Revista Brasileira de Saúde Ocupacional
ISSN: 0303-7657
ISSN: 2317-6369
Fundação Jorge Duprat Figueiredo de Segurança e Medicina do Trabalho - FUNDACENTRO

Freitas, Carlos Machado de; Porto, Marcelo; Machado, Jorge Mesquita Huet; Faria, Mario Parreiras de; Puiatti, Roque Luís Mion

Acidentes ampliados - mais do que um conceito, uma história de luta que precisa ser atualizada

Revista Brasileira de Saúde Ocupacional, vol. 48, 2023, pp. 1-9
Fundação Jorge Duprat Figueiredo de Segurança e Medicina do Trabalho - FUNDACENTRO

DOI: https://doi.org/10.1590/2317-6369/39422pt2023v48edcinq4

RBSO Revista Brasileira de Saúde Ocupacional
ISSN: 2317-6369 (online)

Essay
Dossier RBSO 50 Years

Major accidents: more than a concept, a history of struggle that must be updated

Acidentes ampliados – mais do que um conceito, uma história de luta que precisa ser atualizada

Carlos Machado de Freitas[a]
https://orcid.org/0000-0001-6626-9908

Marcelo Porto[a]
https://orcid.org/0000-0002-9007-0584

Jorge Mesquita Huet Machado[b]
https://orcid.org/0000-0002-1176-1919

Mario Parreiras de Faria[c]
https://orcid.org/0000-0002-3496-8664

Roque Luís Mion Puiatti[d]
https://orcid.org/0000-0003-3901-8964

[a]Fundação Oswaldo Cruz, Escola Nacional de Saúde Pública Sérgio Arouca, Centro de Estudos da Saúde do Trabalhador e Ecologia Humana. Rio de Janeiro, RJ, Brazil.
[b]Fundação Oswaldo Cruz, Diretoria Regional de Brasília. Brasília, Brazil.
[c]Ministério do Trabalho e Emprego, Superintendência Regional do Trabalho e Emprego em Porto Alegre. Porto Alegre, RS, Brazil.
[d]Ministério do Trabalho e Emprego. Belo Horizonte, MG, Brazil.

Contact:
Carlos Machado de Freitas
E-mail:
machado.freitas@fiocruz.br

How to cite (Vancouver):
Freitas CM, Porto M, Machado JMH, Faria MP, Puiatti RLM. Major accidents: more than a concept, a history of struggle that must be updated. Rev bras saúde ocup [Internet]. 2023;48:edcinq4. Available from: https://doi.org/10.1590/2317-6369/39422en2023v48edcinq4

Abstract

Events defined as major accidents emerged with the very industrialization process and alongside the development of new production technologies, becoming more complex in the early 21st century. This essay aimed to describe and contextualize the formulation of a concept that has sought to integrate topics related to workers' safety and health with those of environmental health, workers' struggles, and the democratization process in Brazil in a scenario of international division of labor, risks, and benefits. Considering the accidents and disasters in the 1980s and the more recent ones involving mine tailings dams, oil spills, and the Fukushima nuclear power plant, the authors identify more complex scenarios and new challenges for tackling this issue in the 21st century. Beyond dysfunctions in technological and organizational systems, the intensification of institutional vulnerabilities, added to the vulnerabilities produced by social inequalities, fuel the occurrence of major accidents and aggravate their effects, which, by being amplified beyond their spatial and temporal boundaries, especially affect countries in the Global South. We conclude that the recent events represent systemic expressions beyond organizational dysfunctions, revealing deeper layers of organizational and sociotechnical systems such as those forging the global economy and its profound asymmetries.

Keywords: technological disasters; major accidents; accidents, occupational; environmental accidents, occupational health.

Resumo

Os eventos definidos como acidentes ampliados surgem com o próprio processo de industrialização, assim como junto ao desenvolvimento de novas tecnologias de produção, tornando-se mais complexos neste início de século XXI. O objetivo deste ensaio foi apresentar e contextualizar a formulação de um conceito que buscou integrar os temas relacionados à segurança e saúde dos trabalhadores com os de saúde ambiental, bem como as lutas que envolviam os trabalhadores e o processo de democratização no país, em um cenário de divisão internacional do trabalho, riscos e benefícios. Considerando os acidentes e desastres ocorridos nos anos 1980 do século XX e, também, os recentes, envolvendo barragens de mineração, derrames de petróleo e uma usina nuclear de Fukushima, são apontados cenários mais complexos e novos desafios para enfrentamento desta questão no século XXI. Para além das disfunções dos sistemas tecnológicos e organizacionais encontradas, a intensificação das vulnerabilidades institucionais, somada às vulnerabilidades produzidas pelas desigualdades sociais, potencializam ocorrências e agravam os efeitos dos acidentes, ampliados para além de suas fronteiras espaciais e temporais, afetando sobretudo países do Sul Global. Conclui-se que os eventos recentes constituem expressões sistêmicas, indo além das disfunções organizacionais e revelando camadas mais profundas de sistemas organizacionais e sociotécnicos, como as que forjam a economia global e suas profundas assimetrias.

Palavras-chave: desastres tecnológicos; acidentes industriais ampliados; acidentes de trabalho; acidentes ambientais, saúde do trabalhador.

Introduction

Disasters with technological roots are defined internationally as *major accidents* and in Brazil as *amplified industrial accidents.* They emerged within the process of industrialization and the development of new production technologies that occurred in societies starting with the Industrial Revolution[1].

At first, these events mainly involved energy extraction and production, such as the 19th-century accidents in coal mines and with steam engines, resulting in dozens or hundreds of deaths in a single event. One characteristic of such accidents was that the extent and severity of risks and impacts were usually limited in space and time, with workers as the main direct victims[1].

In the 20th century, advances in the development of technologies to extract and produce raw materials, energy, and various products changed the profile of such events. The level of the risks of accident was also amplified, with a scaled increase in the amount of energy released from hazardous materials, especially in the production, transportation, storage, and final disposal of chemical products. This resulted in both more immediate deaths in some events and long-term risks to health and the environment after the acute event, affecting not only the workers but also nearby communities and populations[1].

Until the 1970s, the most serious accidents were concentrated in Europe and the United States. In 1917, during World War I, the explosion of an ammunition stockpile on a ship in Scotland resulted in 1,800 immediate deaths. In Germany, where a strong chemical industry had been developed, in 1921, an explosion in Ludwigshafen, the headquarters of BASF, resulted in 561 deaths and 1,952 wounded[2]. In the United States, in 1947, a fire followed by an explosion in a French ship anchored in Texas City, transporting ammonium nitrate (used to make fertilizer) killed 27 of the 28 firefighters struggling to extinguish other fires in other anchored ships, one of which was an American vessel also containing ammonium nitrate, which exploded, causing another 700 deaths[3].

In the 1970s, Brazil recorded its first industrial accident involving an oil refinery (the Duque de Caxias Refinery in the state of Rio de Janeiro), the explosion of an LPG tank, resulting in 38 deaths, all members of the Petrobras emergency response team. In the following decade, Brazil, India, and Mexico suffered their single deadliest accidents in 1984[4]. This scenario in Brazil, starting in the second half of the 1980s, established the basis for the development of a set of actions and policies, combined with its process of democratization, strengthening of the labor union movement, creation of a Universal Health System, and expansion of the role of teaching and research institutions. This context also provided the basis for the conceptualization of *amplified industrial accidents* that emerged in Brazil, the theme we address in this study.

Technological disasters, major accidents, and amplified industrial accidents – more than simple concepts

Over the years, various concepts have addressed events that have occurred during the extraction, production, transportation, and storage of hazardous products, such as chemical substances and radioactive materials, expressing distinct (although complementary) targets and objectives.

The main focus of the first concept, *technological disasters*, is the source of the hazard or threat type (especially chemical or radioactive processes or products). Such hazards result in events leading to the severe interruption of the activities of a company (community or society), exceeding its capacity to respond to the situation with its own resources, and causing important human, material, and/or economic and environmental losses[5].

The second concept, *major accidents*, mainly focused on impacts beyond factory walls, with high numbers of deaths and the contamination of the local population. The European Union Seveso Directive of 1982, Article 1, item C, define such an event as "*an occurrence such as a major emission, fire or explosion resulting from uncontrolled developments in the course of an industrial activity, leading to a serious danger to man, immediate or delayed, inside or outside the establishment, and/or to the environment, and involving one or more dangerous substances*[6]". (p. 229). Convention 174 of the International Labour Organization (ILO), which deals with the prevention of major industrial

accidents, defines major accidents as the sudden emission, fire, or explosion of a large quantity of chemical products in the course of an activity in a major hazard installation, involving one or more hazardous substances and leading to serious, immediate or delayed danger to workers, the public, or the environment[7].

The third concept, *amplified industrial accidents*, emerged in Brazil as a collective construct in the early 1990s, involving chemical, petrochemical, and oil workers' trade unions, agencies related to workers' health in state health departments, the Ministry of Health, Regional Labor Divisions of the Ministry of Labor and Social Security, research and teaching institutions, such as the Center for the Study of Workers' Health and Human Ecology (ENSP/Fiocruz), and the Jorge Duprat Figueiredo Foundation for Occupational Safety and Health[8,9].

The *amplified industrial accident* concept has three important characteristics. The first one is that, as the two previous concepts, it mainly focuses on acute events related to production processes involving one or more hazardous products which can potentially and simultaneously cause multiple harms (social, environmental, and exposed human physical and mental health), in which the severity and scope of the effects of the acute event may extend beyond its spatial boundaries (neighborhoods, cities, and countries) and temporal limits (e.g., teratogenesis, carcinogenesis, mutagenesis, harms humans' target organs, plants, and future living beings), besides psychologically and socially impacting exposed populations[1,9].

Second, considering that industrial accidents mainly refer to work accidents, the concept emphasizes that the term *major* is inappropriate since it conveys the idea that such accidents are larger in size, breadth, and intensity than the daily work accidents in production processes. While this is partly true (since many such accidents result in numerous deaths and heavy impacts), it also overshadows and partially underrates more frequent work accidents that are sometimes taken for granted and considered "minor." Amplified industrial accidents originate in work accidents stemming from production processes. Thus, the approaches to their prevention should focus on daily work processes in the production, storage, final disposal, and transportation sites[4].

The definition of amplified industrial accidents was part of a series of investigations in Brazil showing that all such events had been preceded by numerous incidents and work accidents in which abnormalities had been written off as normal or "taken for granted" in degraded modes of production in their respective social and technical systems.

Several authors have been producing studies on the causes of such types of accidents in various countries, including the United States[10,11] and France[12,13]. In Brazil, a set of research results have been compiled in a book on amplified industrial accidents[14].

Importantly, however, the fact that the effects of such accidents have systematically extended beyond factory walls and reached wider populations and environments makes their analysis and prevention even more complex than that of the most commonplace work accidents in this type of industry, even when the substances with the potential for explosions, fires, or poisoning are limited to the factory floor.

In countries such as Brazil, work accidents take a huge toll per year, exceeding the total number of deaths and injuries recorded in events classified as technological disasters, as well as those in major industrial accidents in wealthy countries. Moreover, according to Freitas et al.[4], surveys of victims of these types of accidents in Europe and the United States showed that most deaths mainly occurred to workers in industrial installations, thus originally constituting work accidents. However, in peripheral countries (i.e., peripheral in relation to the global system), emblematic accidents such as those in 1980 in Mexico City, Vila Socó/Cubatão (Brazil), or Bhopal (India) killed many more poor people living in the vicinity of industrial installations, showing the strong correlation between vulnerability and social inequalities in these regions, as well as the lack of adequate public housing and urban planning policies for these individuals.

Finally, the third characteristic of an amplified accident or amplified industrial accident is that it displays the potential to be amplified in space (impacting the environment and affecting populations kilometers away from the event) and in time (environmental impacts and effects on health such as signs, symptoms, and diseases that can appear even days, weeks, months, and years after the event). The concept emerged from struggles and actions to integrate the workplace safety agenda with workers' health, protection of the environment, and the right to health of the populations and communities exposed to (and affected by) industrial accidents.

Amplified industrial accidents as expressions of labor division, risks, and benefits

Although wealthy countries concentrate a major part of industrial production capacities, studies in Brazil and elsewhere have shown that more serious accidents take place in peripheral or semi-peripheral countries. Thus, amplified industrial accidents do not occur in a void. Such events combine global, national, and local processes, in which failure-prone sociotechnical systems interact with populations that are made vulnerable by precarious living and working conditions. Moreover, undermining processes occur simultaneously in the structures and actions of public agencies in charge of controlling and preventing risks within the sphere of health, labor, disasters, and the environment, resulting in a lower standard of industrial safety and environmental and health protection in countries in Global South. As a result of these processes, such accidents in these countries mainly impact the populations living in or circulating near hazardous installations.

From this perspective, amplified industrial accidents should be viewed as an inherent part of the international division of labor process that has led to the international division of risks and benefits. Many human and environmental risks thus concentrate in peripheral and semi-peripheral countries or those in the Global South, especially in peripheral areas and areas with the heaviest impacts on the poorest populations, whereas benefits mainly accrue to the corporations and financial markets of wealthy countries. These characteristics are present both in accidents in chemical factories[15] and in the recent events involving mine tailings dams[16].

1984 was an emblematic year in this process of the international division of labor, risks, and benefits. The accident in Bhopal, India, involving Union Carbide (an American multinational chemical industry specialized in pesticide production) resulted in 2,500 immediate deaths; on the same order as the accident in San Juan Ixhuatepec (a petrochemical factory in Mexico). In Brazil, the accident in Vila Socó, a district of Cubatão, São Paulo, caused by a leak in a Petrobras oil product pipeline, resulted in 98 immediate deaths and an estimated 500 more people died from effects of the spill.[17] These accidents occurred in peripheral areas of large cities, affecting the more vulnerable populations living next to sources of industrial hazards and with precarious safety standards. In India, site of the most serious amplified industrial accident, consumption of products resulting from chemical technology totaled one kilogram per capita, whereas in central countries, such as the USA (the headquarters of Union Carbide, responsible for the Bhopal accident), per capita consumption averaged from 30kg to 40kg[18].

These accidents are not isolated events and reveal a pattern. Until the 1970s, they predominantly occurred in the wealthiest countries and those concentrating chemical industries the most. However, following this period, as the more hazardous production processes and those with the heaviest environmental impact began to be transferred to countries occupying peripheral roles in the global economy, the number of accidents in such countries has grown in both frequency and severity. According to Porto and Freitas,[15] from 1974 to 1987, accidents with more than 50 deaths or 100 wounded occurred mainly in the countries in the Global South, which concentrated 92% of all deaths and 96% of all wounded, even after adjusting for underreporting. Freitas et al.[4] showed that, in the 1980s, the number of deaths from accidents increased about sevenfold compared to the 1960s and 70s, and that countries such as India, Brazil, and Mexico showed the worst indicators for these events. Recently, Freitas and Silva[16] found that a similar pattern has occurred in accidents/disasters in mine tailings dams, with a tendency for more serious events to concentrate in countries in the Global South (with Brazil ranking high in such unfortunate statistics).

The context of the 1980s, mainly involving accidents in chemical industries, was essential to advance discussions, research, policies, and actions related to the issue of industrial accidents in Brazil in the 1990s. Such progress was expressed in publications that involved different actors and institutions and workers in the fields of health and labor — e.g. in the book *Acidentes Químicos Ampliados: A Visão dos Trabalhadores* [*Amplified Chemical Accidents: Workers' View*][8], published in 1998 by Fundacentro —,the actions urging Brazil to ratify ILO Convention 174, and numerous other measures involving investigations of accidents and actions by the Public Labor Prosecution Office.

However, the progress made in preventing and controlling amplified industrial accidents in the 1990s occurred in a context in which adjustments and adherence to the neoliberal model limited the consolidation of such gains on issues related to workers' safety and health or the protection of the environment and of the health of populations exposed to (and impacted by) these events.

A more complex scenario and new challenges in the 21st century

More complex scenarios had already been taking shape with these types of events in the 1980s. Although a large share of them involved producing, transporting, and storing chemical products, others, such the Chernobyl nuclear power plant disaster in 1986 in northern Ukraine, and that involving radioactive materials such as Cesium-137 in Goiania, Brazil, in 1987, pointed to the diversity of events that could be classified as amplified accidents.

In the Chernobyl accident, of the 600 workers on site, 134 suffered acute radiation poisoning and 28 died. An estimated 115 thousand people were exposed to low doses of radiation and were evacuated in Belarus, the Russian Federation, and Ukraine. Besides these, another 530 thousand workers who were active in the area of the accident were exposed to varying levels of radiation from 1986 to 1990[19].

The accident with Cesium-137 initially involved pickers of recyclable scrap materials, but hundreds of other people were soon exposed, resulting in four direct deaths. This accident and that in Vila Socó, Cubatão, São Paulo, illustrate how vulnerability in countries such as Brazil mainly affects poorer populations, whether residents of peripheral neighborhoods or — as in the Cesium-137 case — informal precarious workers involved in collecting recyclable materials. The Brazilian Ministry of Health acknowledged that, in addition to informal scrap pickers, other 429 workers developed some type of illness after exposure, including those who worked in removing the radioactive waste, the police, and firefighters[20]. In all, counting informal and formal workers, hundreds were exposed to the accident, which involved gross negligence in abandoning an old radiotherapy machine in the derelict site where the Goiania Institute of Radiotherapy had operated.

In the early 21st century, besides accidents involving nuclear and radioactive materials, new and more complex risk scenarios appeared. In 2011, a tsunami caused by an earthquake hit a nuclear plant in Fukushima, Japan, causing the meltdown of three of the six reactors in its core. Besides the exposure to the workers directly involved in the emergency response, from 2014 to 2016, an estimated 40 to 50 thousand additional workers were recruited per year to work on the areas where the radioactive materials were scattered[21]. In late 2018, experts from the Office of UN High Commissioner for Human Rights in "management and disposal of hazardous substances, contemporary forms of slavery and the right to physical and mental health" pointed to situations of workers' vulnerability (especially migrants with little to no training) in areas contaminated with radioactivity [22].

In 2015 and 2019, Brazil recorded two serious disasters involving collapses of 21st-century mine tailings dams. In November 2015, the collapse of the Córrego do Fundão Dam of the Samarco S.A. mining company — a joint venture between Anglo-Australian BHP Billiton and the Brazilian Vale S.A, located in Mariana, Minas Gerais state —, resulted in the release of some 50 million cubic meters of waste, affecting 36 municipalities in 663 kilometers along the Rio Doce Basin. In total, 19 deaths were reported, five of which of local (three adults and two children) members of the Bento Rodrigues community (located downstream from the dam) and of 14 workers, 13 of whom were outsourced. Moreover, hundreds of thousands of people were directly affected, including all the residents of the neighboring municipality of Barra Longa and the entire ecosystem of the Rio Doce Basin. The populations of 39 municipalities in the states of Minas Gerais and Espírito Santo are still suffering from the socioeconomic damages of the event, which is considered the worst socioenvironmental tragedy in history of Brazil[16].

In January 2019, the collapse of the B-I Dam at the Córrego do Feijão Mine (belonging to the Vale S.A. mining company in Brumadinho, Minas Gerais) resulted in the release of approximately 11.6 million cubic meters of sludge and tailings on the bed and banks of the Paraopeba rover. This event stands out as the largest work accident in history of Brazil since 258 workers lost their lives — 127 working for Vale S.A., 118 outsourced workers, three trainees, and 10 others who worked outside the mine. Other 64 workers were injured and placed on disability leave. Impacts reached at least 17 municipalities and 308 kilometers along the entire Paraopeba Basin, directly and indirectly affecting the living and working conditions of the population that depended directly on the waters of the river, besides hundreds of traditional communities (Indigenous peoples, *quilombola* communities, forest dwellers, and artisanal fishers). As described in the Report on the Analysis of the Work Accident with the Collapse of the Vale S.A. B-I Dam in Brumadinho, Minas Gerais, on January 25, 2019,[23] "In their path, tailings destroyed part of the Córrego do Feijão district (killing six residents), an inn (killing nine of its workers, including its owners and five guests), a railroad overpass, and several rural properties. Overflow tailings reached the Paraopeba river and impacted the water supply of Indigenous and *quilombola* communities

and various towns and cities, including Brumadinho, Pará de Minas, and Belo Horizonte. Various rural properties along the Córrego do Feijão and Paraopeba river banks were also affected. Alterations in turbidity and levels of heavy metals in the water remain present and have triggered the concern and constant surveillance of authorities, as has the health of the Firefighter Department personnel." The economy of the region was harshly impacted due to the loss of local farm production and the interruption of fishing. In the municipality of Brumadinho, local commerce, tourism, and fishing were severely affected. The socioeconomic and environmental impacts in the entire Paraopeba Valley are still being measured. Meanwhile, mining activities in Minas Gerais have been seriously jeopardized, as the shutdown of several mines has had and a major impact on the entire production chain.

In August 2019, a crude oil spill of more than a thousand tons affected 11 states, 130 municipalities, and 1,009 communities along approximately four thousand kilometers on the Brazilian coastline. Traditional communities and workers living off fishing and tourism were directly exposed and had their ways of life and work seriously harmed, as were large numbers (from hundreds to thousands) of volunteers and frontline public workers (environment and civil defense personnel, among others) who removed the oil and cleaned the beaches, in addition to the environmental impacts to the marine fauna and flora[24].

These three disasters in Brazil (two in mine tailings dams and one crude oil spill), together with the Fukushima tragedy, raised a set of questions that we consider huge challenges for issues related to amplified industrial accidents (or simply amplified accidents). This is even more relevant for a nation as large and heterogeneous as Brazil, one of the countries with the highest rate of serious amplified accidents in the chemical, petrochemical, and oil industries in the 1980s. Furthermore, Brazil entered the 21st century as the country with the most accidents involving mine tailings dams (regarding the size of waste sludge and number of deaths) and one of the largest crude oil spills.

These recent accidents stand out because they involved the production of commodities and the storage and transportation of tailings and no longer the industrial processing of raw materials and products, thus pointing to new potential risk scenarios with such events. This issue calls attention to a neo-extractivist development model based on the production of commodities with heavy corporate influence in various government agencies and at different levels, thus intensifying the institutional vulnerabilities. So, regulatory and oversight agencies end up lacking the infrastructure and autonomy to perform their tasks of creating an adequate and independent legal, technical, and scientific basis to license and inspect hazardous installations.

These three most recent accidents not only directly impacted workers (especially in the case of the tailings dams), but also exposed thousands of other workers' living, working, and subsistence conditions — including small farmers, livestock owners, fishers, and shellfish harvesters, traditional communities, among others — in different ways. This alone raises the challenge of expanding the definition and range of those who are considered workers exposed to (and impacted by) these processes, an issue that also involves structural and environmental racism.

If the notion of amplified industrial accidents already considered company in-house and outsourced workers and those in emergency response teams (ranging from their own emergency crew to rescue teams), crude oil spills require expanding this range since thousands of volunteers without training or information on how to remove oil waste from beaches and its subsequent storage under safe conditions ended up exposing themselves to hazards. In the Fukushima accident as well, the United Nations called attention to the working conditions of a huge contingent of precarious and vulnerable workers, especially migrants outsourced by various companies. Importantly, their work was performed during the recovery and reconstruction phases after the acute phase of the accident. In both amplified accidents involving mine tailings dams in Brazil, recovery work required (and still requires) thousands of outsourced workers, many of whom are migrants from other states of Brazil, made invisible and exposed to sludge and tailings in various ways. Moreover, the country lacks measures (or public accountability) to monitor their working conditions and exposure.

The range of individuals exposed to hazards and impacted by accidents is further amplified by considering these countless workers, their ways of life, and working conditions. Earlier definitions of accidents mainly focused on direct and outsourced workers involved in production processes, as well as the communities outside factory walls. These sets of 21st-century amplified accidents involve an enormous contingent of workers beyond company confines (whether mining companies, nuclear power plants, or oil tankers), further amplified in recovery and decontamination stages and encompassing the workers involved in emergency response activities.

Final remarks

A new concept has emerged in the convergence of amplified accidents typical of the 20th century with the disasters of the 21st century, involving the expansion and diversification of such events from the processes involved in their production to the sites impacted by them. Alongside the changes in the global economy and increasing demands for various products and commodities closely connected in a profoundly unequal and asymmetrical world system, transformations are occurring in the scale and spatiality of affected populations and workers. Their temporal patterns have also changed, becoming cyclical/permanent and bringing multiple characteristics, prolonged and transformed over time, to these impacts.

In the 1980s and 90s, industrial accidents were treated as the tip of an iceberg. According to Llory and Montmayeul[25], such accidents were "[...] evidence of organizational dysfunctions, powerful food for thought, since they challenge our capacity for analysis and diagnosis. Accidents are… 'seeds of concern', since they destabilize our ideas on safety and prevention [...]", even as they "[...] reveal the effects of the blindness that the organization produces insidiously or deliberately [...]" (p. XXXI and p. 63).

In the 21st century, the pattern of accident-proneness has entered a continuous process, organized by a cycle of social and environmental deterioration caused by the form of use of natural resources and their transformations in continuous flux, with the production of permanent threats and ruptures in the modes of social organization in the cities, countryside, and forests. Beyond the above-mentioned dysfunctions in the technological and organizational systems, the intensification of institutional vulnerabilities (in labor, safety, health, and the environment), plus the vulnerabilities produced by social inequalities, exacerbating the occurrence and aggravating the amplified accidents effects far beyond their spatial and temporal boundaries, a situation that is even more critical in countries of the Global South such as Brazil. Such events are systemic expressions, far beyond organizational dysfunctions, revealing deeper layers of organizational and sociotechnical systems, such as those forging the global economy and their profound asymmetries.

Further and more in-depth study is also needed on the economic, financial, and performance management imperatives that come into play to influence technical systems or the maintenance of complex systems, as well as the reasons for failure to appreciate precursory signs, identified as the underlying causes of these disasters. Thus, some authors have hypothesized that the annual corporate bonus system (either via direct payment or in the form of corporate shares) encourages administrators to cut costs and increase production and consequently receive an addition to their annual bonus, acting as a key factor for the increase in accidents[26].

The new scenarios in the early 21st century emphasize that technical and engineering paradigms alone are insufficient to determine the safety of complex socio-technical systems, as are the dose-response and causality models traditionally adopted by toxicology and epidemiology for accidents/disasters involving environmental pollutants. Sociotechnical systems extend far beyond the companies' immediate environment, since they involve a network of actors and institutions in contexts of social and institutional vulnerabilities, as well as externally asymmetric relations between those who feel the impacts in the territories where they live and work and the large corporations acting in the global market. The health impacts and effects extend far beyond those limited to dose-response in target organisms and organs, affecting living and working conditions, besides combining chronic illnesses, communicable diseases, and mental health problems mediated by the socioeconomic processes involved, as expressed accurately in the definition of COVID-19 as a syndemic [27].

The paradigm shifts, including the approaches traditionally involved in the investigation of the causes and consequences of these events, should be in sync with each other and represent updates to the concepts related to amplified accidents and disasters, alongside the struggles of workers and populations exposed to (and impacted by) the hazards. Such mobilizations and struggles point to a radical shift in the model of development and capitalist exploitation comprising the global economy, especially in the recent decades of neoliberalism and neo-extractivism, amplifying the macrostructural processes of social and institutional vulnerabilities and environmental degradation. They also exacerbate the expansion, juxtaposition, and intensity of these accidents and their impacts on the living, working, and health conditions of tens or even hundreds of thousands of workers and other people exposed to and affected by such events.

References

1. Freitas CM. Acidentes Químicos Ampliados: incorporando a dimensão social nas análises de riscos [tese]. Rio de Janeiro: Escola Nacional de Saúde Pública, Fundação Oswaldo Cruz; 1996.
2. Philipp P. 1921: Explosão na fábrica da Basf. Deutsch Welle [Internet]. 21 set 2016 [cited on Set 20, 2022]. Available at: https://www.dw.com/pt-br/1921-explos%C3%A3o-na-f%C3%A1brica-da-basf/a-320428
3. Zanini F. Desastre com nitrato de amônio nos EUA em 1947 mudou normas de segurança. Folha de S. Paulo [Internet]. August 5, 2020 [cited on Set 20, 2022]. Available at: https://www1.folha.uol.com.br/mundo/2020/08/desastre-com-nitrato-de-amonio-nos-eua-em-1947-mudou-normas-de-seguranca.shtml
4. Freitas CM, Porto MFS, Machado JMH. Introdução – A questão dos acidentes industriais ampliados. In: Freitas CM, Porto MFS, Machado JMH, organizadores. Acidentes industriais ampliados: desafios e perspectivas para o controle e a prevenção. Rio de Janeiro: Fiocruz; 2000. p. 25-45
5. United Nations Office for Disaster Risk Reduction. Terminology: Disaster [Internet]. 2020 [cited on July 8 2022]; Available at: https://www.undrr.org/terminology/disaster
6. Council Directive 82/501/EEC of 24 June 1982 on the major-accident hazards of certain industrial activities (Official Journal of the European Communities L 230 05.08.1982, p. 228). [cited 15 July 2022]. Available at: http://data.europa.eu/eli/dir/1982/501/oj
7. International Labour Conference. C174 - Prevention of Major Industrial Accidents Convention, 1993 (No. 174) [Internet]. 1993 [cited 16 July 2022]. Available at: https://www.ilo.org/dyn/normlex/en/f?p=NORMLEXPUB:12100:0::NO::P12100_ILO_CODE:C174
8. Freitas CM, Porto MFS, Freitas NBB. Acidentes Químicos Ampliados: A Visão dos Trabalhadores. São Paulo: Fundacentro; 1998.
9. Freitas CM, Porto MFS, Gomez CM. Acidentes químicos ampliados: um desafio para a saúde pública. Rev Saúde Pública. 1995;29(6):503-14.
10. Perrow C. Normal accidents: living with high-risk technologies. Princeton: Princeton University Press; 1984.
11. Vaughan D. The challenger launch decision: risky technology, culture, and deviance at NASA. Chicago: University of Chicago Press; 1996.
12. Llory M. Accidents industriels: le coût du silence. Opérateurs privés de parole et cadres introuvables. Paris: L'Harmattan; 1996.
13. Wisner A. A inteligência no trabalho. São Paulo: Fundacentro; 1994.
14. Freitas CM, Porto MFS, Machado JMH, organizadores. Acidentes industriais ampliados: desafios e perspectivas para o controle e a prevenção. Rio de Janeiro: Fiocruz; 2000.
15. Porto MFS, Freitas CM. Major Chemical Accidents in Industrializing Countries: The Socio-Political Amplification of Risk. Risk Analysis. 1996;16(1):19-29.
16. Freitas CM, Silva MA. Acidentes de trabalho que se tornam desastres: os casos dos rompimentos em barragens de mining no Brasil. Rev Bras Med Trab. 2019;17(1):21-9.
17. Porto MFS. A tragédia da mining e do desenvolvimento no Brasil: desafios para a saúde coletiva. Cad Saúde Pública. 2016;32(2):e00211015.
18. Murti CRK. Industrialization and Emerging Environmental Health Issues: Lessons from the Bhopal Disaster. Toxicol Ind Health. 1991;7(5-6):153-64.
19. Canadian Nuclear Safety Commission. Health Effects of the Chernobyl Accident [Internet]. 2022 Mar [cited on Jul 25, 2022]. Available at: https://nuclearsafety.gc.ca/eng/resources/health/health-effects-chernobyl-accident.cfm#:~:text=The%20530%2C000%20registered%20recovery%20operation,by%20high%20levels%20of%20radiation.
20. Senado Notícias. CCJ aprova projeto que amplia indenizações a vítimas do Césio 137 [Internet]. Jun 27, 2007 [cited on Jul 26, 2022]; Available at: https://www12.senado.leg.br/noticias/materias/2007/06/27/ccj-aprova-projeto-que-amplia-indenizacoes-a-vitimas-do-cesio-137
21. Sawano T, Ozaki O, Tsubokura M. Review of health risks among decontamination workers after the Fukushima Daiichi Nuclear Power Plant Accident. Radioprotection. 2020;55(4):277-82.
22. UN News. Global perspective Human stories. UN experts cite 'possible exploitation' of workers hired to clean up toxic Japanese nuclear plant [Internet]. 16 aAug 2018 [cited on July 20 2022]; Available at: https://news.un.org/en/story/2018/08/1017232
23. Brasil. Relatório de Análise de Acidente de Trabalho Rompimento da barragem B I da Vale S.A. em Brumadinho/MG em 25/01/2019 [Internet]. Brasília, DF: Ministério da Economia; 2019 [cited on Jun 24 2022]; Available at: https://www.gov.br/trabalho-e-previdencia/pt-br/composicao/orgaos-especificos/secretaria-de-trabalho/inspecao/seguranca-e-saude-no-trabalho/acidentes-de-trabalho-informacoes-1/relatorio_analise_acidentes_brumadinho.pdf

24. Pena PGL, Northcross AL, Lima MAG, Rêgo RCF. Derramamento de óleo bruto na costa brasileira em 2019: emergência em saúde pública em questão. Cad Saúde Pública. 2020;36(2):e00231019.

25. Llory M, Montmayeul R. O acidente e a organização. Belo Horizonte: Fabrefactum; 2014.

26. Armstrong M, Petter R, Petter C. Why have so many tailings dams failed in recent years? Resources Policy. 2019;63:101412.

27. Singer M, Clair S. Syndemics and public health: reconceptualizing disease in bio-social context. Med Anthropol Q. 2003;17(4):423-41.

Authors' contributions: Freitas CM, Porto M, Machado JMH, Faria MP, and Puiatti RLM contributed equally to this study by collecting, analyzing, and interpreting data, writing and critically reviewing the manuscript, and approving its final version for publication. All authors take full responsibility for the work performed and the content published.

Data availability: the authors inform that this study has not been presented at any scientific event.

Funding: the authors declare that the study was not subzidized.

Competing interests: the authors declare that there are no conflicts of interest.

Presentation at a scientific event: the authors inform that this study has not been presented at any scientific event.

Received: October 24, 2022
Revised: December 21, 2022
Approved: February 01, 2023

Editor-in-Chief
José Marçal Jackson Filho