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Application of the DPSEEA Model to Healthcare Waste Management

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Abstract *The use of health indicators is indispensable for understanding the complex relationship between the environmental and health fields. For the proposition of environmental health indicators, the Brazilian Ministry of Health (MH) recommends using a model proposed by the World Health Organization. This model is composed of the following elements: Driving Force, Pressure, State, Exposure, Effect, and Action; it is called the DPSEEA model. The objective of this study is to propose the application of this model in healthcare waste (HCW) management. This study was performed by documentary research using two data sources: a) technical reports on research on HCW from the last 15 years (outpatient, dental, hospital, veterinary, university, and primary care unit) at the University of Caxias do Sul, Brazil; and b) the MH manual entitled "Environmental Health: Basic Guide for the Construction of Indicators". The results show that the model is relevant because it makes it possible to analyse a particular context, proposing indicators and defining specific actions for the case of this study, to monitor and improve methods of managing HCW. The results also show that the proposed model is an important analytical tool for both medical waste management and planning actions that will minimize risks, particularly chemical and biological, resulting in environmental health and protection.*

Key words *Environmental health, Health indicators, Healthcare waste*

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Introduction

The productive processes of work and consumption influence the state of human and environmental health. Addressing the subject of environmental health, the Brazilian Ministry of Health (MH)[1] states that the means of production and of social and economic development interfere in ecosystems, which are determinants of and contributors to changes in the patterns and levels of population health. This interference results in changes in the epidemiological and morbidity-mortality profile due to the exposure of humans to different and altered environments.

In addition to environmental interferences that produce illness, how healthcare services focus their actions on disease also impacts health and the environment. The healthcare logic focused on pathophysiology – centred on the biomedical model, which prioritizes treatments and procedures – and the organizational characteristics of services lead to a trend of progressive increase in the use of disposables and, consequently, increase in the volume of generated waste. Disposables have a higher acceptance in the health sector due to their practicality and because they reduce the risk of disease transmission, particularly for diseases carried by blood and secretions. Thus, the generation and management of waste generated in healthcare may lead to risks for both those directly involved in health services and users, their families, and society as a whole if these wastes are inadequately disposed of in the environment[2]. Therefore, they constitute an environmental health problem.

The issue of environmental health may be considered to be fairly recent in Brazil. Since the proposition of the document entitled *Information for the Construction of the National Environmental Health Policy*[3], several initiatives in different areas have been striving to approximate health and the environment to understand the complex relationship between the two.

There is also an effort to develop legislation to protect the environment and health. An example is the National Solid Waste Policy (NSWP)[4], which classifies waste according to origin (household, construction, industrial, healthcare, among others) and hazardousness (hazardous or non-hazardous). Healthcare waste (HCW) is defined in the NSWP as "[...] those generated in health services [...]"[4], and it is considered dangerous due to having characteristics of "[...] flammability, corrosiveness, reactivity, toxicity, pathogenicity, carcinogenicity, teratogenicity, mutagenicity [...]"[3] and because it presents significant risks to public health and environmental quality, particularly in the case of waste from the following categories: infectants (group A), chemicals (group B), radioactives (group C), and sharps (group E)[5].

The generation of HCW, despite being relatively small compared to solid urban waste, becomes significant when the potential risks associated with it is considered. These include the presence of pathogenic organisms and/or their toxins, chemical products of a diverse nature (drugs, chemotherapeutics, solvents, among others), and radiological risks. The HCW problem is also a consequence of other factors, such as the mixing of wastes of different natures, dumping on public roads, and/or inadequate disposal in landfills, which are not always sanitary or controlled[2].

These risks are increased when the forms of waste management are inadequate. The inadequacies in waste management in contemporary society compromise the quality of life of the population and the quality of the environment, resulting in risks to both physical health (infectious and degenerative diseases) and mental health (anxiety attacks, panic attacks, and depression) as well as social disintegration (social isolation, exacerbation of violence, among others)[6]. The inadequate management of these wastes may expose the health of workers to direct risks and the population to indirect risks through the action of the wastes on the environment[7,8].

These aspects point to the inseparable relationship between health, environmental health, the environment, and HCW, which can have adverse effects on the environment and organisms. Thus, the Brazilian MH emphasizes that the "environment and health are interdependent and inseparable"[3].

The concept of environmental health links the aspects involving human health and quality of life that are determined by physical, chemical, biological, social, and psychological factors in the environment. It also addresses environmental factors that can potentially affect the health state of current and future generations[9].

To illuminate the relationship between health and the environment, the health field has used indicators that contribute to the proposal of strategies for health promotion, prevention, and risk control. An indicator is defined as the discovery and/or information of a set of data on a given reality. They are tools for management and decision making. The MH also defines an indicator as a model that simplifies reality with the pur-

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pose of understanding phenomena and events to enhance the communication of raw data and to harmonize the information with the language and interests of different social actors[1].

According to the definition of the Interagency Network of Information for Health (RIPSA, for *Rede Interagencial de Informações para a Saúde*)[10], an indicator can be understood as a synthesis measurement that contains relevant information on the state of health and the performance of the health system. Therefore, the role of an indicator is to identify trends and to highlight and prioritize actions against problems and decisions to formulate and evaluate policies and programmes. Indicators also serve to simplify a complex set of data on health and environmental aspects, contributing to better communication between the public sector and managers[10].

There are specific indicators for each field (health and the environment) and indicators related to both (environmental health). For the health sector, mortality, morbidity, services, and healthcare coverage indicators, among others, are traditionally used. The indicators for the environmental and environmental health sectors are more recent compared to the social and health areas, which drives the efforts for improvement and intersectoriality between fields[1].

As a resource for the development of environmental health indicators, the WHO proposed the use of a model that has been used worldwide as a tool for environmental management and that is also recommended in Brazil by the MH. Since then, the model has been used by governments and non-governmental organizations as a strategy for fighting environmental problems arising from the current development model.

The initial model, named the PER model, was proposed by the Canadian statistician Anthony Friend in the 1970s and was composed of three basic elements: pressure, state, and response. At the end of the 1990s, this initial model was expanded by the WHO, becoming a tool for proposing environmental health indicators and comprising six elements: *Driving force – Pressure – Situation – Exposure – Effect – Action*; it was designated the DPSEEA model[11]. In 2011, the MH recommended the use of the DPSEEA model in Brazil[1].

The purpose of the DPSEEA model is to serve as an instrument for understanding the comprehensive and complex relationships between health and the environment, allowing environmental health problems to be analysed throughout their entire causal chain. It makes it possible to understand and measure the environmental health determinants that contribute to the clarity of decision making for risk control and to formulate indicators that favour the integration of information systems and decision making by professionals and managers. It is important to note that the solution of public health problems related to environmental issues has, as a prerequisite, the implementation of public policies that create and guarantee the maintenance of healthy environments based on participatory management[12]. The DPSEEA model enables intersectoriality because it integrates information from several sectors, particularly the inseparable relationship between health and the environment.

It was with this focus that in 1998, the MH and the Pan American Health Organization (PAHO, or OPAS for *Organização Pan-Americana da Saúde* in Portuguese) began the implementation of a joint agenda to build environmental health indicators. They pioneered the use of the DPSEEA model in Brazil, which allowed the construction of indicators that were the basis for the implementation of important health surveillance programmes in the country, such as the Programme for Quality Surveillance of Water for Human Consumption (VIGIAGUA, for *Programa de Vigilância da Qualidade da Água para Consumo Humano* in Portuguese) and the Information System for the Quality Surveillance of Water for Human Consumption (SISAGUA, for *Sistema de Informação para a Vigilância da Qualidade da Água para Consumo Humano* in Portuguese) in the Office of Health Surveillance of the MH[13].

The DPSEEA model has been used by many researchers in different countries and situations. Examples include studies on the risks associated with the use of agrochemicals in agricultural activities[14], on hantavirus infection, dengue, and respiratory problems in the Brazilian Federal District[15], and on the socio-environmental determinants of health[16]; environmental health indicators for Europe (water quality, air quality, household conditions, traffic accidents, noise, waste and soil contamination, radiation, safe foods, chemical emergencies, and work site)[17]; methods for the organization of WHO environmental health indicators at the local and international levels (child mortality, household waste, poverty, among other examples of application)[18]; indicators related to children's health[19]; the formulation and evaluation of sustainable development policies[20]; and the risks related to inadequate sanitation[21].

It is worth noting that it is for the factors of greatest impact in this chain (driving force, pres-

sure, and situation) that interventions are more resolving and allow the integration of the health sector with other sectors, which are determinant of environmental health and exert influence on the "causes of causes"[1]. In other words, it is in these domains that political decision making affects the collective reality and the actions of professionals.

Therefore, the DPSEEA model enables a differentiated organization of environmental health indicators, aiming to measure and monitor possible health harms and risks that result from the constant and intense interference of social, economic, and environmental changes[1]. A schematic representation of the model is provided in Figure 1.

The objective of the present study is to apply the DPSEEA model to HCW management, given the impact of this type of waste on public and environmental health. Another objective is to identify the indicators related to the phenomenon.

Methods

This is a documentary research study. Documentary research is defined as the method that uses resources that have not been analytically analysed or that can be re-elaborated according to the objectives of the study. This method is based on the exploration of diverse and dispersed documents, such as files from public and private agencies, personal letters, diaries, photographs, memos, and bulletins[21]. The documents used in this study are presented in Chart 1.

The documents were read in full by means of the floating reading method. Subsequently, sections of the texts and data related to the objectives of the study were selected and then organized in previously constructed spreadsheets. The systematized data set was analysed, resulting in the proposition of determinants, indicators, and actions. The selected text sections were systematized and organized according to the elements of the DPSEEA model. Subsequent interpretation followed the precepts of content analysis[22,23]. The results were presented in the form of a summary table.

The HCW information was applied to the DPSEEA model based on the definitions of its constituent elements: a) *driving force*, which corresponds to macro-scale factors in the various processes that affect environmental and human

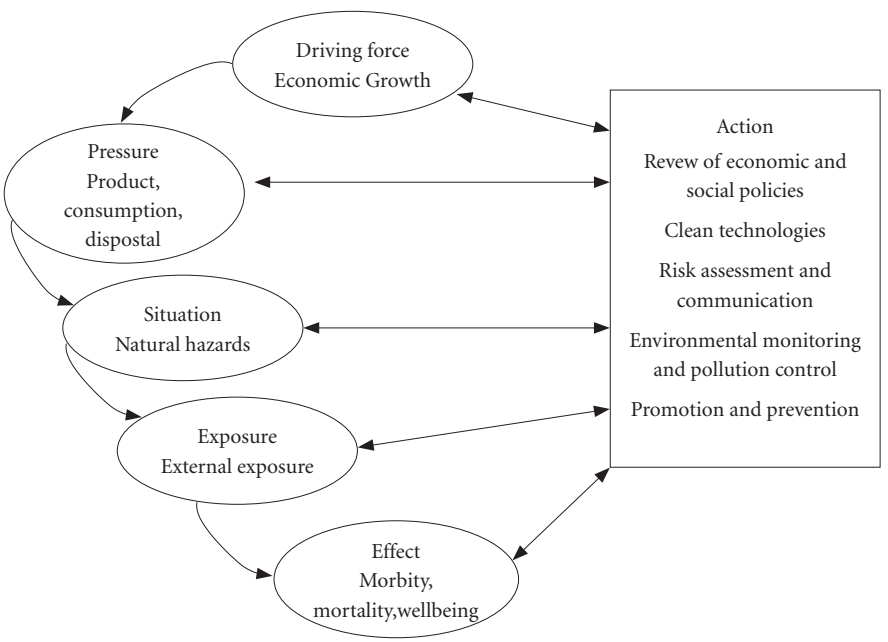

Figure 1. A schematic representation of the model is provided in Figure 1.

Source: Adapted from Corvalán *apud* Oliveira and Faria[12].

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Chart 1. Documents used to compose the *corpus* of the study.

Title	Year	Place of origin	Selection Criteria
Environmental Health Manual: Basic Guide for the Construction of Indicators	2011	Brazilian Ministry of Health	This text is the basic guide for the formulation of environmental health indicators in Brazil.
Technical reports of the following studies: . Systematization of solid waste sources from healthcare services . Study of solid dental waste generation (SDWG) in the city of Caxias do Sul as support for the formulation of management policies . Solid waste management in basic health units in the city of Caxias do Sul – Information for model development . Systematization of HCW in universities . Management of HCW in teaching hospitals and outpatient clinics . Waste management in healthcare and research units at the University of Caxias do Sul: Assessment of scenarios and perspectives . Healthcare waste: The impact of a permanent education programme on the segregation and minimization of generation . Systematization of veterinary waste generating sources: Mapping for the development of management models . Health permanent education and information as strategies for strengthening primary care	2000 2001 2005 2008 2009 2010/ 2011 2013 2015 2015	ISAM/UCS (Environmental Sanitation Institute of the University of Caxias do Sul)	The technical reports contain reliable data on HCW management at different generating sources, including management indicators of interest for this study.

health (for example, the urbanization rate and the population growth rate); b) *pressure*, which is expressed by the consequences of these processes (for example, energy consumption); c) *situation*, which is the result of pressure on the environment; the situation results in an increase in the frequency or magnitude of environmental conditions that negatively affect health (examples: rates and indicators of drought, water quality, and air quality); d) *exposure,* which is the result of the situation resulting from the pressure and the driving force; it is defined as a key concept because it establishes the relationships of environmental situations and their effects on the health state of the community and the population; e) *effect,* which is the result of the exposure for human and environmental health; it may manifest subclinically (by reducing wellbeing) or even as extreme diseases and conditions (e.g., morbidity and mortality indicators); and f) *action*, which is the component of management and decision making against systematized problems; these actions must be performed by the government to develop and plan solutions so that the environment and the population can live and be healthy to perform their functions[1].

Results and Discussion

The scenario studied is presented in Chart 2, which shows the application of the DPSEEA model to HCW management. The table is not intended to be exhaustive in regard to the number of indicators and actions required but, rather, to demonstrate the possibility of using this tool with the phenomenon under study and to show its scope.

The scope of Chart 2 indicates that the application of the DPSEEA model is relevant for supporting the construction of indicators and analysing the problem studied. It reinforces the work of researchers who, when evaluating available tools for proposing health and environmental

Chart 2. Application of the DPSEEA model to healthcare waste management.

Model Level	Determinants	Indicators	Actions
Driving Force	Current economic model.	- GDP per capita. - Sustainable development indicators. - Urbanization and population growth rates. - Vehicle fleet index. - Air and water quality rates. - Employment and income rates. - Increase in disposable use index.	- Establish and implement public policies for sustainable development. - Implement environmental education for communities in formal education situations. - Reduce the emission of pollutants in air, soil, and water. - Modify the healthcare services logic, emphasizing prevention. - Promote quality of life, access to education, health, work, and safety. - Promote actions for health education and the prevention of diseases and injuries.
	Organizational logic of healthcare.	- Hospitalization rate in healthcare services. - Chronic disease rate. - Mortality rate. - Morbidity rate.	
Pressure	Increase in services at healthcare facilities (primary health units, clinics, outpatient clinics)	- Hospital occupancy rate. - Healthcare service rate. - Rate of procedures performed.	- Promote a healthy lifestyle that does not cause the population to become sick. - Reduce hospitalizations and the need for healthcare service procedures through promotional and preventive action. - Educate healthcare professionals in sustainable materials use. - Appropriately store, treat, and dispose of each type of HCW according to its classification and handling. - Minimize HCW generation and encourage reuse and recycling.
	Increase in HCW generation.	- Index of HCW generated by establishment type. - Existence of an HCW management plan. - HCW management costs. - HCW generation rate per bed. - HCW generation rate per procedure.	
	Increase in the demand for the appropriate treatment and final disposal of HCW	- Volume of waste generated and segregated. - Amount of packaging containers. - Existence of a permanent education training programme that includes the topic of waste. - Final disposal costs.	

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health indicators in situations of climate change and health[24] and sustainability[25], conclude that the DPSEEA model is the most indicated and complete when the objective is to perceive a complex situation and propose indicators for the management and monitoring of processes that determine and condition health.

The systematization of the elements (DPSEEA) in Chart 2 increases the visibility of the HCW phenomenon and allows the proposition of actions and indicators, which makes the phenomenon analysed by this tool – HCW – more easily visualized and understood. Its importance is even greater, given that, to the best of the authors' knowledge, there are no other studies using the DPSEEA model to propose indicators for HCW management.

It should be emphasized that it is during the initial phases of DPSEEA model application (driving force, pressure, and situation) that the proposal of interventions planned through public policies and healthcare and environmental managers is fundamental to intervene in the final outcome of the problem (situation, expo-

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Chart 2. Application of the DPSEEA model to healthcare waste management.

Model Level	Determinants	Indicators	Actions
Situation	Environmental contamination, mainly by infectious and chemical waste, changing water, soil, and air quality.	- Water and soil quality indicators. - Air quality indicators. - Environmental pollution rate. - Rate of emission of gases in the atmosphere.	- Protect groundwater and water sources. - Reduce drinking water contamination. - Decrease the use of drinking water for waste treatment. - Reuse water. - Reduce the emission of polluting gases to promote air quality. - Treat all chemical waste before disposal. - Treat all infectious waste before discarding and/or final disposal. - Develop and implement an HCW management plan. - Supervise facilities responsible for HCW treatment. - Supervise regular landfills and hazardous industrial waste landfills.
	Risk of increased number of occupational accidents.	- Rate of occupational accidents. - Work leave days - Occupational accident treatment costs. - Index of contamination due to work accident.	- Segregate waste appropriately. - Promote permanent education actions to prevent and monitor the causes of accidents. - Correct use of personal protective equipment (PPE).
	Increased risk of infections.	- Hospital infection rate. - Cross infection rate. - Rate of rehospitalization due to infection.	- Discourage inappropriate forms of management. - Proper segregation, disposal, packaging, collection, and transportation of waste.

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sure, and effect). On the other hand, there is a concentration of strategies in the exposure and effect dimensions that can be developed within the institutions composing the healthcare services network. This study proposes 32 indicators distributed among the situation-exposure-effects elements of the model. These indicators can be used to monitor HCW management and, consequently, to improve the Healthcare Waste Management Plan or Integrated Municipal Waste Management Plans, which are legal requirements in Brazil for all healthcare institutions that generate HCW and for the government, respectively. These elements can also serve as reference for the establishment of specific permanent education programmes.

The complexity of the situation shows the need to integrate knowledge and to promote decision making in the health sector to improve the mitigation of the impacts of HCW on public health (specifically, users, family members, and workers in the service network) and in ecosystems (water, soil, and air quality and vector proliferation[26]). To achieve this priority, multidisciplinarity and interdisciplinarity are fundamental elements for the implementation of measures that identify and control the risks that health institutions (composed of their many particularities) pose to the environment and to life[27].

It is worth noting that the HCW management conditions in Brazil are sometimes inadequate, which increases the risks noted in this study. Therefore, considering this fact and the complex situation of health institutions, the applicability of the DPSEEA model to HCW is relevant, particularly when considering that managing HCW is fundamental for the protection and promotion of the environment and public health.

Chart 2. Application of the DPSEEA model to healthcare waste management.

Model Level	Determinants	Indicators	Actions
Exposure	Population exposed to a higher number of determinant factors of health impairment.	- Hospital occupancy rate. - Incidence of respiratory diseases in children and the elderly. - Hospitalization rate due to respiratory problems. - Hospitalization rate due to chronic diseases. - Readmission rates.	- Promote public policy related to water, soil, and air quality. - Integrate institutional actions with epidemiological and environmental surveillance actions.
	Water and soil potentially contaminated by medications and other chemicals.	- Water quality. - Rate of contaminants present in water. - Rate of households with potable water. - Rate of coverage of selective collection.	- Promote public policy for water protection and correct use for activities. - Train health institutions (professionals and users) in correct HCW segregation. - Reduce the contamination of water sources and groundwater via correct handling and treatment of waste. - Reduce water waste.
	High air pollution rates and polluting gases.	- Air quality. - Rate of emission of polluting gases. - Rate of polluting gases present in ambient air.	- Establish an environmental protection policy to promote air quality for the population and the environment. - Reduce pollutant emission into the atmosphere. - Decrease vehicle fleet. - Decrease release of untreated gases. - Monitor incinerator efficiency.
	Exposure to pathogens or hazardous waste (chemicals) due to inappropriate management.	- Occupational disease rate. - Index of occupational accidents for health professionals. - Rate of work leave due to occupational injuries or illnesses. - Rate of hospital occupancy due to respiratory disease.	- Educate professionals to handle waste properly. - Encourage the use of PPE and Collective Protective Equipment (CPE). - Provide PPE according to the risk level. - Promote surveillance and healthcare measures. - Establish a flow for notification of diseases and injuries. - Establish measures for disease prevention. - Prepare and implement an HCW management plan. - Comply with all existing legal provisions.

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It must also be considered that HCW has different characteristics compared to other waste categories, given that this type of waste contains a large amount of biological material resulting from the direct care of human health, in addition to a large amount of chemical substances, such as disinfectants, antibiotics, and drugs, which pose biological and chemical risks[26]. Such risks can also be minimized by actions related to "exposure", as presented in Chart 2.

Chart 2. Application of the DPSEEA model to healthcare waste management.

Model Level	Determinants	Indicators	Actions
Effect	Infectious diseases transmitted by sharps.	- Rate of sharps injuries. - Rate of retrovirals use by injured health professionals. - Hospital occupancy rate due to infectious diseases. - Rate of outbreaks due to diarrhoeal diseases. - Rate of diseases transmitted by potentially contaminated and altered natural elements.	- Promote in institutions permanent education on biosafety and HCW. - Promote appropriate treatment of injured professionals. - Promote appropriate forms and processes for the storage, treatment, and disposal of waste.
	Increased infection rate.		
	Increase in diseases and health problems caused by water, soil, and air components.		

Source: based on Pinto et al. (2012)[14].

Regarding biological risks, pathogens such as *Mycobacterium tuberculosis*, the hepatitis A and B virus, *Escherichia coli*, and *Staphylococcus aureus* are able to survive or resist in the intra- or extramural environments of health services when not properly treated. The magnitude of these biological risks in respect to the impairment of human and environmental health is directly related to HCW management[28], which, when inadequate, increases the likelihood of damage to health and the environment. The protection of the environment is more directly linked to the elements "pressure" and "situation", requiring actions not only within health institutions but also by public agencies, particularly in establishing city plans for integrated waste management. Consequently, these actions must be jointly developed in the general context of society.

Therefore, management is indispensable because its purpose is to reduce the threats posed by HCW. Thus, adequate management aims to reduce sanitary and environmental risks and to promote quality of life, collective health, and sustainable development[29].

The application of the DPSEEA model to HCW (Chart 2) provides information for actions to fight the problem to preserve, protect, and promote environmental and public health and the environment. Therefore, incorporating environmental indicators together with health indicators in the DPSEEA model allows for an expanded conception of health, overcoming the fragmented view of the health-disease process[16]. The application of the model to HCW management is represented in Figure 2.

Figure 2 is a schematic representation of the implication of HCW generation in each element of the model. Given the economic, social, and cultural contexts that produce pressures on the health status of the population, this pressure results in an increase in healthcare and, consequently, in HCW generation. Thus, the resulting situation can be perceived through environmental contamination, occupational accidents, and infections. This situation exposes the population to factors that determine health state impairment, contaminated and polluted natural elements, and exposure to pathogens and hazardous waste. Finally, the effect of this entire network will be changes in the health state, producing disease and impacting public health. Reversing this situation implies using the indicators for monitoring waste generation settings and implementing actions that may have beneficial effects on health.

Final considerations

HCW management is complex because it involves hazardous wastes that are increasingly generated in the healthcare of the population. The proper management of HCW represents a minimization of the risks involved. Conversely, when handled incorrectly, HCW affects physical and environmental health.

Proper management requires the analysis of each specific situation in which HCW is generated and the proposition of indicators that can be used to monitor the process and control the associated risks. The DPSEEA model is indicated

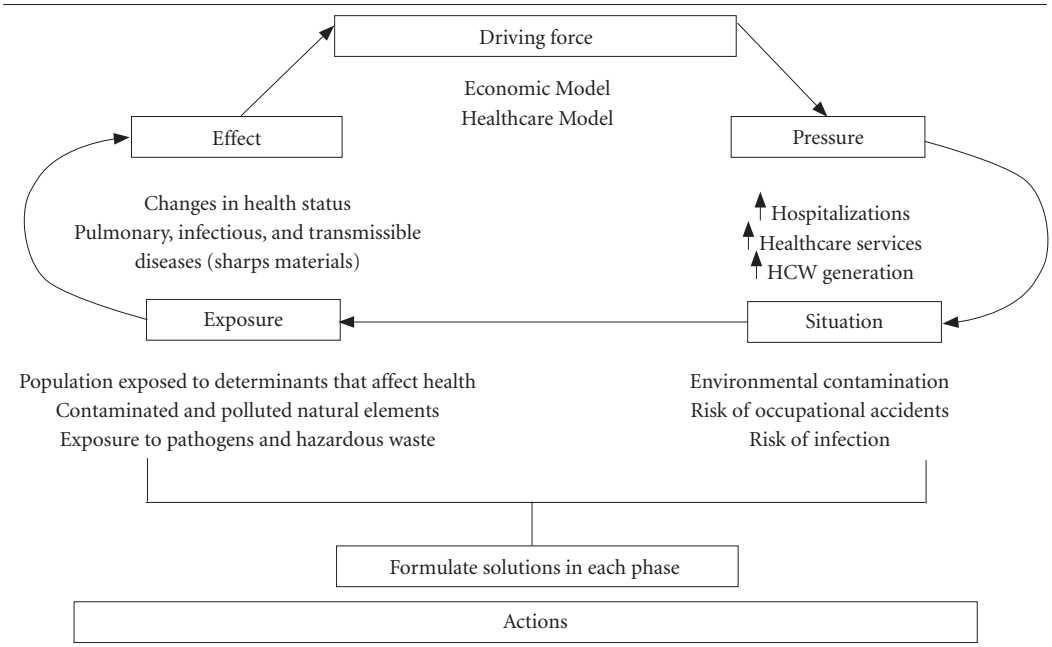

Figure 2. Application of the FPSEEA Model to RSS management.

Source: prepared by the authors.

for HCW management because it allows the visualization and analysis of the situation in which this type of waste is generated, in addition to the proposal of indicators and actions that can potentiality achieve the desired results. In other words, the DPSEEA model makes it possible to intervene in the problems to be monitored and solved, and it integrates actions at different driving force levels that affect health and the environment[18,25,30,31].

The usefulness of the DPSEEA model is even greater considering that environmental health is a new field in which different areas of knowledge emerge and, therefore, it lacks specific indicators to help elucidate the complex relationships between health and the environment; additionally, the model aids in establishing the causal links between these two areas.

Environmental preservation and the promotion of quality of life depend on the actions of health and environmental professionals and managers. A vision focused on the prevention and planning of actions is fundamental for providing better work, study, growth, conditions, and development for individuals and communities as well as the protection of society. The application of the DPSEEA model to HCW management is found to be useful in defining indicators and proposing intersectoral actions. Additionally, it allows for a more detailed view of the factors that must be considered in permanent education programmes that enable professionals and managers to use tools favouring decision making to achieve a better quality of life of society and the preservation of life on the planet.

Collaborations

NLR Stedile worked on the design, data delineation and analysis, critical review and approval of the version to be published. VE Schneider worked on the critical review and approval of the final version. MW Nunes worked on article writing, research, methodology, data analysis. AC Kappes worked on data analysis and critical review.

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