3 Public health risks induced by vehicular pollution

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ABSTRACT: This study examines severe atmospheric pollution in Brazilian metropolises and its impacts on public health, employing a deductive approach and bibliographic review. The investigation highlights how the predominance of fossil fuels in the vehicular energy matrix significantly contributes to the degradation of air quality, perpetuating adverse health conditions that culminate in respiratory and cardiovascular diseases, reducing life expectancy. The text aims to discuss the importance of integrated public policies and the modernization of the vehicle fleet as measures to mitigate pollutant emissions. Collaboration between the Ministries of Health and Environment, along with active societal participation, is essential to implement effective intersectoral solutions, considering fundamental aspects of public health and environmental sustainability, promoting a future with cleaner air and better quality of life in urban centers.

KEYWORDS: Vehicular emissions • Health impacts • Particulate matter • Sustainable development goals • Public policies.

Riscos à saúde pública provocados pela poluição veicular

SUMÁRIO: *1 Introdução • 2 Impactos da poluição veicular na saúde pública • 3 Redução da poluição atmosférica durante a pandemia: efeitos, lições e caminhos futuros • 4 Conclusão • 5 Referências.*

RESUMO: Este estudo examina a severa poluição atmosférica em metrópoles brasileiras e seus impactos na saúde pública, utilizando uma abordagem dedutiva e revisão bibliográfica. A investigação destaca como a predominância de combustíveis fósseis na matriz energética veicular contribui significativamente para a degradação da qualidade do ar, perpetuando condições adversas à saúde que culminam em doenças respiratórias e cardiovasculares, reduzindo a expectativa de vida. O texto tem como objetivo discutir a importância de políticas públicas integradas e a modernização da frota veicular como medidas para mitigar a emissão de poluentes. A colaboração entre os ministérios da Saúde e do Meio Ambiente, juntamente com a participação ativa da sociedade, é essencial para implementar soluções intersetoriais eficazes, considerando aspectos fundamentais da saúde pública e sustentabilidade ambiental, visando promover um futuro com ar mais limpo e melhor qualidade de vida nos centros urbanos.

PALAVRAS-CHAVE: Emissões veiculares • Impactos na saúde • Material particulado • Objetivos de desenvolvimento sustentável • Políticas públicas.

Risques pour la santé publique induits par la pollution véhiculaire

RÉSUMÉ : Cette étude examine la pollution atmosphérique sévère dans les métropoles brésiliennes et ses impacts sur la santé publique, en utilisant une approche déductive et une revue bibliographique. L'enquête met en évidence comment la prédominance des combustibles fossiles dans la matrice énergétique véhiculaire contribue de manière significative à la dégradation de la qualité de l'air, perpétuant des conditions de santé défavorables qui aboutissent à des maladies respiratoires et cardiovasculaires, réduisant ainsi l'espérance de vie. Le texte vise à discuter l'importance des politiques publiques intégrées et la modernisation du parc de véhicules comme mesures pour atténuer les émissions de polluants. La collaboration entre les Ministères de la Santé et de l'Environnement, ainsi que la participation active de la société, est essentielle pour mettre en œuvre des solutions intersectorielles efficaces, considérant les aspects fondamentaux de la santé publique et de la durabilité environnementale, promouvant un avenir avec un air plus pur et une meilleure qualité de vie dans les centres urbains.

MOTS-CLÉS : Émissions Véhiculaires • Impacts sur la santé • Matériel particulaire • Objectifs de Développement Durable • Politiques publiques.

1 Introduction

Since the advent of the social contract, cities have transformed into dynamic poles of attraction, shaped by profound metamorphoses in their landscapes. The automobile revolution and the expansion of commercial activities have played crucial roles in this process, redefining urban space and driving economic and social development.

Currently, approximately 84% of the Brazilian population is concentrated in capitals, metropolises, and coastal areas. The technological revolution, by increasing the efficiency of food production in rural areas, catalyzed the migration of their inhabitants to large urban centers. This phenomenon intensified the circulation of people in increasingly inhospitable and disputed spaces.

In this scenario of accelerated urbanization, air quality, a fundamental element for life in cities, did not receive due priority, especially at the beginning of the 20th century. This historical neglect contrasts with the vital importance of this resource for the health and well-being of the urban population, revealing a mismatch between urban development and environmental preservation.

The advance of modernization, paradoxically, brought with it a series of challenges, highlighting the adversities arising from the interaction between human progress and nature. Environmental issues, fundamental to quality of life, are often overshadowed by the impetus of economic development.

Currently, we face an alarming reality: the air we breathe is considered the worst in 800,000 years, characterized by high concentrations of methane and nitrous oxide. In Brazil, the situation is particularly concerning, as air quality standards still reflect norms established in the 1980s, evidencing a serious lag in public health preservation actions.

Emissions of pollutant gases and particulate matter represent an invisible yet extremely dangerous risk to collective health. This danger manifests primarily through respiratory difficulties caused by the increasing level of atmospheric pollution. This scenario underscores the urgency of a more rigorous and updated approach to air quality management, aligning public policies with the contemporary health and well-being needs of the population.

While the Ministry of Environment has the prerogative to implement interdisciplinary measures through the National Environmental Council, the effectiveness of these actions is intrinsically linked to the commitment of society

as a whole. The synergy between government policies and citizen awareness is fundamental for the success of long-term environmental initiatives.

Furthermore, strategic government interventions can catalyze the adoption of more sustainable industrial practices, promoting a virtuous cycle that benefits both the environment and the quality of life of the urban population. These measures, when well-formulated and executed, have the potential to encourage technological innovation and the adoption of cleaner production processes, contributing to the reduction of atmospheric pollution and the improvement of public health.

This study aims to examine how the ineffectiveness of public policies contributes to the deterioration of air quality and its consequent repercussions on public health. The investigation starts with the hypothesis that a more integrated approach between government agencies and civil society can significantly mitigate the adverse effects of atmospheric pollution. Such synergy has the potential to reduce public spending on health and simultaneously improve urban quality of life.

In alignment with Sustainable Development Goal (SDG) number 11, which advocates for sustainable cities and communities, it becomes imperative to adopt policies that promote air quality improvement and foster urban sustainability. This approach not only meets global sustainable development guidelines but also responds to local public health needs and collective well-being.

The general objective of this study is to analyze the impact of environmental policies on air quality and public health in major Brazilian metropolises. To achieve this purpose, the research unfolds into three specific objectives: firstly, it seeks to evaluate the effectiveness of current air quality regulations in Brazil, emphasizing their application in large urban centers. This analysis aims to understand the adequacy and effectiveness of the current legal framework in face of contemporary environmental challenges; secondly, the study proposes to investigate the role of integrated public policies among different governmental bodies in mitigating the effects of atmospheric pollution. This aspect is crucial to understand how intersectoral articulation can enhance air pollution prevention and control actions; finally, it aims to develop recommendations to improve governmental strategies, targeting effective reduction of atmospheric pollution and its deleterious consequences on public health. These proposals will seek to consolidate an integrated approach to air quality management in Brazilian metropolises.

Throughout this article, the main sources of atmospheric pollution in urban areas will be explored, emphasizing the crucial role of motor vehicles and industrial

activities in the degradation of air quality. Subsequently, the direct and indirect impacts of this pollution on public health will be examined, focusing on respiratory and cardiovascular problems prevalent in densely populated and industrialized cities. Current public policies will also be analyzed, evaluating their effectiveness and gaps in Brazilian legislation compared to international emission standards.

Furthermore, interdisciplinary measures to improve air quality will be discussed, including programs for modernizing the vehicle fleet, incentives for renewable energy, and the implementation of urban green areas. Improvements in public policies will be proposed, based on successful examples from other nations that have managed to mitigate problems associated with atmospheric pollution.

Finally, the article will address the need for more effective integration between government agencies and civil society in formulating and implementing sustainable solutions. These solutions will aim not only to reduce pollution levels but also to promote a better quality of life in urban centers, aligning with sustainable development goals and contemporary demands for public health and collective well-being.

For the development of this study, the deductive method is adopted, complemented by bibliographic and documentary research techniques. This methodological framework will provide the basis for a careful and well-grounded analysis of the subject matter.

With these methodological tools established, an in-depth discussion on the fundamental right to health will begin, exploring its interrelation with air quality in densely industrialized cities. This approach will allow an understanding of the challenges faced by urban centers in guaranteeing this constitutional right, considering the impacts of atmospheric pollution.

2 Impacts of vehicular pollution on public health

As the life expectancy of Brazilians rises, the demand for health care intensifies as a direct reflection of the progressive aging of the population. The elderly, in particular, require special attention regarding the various aspects of natural aging. In this context, health emerges as one of the essential social rights safeguarded by the Constitution, which imposes on the State the duty to ensure that all individuals have access to the minimum conditions of subsistence.

The interpretation of what constitutes the minimum existential is complex in both doctrine and jurisprudence. Ana Paula Barcellos describes the minimum

existential as "the set of minimal material circumstances to which every human being is entitled," constituting "the irreducible core of human dignity and, therefore, the maximum reduction that can be made in consideration of other principles" (Barcellos, 2002, p. 45).

Similarly, Ingo Wolfgang Sarlet defines the minimum existential as "a set of material guarantees for a dignified life" (Sarlet, 2007, p. 103). The author argues that although the minimum existential is fundamental, it is not limited to the vital minimum, as the latter is only the starting point for ensuring a dignified life, but not its limit.

The Brazilian Constitution seeks to expand fundamental guarantees to the maximum extent possible, contrasting with trends of reducing rights. In this context, Sarlet emphasizes the intrinsic relationship between human dignity and the foundation of social rights, stating that "where there is no respect for human life and physical integrity" and "where minimum conditions for a dignified existence are not ensured, there will be no space for human dignity" (Sarlet, 2005, p. 120).

The right to health, enshrined in Article 6 of the Federal Constitution as a fundamental social right, has its understanding and scope expanded through complementary legislation. Notable in this area is Law No. 8.080/90, which establishes health as a fundamental human right and assigns to the State the responsibility of providing the indispensable conditions for its full exercise.

Moreover, it is important to note that health is influenced by a series of factors, as pointed out by Dias *et al*. (2018, p. 165), such as "food, housing, basic sanitation, environment, work, education, transportation, and leisure", showing the interdependence between health and environment.

According to the principles of the World Health Organization's Constitution, "health is a state of complete physical, mental and social well-being", and not merely the absence of disease or infirmity (WHO, 1946, p. 1). WHO further states that the fullness of health is attainable and constitutes one of the fundamental rights of every human being, regardless of race, religion, political beliefs, economic or social condition (WHO, 1946).

However, Segre and Ferraz (1997) question WHO's concept of complete health, considering it outdated for aiming at an unattainable perfection, disregarding the intrinsic peculiarities of human personality. The authors, adopting a more holistic perspective, understand health as a state of reasonable harmony between the subject and their own reality. They argue that while it is possible to seek balance, full realization of this ideal health state is rarely achieved.

In the same line of thought, Christophe Dejours defines health as the ability of each individual, whether man, woman, or child, to chart a personal path towards biopsychosocial well-being (Dejours, 1986). This view aligns with SDG 3 – Good Health and Well-being, which aims to ensure quality health and promote well-being for all, at all ages.

Thus, health transcends the mere absence of disease, as it encompasses other elements essential to the effective protection and promotion of human well-being. According to Bydlowski, Westphal and Pereira (2004, p. 16), these aspects include "nutrition, housing, education and environment". In this context, the expanded concept of health emerged from the Ottawa Charter, presented at the First International Conference on Health Promotion in 1986, redefining health as "a resource for everyday life, not the objective of living" (Brasil, 2002, p. 19). This new perspective emphasizes social and personal resources, as well as individuals physical capacities.

Health promotion, from this viewpoint, is not restricted to the exclusive responsibility of the health sector but is configured as an intersectoral task. Haeser, Büchele and Brzozowski (2012, p. 609) highlight that this approach "emphasizes political and environmental action as fundamental for improving quality of life and health". Thus, the complexity and interdependence of factors influencing collective well-being are recognized, demanding a holistic and integrated approach in public health policies.

Furthering this perspective, Pilau Sobrinho offers an even more comprehensive conception of health, defining it as "an individual right of every citizen, aiming at complete physical and mental well-being, in which models of health promotion and prevention are simultaneously applied" (Pilau Sobrinho, 2003). The author emphasizes that this concept seeks to provide "equal conditions to people, with the aim of elevating life expectancy and quality" (Pilau Sobrinho, 2003, p. 128). This view not only reinforces the importance of a holistic approach in health promotion but also highlights its equitable nature, recognizing it as a state of physical and mental fullness that should be accessible to all citizens.

In highlighting the interaction of human beings with the environment, Reale (2002, p. 188) states that "health is the right proportion, the natural harmony, the intrinsic agreement of the organism with itself and with what is external to it". In this sense, health promotion requires a holistic approach that considers the interdependence between biological, social, and environmental factors.

Studies demonstrate that only through integrated public policies is it possible to ensure the full well-being of the population (WHO, 2021). Thus, it becomes evident that health cannot be dissociated from the context in which people live, demanding an "intersectoral approach" (Amri; Chatur; O'Campo, 2022, p. 2). This perspective recognizes the complexity of health determinants and proposes a more comprehensive and integrated view of strategies for promoting collective well-being.

Aiming to promote intersectoral collaboration to identify and maximize opportunities for improving health and equity, prevent negative impacts, and foster policies that benefit collective health, the approach known as Health in All Policies (HiAP) emerges. Guglielmin *et al*. (2018, p. 284) define it as "an approach to public policies across sectors that systematically takes into account the health implications of decisions, seeks synergies, and avoids harmful health impacts". This strategy proposes a holistic and integrated view of public policy formulation, recognizing the interconnection between health and various other governmental sectors.

Health problems related to environmental degradation have caught the attention of the United Nations Environment Programme (UNEP), which has compiled an extensive list of adversities arising from this deterioration. According to the World Health Organization (WHO), environmental factors are responsible for 23% of premature deaths worldwide, totaling about 12.6 million deaths in 2012 alone. Regrettably, this percentage rises to 36% among children (UNEP, 2016).

Ambient air pollution currently ranks among the main risk factors contributing most to the global burden of disease, preceding more widely known risks such as hypercholesterolemia and physical inactivity. By 2050, air pollution will be the leading cause of premature death due to environmental factors, surpassing malaria and diarrhea (OECD, 2012).

According to the 1946 Constitution of the World Health Organization (WHO), health is defined not merely as the absence of disease, but as a state of complete physical, mental, and social well-being. This broad definition emphasizes that health encompasses various aspects of human life, which are directly impacted by "adverse environmental factors, such as air pollution" (Radicchi; Lemos, 2009, p. 29). WHO recognizes that achieving full health is a fundamental right of all, regardless of socioeconomic or political distinctions (WHO, 1946).

Segre and Ferraz (1997) question WHO's definition of health, considering it too idealistic, proposing instead a view of health as a balance or harmony between the individual and their environment. Dejours (1986, p. 8) echoes this thought by

suggesting that health involves the individual capacity to chart a personal path towards biopsychosocial well-being, emphasizing that it is *a state we seek to approach* and highlighting the importance of the environment in this process.

The interaction between health and environment is corroborated by studies from the United Nations Environment Programme (UNEP), which show how environmental degradation, particularly air pollution, significantly contributes to global diseases. It is estimated that poor environmental conditions are responsible for about 23% of premature deaths globally, a number that increases to 36% among children, according to 2016 UNEP data.

Projections from the Organisation for Economic Co-operation and Development (OECD) for 2050 indicate that air pollution could become the leading cause of premature death, surpassing diseases such as malaria and diarrhea. This data reinforces the urgent need to address emissions from urban sources, especially vehicles, which are significant contributors to air pollution and associated public health risks (OECD, 2012).

In addition to the aforementioned impacts of air pollution on health, it's important to highlight that the urban lifestyle also influences our physical condition in other ways. It is known that physical exercise increases heart rate (Correa Filho, 2022), while sleep decreases it (Criscuolo, 2024). According to Oliveira *et al*. (2021), this is an adaptive capacity of the body to regulate our heart and our frequency according to the need of the moment.

However, factors such as time spent in traffic, heat islands, air pollution, noise, low humidity, and constant wildfires raise questions about how urban life compromises human body health. In particular, air pollution "constrains" this adaptive capacity of the body, "altering heart rate" (Koehle, 2024, p. 6).

The implementation of urban green areas is an effective strategy to improve air quality in cities. According to Nowak, Crane and Stevens (2006, p. 115), urban vegetation has "the ability to remove significant amounts of air pollutants" and, consequently, improve environmental quality and human health through the natural filtering process of plant leaves and roots. Moreover, Pivetta (2023) warns that, as "asphalt and concrete absorb more heat than vegetation and take longer to release this thermal energy", green areas contribute to the reduction of urban heat islands, which, in turn, prevents the "increase in ozone concentrations" (Santamouris, 2014, p. 683).

The presence of vegetation also promotes psychological and community benefits, encouraging physical activities that help "in reducing obesity" and "in building social connections", reinforcing the importance of public policies aimed at expanding green areas in urban zones (Sander; Ghosh; Hodson, 2017, p. 1). This initiative aligns with SDG 13 – Climate Action, which promotes the adoption of urgent measures to combat climate change and its impacts.

The SDGs establish normative guidelines that orient actions and confer legitimacy to the path to be followed. According to Kanie *et al.* (2019), they provide a clear logic and convergence points for a more integrated approach, as well as allow the identification of stakeholders to be involved in analyzing specific issues. The SDGs create the opportunity to address significant problems transparently, through the involvement of multiple stakeholders, and promote a clear reporting process through coordination in national development and other stakeholders' plans.

Throughout this work, it is evident that several Sustainable Development Goals (SDGs) are correlated to the issue at hand, as "if any sector involved looks at an issue only without considering others, the realization of the rest may be impeded" (Kanie *et al.*, 2019, p. 1746).

In cities, besides natural gases, there is emission of particles that may or may not be pollutants. Under certain meteorological conditions, these particles react with each other, forming new pollutants that intensify the load of those already present, aggravating urban pollution. "The atmosphere is composed of gases, solid and liquid particles" that interact physically and chemically continuously (Castanho, 1999, p. 1). This set of elements forms aerosols, which are solid or liquid particles suspended in atmospheric air. Castanho (1999, p. 2) defines these particles as "ultrafine particulate matter". With size comparable to gas molecules, these particles penetrate deeply into the lungs and bloodstream, representing a significant risk to human health.

To illustrate the gravity of the situation, consider a simple walk in Ibirapuera Park between 10 AM and 4 PM. During this period, an individual may be exposed to an ozone concentration approximately 70% higher than the limit recommended by the World Health Organization (WHO, 2017, p. 9).

The WHO (2017, p. 21) establishes stringent guidelines for air quality, recommending that the concentration of the finest particulate matter, PM2.5, should not exceed 10 μg/m³ in the annual average and 25 μg/m³ in the 24-hour average. These recommendations are particularly important on colder days or under conditions unfavorable to pollutant dispersion.

However, urban reality often exceeds these guidelines. On avenues with heavy traffic, the concentration of particulate matter can reach alarming levels, reaching approximately 120 μg/m³. This value is about four times higher than the minimum limit recommended by WHO, representing a significant risk to public health. Prolonged exposure to such pollution levels can trigger inflammatory processes and, in the long term, contribute to premature death (IEMA, 2022).

In a comparative analysis, CONAMA Resolution No. 491 of 2018 establishes less stringent parameters for fine particulate matter concentration. According to this regulation, the acceptable limits are up to 20 μg/m³ in the annual average and up to 60 μg/m³ in the 24-hour average. These values represent twice those recommended by the World Health Organization (WHO, 2017, p. 21), evidencing a significant discrepancy between national guidelines and international public health standards.

Despite substantial technological advances observed in the last five decades, it is remarkable that Brazilian regulatory standards remain below those established as minimally healthy by the international scientific community. This scenario contrasts markedly with the reality in various European countries, the United States, and Canada, where acceptable levels of atmospheric pollutants have been progressively reduced. Such changes resulted from the incorporation of epidemiological and clinical studies that evidenced adverse effects on human health at significantly lower pollutant concentrations than previously presumed.

Paradoxically, Brazil and most developing countries maintained permissive limits, "as if ignoring new knowledge or preferring to increase their productive capacity even at the cost of damage to human health" (Saldiva, 2018, p. 18). This discrepancy between current scientific knowledge and environmental policies in force in the country underscores the urgency of a critical review and update of regulatory norms, aiming at effective protection of public health and promotion of truly sustainable development.

Dr. Evangelina Vormitagg, a physician and director of the Health and Sustainability Institute, emphasizes that "Brazilian air quality standards are outdated", even after recent updates. According to the Institute, the daily emission of particulate matter should not exceed 25 μg/m³ (micrograms per cubic meter), with levels from 50 μg/m³ already considered emergency levels, with the potential to cause significant health damage (Minuano, 2017, n.p.).

In stark contrast to these recommendations, CONAMA Resolution No. 491 established a concentration of 250 μg/m³ as the emergency level. This value is five times higher than that indicated by the Health and Sustainability Institute, highlighting an alarming discrepancy between scientific guidelines and current regulatory norms in the country.

Pollutant microparticles, in association with harmful gases, when inhaled, trigger a series of deleterious effects in the human body. These substances cause inflammation, oxidative stress, and can even alter gene expression. Although air pollution is a complex phenomenon, particulate matter emerges as its main harmful agent.

When penetrating deeply into the lungs and cardiovascular system, particulate matter becomes a catalyst for a range of serious health conditions, such as strokes, heart diseases, lung cancer, chronic obstructive pulmonary diseases, and respiratory infections, including pneumonia (Paho, 2018).

The severity of this scenario was further evidenced during the COVID-19 pandemic. A study conducted by researchers at Harvard University revealed an alarming correlation: American cities with just 1 μg/m³ more of particulate matter 2.5 in the air showed a 15% higher mortality rate from COVID-19. Francesca Dominici, a professor of biostatistics at Harvard and author of the study, uses a striking metaphor to describe this interaction: contracting COVID-19 in an environment with polluted air would be equivalent to throwing gasoline on fire (Gardiner, 2020).

During periods of heavy traffic, exposure to carbon monoxide (CO) and microparticles becomes particularly harmful. It is estimated that each hour of exposure to these pollutants is equivalent to the deleterious effects of smoking a cigarette. The impacts of air pollution in large metropolises are ubiquitous, manifesting at every corner, where industrial chimneys and vehicles emit a myriad of pollutants.

Indeed, the health effects on people breathing polluted air in metropolises alarmingly mimic the damage observed in smokers (Apple; Izidro, 2019). This analogy highlights the severity of daily exposure to urban pollution, equating it to a recognized harmful habit.

Paradoxically, even spaces that appear to offer protection may intensify exposure to pollutants. Wei *et al*. (2023, p. 43392) warn that air conditioning filters in aging vehicles can, in reality, concentrate particulate matter, making "the indoor air more saturated" than the external environment. This finding dispels the illusion of safety often associated with vehicle interiors.

In short, in older vehicles or those with poor maintenance, the common practice of closing windows to avoid external pollution may, ironically, exacerbate exposure to pollutants, representing an additional health risk to occupants.

Global statistics related to pollution and its consequences for public health are alarming. Fuller *et al*. (2022) estimate that approximately 9 million people worldwide lose their lives annually due to pollution. This number significantly exceeds other causes of mortality often considered priorities in public health policies, as will be seen below.

In comparison, the Pan American Health Organization (Paho, 2018) reports that about 4 million annual deaths are attributed to strokes or myocardial infarctions. Additionally, Queiroz (2023) points out that road accidents are responsible for 1.35 million fatalities per year.

The juxtaposition of these data reveals a disturbing reality: pollution claims more lives than strokes, heart attacks, and traffic accidents combined. Paradoxically, despite its magnitude, the causes of pollution and its impacts on public health do not receive attention proportional to their severity.

Exposure to air pollution, even for short periods, can have alarming consequences for human health. In just 20 minutes of staying on a congested avenue, the amount of carbon monoxide (CO) in the lungs doubles. This scenario worsens drastically in closed and polluted environments, such as tunnels. Cyro (2005, p. 104) warns that, in the same time interval in a tunnel, "people begin to experience effects on the central nervous system, including decreased ability to distinguish time and space, failures in visual acuity, and alterations inmotor functions". Under these circumstances, any individual, regardless of their habits, becomes equivalent to a smoker in terms of exposure to harmful substances.

The physiological repercussions of this exposure are equally concerning. Chiarelli (2009, p. 11 and 13) highlights that "blood pressure elevation occurs", and blood vessels lose their ability to dilate, compromising adequate blood supply to tissues and *increasing the risk of heart attack*. In fact, the risk of heart attack or stroke quadruples under these conditions, representing a particularly pronounced danger for individuals with pre-existing pathologies (Chiarelli, 2009).

The contrast in environmental impact assessment practices sometimes reveals notable and worrying discrepancies. An emblematic example is the case of the ring road in São Paulo, where studies necessary to minimize the impact on the city's green belt demanded eight years of meticulous analysis. Paradoxically, projects

such as the construction of avenues in residential areas often advance without adequate environmental impact studies. This disparity evidences significant gaps in urban environmental protection and, by extension, in safeguarding public health.

In light of these inconsistencies, Saldiva (2018, p. 19) raises a provocative and essential question: "shouldn't we reflect on whether humans deserve the same care that other living beings have received?". This inquiry highlights the pressing need to include human well-being as an integral and inseparable part of the environmental issue.

The OECD Environmental Outlook estimates that the number of premature deaths related to the inhalation of PM10 and PM2.5 particles will reach about 3.5 million by 2050 (OECD, 2012, p. 4). However, given the annual sale of 2.5 to 3 million new automobiles in Brazil alone, is it possible to find a solution?

In cities with exclusive lanes for public transport, traffic becomes more fluid, encouraging citizens to opt for collective transport over individual vehicles. This shift reduces the number of pollutant-emitting engines and alleviates congestion. The conscious choice of public transport by those who could use private vehicles reflects the principle of solidarity. In the social context, solidarity emerges from a rational conception, "according to which the survival of the whole depends on the relationship of all citizens with each other or of society, taken here as the set of citizens, with any of them" (Boiteux, 2010, p. 529).

About 98% of Europeans live in areas where particulate matter concentration exceeds WHO limits, with two-thirds living in zones with pollution more than double these standards (The Guardian, 2023). Faced with this problem, since 2016, Paris has banned the circulation of cars over 19 years old on weekdays (Müzell, 2016). This measure is relevant, as studies show that old vehicles are substantially more polluting than new ones equipped with advanced emission control technologies. The Environmental Protection Agency reveals that 1960s vehicles emitted almost 99% more pollutants than current ones, equating one old car to a hundred modern ones in terms of pollution (EPA, 2024). However, Brazilian state governments exempt vehicles over 20 years old from IPVA (vehicle tax), encouraging the use of more polluting automobiles. In contrast, Japan adopts a progressive tax, stimulating the use of new and less polluting vehicles (Reis, 2021).

The urgency of measures against air pollution is not recent. A historical episode illustrates the consequences of environmental negligence: in December 1952, an immense cloud of smoke covered the city of London. Gases from the burning of

coal, wood, industrial and vehicular emissions were trapped by the absence of wind for five days, causing a severe health crisis. It is estimated that 4,000 people died prematurely due to pollution, and another 7,000 in the subsequent months. The British, recognizing the urgency of reducing pollutant emissions, approved the Clean Air Act in 1956 (Calixto, 2013).

The resolution of these problems is intrinsically linked to the implementation of effective environmental policies aimed at reducing air pollution in large urban centers. Although the National Environmental Council (CONAMA) resolution on air quality is outdated, the Air Pollution Control Program for Motor Vehicles (PROCONVE) established pioneering emission limits for light vehicles. This program has already significantly improved the standards of the Brazilian automotive industry, although there is still considerable room for advancement.

In the presentation of the work "From structure to function: new studies in the theory of law", Celso Lafer observes that Norberto Bobbio applied an innovative analytical dimension when reflecting on the functions of law, including a critical review of the concept of sanction. Bobbio argues that law transcends the mere imposition of permissive and prohibitive norms, and can also act as a promoter of socially desirable behaviors.

From this perspective, the positive dimension of sanctions emerges, materialized through the offering of incentives and rewards. This promotional function of law aims to stimulate beneficial conducts, catalyzing results that would otherwise demand a long process of natural evolution. Reward sanctions, therefore, present themselves as effective instruments of social direction, offering a constructive alternative to merely punitive approaches.

To revolutionize the paradigm of current polluting automobile technology, Bobbio (2007, p. XII, author's emphasis) proposes an approach based on incentives, rather than punitive restrictions. He conceptualizes "the 'promotional function' of law as the action exercised through 'positive sanctions', that is, mechanisms widely recognized as 'incentives'" (Bobbio, 2007). This perspective suggests a shift in focus in public policies, prioritizing stimuli that foster the adoption of cleaner and more sustainable technologies in the automotive industry.

The incentive to replace fossil fuels with biofuels, electric energy, or hybrid models[1] could significantly reduce this problem. Envisioning the need to improve

1 Hybrid vehicles have two engines: an electric one and a fossil fuel one. This combination significantly reduces emissions in urban environments, where the electric motor operates more frequently.

and innovate environmental legislation, it is necessary to stimulate popular participation to change the reality imposed by an obsolete industry and a barely active Public Power. "There is still a need to act with the Legislature, within the scope of the Environment Committees, which exist permanently in the Chamber and the Federal Senate" (Campello, 2007, p. 15). These committees play an initial role in the legislative process, as Campello highlights, "these are technical bodies responsible for analyzing, evaluating, and deciding on all proposals for new laws" (Campello, 2007, p. 15).

Aligning with European restrictions imposed on the automotive industry and driven by alarming statistics from the 2022 Annual Report of the National Transport Confederation (CNT) - which revealed a significant increase in the Brazilian vehicle fleet, from approximately 32 million in 2001 to over 111 million in 2021 - Bill 454/2017 proposed a gradual reduction in the sale of vehicles powered by fossil fuels in Brazil. The plan envisioned the transition beginning in 2030, culminating in a total ban by 2060. Despite its relevance to sustainability efforts, the project was archived at the end of the legislative session, creating a significant gap in policies to mitigate vehicular pollutant emissions.

Within the Executive branch, the federal government launched the Rota 2030 program in July 2018, aiming to stimulate the automotive industry to improve efficiency in the use of fossil fuels, offering IPI (tax on industrialized products) discounts for electric and hybrid vehicles. In 2024, this program was succeeded by Green Mobility and Innovation, or Mover (Brazil, 2023). This new initiative, an evolution of Rota 2030, proposes to expand sustainability and energy efficiency requirements in the automotive sector, representing a significant advance in policies to encourage green mobility and technological innovation in the national vehicle industry.

The guidelines of Mover demonstrate a continuous stimulus for technological development and the use of biofuels, such as ethanol. Although less polluting than traditional fossil fuels, these still involve carbon emissions through combustion (Brazil, 2023). This incentive can be interpreted as both progress and a limitation in the transition to zero-emission technologies, such as electricity or hydrogen. Thus, the Mover program, despite representing an advance in terms of promotional incentives, does not constitute a definitive break from dependence on polluting technologies, reflecting a compromise between innovation and established practices in the Brazilian automotive industry.

3 Reduction of atmospheric pollution during the pandemic: effects, lessons, and future pathways

The decrease in industrial activities and traffic, motivated by the COVID-19 pandemic, resulted in a significant reduction in atmospheric pollution between March and July 2020. In Europe, this drop in pollutant concentration prevented approximately 11,000 deaths, while in China, cleaner air may have saved up to 77,000 lives (Ferreira, 2020). Paradoxically, prolonged exposure to more polluted air before the pandemic contributed to an increase in the number of victims during quarantine. According to Ogen (2020, p. 5), this phenomenon "demonstrates that long-term exposure to unhealthy environments can contribute to the high COVID-19 fatality rates", even in the face of a temporary improvement in air quality.

Analyzing the average pollutant emissions in March from 2015 onwards, São Paulo recorded a reduction of 13% for NO2, 4% for PM2.5, and 20% for CO. In comparison with the same period, Paris and New York showed reductions in particulate matter emissions of 16% and 29%, respectively (Connerton *et al.*, 2020). These data suggest that older vehicles and utilities that continued to circulate in São Paulo emitted extremely high amounts of fine particulate matter, indicating the need for additional measures aimed at both fleet renewal and proper maintenance of existing vehicles.

It is assumed that older and more polluting vehicles remained in operation due to the economic conditions of their owners, who needed to work to maintain their livelihood. Thus, even with the incorporation of new vehicles with hybrid or electric technologies in the fleets of developing countries, measures such as vehicle inspection and the installation of gasoline filters, or GPF (Gasoline Particulate Filter), become necessary. These filters, whose structure is composed of channels that allow only the passage of gases and retain particulate matter, are capable of retaining approximately 75% of the soot emitted by engines, requiring no maintenance (Grande, 2019).

Since 2012, diesel vehicles, known to be more polluting than those powered by gasoline or with flex engines, have been equipped with a sophisticated gas filter. This device is capable of converting nitrogen oxide (NOx), a carcinogenic substance, into pure nitrogen and water vapor, elements harmless to health. Unlike GPF filters used in gasoline vehicles, this mechanism requires regular maintenance and refilling with a specific additive, known as ARLA 32. In the absence of this

additive, the vehicle's safety system should automatically reduce engine power, thus ensuring the operation of the anti-pollution device.

However, a pernicious practice has spread among Brazilian fleet operators: the installation of a chip that circumvents this safety system. This illegal device allows the engine to maintain its maximum power even without the use of ARLA 32, effectively nullifying all intended environmental benefits. As a result, new trucks end up polluting as much as old and unregulated models (Bazani, 2014).

The lack of rigorous enforcement means that fleet operators use this fraudulent chip, aiming for savings of approximately 5 to 6% in diesel fuel expenses. The consequences of this practice are particularly evident in large urban centers. In São Paulo, for example, although trucks represent only 5% of the total vehicle fleet, they are responsible for half of the city's air pollution (Exame, 2018). This widespread fraud significantly contributes to the worsening of pollution levels, compromising air quality and, consequently, public health.

The observations made during the pandemic months offer an opportunity to rethink approaches to environmental management and urban pollution control. The improvement in air quality over a short period demonstrated the direct impact of human activities and reinforced the urgent need for sustainable policies that prioritize public health. These changes show how public policies can quickly result in significant improvements, suggesting that the implementation of more stringent and sustainable environmental strategies can provide benefits for both the environment and the population.

4 Conclusion

This work addressed the serious problem of air pollution in Brazilian metropolises and its repercussions on public health. It was evident that air pollution, shaped by the predominant energy choices in the fossil fuel era, imposes significant risks to the health and quality of life of the population.

The initial problematization questioned the effectiveness of public policies on air quality management, proposing that a more integrated approach between government agencies and civil society could mitigate the adverse effects of pollution. The investigations' results corroborated this hypothesis, demonstrating that, despite the standards established by CONAMA, continuous exposure to current levels of atmospheric pollutants is highly detrimental to health, reinforcing the need for revision and strengthening of existing policies. In conclusion, intersectoral

approaches are fundamental to address global health challenges and to achieve the Sustainable Development Goals, especially SDG 3 - Good Health and Well-being and SDG 11 – Sustainable Cities and Communities.

The outlined objectives were achieved through a rigorous analysis of the impacts of vehicular pollution on public health. Findings show that the significantly polluting Brazilian vehicle fleet contributes to the high incidence of respiratory and cardiovascular diseases, reducing life expectancy. In response, this study proposed the implementation of measures such as the modernization of the vehicle fleet, including the adoption of electric and hybrid vehicles, the mandatory installation of particle filters, and more effective enforcement, especially for heavy vehicles that disproportionately contribute to air pollution.

Additionally, the implementation of urban green areas proves to be an effective strategy for improving air quality in cities. Urban vegetation demonstrated the capacity to remove significant amounts of atmospheric pollutants, enhancing environmental quality and human health. Moreover, it contributed to mitigating urban heat islands and preventing increases in ozone concentrations. The presence of vegetation also promoted psychological and community benefits, encouraging physical activities and strengthening social connections. This initiative is aligned with SDG 13 - Climate Action, which advocates for urgent measures to fight climate change and its impacts.

The period of the COVID-19 pandemic inadvertently provided a valuable case study on the impacts of temporary reduction in polluting activities, offering insightful perspectives on how immediate actions can result in significant improvements in air quality. The outstanding improvement observed during the quarantine months unequivocally illustrates that specific policies aimed at reducing pollutant emissions can have substantial and immediate effects. This experience not only reinforces the urgency of more stringent environmental measures but also demonstrates the feasibility of rapid and impactful transformations in urban atmospheric quality.

In conclusion, it is imperative that public policies not only focus on mitigating existing problems but also promote sustainable development that ensures long-term public health and environmental preservation. The synergistic collaboration between the Ministries of Health and Environment, combined with the active involvement of civil society, proves fundamental for the formulation and implementation of effective solutions that guarantee a less polluted and healthier future.

In this context, the *Health in All Policies* approach emerges as a valuable tool for developing public policies that systematically consider health implications in all governmental decisions. This strategy seeks not only to identify and explore synergies between different sectors but also to prevent harmful impacts on health, thus promoting more integrated and efficient governance.

The adoption of this intersectoral approach not only enhances efforts to improve air quality and, consequently, public health, but also contributes to the construction of more resilient and sustainable cities. By aligning policies from various sectors around the common goal of promoting population well-being, a conducive environment is created for innovations and solutions that meet the complex demands of contemporary society.

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