case study	Environ Sci Pollut Res	Evaluation of environmental compartments, including air, and food potentially contaminated by pesticides classified as persistent organic pollutants (POPs) in landfills and their former storage sites.	To analyze four areas of Armenia selected for containing POP residues in terms of potential human exposure, health risk, and the capacity to disseminate contaminants to the environmental matrix on a local scale	In the samples collected in regions of old landfills and pesticide depots of four different locations in Armenia, all showed some level of environmental contamination. In Jrarat, one of the localities investigated as a former depot and center for the distribution of government agrochemicals (pesticides and fertilizers), soil contamination by pesticides was found in the vicinity of the facilities runoff and dispersed in the form of dust by the wind (256.91 mg Kg ⁻¹ p, p'-DDT). A more plausible hypothesis than volatilization in this case, according to authors. Also in this location, collected air samples were highly contaminated by DDT (sum of isomers equal to 4,320.4 µg disc ⁻¹) with decreasing pollution as it moved away from the ruins of the contaminated warehouse. Also in this region, air pollution by evaporation of lindane and B-endosulfan was detected. In Nubarashen, site of landfill of agrochemical residues, air pollution by HCH (2,376.8 µg disc ⁻¹) was verified.

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Chart 1. continuation

Authors (year) / country	Paper title	Journal	Study type	Objective	Main results
Ratola et al. (2014) / Portugal ²¹	Biomonitoring of pesticides by pine needles - Chemical scoring, risk of exposure, levels and trends	Science of the Total Environment	Environmental assessment of air contaminated by pesticides based on biomonitoring	To determine the levels of 18 types of pesticides by means of the analysis of pine leaves (<i>Pinus pinea</i>) collected in 12 different localities of Portugal	Eighteen pesticides were selected among 70 for evaluation of air contamination through biomonitoring using pine leaves in 12 regions of Portugal. Of these, molinate, pirimicarb, parathion-ethyl, ametryn, prometryn and pendimethalin were classified as very high and high risk of exposure. In addition, air pollution was higher in rural areas, followed by industrial and urban areas.
Mahmood et al. (2014)/ Pakistan ²²	Human health risk assessment and dietary intake of organochlorine pesticides through air, soil and food crops (wheat and rice) along two tributaries of river Chenab, Pakistan	Food and Chemical Toxicology	Environmental and toxicological evaluation	To assess the potential risks to human health related to organochlorine contamination.	Six air samples were evaluated in the province of Punjab, Pakistan, whose organochlorine concentrations ranged from 123 to 625 pg m ⁻³ . However, excess health risk (Hazard Ratio) was observed only in wheat and rice samples.
Kumar et al. (2014)/ USA ¹⁶	Glyphosate-rich air samples induce IL-33, TSLP and generate IL-13 dependent airway inflammation	Toxicology	Toxicological	To explore the mechanisms of glyphosate induction in pulmonary pathology using rat models and real environmental samples	Exposure of rats to glyphosate-rich or glyphosate alone air increased in the lungs: eosinophils and neutrophils, mast cell degranulation, and IL-33, TSLP, IL-13 and IL-5 production. Glyphosate-rich farm air samples (collected at the herbicide-spraying period) or glyphosate alone air samples were shown to be able to induce IL-13-dependent lung inflammation and promote Th2-type cytokines.
Sultana et al. (2014)/ Pakistan ²³	Investigation of organochlorine pesticides from the Indus Basin, Pakistan: Sources, air-soil exchange fluxes and risk assessment	Science of the Total Environment	Environmental assessment	To assess the level of contamination by organochlorines (OCs) and their potential to migrate between environmental compartments: air-soil, in addition to assessing health risks in the Indus Basin / Pakistan	Most prevalent organochlorines in the studied region, including air were DDTs and HCHs. The highest concentration of DDTs in the air in agricultural regions (743 pg/m ³), although it was spatially found throughout the studied area. The risk of cancer found in the Indus Basin resident population was high (RC > 1 X 10 ⁻⁶)

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Chart 1. continuation

Authors (year) / country	Paper title	Journal	Study type	Objective	Main results
Malek et al. (2015)/ USA ¹⁷	Exposure to hazardous air pollutants and the risk of amyotrophic lateral sclerosis	Environmental Pollution	Case control	To investigate the relationship between exposure to hazardous air pollutants with neurotoxic potential (PAPs) and amyotrophic lateral sclerosis (ALS)	Although it found a significantly increased risk for ALS from residential exposure to aromatic solvents in 2002 (OR=5.03, 95% CI: 1.29, 19.53), no association was found between ALS and pesticides.

Discussion

This work was motivated by the need to better understand the potential routes, sources, mechanisms and possible health impacts of populations potentially exposed to air contaminated by pesticides, in order to initiate discussions among researchers, managers and interested stakeholders, given the relevance of this theme to the consolidation of Environmental Surveillance actions in the country.

Equally important would be to perform further studies on the issue addressed in order to consider the possibility of elaborating and adopting future Environmental Surveillance measures aiming at risk mitigation or elimination, prevention and control.

The agricultural sector is the main responsible for the release of pesticides in the environment. As shown by Ratola et al.²¹, rural areas are potentially more polluted than areas close to industries, followed by urban areas, in terms of air pollution by pesticides.

Municipalities surrounded by large plantations or close to the rural area, as occurs in regions of Brazil with predominance of the agricultural model based on monoculture and focused on supplying the international market, should also be a priority in terms of Environmental Surveillance, including with regard to air contamination. This is because the distribution of risk occurs unevenly in the territory, especially affecting rural or urban communities influenced by this type of agriculture.

At the beginning of the search, we expected to find in scientific literature a sufficient number

of papers that explored the issue of air contamination by pesticides related to the application method – spray drift of pesticides in plantations – contaminating populations and surrounding areas. This example may be related to the episode occurred in the Mato Grosso state's municipality of Lucas do Rio Verde in March 2006, referred to as an expanded rural accident, which brought the theme of the issue to Brazilian public health, culminating with publication in scientific journals²⁴.

However, the bibliographic research that considered the environmental air contamination, excluding the specific work environments – occupational exposure – was scarce and returned 12 papers in the last five years. Surprisingly, none of them referred to studies carried out in Brazil, revealing a contradiction, given the prevailing agricultural production process model in the country, with a high dependence on agrochemicals (pesticides and fertilizers), as previously discussed.

In other countries, air pollution by pesticides is commonly addressed based on analysis by specific chemical classes of pesticides and possible health effects associated with them, and also it does not place the use of these products in the agro-industry associated with air pollution at the core of scientific investigations.

The legal definition of pesticides in Brazil was considered in this study. Thus, all identified studies explore the contamination of air by pesticides and the products of their degradation, regardless of release sources and routes of pesticides to the atmosphere.

In the analysis of the results, we observed that pesticide air pollution varied from the domestic use as repellent of undesirable animals, environ-

mental deodorizer, to possible air contamination by solid waste incineration products.

Likewise, the health effects investigated in the analyzed studies considered the risk for cancer development in general¹⁸ and more specific neoplasms¹⁹, such as non-Hodgkin's lymphoma (NHL).

The most likely route of exposure shown in the studies evaluated, though tacitly, was airways with inhalation of air contaminated by some pesticide or by-product, while the possibility of dermal exposure or intake of contaminated food has not been ruled out.

Our findings reflect the lack of studies addressing the theme by the health sector. Regarding Brazil, where profits generated by the agricultural sector are an important contribution to the current national economic setting, the lack of scientific studies and public sector's neglect vis-à-vis the population potentially exposed to air contaminated by pesticides is even more worrying.

In addition, the country faces difficulties over the promotion of adequate migration to a more

sustainable agricultural model, while at the same time producing a profit, which would result in long periods of exposure by the population. Developed countries tend to have a more advanced monitoring and surveillance system.

As we have seen in this study, the development of new techniques and methodologies for the monitoring of air contaminated by pesticides has unfolded in the world and points to a pathway to be followed by Brazil, both from the academic viewpoint and the improvement of health sector's measures regarding Environmental Surveillance.

The expansion of the current traditional approach – focusing on health risks related to the presence and contamination of soil and water by pesticides, or occupational problems resulting from this type of chemical exposure – toward a more comprehensive Environmental Surveillance model that also considers air contamination is required within the SUS and could not start differently than through the bibliographic survey involving this theme.

Collaborations

GS Souza worked on the design, methodological outline, analysis and interpretation of results and paper writing and review. YAP Pamplona contributed the design, analysis and interpretation of results and critical review of paper. AC Maciel worked on the methodology and analysis of results. FDV Reis participated in the bibliographic research and interpretation of results. LCA Costa contributed to the conduction of the bibliographic review and analysis of results.

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