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Assessment of Pesticide Contamination in Cidade Dos Meninos, Rio de Janeiro, Brazil, Using Regional Screening Levels (RSL)

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Abstract

In the mid-20th century, the Malaria Institute in Brazil researched hexachlorocyclohexane (HCH), dichlorodiphenyltrichloroethane (DDT), and other organochlorines in Cidade dos Meninos, Rio de Janeiro, Brazil. After Malaria Institute closure, there was a 200-ton stock of chemicals compounds abandoned without any surveillance, which led to massive contamination of the nearby community by carcinogenic organochlorines. This article presents a new review of the Cidade dos Meninos' case, analyzing the HCH and DDT contamination using a Haddon Matrix and Regional Screening Levels (RSL).

Keywords

Organochlorines, DDT, HCH, Cidade Dos Meninos, Contamination, Environmental Chemistry, Haddon Matrix, RSL

1. Introduction

The 1948 Nobel Prize award in Physiology and Medicine was to Paul Mueller for elucidating DDT (dichlorodiphenyltrichloroethane) toxic effects in insects. Since then, DDT has been indiscriminately used in pest and insect control by the agricultural sector, even for malaria control, and according to some records, sprayed directly on the skin of individuals to control lice-borne diseases during World War II. [1]

Wolmarans *et al.* [2] conducted research in conservation areas within malaria risk regions and found substantial bioaccumulation of DDT and other organochlorine pesticides in amphibians. Kumar *et al.* [3] examined residential soils in Korba, India, and detected the presence of DDT and HCH, raising concerns about potential health risks to the human population. Additionally, research by

Li *et al.* [4] delved into the environmental persistence of DDT by analyzing sediment records from Tibetan lakes, shedding light on the contribution of primary emissions to the current DDT levels. This collective body of recent research underscores the global relevance of DDT contamination and its detrimental impact on both natural and human environments.

Rachel Louise Carson's book of 1962, "Silent Spring", was one of the first works in the world to warn the international community about the toxic effects of DDT. In her book, the scientist revealed that DDT accumulates in the adipose tissues of living organisms through a biomagnification process that can even affect humans. Genetic damage and, in more severe cases, cancer are among the deleterious effects caused by DDT. "Silent Spring" was extremely important in revealing the dangers of DDT use but even more crucial in advancing public awareness of technological advancement impacts can have on the environment and public health. [1]

Parallel to the early history of DDT, another chemical compound, or a family of chemical compounds was used to a greater extent in Brazil in Cidade dos Meninos, a municipality in Duque de Caxias, Rio de Janeiro, in complete disregard of its toxic and potentially harmful effects on human health. In the mid-1940s, Cidade dos Meninos was conceived as a complex of housing and schools initially intended to accommodate orphaned girls but was later reformed and designated to receive only boys. As this region of Duque de Caxias was considered an endemic malaria zone, the Malaria Institute, an agency under the National Department of Health of the Ministry of Education and Health, was later established. [5]

The Malaria Institute researched on hexachlorocyclohexane (HCH), or "Broca powder", an organochlorine pesticide used for seed treatment, soil, leaves, forests, animals, and public health. HCH use was banned from Brazilian agriculture in 1985, although it continued to be used in public health campaigns to eliminate disease vectors. For the HCH synthesis route, the Institute carried out the low-temperature chemical catalysis reaction between benzene and chlorine, compounds that also a risk to human health. In addition to the HCH research, the Institute had areas dedicated to studying pesticides such as copper arsenite, trichloro bis (chlorophenylethane), or DDT, producing various products containing enriched DDT isomers. [5]

The factory ceased operations in 1961 due to economic difficulties caused by the shift of chlorine suppliers to São Paulo—transporting chlorine, a hazardous material, from São Paulo to Duque de Caxias would be prohibitively costly and impractical—and the existence of more domestic pesticide producers. After the closure of operations, the institute left behind 112,407 liters of Triton X-151, 109 drums of xylene, and approximately 300 to 400 tons of Broca powder in its industrial plant. With the complete abandonment of the institute and its chemical materials stock, the structure of the buildings naturally deteriorated, and the products dispersed. [5] [6] [7]

The closure of the Malaria Institute's activities, the seizure of materials related to pesticide production, and other relevant events to understand the Cidade dos Meninos' history were grouped on the timeline depicted in Figure 1. The proposed timeline does not suggest an evolutionary connection between events, as it only serves as a visual tool for each event historical and temporal context.

As seen in Figure 1, between 1960 and 1980, the world saw discoveries regarding the impact of organochlorines that pressed the international community for new policies for protecting the environment and the public against the effects of these pollutants. The Stockholm Declaration (1972) inaugurated the first instrumentalist approach to the environment in which its signatories committed to developing instruments to identify and reduce the release of persistent pollutants, especially those considered mutagenic, teratogenic, or carcinogenic. Almost 30 years later, the Stockholm Convention of 2001 postulated that all signatories must restrict or prohibit a group of 10 different organochlorines. Among them, there was the restriction of the DDT use for general situations—except for health campaigns to control of diseases. [8] [9]

In 1989, the police department removed around 40 tons of HCH from the Malaria Institute's abandoned warehouses, but this delayed seizure did not prevent the overall spreading of organochlorines in the region. A 4-kilometer road crossing Cidade dos Meninos was filled with soil contaminated by the Institute, further contributing to the dissemination of chemical compounds. As more residents (predominantly of rural origin) settled in the surrounding area, more cattle and poultry began to feed in the contaminated region. Since HCH and other organochlorines are bioaccumulative, these compounds increased in concentration in the bodies of these animals and transferred to local inhabitants through the consumption of milk, eggs, and meat. [7]

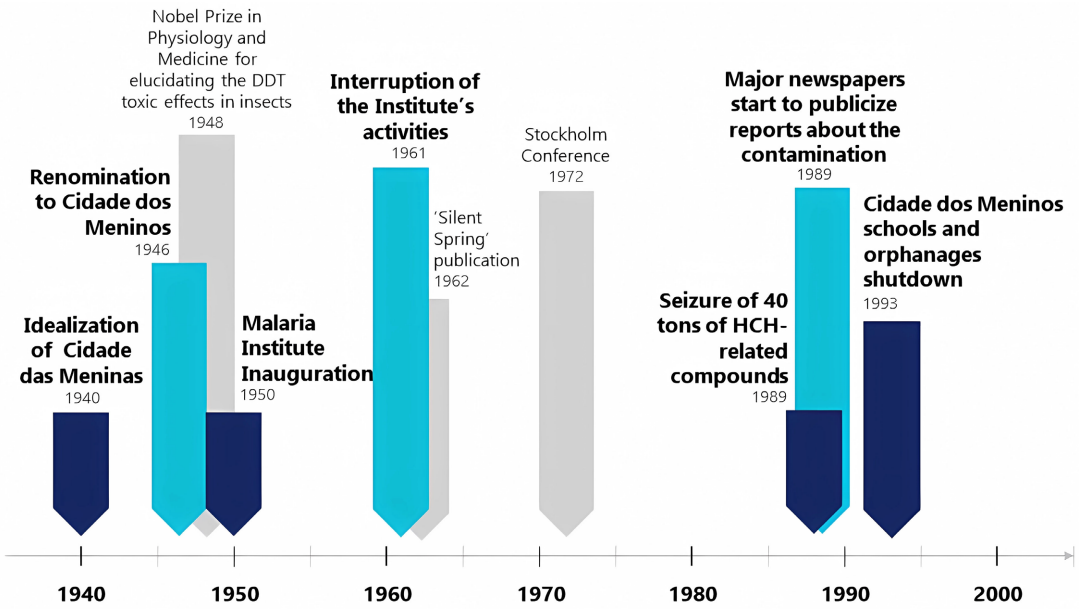

Figure 1. Timeline of significant events for the context. Source: adapted from [1] [5] [8].

In addition to physical documents attesting to the abandonment of a large volume of organochlorines and supplies of the Malaria Institute's stock, there are testimonies from Cidade dos Meninos' residents indicating that the material left in the institute had a high circulation in the community, and freely sold in markets for controlling termites, rats, lice, and even applied directly to children's heads. The case became publicly known by publishing reports and investigations in the mainstream media in 1989. However, it was only in 1993, with the suspension of that all social assistance and education activities for vulnerable children resulted in the orphanage residents relocation. [5]

Some studies with children and families living in Cidade dos Meninos indicate that α and β HCH isomers were higher in those living near the institute's ruins. In summary, HCH is primarily composed of α, β, γ, and δ isomers, which differ from each other in physicochemical properties, such as solubility, persistence, applications, and toxicity, as will be further detailed. [7]

Since the confirmation of the organochlorines contamination in 1995, the Ministry of Health contracted a company to carry out a remediation procedure in Cidade dos Meninos. The process involved the addition of calcium oxide and the removal of contaminated soil. Upon completing of the procedure, the company reported the decontamination of the area. However, subsequent assessments revealed that Cidade dos Meninos remained highly contaminated with HCH, DDT, and compounds derived from DDT. Despite communication warnings, in 1997, the Ministry of Social Security began organizing meetings to define a project to build a housing complex in that area. [7]

This scenario, in which an institute that produces an industrial compound with certain environmental and human health risks located alongside an institution providing care for vulnerable children in a historically disadvantaged area, resembles the context of contaminated sites analyzed by Tavares in 2019 [10]. The establishment of the Malaria Institute in Cidade dos Meninos and the subsequent scenario of abandonment, both of the precursor and pesticide stockpiles and of the affected population, characterizes what the author calls environmental injustice, a socio-spatial condition in which the impact of environmental damage is distributed unequally due to social class, racial ethnicity, and other variable influences. [10]

Tavares assesses the establishment of a steel mill in the Santa Cruz neighborhood, located in the west zone of the municipality of Rio de Janeiro, where there is abundant evidence of environmental contamination and reports of illness affecting the local population [10]. The central concept of his thesis was to analyze the case of Cidade dos Meninos (a neighborhood also belonging to an economically disadvantaged area in the metropolitan area of Rio de Janeiro), a 'sacrifice zone'. Sacrifice zones are areas where companies chosen to install facilities with high potential of harm to human health and located in distant regions where the inconvenience and the environmental damage affect only a lower-income population. [10]

The high availability of data describing the local contamination allows applying various tools to quantify the risk to the remaining neighborhood population. The United States Environmental Protection Agency (EPA)—the governmental department responsible for protecting human and environmental health—provides robust tools for modeling pollutant contamination events. The tool known as RSL Calculator allows the calculation of the risk attributed to exposure to one or more chemical compounds based on the estimated ingested dose and reference guideline values defined by the EPA for a given compound. With the provision of the component's identity (nomenclature or CAS number), the platform calculates the Regional Screening Levels (RSL), a parameter that assesses the safe concentration for a given compound dispersed in the environment, considering mobility and toxicity factors. [11]

The RSL calculation facilitates the identification of areas where further investigation by the public sector is necessary. Besides aiding the identification and initial analysis of contaminations for reporting to policymakers, the tool has significant value for the academic community as it avoids the use of a series of equations for risk calculation compound mobility in soil, water, and air, and because it integrates with the EPA's reference value database. [11]

The characterization of the Cidade dos Meninos contamination event was a succession of governmental negligence and an arduous legal battle by those affected to recognize the full extent of the damage to the Cidade dos Meninos resident community. In this context, this work proposes a literature review of the case—guided by an applied Haddon Matrix and an assessment of contamination by the main organochlorines present in Cidade dos Meninos by the calculating the Regional Screening Levels (RSL).

2. Methods

This study was conducted based on a review of available internet literature regarding the contamination case in Cidade dos Meninos. This approach aimed to combine documents published when the issue had its highest impact (the late 1980s and the 1990s) with current articles, theses, and dissertations, contributing to a comprehensive understanding of all available data.

The Haddon Matrix is a facilitative tool for organizing crucial events and describing the history of contamination in Cidade dos Meninos. Likewise, it supplies the identification process of implemented actions that minimize potential harm to the population and the environment. Regarding the allocation of responsibility, the Haddon Matrix uses a methodological structure that attributes greater responsibility to the authorities and executives who accumulate power, preventing the revictimization of the affected population. [12]

Organized in a two-dimensional plane, the Haddon Matrix has columns—identifying the affected population, the agent or vehicle of contamination, the contaminated physical environment, and the socio-environmental factors—crossed by lines (called phases) before the event, during the event, measures and

after the event. The phases act as time frames for separating the moments by prioritizing preventive actions (before the event) and remedial actions (after the event). As a first step in designing the matrix, the Malaria Institute's closure (and consequently the abandonment of 200 tons of organochlorine production components) was the critical event and episode that made up the 'during the event' line. Based on this time frame, the delimitation of the events preceding and following the Institute's closure was objectively analyzed. The Haddon Matrix generated with these definitions is in **Table 1**. [12]

This research considered the assessment conducted by Asmus, 2008. The selection of the maximum concentrations only for the primary HCH isomers and DDT metabolites evaluation presented in **Table 2**. [14]

The samples data presented in **Table 2** result from the extraction of soil and wells within the main axis of Cidade dos Meninos, defined by the area near Avenida Darcy Vargas, a main avenue that cuts across Cidade dos Meninos from end to end. The samples were collected in the region highlighted in **Figure 2**. The map depicts the georeferenced linear area within the UTM coordinates

Table 1. Haddon matrix applied to the malaria institute shutdown and post-contamination.

Phases	Factors			
	Host—Cidade dos Meninos residents and workers	Agent/vehicle—Compounds related to organochloride production (mostly HCH and DDT isomers or by-products)	Physical Environment—Cidade dos Meninos, Duque de Caxias, Rio de Janeiro	Social Environment
Before the event	Offering general information and training about the Institute's activities to the public close to the Institute	All chemicals stay under rigorous surveillance	Installation of chemical institutes in appropriate locations to minimize risk for neighbors, especially those in early ages and vulnerable conditions	Community participation in processes for new facilities positioning. Zoning rules for protecting places inhabited by vulnerable communities.
During the Malaria Institute Shutdown (1961)	Instructions to avoid the area next to the Institute and not to drink nor eat local products to the Cidade dos Meninos residents	Correct treatment (deposition in a safe place, incineration, biochemical or redox process) to chemical compound leftovers	Surveillance to prevent further leakage	Medical, social, and psychological support and temporary homes for the affected residents.
After the event	Relocation of the Residents within the affected area to interrupt every sort of exposure	Remediation of the affected area to eliminate all present organochlorines. The affected perimeter stays isolated until the area's safeness is confirmed	Cleansing of the affected area and demolition of the remaining buildings	New homes and guaranteed health accompaniment to the affected population Prohibition or restriction to dangerous chemical components and laws determining specific zones for monitoring and positioning of dangerous activities.

Source: adapted from [13].

Figure 2. Graphic representation of sample collection area. Cidade dos Meninos, Duque de Caxias, Rio de Janeiro, Brazil, 2020. Source: adapted from [15].

−22.671371, −43.327572 and −22.703641, −43.315470. The line representing Ave. Darcy Vargas runs vertically across the map.

Table 2. Maximum concentrations of the contaminants of interest in environmental compartments within the Primary Focus Area, Cidade dos Meninos, 2002.

Compounds	Soil (μg/Kg)	Underground water (μg/L)
Alfa-HCH	89467.6 (2)	928.4
Beta-HCH	6206.5 (1)	62.61
Gama-HCH	32244.1 (1)	1208.60
Delta-HCH	22270 (3)	1265.30
o,p-DDE	322.51 (1)	10
p,p-DDE	1506.81 (1)	0.22
o,p-DDD	7040.4 (1)	ND
p,p-DDD	3640.72 (1)	0.2
o,p-DDT	709.06 (1)	0.37
p,p-DDT	5655.3 (1)	0.89

Observations: 1) Sample collected in a trench up to 50 cm deep. 2) Sample collected with an auger at a depth of 1.0 m. 3) The sample collected with an auger at a depth of 4.0 m. Source: adapted from [14].

Once the concentration of each contaminant in Cidade dos Meninos was determined, it was possible to calculate the Regional Screening Level (RSL) using the RSL calculator. [16]

The RSL Calculator platform enables users to perform modeling by entering specific data or using EPA's database values. This study uses the database constants and the option for Regional Screening Levels (RSLs) analysis. Subsequently, chose the constants recommended by the User's Guide provided by the EPA and include a hazard quotient of 0.1 and a target risk of 10^{-6}, thereby also assessing the carcinogenic risk associated with exposure. The calculation of Cidade dos Meninos residents' risk, uses the resident's scenario and the assumption of the contamination dispersion was through soil and water, considering specific conditions of the analyzed event and apply chemical constants existing in the EPA's database. [11]

Finally, the selection of view the risk result. The selection of the compounds listed is in **Table 3** for analysis.

The base of the calculation of carcinogenic risk and non-carcinogenic HQ (Hazard Quotient) were on the values obtained from RSL (Regional Screening Level) using the following equations [11]:

Carcinogenic risk:

$$\frac{\text{TR}}{\text{RSL}} = \frac{\text{Risk}}{\text{C}} \tag{1}$$

Non-carcinogenic HQ:

$$\frac{\text{THQ}}{\text{RSL}} = \frac{\text{HQ}}{\text{C}} \tag{2}$$

The rearrange of the Equations (1) and (2) isolate the risk [11]:

Table 3. Identification of the analyzed chemical compounds.

Compound	Number CAS
DDD, o,p'	(53-19-0)
DDD, p,p'	(72-54-8)
DDT, o,p'	(789-02-6)
DDT, p,p'	(50-29-3)
DDE, p,p'	(72-55-9)
Delta-hexaclorociclohexane	(319-86-8)
Gama-hexaclorociclohexane (Lindane) (γ-HCH)	(58-89-9)
Alfa-hexaclorociclohexane (α-HCH)	(319-84-6)
Beta-hexaclorociclohexane (β-HCH)	(319-85-7)

Source: adapted from [11].

Carcinogenic risk:

$$\text{Risk} = \frac{\text{C} \cdot \text{TR}}{\text{RSL}} \tag{1.1}$$

Non-carcinogenic HQ:

$$\text{HQ} = \frac{\text{C} \cdot \text{THQ}}{\text{RSL}} \tag{2.1}$$

wherein:

Risk is the dimensionless probability of an individual developing cancer over their lifetime.

HQ is the dimensionless ratio between the exposure and reference concentration, with a value less than or equal to 1 indicating that exposure is unlikely to cause adverse health effects.

C is the concentration entered by the user in the customized analysis mode, given in (mg/kg), (μg/m^3), or (μg/L).

TR is the target risk chosen in the customized analysis mode.

THQ is the hazard quotient chosen in the customized analysis mode.

RSL is the Regional Screening Level, automatically determined based on the values chosen in the customized analysis mode, also in terms of (mg/kg), (μg/m^3), or (μg/L).

It is important to note that in risk calculation, assuming the Cidade dos Meninos' residents had an exposure duration of 26 years to the concentration limits described by Asmus, 2008. In this hypothetical scenario, such compounds do not undergo degradation or increase; they remain static in the environment. [11], [14]

3. Results and Discussion

Since the revelation of high levels of organochlorines contamination in Cidade dos Meninos, numerous research efforts had to trace the dispersion of contami-

nants and potential health interactions. Analyses typically seek patterns between the concentration of contaminants in soil, plants, water, residents' blood, chicken eggs, and other animal products consumed in the region and the disease increase during exposure to these compounds. The most common method for analyzing contamination is determining of concentration in water and soil and, in some instances where the pollutant is volatile, in the air. As the RSL (Regional Screening Level) calculation tool models events where the contaminant affects soil, water, and air, and DDT, HCH, and their derivatives are relatively non-volatile, the selection of options focused on soil and water dispersion. The results of the RSL compiled calculation in Table 4 and Table 5.

The RSL Calculator platform calculated the Screening Level for each chemical compound, and based on the concentrations seen in Table 2, it calculated the relative risk for each possible scenario and the assumption of Cidade dos Meninos'

Table 4. Carcinogenic or non-carcinogenic risk related to the sum of both exposure pathways (ingestion and skin contact) for adults and children.

Compound	Soil				Underground Water			
	Screening Level (mg/kg)	Non-carcinogenic HQ: Adults	Non-carcinogenic HQ: Children	Carcinogenic Risk	Screening Level (µg/L)	Non-carcinogenic HQ: Adults	Non-carcinogenic HQ: Children	Carcinogenic Risk
DDD, p,p'	2.26E+00	1.24E−02	1.15E−01	1.61E−06	3.17E−02	1.24E−04	1.89E−04	6.31E−09
DDE, p,p'-	4.41E−01	6.02E−03	6.42E−02	3.41E−06	1.63E−02	2.20E−05	3.66E−05	1.35E−08
DDT	4.18E−01	1.53E−02	1.55E−01	1.35E−05	7.37E−02	5.33E−05	8.88E−05	1.21E−08
α-HCH	1.93E−02	-	-	4.62E−03	2.32E−03	-	-	4.00E−04
β-HCH	6.77E−02	-	-	1.57E−03	8.13E−03	-	-	7.71E−05
γ-HCH (Lindane)	1.26E−01	1.51E−02	1.50E−01	2.55E−04	1.33E−02	2.07E−02	3.31E−02	9.09E−05
Total Risk/HI		*4.88E−02*	*4.85E−01*	*6.46E−03*		*2.09E−02*	*3.34E−02*	*5.68E−04*

Source: adapted from [11].

Table 5. Comparison between the screening level calculated by the RSL calculator and the values described by Asmus, 2008 in Cidade dos Meninos.

Compound	Soil			Underground Water		
	Screening Level (mg/kg) - SL	In situ Concentration (mg/kg) - C	C/SL Ratio	Screening Level (µg/L) - SL	In situ Concentration (µg/L) - C	C/SL Ratio
DDD, p,p'	2.26	3.64	1.6	0.032	0.2	6.31
DDE, p,p'-	0.44	1.51	3.4	0.016	0.22	13.50
DDT	0.42	3.64	8.7	0.074	0.89	12.08
α-HCH	0.02	89.47	4635.6	0.002	928.4	400172.41
β-HCH	0.07	106.21	1568.8	0.008	62.61	7701.11
γ-HCH (Lindane)	0.13	32.24	255.9	0.013	1208.6	90872.18

Source: adapted from [11] and [14].

residents consumed the groundwater described by Asmus, 2008 and both exposed adults and children were through the same exposure pathways (ingestion and skin contact). **Table 4** contains the adult and child population results for better visualization. In addition to the carcinogenic risk caused by exposure to each chemical compound, the non-carcinogenic HQ (Hazard Quotient) was also calculated, indicating the risk of immediate effects from exposure. Estimating the risk for some components was impossible due to a lack of physicochemical or toxicity data. Therefore, some isomers, such as delta-hexachlorocyclohexane, were removed from the table.

For ease of discussion, in **Table 5**, the potation of individual concentration data were alongside the specified RSL value for each compound. This allows for a quick observation of isomers with concentrations above what is considered safe for human exposure. In the column labeled "C/SL Ratio", it is evident that all substances are above what is considered safe, with concentrations ranging from 1.6 times more than the recommended level (as seen in the case of DDD, p,p' in soil) to approximately 400,172 times (alpha-hexachlorocyclohexane in water). The comparison of the C/SL values for water and soil stated that the water medium is more critical, with concentrations for DDT and its derivatives about 10 times higher, on average, than the recommended values by the EPA platform, and concentrations of HCH isomers approximately 166,000 times higher, on average than the acceptable values calculated by RSL. HCH isomers are known as agents responsible for immune and nervous system damage and to cause teratogenic problems probably; therefore, these extremely elevated values above the safety threshold represent a serious health risk to the population in contact with the Cidade dos Meninos' contaminated area. [17]

Regarding non-carcinogenic risk, risks equal to or less than 1 are considered acceptable. Therefore, when considering ingestion via groundwater and soil separately for adults or children, the sum of all available components is less than 1, indicating that, although close, the organochlorines concentration is within the acceptable limit for immediate adverse health effects. However, some components could not be calculated, and they could increase the risk to unacceptable levels. Additionally, issues related to bioaccumulation are not assessed in this method, which could impact the exposure dose of OCs to the population. It emphasized the most significant expected health impact of the pollutants present in Cidade dos Meninos is through the carcinogenic or teratogenic pathways.

In 2023, the Ministry of Health, in conjunction with the National Cancer Institute, published a report on cancer incidence in the population of each Brazilian state. In this report, the prediction of the state of Rio de Janeiro would have 276.52 new cancer cases per 100,000 inhabitants, resulting in a risk rate of 2.76E−03. [18]

The analysis using the RSL, as shown in **Table 3**, revealed that considering the sum of all compounds with available data, there is a carcinogenic risk of 6.46E−03 for the soil and 5.68E−04 for water, disregarding the fact that these compounds undergo bioaccumulation and may reach the Cidade dos Meninos'

population in a concentration different from that described by Asmus, 2008. When compared to the data from the National Cancer Institute, the calculated carcinogenic risk (6.46E−03 and 5.68E−04) is already similar in terms of units of measurement to the overall cancer risk for the entire population of Rio de Janeiro (1.44E−04). Thus, it is possible to suggest that exposure to these levels of carcinogenic compounds may already be sufficient to increase the likelihood of an individual developing cancer over their lifetime. Epidemiological studies need to examine the incidence rate of cancer to confirm or reject the possibility that exposure to organochlorines in Cidade dos Meninos is causing an increase in local cancer cases. [18]

The comparison of RSL values with the data collected by Asmus, 2008 indicates high contamination of the soil and water in Cidade dos Meninos by the analyzed organochlorines (compounds with high carcinogenic potential) at unusual levels, a finding corroborated by numerous scientific studies and reports from environmental agencies. The aggravation of the situation in Cidade de Meninos was the fact that the polluting agent is a public company linked to the Ministry of Health and, as pointed out by Herculano (2002), it mainly affects a vulnerable population composed of impoverished children under the care of the Cidade dos Meninos' shelters, as well as former workers who lost their jobs due to the closure of the Malaria Institute—some of whom are seeking compensation and medical support due to exposure–related illnesses. [5]

The contamination by organochlorines in Cidade dos Meninos may illustrate a Brazilian socio-political context marked by a series of inequalities: an institute that is known to use hazardous inputs to produce compounds that also pose risks to public health, and the environment located in a region with a historically vulnerable population. In this context, Cidade dos Meninos resembles a 'sacrifice zone', where the environmental damage caused to a disregarded vulnerable population in favor of the economic development generated by industrial production. [10]

The confirmation of high contamination levels by organochlorines in Cidade dos Meninos underscores the importance of further studies that assess the impact on the affected population health. Moreover, studies that also evaluate the social and political aspects are needed to confirm whether this case fits the pattern of environmental injustices mentioned by Tavares (2022), thus helping to build an environmental framework for communities that may also be experiencing contamination situations and are neglected, and in need for public or private intervention.

4. Conclusions

Significant soil and water contamination has been confirmed in the vicinity of the former Malaria Institute. When applied to the calculation of Risk-Specific Levels (RSLs), the data revealed a substantial presence of chemical organochlorines in both soil and water. The quantities detected were at least 1.6 times high-

er than what the EPA deems safe, with some compounds, like alpha-hexachlorocyclohexane, exceeding safe levels by a staggering 400,172 times. Moreover, the EPA's methodology for estimating carcinogenic risk suggests that these organochlorine concentrations could significantly elevate the likelihood of individuals developing cancer over a hypothetical 26-year exposure period. The calculated probability of cancer incidence stood at 6.46E−03 for exposure via soil and 5.68E−04 via groundwater, which is considered high in comparison to the standard public exposure risk of approximately 10E−6 for daily activities.

The results obtained through the RSL Calculator signal both extensive contamination in the area known as Cidade dos Meninos and a heightened risk of carcinogenic effects on the population exposed to these adverse health conditions. However, it's important to note that there is a lack of comprehensive theoretical parameters for assessing these adverse risks, which may have resulted in an underestimation of the actual risk levels. The RSL Calculator's analysis is preliminary and primarily underscores the urgent need for further investigations, particularly with regard to direct contamination among the population and through epidemiological studies on disease incidence before and after contamination confirmation.

The comparison between RSLs and the concentration of OCs demonstrated that, at the time of sampling in the studied location, all of these compounds significantly exceeded acceptable levels. The high degree of water and soil contamination can be attributed to government negligence, stemming from the selection of a populated site for the construction of the Malaria Institute and the subsequent abandonment of 300 tons of potentially carcinogenic chemicals. In light of these findings, there is a collective responsibility for the government and society to fully map the contaminated area, assess the health damages caused, and ensure the inclusion and social support of the affected population in Cidade dos Meninos as part of a comprehensive decontamination project for the region.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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