Internal air quality in automotive vehicles in terms of carbon dioxide concentration: case study on the justice officer activity and possible benefits of technology to health and the environment

The indoor air quality of vehicle cabins contains in its physical and chemical characteristics the tendency to a low air renewal due to the continuous use of artificial air conditioning. Thus, carbon dioxide concentration rates tend to be high, which can harm the health of ordinary vehicle occupants. The Justice Officer is the professional of the Judiciary responsible for complying with external procedural demands and acts by moving to the recipients of these orders. Faced with this routine of accentuated use of the car for professional purposes, this category of workers is exposed daily to high levels of internal vehicular pollutants. Based on the above, the general objective of this work is to analyze the quality of the internal air of the vehicular cabin of the Probation Officer, in the exercise of his functions, regarding the concentration of carbon dioxide. The methodology employed highlights the exploratory bias, from a qualitative and quantitative approach, since it focused on bibliographic and documentary apparatus to understand the environmental pollution emitted by cars and the human and environmental risks arising from it, and also obtained results collected from a questionnaire addressed to the Justice Officers assigned to the Court of Justice of Pernambuco, which sought to understand the vehicular routine during the course of professional diligence. The results obtained suggest that the Justice Officers’ exposure to carbon dioxide during his work activities affects the physical health of these servers and could be resolved by complying with electronic warrants.

Keywords: Occupational disease; Air quality index; Work environment; Internal vehicle pollution.

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Qualidade do ar interno em veículos automotivos em termos de concentração de dióxido de carbono: estudo de caso na atividade do oficial de justiça e possíveis benefícios da tecnologia à saúde e ao meio ambiente

A qualidade do ar interno das cabines veiculares contém em suas características físicas e químicas a tendência a uma baixa renovação de ar em virtude do uso contínuo da climatização artificial. Assim, taxas de concentração de dióxido de carbono tendem a serem elevadas, o que pode causar prejuízos à saúde dos ocupantes dos veículos. O Oficial de Justiça é o profissional do Poder Judiciário responsável pelo cumprimento de demandas processuais externas e atua se deslocando até os destinatários dessas ordens. Diante dessa rotina de acentuado uso do carro para fins profissionais, esta categoria de trabalhadores é exposta cotidianamente a elevados índices de poluentes veiculares internos. O objetivo geral deste trabalho foi analisar a qualidade do ar interno da cabine veicular do Oficial de Justiça, no exercício de suas funções, no que se refere à concentração de dióxido de carbono. A metodologia empregada destaca o viés exploratório, por uma abordagem qualitativa e quantitativa, vez que se debruçou sobre aparelho bibliográfico e documental para compreender a poluição ambiental emitida pelos automóveis e os riscos humanos e ambientais dela advindos, e também obteve resultados coletados de um questionário-endereçado aos Oficiais de Justiça lotados no Tribunal de Justiça de Pernambuco, que buscou compreender a rotina veicular durante o andamento das diligências profissionais. Resultados obtidos sugerem que a detecção de CO2, umidade relativa do ar e temperatura na cabine veicular climatizada artificialmente aumenta a exposição do Oficial de Justiça a efeitos deletérios de índices elevados dos componentes mensurados durante suas atividades laborais. Os danos à saúde física desses servidores poderiam ser minimizados pelo cumprimento de mandados eletrônicos, a exemplo do que ocorreu durante o expediente remoto dos anos 2020 e 2021.

Keywords: Doença ocupacional; Índice da qualidade do ar; Meio ambiente do trabalho; Poluição interna veicular.

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INTRODUCTION

The accelerated growth of urban centers has made environmental pollution one of the biggest contemporary problems, mainly due to the burning of fossil fuels arising from the automotive transport use. In the last decades, carbon dioxide (CO₂) emissions have grown exponentially due to the new demands of modern life, such as factories and automobiles, especially for those who inhabit urban centers.

The impacts generated by pollution on gas emissions in road transport contribute to the increase of respiratory diseases worldwide. The emission of harmful gases to the environment and the concentration of people in large urban centers facilitate the emergence of diseases with characteristics arising from the use of fossil fuels. External pollution was responsible for 20 thousand deaths in Brazil and 1.15 million worldwide, corresponding to about 2% of all deaths (FREITAS et al., 2020).

Some studies indicate that the CO₂ existence in very accentuated proportions occurs more in internal environments than in external spaces. Indoor air is understood to be that verified in non-industrial areas, such as homes, hospitals, classrooms and vehicular cabins, which are increasingly present in human daily life motivated by current habits, which values artificially air-conditioned places for studies, work and even leisure, such as movie theaters, restaurants and shopping malls. This way, the study of the air quality in the internal enclosures reveals itself as important to guarantee the health of its occupants.

Meanwhile, the indoor air quality (IAQ) of vehicle cabins deserves attention, as people spend more and more time inside their vehicles under the effects of the climate control system, which is currently a mandatory requirement for maintaining thermal comfort, especially in tropical and subtropical climates such as Brazil, in addition to being an important safety item, as it prevents drivers and passengers from having to be exposed to violence acts when windows are open.

Such sealed environments, under the influence of CO₂, also generated by human metabolism, in addition to other physical-chemical contaminants, are capable of negatively affecting the life quality of its users. So, workers who depend directly on the constant vehicular locomotion can suffer health damages due to the low quality of the air, either inside the car or in the external environment.

Among the class of workers who depend on constant locomotion in vehicles, the Justice Officers are professionals working in the Brazilian state and federal Judiciary who work in the fulfillment of judicial determinations and do it constantly in displacements to the place where people or goods of judicial interest. The Officers are responsible for carrying out procedural communication between magistrates and parties, as well as carrying out procedural acts in places outside the forum, such as search and seizure demands, arrest and property evaluation, for example.

However, with the arrival of the COVID-19 pandemic, most of the execution of the warrants in person remained impossible, which led these justice servers to receive an extraordinary permission, through Normative Instruction prepared by the Judiciary, to comply with certain acts through electronic communication with the parties, such as messages via Whatsapp, e-mail and other virtual forms of information and procedural movement.
This possibility of complying with court orders through the use of technology demonstrates the so far underused opportunity to optimize travel time and reduce non-essential travel, as well as it has been able to accelerate the action of the Judiciary towards the environmental adequacy goals of the public administration, given the reduction of motor vehicles that stopped circulating daily in cities due to remote working hours, in addition to mitigating the exposure of these servers to the deleterious effects of CO$_2$.

In this way, the present study has as general objective to analyze the internal air quality of the vehicular cabin of the Justice Officer, in the exercise of his functions, regarding the concentration of carbon dioxide.

**THEORETICAL REVIEW**

The emission of vehicular pollutants is one of the biggest contributors to the high levels of pollutant concentration in the earth's atmosphere. However, despite the numerous debates that are dedicated to analyzing the external pollution caused by the automotive fleet, little is said, in comparison, to the internal pollution of vehicles. From this perspective, it must be noted that poor indoor air quality is equally harmful to the person exposed to it, compared to pollution outside the vehicle.

The increase in urban population that the whole world has been facing can cause increased tensions on space, ecosystems, infrastructure, facilities and personal lifestyles, which has been reflecting on the life quality of this population. The increased need for mobility and the consequent increase in road traffic have caused a significant increase in the volume of gases from the burning of fossil fuels, whether they are linked to personal vehicles powered by gasoline/alcohol or those that depend on diesel oil. In urban areas, typical anthropogenic sources of air pollution are mainly road traffic and, when existing, industrial activity (FERREIRA et al., 2016).

The vehicular fleet in urban centers has increased exponentially in recent years, and this is one of the main reasons for the air pollution increase in these regions; thus, it becomes increasingly important to search for solutions to mitigate these consequences (OLIVEIRA et al., 2019).

Despite not being considered a polluting gas in outdoor environments, in confined spaces, with human occupation and without ventilation or insufficient ventilation, Carbon Dioxide (CO$_2$) tends to accumulate, reaching levels above the recommended maximum values (PRESTRELO et al., 2019).

The large concentrations of pollutants found in the atmosphere result in inherent characteristics of the environment and in infections, not only of the respiratory tract of human beings, but also other diseases. Carbon dioxide is one of the chemical products released into the atmosphere, and the thermal absorption of this, and other gases that contribute to pollution directly interfere with the thermal balance of the Planet and Public Health (SILVA et al., 2016).

Air pollution is considered the biggest environmental cause of illness and premature death in the world. According to a WHO survey, more than 90% of the world population does not breathe air of acceptable quality and is exposed to daily risks, resulting in about 11.6% of all deaths accounted for in the world,
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equivalent to 7 million deaths annually, of which 600 thousand are children. These numbers are 15 times greater than the number of deaths caused by wars and other forms of violence (SIMONI et al., 2021). The emission of carbon dioxide in the atmosphere is crucial for climate change, as this chemical component is one of those responsible for the greenhouse effect (BRAZ et al., 2020).

Brazil is among the countries that have considerably increased vehicle traffic in large urban centers, thus also increasing environmental impacts during the last decades. Carbon dioxide (CO₂) is one of the compounds released into the atmosphere by mankind, through production, handling and incorrect disposal of burning oil derivatives and by cement producing industries. Thus, CO₂ and other gases released uncontrollably into our planet’s atmosphere become responsible for the greenhouse effect, which results in a significant rise in the temperature of our terrestrial globe, its composition and balance. Thus, harming the environment and the most varied forms of life. Among the damages caused to the environment are: Acidification of rivers and forests, making life difficult for animals and the development of flora, climate change and acid rain (SILVA et al., 2016).

The transport sector is an important source of urban pollutants, in which 90% of the emissions of polluting gases and carbon dioxide come from the burning of fuels by road vehicles. It is worth mentioning that in large Brazilian urban centers, individual transport accounts for about 57% of carbon dioxide emissions, collective public transport, for 27% of emissions, while heavy vehicles for cargo transport, for 12% (SIMONI et al., 2021).

As a result of the lack of care and inspection with the quality of indoor air, the term Sick Building Syndrome (SED) emerged, where sealed environments, without proper air renewal, have high concentrations of carbon dioxide (CO₂), which are the cause of symptoms such as: tiredness; fatigue; lack of concentration; eye irritation; nose; throat and dry skin (CORDEIRO et al., 2019).

Some physical effects of human exposure to CO₂ concentrations above 1000 ppm are dizziness, headache, nausea and lethargy. This gas becomes fatal for humans in high concentrations, around 30,000 ppm for 10 min exposure, as it can cause asphyxia by displacing oxygen, so it is recommended that indoor air saturation is avoided by this gas, facilitating the exchange of air with the external environment through an adequate ventilation rate (COMIM, 2016).

Indoor air quality can deteriorate when one or more parts of this process are inadequate. For example, carbon dioxide can accumulate in some parts of the closed environment if insufficient amounts of air are introduced and mixed inside. CO₂ is just one of many gaseous pollutants that, alone or in combination, can cause adverse health effects such as headache, malaise, dizziness and even skin1.

The tendency to opt for closed environments, whether for aesthetic reasons, noise reduction or temperature control, has reduced air quality due to the cumulative effect of the concentration of carbon dioxide, which is associated with high density and prolonged permanence of individuals near the insufficient air renewal in the environment. The consequences range from excessive yawning, malaise and reduced

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1 http://repositorio.asces.edu.br/bitstream/123456789/418/12/Cap%209%20Qualidade%20do%20ar%20interno.pdf
performance to suffocation (ARAÚJO et al., 2018).

Carbon dioxide is an odorless chemical compound with linear geometry and nonpolar character. Due to very weak intermolecular attractions, under normal conditions of temperature and pressure, it appears in the gaseous form (LEE, 2001). It originates mainly from the burning of fossil fuels and as a product of the respiration process in which animals and plants produce energy. The level of CO$_2$ in interiors can be considered as an indicator of the IAQ, as it is potentially harmful to the health of the occupants, because of its relationship with other internal contaminants and with the external ventilation rate, among others (COMIN, 2016).

The largest source of pollutant and GHG emissions in the world is the burning of liquid (gasoline, diesel, fuel oil) and solid (coal and waste) fossil fuels. Vehicles have obeyed more restrictive limits on pollutant emissions, but they are still the main sources in urban areas, although emissions from industrial processes are also relevant in many urban areas (SIMONI et al., 2021).

The current patterns of urban mobility have been marked by the increase in individual motorization - and this entails high social, economic and environmental costs - however, actions that prioritize the reduction of greenhouse gases (GHG) are not on the list of effective policies in most countries, although they are increasingly present in the developed countries political discourses (RODRIGUES et al., 2021).

Indicators of indoor air quality (IAQ) and external air quality (EAQ) that influence health of constant displacement workers

IAQ is the state of indoor air, derived from the process of occupying a closed environment with or without artificial air conditioning. However, this concept is generally complex and extensive, since it depends on parameters: chemical, such as the concentration of carbon dioxide (CO$_2$) or other gases of a more harmful nature; physical, such as temperature, relative air humidity and ventilation rate; in addition to biological parameters, such as fungi and bacteria. Therefore, in order to obtain a good IAQ, it is necessary to achieve adequate ventilation and air renewal rates, a high air purity, as well as an effective filtering of the external air before it enters the interior environments (OLIVEIRA, 2019, p. 12).

According to studies carried out by the WHO, indoor pollution is considered a threat to public health and varies dramatically according to the level of economic development. Statistical data claim that in countries with high mortality rates, indoor pollution is responsible for up to 3.7% of disease burden (COSTA et al., 2019).

The higher the quality of the air in a given space, the greater the vigor and well-being of its occupants. Thus, it appears that invariably, automotive air conditioners are correlated with a matter of safety and public health, since their use guarantees greater convenience to their users, and temperature and humidity conditions are determining factors for the proliferation or not of diseases (DANTAS et al., 2019).

The indoor air quality (IAQ) of vehicular cabins deserves attention, since people spend more and more time inside their vehicles under the effects of the vehicular air conditioning system, which is currently a mandatory requirement for maintaining good air quality and comfort of cars. However, such systems can
bring risks regarding the presence of pollutants in the indoor environment (OLIVEIRA, 2019).

Human presence is one of the main sources of indoor air pollution, not only through the release of carbon dioxide through breathing or chemical substances through perspiration, but also through the transport of microorganisms such as bacteria, fungi, viruses and mites, as well as the transport of microorganisms such as bacteria, fungi, viruses and mites, as well as their respective occupational activities (COSTA et al., 2019).

Indoor air quality has a direct influence on the well-being of people who occupy or transit in these places. Air conditioning arises from the need to offer comfort conditions for its occupants, as well as having systems that protect them from impurities contained in the air. In some environments with artificial air conditioning, its occupants may develop illnesses, such as: fatigue, infections, eye and mucous membrane irritation, nausea, dizziness. (CAVALCANTI et al., 2015).

Vehicle sources have been highlighted in the degradation of atmospheric air quality, emissions caused by motor vehicles carry a wide variety of toxic substances, which when in contact with the respiratory system, can have the most diverse negative effects on health. These emissions, due to the combustion process and incomplete burning of the fuel, are composed of gases such as: carbon oxide (CO and CO₂), nitrogen oxide (NOx), hydrocarbons (HC), among which are some considered carcinogenic, sulfur (SOx), and inhalable particles (MP10) (VICENTE, 2017).

The presence of fungi that cause respiratory diseases (and potentially toxigenic) in the internal air circulation of vehicles deserves the attention of researchers in environmental health and even in the automotive industry, to improve the quality of life of the population and professional drivers (AQUINO et al., 2018).

It is notorious the growing importance that vehicles have in the 21st century, due to the fact that they are increasingly being used, either as a means of transport or even as a necessary input for the accomplishment of the workers' jobs. On the other hand, thermal comfort inside these vehicles is an important factor to be considered, considering that its absence can cause disturbances to workers, which can cause accidents, due to the nature of the activity being carried out (MEDEIROS et al., 2013).

The ventilation rate in an indoor environment can be measured through the concentration of CO₂, making it possible to determine the proportion of outdoor air mixed with the recirculated air, providing an indication of how the Air Quality Index (IAQ) is doing. Ventilation in an environment is important as it has the power to dilute other more harmful pollutants that may be present (CORDEIRO et al., 2019).

The maintenance of automotive air conditioning systems is crucial, as it prolongs the life of the equipment, avoids breakdowns, reducing the costs of changing parts and, most importantly, keeps the devices clean and prevents the concentration of mites, fungi, molds and bacteria, thus contributing to the maintenance of pure indoor air. In addition, without proper periodic maintenance, the efficiency of the air conditioning unit is reduced, which makes it difficult to filter the external air when used in the air renewal mode, thus exposing the interior of the vehicle and its occupants to pollutants from the outside (OLIVEIRA,
Scientific evidence has clearly demonstrated the serious harm of toxic air to health for at least four decades with worse prognosis in the last two years. The need for urgency is clear. Alarming and worrying, Harvard researchers recently point out that exposure to a higher concentration of pollutants in the long term has led to an increase in the death rate from Covid-19 and further reveal the close relationship between health and the impacts of human action on the environment (VORMITTAG et al., 2021).

The air has particles in suspension of different origins, responsible for the symptoms that characterize poor indoor air quality. The total indoor pollutant concentration depends on the pollutant production rate, pollutant removal rate, outdoor air exchange rate and outdoor pollutant concentration. The internal sources of pollutants can be the people themselves and activities linked to them, or materials that emit substances harmful to health, such as wood chipboard furniture that release volatile organic compounds (VOCs) and formaldehyde. The indoor air quality can be affected when the ventilation in the environments is not adequate, that is, when the processes related to the intake of external air, conditioning and mixing of the internal air, good distribution of the air in the environment and the renewal of the air present deficiencies of operation (PRESTRELO et al., 2019).

Air quality in the vehicle environment can change for a number of reasons. The substances accumulated inside air conditioners generate air pollution in the indoor environment, along with pollutants in the outdoor air. These components, along with other pollutants generated by the occupants inside the vehicles, are deposited mainly in the filters of the air conditioners. Over time, large amounts of particulate matter accumulate in all components of the mechanism installed in the vehicle, including biological products, and can be released inside the vehicle, reaching the occupants (OLIVEIRA, 2014).

There are feasible ways to reduce the emission of atmospheric pollutants, and the control of emissions from transport, industrial processes and burning is essential for socioeconomic development and the mitigation of climate change (SIMONI et al., 2021).

Currently, cars have been manufactured with the option of two conditioning modes, namely: air renewal, in which the outside air is absorbed and cooled by the system that will later be released into the vehicle’s cabin; and air recirculation, in which the vehicle’s internal air is extracted and released into the system, after which it is cooled by the system and returned to the environment, thus causing a decrease in its temperature (OLIVEIRA, 2019).

Technological Instruments favorable for mitigating the impacts of indoor and outdoor air quality

Data and their analysis work as input for different moments of an air quality management system, from its formulation to its assessment and adequacy. Air quality management systems have different designs around the world but share the same basic structure (SIMONI et al., 2021).

Data on air quality is becoming increasingly available and the science underlying health-related impacts is also rapidly evolving. To date, air pollution, both environmental (outdoor) and domestic (indoor),
is the biggest environmental health risk, leading to responsibility for about one in nine deaths annually (TEIXEIRA et al., 2019).

The governments of several countries have been trying to find ways to minimize the effects caused by $\text{CO}_2$ and its emission, controlling the flow of cars and motorcycles in big cities, forms of clean and renewable technologies, planting trees, among other means (SILVA et al., 2016).

The technology in favor of reducing the deleterious rates caused by poor air quality has several alternatives and fronts of action. First, we must talk about the environmental crisis that plagues the entire planet and requires reformulation in the way of dealing with issues related to the environment and the socio-environmental responsibility of States and society.

In general, air quality is influenced and dependent on some aspects: (i) quantity of pollutants emitted from any substance that makes the air inappropriate, harmful or offensive to health and the ecosystem; (ii) ability to disperse the environment; (iii) meteorological phenomena; and (iv) topography of the region. Thus, measurements of atmospheric gases are very important for monitoring air quality and, consequently, for the public health of the local community (OLIVEIRA et al., 2019).

Historically, the control of air pollution is treated as a subject limited to the environmental area, but advances in scientific knowledge show that the challenge goes beyond and is transversal in strategic areas for the country’s sustainable development. New studies and policies that address the issue more broadly, covering sectors such as the economy, health and climate, are essential for a better understanding and management of air pollution throughout Brazil, both in urban and rural areas. The impacts of air pollution on human health are linked to the incidence of premature deaths, lung and cardiovascular diseases, stroke, cancer and diabetes disposition, as well as impaired cognitive development in children and dementia in the elderly. These impacts are well established within scientific knowledge and affect more deeply vulnerable groups such as children and the elderly. The health sector is notoriously lacking in air quality governance at the national level (SIMONI et al., 2021).

Environmental monitoring is a multidisciplinary field of research, whose focus can be the assessment of air quality, the analysis of acoustic, thermal and light comfort, the identification of emitting sources of chemical and microbiological pollutants, among others. Scientific evidence, such as that low rates of air exchange between indoors and outdoors contribute to the increase in the concentration of chemical and microbiological pollutants, harmful to human health, aroused interest in research on indoor air quality (IAQ) which, in decades, gained prominence in the world scenario (COMIN, 2016).

In Brazil, to the same extent that the problems resulting from the strong urban concentration are accentuated, the improvement and expansion of environmental pollution control policies, continuous practices of production and dissemination of information and technologies on air quality and on the behavior of the different sources of emissions become progressively important. Faced with the increase of polluting sources, an adequate diagnosis of air quality is necessary, with the application of increasingly accessible, accurate and continuous monitoring technologies, in order to subsidize public policies and direct the
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Brazil has a series of laws and regulations that establish air quality management and pollution control, but a large part of the normative basis that supports the National Air Quality Control Program (PRONAR) is illegal, as it only contains in resolutions of the National Council for the Environment (CONAMA). This represents a relevant weakness for the creation of a robust, integrated and transparent national air pollution control policy, as well as for legal certainty to whom the law is addressed (issuers) (Simoni et al., 2021).

Ministry of Health ordinance No. 3,523, of August 28, 1998, refers to the basic measures that must be adopted in relation to the procedures for visual verification of the cleanliness state, removal of dirt by physical methods and maintenance of the integrity and efficiency state of all components of the air conditioning system, aiming to guarantee indoor air quality and prevent risks to the occupants of air-conditioned environments health (Fialho et al., 2017).

National Health Surveillance Agency (ANVISA) resolution RE nº 9, of January 16, 2003, brings a series of informative criteria to the population, on the indoor air quality in artificially conditioned environments. These rules are valid for both public and collective use, seeking to equip professional teams to carry out indoor air quality control. In addition to these recommendations, those responsible for closed buildings, which use air conditioning, should keep in mind the planning, elaboration, analysis and execution of physical projects in the inspection actions of these environments (Fialho et al., 2017).

Aiming to protect the health of servers so essential to judicial provision and, at the same time, ensure that Justice will not stop, justice has brought devices that authorize the remote work of Justice Officers (Bona, 2020).

One of the fundamental needs of environmental public policies is the establishment of indicators that allow decision-making. There is a growth in “green cities”, with a focus on reducing the adverse effects of environmental pollution (Martins et al., 2021).

Indoor air quality is a parameter with the purpose of informing the level of concentration of pollutants that may endanger the health of occupants. The data obtained from monitoring the indoor environment depends on a large number of factors such as: temperature; relative humidity; gas concentration; air speed; existence of odors; concentration of microorganisms or dust suspended in the air; noise level; lighting; pollution generated by metabolism; among others. This monitoring aims to provide information on internal environmental conditions and, based on the analysis of the data obtained, propose solutions to make the internal air suitable for the occupants of the place. ANVISA also estimates that the main corrective measures to control the concentration of CO₂ consist of increasing the renewal of external air, restricting sources of combustion and smoking in closed areas and eliminating infiltration from external sources (Cordeiro et al., 2019).

The technology of rolling stock, the organization of urban traffic, land use planning and transport policy are some of the determining factors in the emission of pollutants from road transport. In this sense,
the sector’s emission control strategies should encompass policies that promote more efficient and less impactful modes, the use of cleaner fuels and more efficient vehicle technologies (SIMONI et al., 2021).

**METHODOLOGY**

**Locus Research**

The locus of the research was based on the territorial jurisdiction of the Court of Justice of Pernambuco, a state agency linked to the Brazilian Judiciary, based on the structure and composition provided in article 92 of the Federal Constitution.

The Pernambuco Court of Justice was created by the charter of February 6, 1821, signed by Dom João VI, then King of Brazil - United Kingdom to Portugal, receiving the name of Pernambuco Court of Appeal. Its installation took place on August 13 of the following year, in the property of the former Royal Treasury, with some rooms hastily adapted and still improvised furniture (PERNAMBUCO, 2022).

**Measurement of CO2 concentration on the vehicle cab**

As previously recorded, a series of measurements were carried out regarding the concentration of carbon dioxide (CO₂) inside the private vehicle of this researcher, also a Justice Officer, during the fulfillment of in-person diligences between the months of September and December 2021, in the morning and afternoon shifts.

**Equipment and measuring method**

In order to evaluate the AIQ inside the car cabin and the environmental conditions, the following parameters were taken into account: CO₂ concentration (ppm), temperature (%) and relative air humidity (%). The equipment used in this research was the Carbon Dioxide Detector JD-112.

For measurement method purposes, the following conditions were taken into account: device position; measurement shifts; air conditioner system modes (renewal and recirculation); average daily mileage; and traffic conditions.

![Figure 1: Carbon Dioxide Detector JD-112 image.](image-url)

The choice of air monitoring technologies must take into account, in addition to legal requirements, the resources needed for the acquisition, operation and maintenance of the equipment. As with any
measuring equipment, the reliability of the values obtained depends on the sensitivity and precision of the equipment (Figure 1) (TEIXEIRA et al., 2019).

A correct diagnosis of air quality is essential for the Government to promote improvements in the monitoring structure. It is also essential that, in addition to disseminating information and making it available in reports and electronic addresses, educational programs to raise awareness of atmospheric pollution are carried out, bringing the community information about how pollution occurs, with 77% from mobile sources, how measurement of air quality occurs, and also what to do to improve these indices, which tend to increase with urban growth (TEIXEIRA et al., 2019).

RESULTS AND DISCUSSION

The research field covered in this case study operated on two fronts: the first was dedicated to individually measuring the CO$_2$, temperature and humidity indices inside this researcher’s vehicle during the months of September, October, November and December 2021, while the same proceeded with the customary displacements due to the fulfillment of court orders.

It is worth noting that the final months of the 2021 working hours were already heading towards the return to normality of physical working hours after almost 2 years of interruption of the traditional judicial service due to the Covid-19 pandemic. Despite the maintenance of some face-to-face displacements during the suspension of the physical deadlines, it is certain that the routine of the Justice Officers was intensely changed during most of the time between 2020 and 2021.

In this sense, item 5.1 presents the measurements of the internal conditions of CO$_2$, temperature and humidity during the fulfillment of court orders that were operated already in the scenario of return of physical acts. Since this is the great historical reality of the work of the Justice Officers, such measurements accurately delineate the traffic routine, traffic and usual time behind the wheel at the behest of the Judiciary.

**CO$_2$, Relative humidity and vehicle cabin measurements results**

![Figure 2: Internal vehicle cabin measurements - 20/09/2021 (Morning).](image)

On the first measurement day, during the 09/20/2021 morning shift, it was detected that the carbon
dioxide level remained stable, orbiting the range of 1,000 ppm, with a peak that exceeded 2,000 ppm between 7:55 am and 8:00 am (Figure 2). Regarding relative humidity, the index on 09/20/2021 remained above 30% throughout the measurement and approached 50% at two times, namely: around 7:40 am and 8:00 am. The temperature inside the vehicle cabin was the index that presented the most variability, since the minimum detected was 22ºC around 8:30 am, and the maximum reached 33ºC around 7:55 am.

The second measurement day took place during the 09/22/2021 afternoon professional shift. At that moment, the carbon dioxide concentration level showed some stability during most of the time, with an average of 1,000 ppm; except for the peak of 3,000 ppm at 15:30 (Figure 3).

The relative humidity inside the vehicle showed a decreasing graph throughout this afternoon, starting at 60% at 3:14 pm and decreasing to almost 40% at 4:12 pm. The temperature measured in the vehicular cabin, as well as the relative humidity, also registered a downward trend as the afternoon progressed, since at 3:14 pm it was 28.4ºC and its last detection, at 4:06 pm, recorded 26.8ºC. Several other measurements were performed, which will be summarized in the following item.

**Detection averages relation**

Once the daily detections of carbon dioxide, relative humidity and temperature have been completed, it is necessary to present the graphs that define the relationship between these variables.

The graph shows a relative CO₂ pattern in the detections carried out between the morning and afternoon shifts of up to 1,000 ppm, as can be seen from the representations in pink and lilac colors, with the air conditioner set in air renewal mode; however, the final indexes, measured between the end of
October and the beginning of December 2021 (represented by the elements in the green color), show an increase in the particle per million of carbon dioxide when the automotive air conditioner was configured for the air recirculation option. In these scenarios, the CO$_2$ level was above 2,000 ppm (Figure 4).

Figure 4: CO$_2$ measurements average

Figure 5: Temperature and CO$_2$ average relation

ANVISA resolution no. 9/2003 imposes that in artificially acclimatized environments, the recommended operating range of Dry Bulb Temperatures, in indoor conditions for summer, must vary from 23°C to 26°C, with the exception of art environments that must operate between 21°C and 23°C. The maximum operating range should vary from 26.5°C to 27°C (Figure 5).

Regarding the recommended operating range of relative humidity, ANVISA confirms that in indoor conditions for summer, it should vary from 40% to 65%, (Figure 6) with the exception of art environments that should operate between 40% and 55% throughout the year. The maximum operating value must be 65%, with the exception of access areas that may operate up to 70%. The range selection depends on the purpose and location of the installation. For indoor winter conditions, the recommended operating range should vary from 35% to 65% (BRASIL, 2003).

From the comparisons presented in the graphs concatenated in Figures 4, 5 and 6, it is necessary to make some comments. The graphic in Figure 4a shows a relative CO$_2$ pattern in the detections carried out between the morning and afternoon shifts of up to 1,000 ppm, as can be seen from the representations in pink and lilac colors, with the air conditioner set in renewal mode of air; however, the final indexes, measured...
between the end of October and the beginning of December 2021 (represented by the elements in the green color), show an increase in the particle per million of carbon dioxide when the automotive air conditioner was configured for the air recirculation option. In these scenarios, the CO₂ level was above 2,000 ppm.

Figure 6: Humidity and CO₂ average relation.

It should be noted that ANVISA resolution no. 9/2003, when defining reference standards for indoor air quality for climate-controlled environments, determines values below 1,000 ppm of carbon dioxide (CO₂), as an indicator of outdoor air renewal, recommended for comfort and well-being. Regarding the recommended operating range of relative humidity, ANVISA confirms that in indoor conditions for summer, it should vary from 40% to 65%, with the exception of art environments that should operate between 40% and 55% throughout the year. The maximum operating value must be 65%, with the exception of access areas that may operate up to 70%. The range selection depends on the purpose and location of the installation. For indoor winter conditions, the recommended operating range should vary from 35% to 65% (BRASIL, 2003).

Finally, the aforementioned Resolution imposes that in artificially air-conditioned environments, the recommended operating range of Dry Bulb Temperatures, in indoor conditions for summer, should vary from 23°C to 26°C, with the exception of art environments that must operate between 21°C and 23°C. The maximum operating range shall vary from 26.5°C to 27°C, with the exception of access areas that may operate up to 28°C. The range selection depends on the purpose and location of the installation. For indoor winter conditions, the recommended operating range should vary from 20°C to 22°C (BRASIL, 2003).

The green element that symbolizes the use of recirculation inside the vehicle is shown as enriched with carbon dioxide also in Figures 5 and 6, which links parallels between this with the temperature (Figure 4) and with the humidity (Figure 5). These results confirm that the quality of the car’s internal air has the greatest potential to cause damage to the vehicle’s occupants when the user opts for air recirculation.

Currently, cars have been manufactured with the option of two conditioning modes, namely: air renewal, in which the outside air is absorbed and cooled by the system that will later be released into the vehicle’s cabin; and air recirculation, in which the vehicle’s internal air is extracted and released into the system, after which it is cooled by the system and returned to the environment, thus causing a decrease in its temperature (OLIVEIRA, 2019).
The heated air from the passenger cabin goes to the evaporator, where it exchanges heat with the refrigerant fluid (the most used fluid currently in Brazil is R-134a), which is in two phases, liquid and vapor. The coolant absorbs heat from the air coming from the passenger compartment. The refrigerant fluid leaves the evaporator (1) at low pressure and, depending on the amount of heat exchanged, it can leave in the vapor state or in a vapor-liquid mixture. The refrigerant fluid passes through the compressor (2), which performs work to compress and raise the temperature of the fluid. The fluid becomes superheated steam and goes to the condenser (3). In the condenser, the fluid rejects heat to the car engine air and changes to a liquid state. The condenser is normally located in front of the vehicle’s radiator. The fluid then goes to the expansion valve (4) where it is expanded and enters the evaporator at low pressure, in a mixture of liquid and gas. The expansion valve regulates the flow of fluid that reaches the evaporator and so the cycle starts again. Passenger cabin air can be recirculated or air renewed, depending on the option selected by the passenger (DIAS, 2017).

It is important to highlight that CO\textsubscript{2} already has technology developed for optimization and use in automotive air conditioning systems, which leads to the conclusion that CO\textsubscript{2} must be the coolant fluid of the next decade in Europe and, later, in other continents. However, given the high costs (the CO\textsubscript{2} system is estimated to be about USD 300.00 more expensive than the R134a system), many automakers are waiting for trials with potential new fluids, to evaluate the best possibility, mainly in relation to cost/benefit. Furthermore, there is a need to carry out research in climates such as Brazil, in order to obtain performance results from vehicles with CO\textsubscript{2} and HFO-1234yf in automotive air conditioning systems, so that it is possible to verify the effectiveness of its use (BANDARRA, 2011).

It is known that, currently, most people spend more than an hour a day inside their car with the cooling/air recirculation system on, which makes this an air-conditioned environment. In this way, attention is needed in relation to the air quality inside cars, since pollution in indoor environments can cause severe harm to human health. There are several factors that influence IAQ in automobiles, the most important being: the renewal of internal air; the air conditioning mode used; the vehicle speed when the air renewal mode is chosen; thermal comfort correlated with the efficiency of the air conditioning system; the frequency of system maintenance, which mainly refers to the period of changing, cleaning and sanitizing the cabin filter; outdoor air quality; the composition of internal materials; cleaning, sanitizing and internal and external washing of the vehicle itself; as well as the habits of owners and occupants, such as eating, smoking, using deodorants/flavoring agents and perfuming themselves in the cabin (OLIVEIRA, 2019).

It is understood, therefore, that the 3 obtained metrics indicate that the conditions of the interior of the vehicle cabin are not within the technical standards of ANVISA, since the recommended levels were occasionally exceeded regarding relative humidity, temperature and also regarding the level of ppm of carbon dioxide, when the air conditioner is set to the recirculated air option.

During the detections carried out in the morning shift, the average percentage of relative humidity reached the level of 70% on 09/27/2021, 09/30/2021, and on the 12/05/2021 afternoon. As a result, the
stipulation of up to 60%, or, exceptionally, 65% of ANVISA, were disobeyed.

Regarding the appropriate temperature for air-conditioned environments, the reference limit of 26°C in the summer and up to 27°C of maximum operating range recommended by ANVISA were also not complied with, as the vehicle averages of 33°C on the 09/20/2021 morning are included; 28.4°C on the 09/22/2021 afternoon; 30°C on the 09/23/2021 morning; 29.5°C on the 09/27/2021 morning; 30°C on the 09/30/2021 morning; 28.5°C on the 10/04/2022 afternoon; 30°C on the 10/06/2021 afternoon; 31°C on the 10/07/2021 afternoon; 32°C on the 10/25/2021 morning; 28°C on the 12/01/2021 morning; and over 30°C on the 12/05/2021 afternoon.

Finally, the limit reference for the concentration of carbon dioxide, stipulated by ANVISA as adequate for ≤ 1,000 ppm, was also not complied with when it was verified that the measurements, although they usually remain below 1,000 ppm, recorded peaks of 2,000 ppm on the 09/20/2021 morning; 3,000 ppm on the 09/22/2021 afternoon; 1,200 ppm on the 09/23/2021 morning; 2,000 ppm on the 09/27/2021 afternoon; 1,400 ppm on the 09/30/2021 morning; 1,200 ppm on the 10/04/2021 afternoon; 1,200 ppm on the 10/06/2021 afternoon; 1,200 ppm on the 10/07/2021 afternoon; 3,000 ppm on the 10/25/2021 afternoon; 1,500 ppm and 3,000 ppm on the 12/01/2021 morning; and 2,500 ppm of CO₂ on the 12/05/2021 afternoon.

Some physical effects of human exposure to CO₂ concentrations above 1000 ppm are dizziness, headache, nausea and lethargy. This gas becomes fatal for humans in high concentrations, around 30,000 ppm for 10 min exposure, as it can cause asphyxia by displacing oxygen, so it is recommended that indoor air saturation is avoided by this gas, facilitating the air exchange with the external environment through an adequate ventilation rate. Outside, however, the great interest in CO₂ monitoring is its relationship with global warming, a phenomenon called the “greenhouse effect”, which is a recurring theme in scientific research and the pivot of some controversies among specialists (COMIN, 2016).

Brazil has a series of laws and regulations that establish air quality management and pollution control, but a large part of the normative basis that supports the National Air Quality Control Program (Pronar) is infralegal, as it only contains in resolutions of the National Council for the Environment (Conama). This represents a relevant weakness for the creation of a robust, integrated and transparent national air pollution control policy, as well as for legal certainty to whom the law is addressed (issuers) (SIMONI, 2021).

With this metric, it can be seen that on all the days that the measurements were carried out, there were peaks of CO₂ concentration higher than ANVISA recommendation no. 9. As a result, indoor air quality (IAQ) proves to be at risk for professionals who perform usual functions in vehicles, which applies to TJPE Justice Officers, who traditionally carry out their professional activities in transit during the traditionally face-to-face working hours.

National legislation must evolve in a way that shows results closer to reality, contributing to environmental policies and to the final consumer and also promoting technological development incentives by the automotive industry (DIAS, 2017).

Aspects related to IAQ, especially when associated with design practices, can be improved through
the diagnosis of situations observed in the present study, still in the design phase. In this scenario, the continuous assessment of the environment, as well as environmental education programs that involve users' awareness of healthy habits and knowledge about the main sources of air pollution and the respective improvement strategies, are fundamental for the quality of breathing air inside buildings, resulting in a positive impact on the improvement of the occupant's health and throughout the life cycle of the building (COSTA et al., 2019).

Atmospheric pollution caused by the burning of fuels has been representing serious problems to public health and severe environmental impacts to the environment, which is negatively and constantly affected by high levels of pollution, since air quality is influenced by the large fleet of automobiles vehicles in big cities. The governments of several countries have been trying to find ways to minimize the effects caused by CO₂ and its emission, controlling the flow of cars and motorcycles in big cities, forms of clean and renewable technologies, among other means (SILVA et al., 2016).

One of the fundamental needs of environmental public policies is the establishment of indicators that allow decision-making. There is a growth in “green cities”, with a focus on reducing the adverse effects of environmental pollution. This urban triad – with an increase in cars, more people living near congested traffic corridors and low vegetation cover – contributes to the degradation of the environment. Trees can contribute to monitoring the impact of traffic on air quality, as well as reducing the exposure of the population living near the corridors. Trees also allow characterizing air contaminants from gasoline and diesel-powered vehicles (MARTINS, 2021).

Regarding the sustainability goals of the TJPE, it is worth mentioning that the fleet of official vehicles of the Judiciary does not include the private cars used by the Officials of Justice, although these professionals have reimbursed their fuel costs. Thus, the measurement and graphics periodically presented by the court related to the use of official cars and fuel consumption excludes the private cars used from the results.

It should be noted that CNJ Resolution n.201/2015 established two indicators about the purpose of the vehicle in the Judiciary, whether for the exclusive use of the magistrate or for the use of service (here enters transport of servers, employees or service provision, for example, mail transport) (BRASIL, 2021).

The UN's 2030 Agenda includes 17 Sustainable Development Goals (SDGs) and 169 targets, which, from an economic, social and environmental perspective, aim to ensure a decent life for all. They are based on five fundamental pillars: people, planet, prosperity, peace and partnership. Achieving sustainable development and honoring the commitment to the UN 2030 Agenda through the adoption of concrete measures is a challenge for all countries in their most different spheres. It is a universal task that must be performed by governments, society, institutions or even individuals in isolation, with the participation of the Judiciary being essential. In November 2019, based on a proposal from the National Council of Justice, Goal 09 was approved, which consists precisely of the integration of Agenda 2030 to the Brazilian Judiciary. With this measure, the Judiciary became a precursor, in the world, by including adherence to the global pact in its strategic planning, institutionalizing the participation of all courts in the implementation of the Sustainable
Development Goals provided for in the commitment signed at the UN (BALDRESCA, 2022).

The judicial process as an instrument must enable a quick and effective judicial response, that is, it must allow the rights that have been injured or violated to be reconstituted within the democratic context of society, allowing the achievement of social peace. SDG 16 has the content of guaranteeing unlimited access to justice, as well as intending that States have solid institutions articulated with mechanisms that are capable of extending protection to civil, political, social, cultural and economic rights, which are fundamental and necessary for the dignified life and sustainable development, a goal of the United Nations when it established the 2030 Agenda. This agenda aims to allow global action undertaken by the union of international and local leaders, in order to achieve an inclusive, better and less unequal world. It must be considered that the 17 objectives outlined with their 169 goals to be fulfilled address the causes of poverty and the need for universality so that development reaches all people so that they can have a better and more dignified life. Thus, the bases of these objectives are based on three great umbrellas: economic growth, social inclusion and protection of the environment (NAHAS, 2022).

The 2030 Agenda works as an important guiding element of public policies across the planet, which takes the form of laws and also as government, business and civil society initiatives. As Brazil is a signatory to this agenda, together with the other 192 UN Member States, the horizons of action to reduce carbon emissions must be translated into concrete actions and, naturally, into scientific production capable of supporting and guiding all actors involved (BRAZ et al., 2020).

Digital tools have the ability to eliminate dependence on various inputs and services performance of the Justice Officers, but guarantees advantages for the entire chain of those involved in the conduct of a judicial process.

FINAL CONSIDERATIONS

The intense accumulation of carbon dioxide levels in averages above those indicated by ANVISA resolution n. 9 (above 1,000 ppm) was a situation found in all measurements carried out between September and December 2021, so it is possible to conclude that the refrigerated vehicular cabin carries a high potential to cause damage to the health of passengers and motorcyclists of the vehicle.

Considering that the Justice Officer is a worker who works professionally moving to locate people and goods, it is concluded that the level of exposure of these professionals to deleterious CO2 levels in their own vehicles during the working hours of external journeys can attract damage to health that would probably never be intuited as a consequence of poor indoor air quality in the vehicle.

Being aware of the threats to health, it is imperative to point out that the fulfillment of virtual diligences could eliminate, in whole or in part, the exposure of Justice Officers to the weather in physical journeys when using remote communication tools. During the years 2020 and 2021, the Covid-19 pandemic forced the Judiciary to adapt and create digital solutions that could give vent to the procedural progress without the physical presence of those involved in the dispute.
Virtual judicial acts can help Justice Officers to locate the recipients of their demands more quickly and save the health of these professionals from intense exposure to traffic, to external pollution in urban centers and to the internal pollution of the vehicular cabin itself.

In order for the risks of internal car pollution to be recognized, the TJPE must give vent to its mission for the quality of life of its employees and with technological solutions capable of raising the socio-environmental commitment of this state court of justice. Unwanted levels of CO$_2$ need to be faced with the seriousness they actually have, since it is possible and widely probable that the habitual user of vehicular transport in an artificially air-conditioned cabin will in the future bear harmful interference in their respiratory, cardiovascular and psychological health that condition face-to-face activities. From the unnecessary use of paper to saving time and fuel to comply with due diligence in the virtual environment, it is certain that the digital universe of the digital process can increase the achievement of environmental goals with the support of these technological tools. It is worth emphasizing that this benefit is not limited to the performance of the Justice Officers, but guarantees advantages for the entire chain of those involved in the conduct of a judicial process.

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Internal air quality in automotive vehicles in terms of carbon dioxide concentration: case study on the justice officer activity and possible benefits of technology to health and the environment


