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Fibropapillomatosis on Sea Turtles, a Sentinel of Ecosystem Health? †

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Abstract: Cutaneous fibropapillomatosis, first reported in green turtles (*Chelona mydas*) in 1930, is considered a global epizootic that affects up to 97% of sea turtles, with major consequences for threatened populations. Although this is a benign tumour that arises on the skin or internal organs, it can have serious and potentially fatal consequences when it compromises critical functions such as swimming, feeding, or breathing. The aetiology of this tumour is not yet well defined, but it has been primarily associated with Chelonide herpesvirus 5. Some studies also highlight exogenous environmental factors such as water temperature and pollutants, which may have caused a host-virus–host imbalance and the onset of the disease. Climate change seems to have a role in the dissemination of this pathology among sea turtle populations. Although not fully understood, the relationship between fibropapilomatosis and the state of environmental health is well recognized. Further research is needed to better understand this disease, which silently devastates entire populations of marine turtles. Daily human activities may have a greater impact on wildlife populations than can be expected. There is an urgent need to reverse human threats to wildlife.

Keywords: sea turtles; fibropapiloma; virus; climate change

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1. Introduction

Sea turtles are large aquatic reptiles that inhabit tropical and subtropical seas. They spend most of their lives on the high seas and do not return to land except for every 2–4 years after reaching sexual maturity [1,2]. The wild populations of sea turtles have been declining in the last decades, due to illegal hunting, ingestion and entanglement of marine debris, marine pollution, artificial lighting of the nidification sites, beach erosion, habitat destruction, invasive species predation, and warming of the oceans due to climate changes [3–5]. In recent years, fibropapillomatosis, a neoplastic disease, has been affecting sea turtle populations throughout the world and contributing to their decline. Little is known about the disease, although recent studies suggest a viral aetiology, linked to environmental factors such as pollution or climate change [6,7].

The first occurrence of skin fibropapillomatosis was reported in a green sea turtle (*Chelonia mydas*) from Florida (USA) in 1930 [8]. Even though the prevalence is higher in *C. mydas*, this disease has also been reported in Loggerhead (*Caretta caretta*), Kemp's Ridley (*Lepidochelys kempii*), Hawksbill (*Eretmochelys imbricata*), Flatback (*Natator depressus*), Olive ridley (*Lepidochelys olivacea*), and the Leatherback (*Dermochelys coriacea*) [7].

2. Etiology and Transmission

The principal etiological agent of fibropapillomatosis appears to be Chelonid herpesvirus 5 (ChHV5), a nonzoonotic agent [9]. Some authors posit that is possible that ChHV5 has existed within turtles for at least 8.9 million years and evolved during this period without harming the hosts [10]. However, exogenic factors such as water temperature and pollutants may have caused a virus–host imbalance and the onset of the disease [9,11]. Recent studies have shown a higher prevalence of disease in areas of highly polluted waters (chemicals, pesticides, algae, and others) [7].

The transmission method of this virus is still unknown since it is hard to culture in the laboratory and almost impossible to study in vivo since most sea turtle's species are near extinction [4,10]. The literature suggests that the virus may be spread through direct contact with infected animals or through contact with virus-containing substrates, horizontally [9,12]. Juveniles appear to be unaffected at birth [10]. Also, mechanical vectors (coral reef cleaner fish, the saddleback wrasse, marine leeches) may have a role in the transmission of the virus [13].

3. Clinical Presentation

Skin fibropapillomas in sea turtles present as elevated formations, 0.1 to 30 cm in diameter, well-defined from the surrounding tissues. Neoplasms are usually smooth, firm, and white, but others may be gelatinous and translucent. They are commonly ulcerated or necrotic [10]. These masses are found especially on soft skin but can be found anywhere on the body of the turtle (e.g., flippers, neck, chin, inguinal and axillary regions, and tail). In addition, some animals may develop internal nodules (Figures 1 and 2) [10]. Fibropapillomas can develop all over the body and become large enough to interfere with locomotion and vision (panophthalmia and destruction of the eyeball) and compromise other organic functions, such as feeding [12]. The animals end up dying of starvation and dehydration or secondary infection from ulcerated masses [10,12].

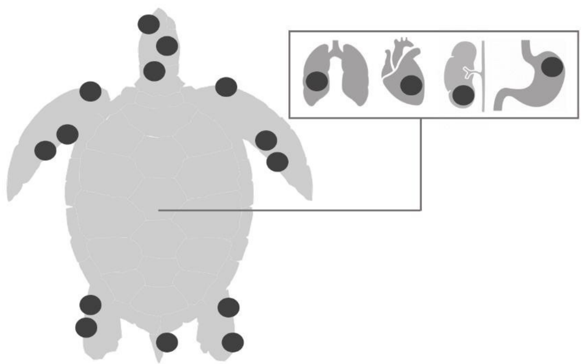

Figure 1. Common anatomical location masses on the soft skin of the turtle's body (flippers, neck, chin, inguinal and axillary regions, tail) and internal organs (heart, lungs, kidney, digestive tract).

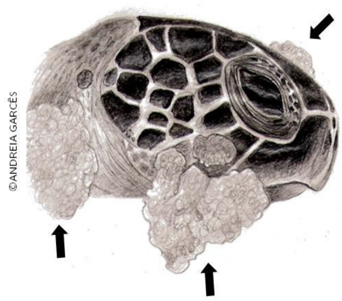

Figure 2. Sea Turtle Fibropapillomatosis.

4. The Impact of Climate Change

Some studies have shown that water temperature impacts tumors formation and the spread of the infectious agent [7,14]. Some researchers suspect that the increase in water temperature is realizing an excess of chemicals (eutrophication), such as nitrogen, that accumulates in the food of turtles (e.g., algae) and can be a factor that induces the occurrence of the disease [15].

The increase in ultraviolet light (UV) due to climate change is suspected to contribute to the emergence of tumours in ChHV5-infected animals. This is because UVB is associated with damage to DNA and increases its mutation rate, being responsible for the development of tumours in other animals [1].

Experiences with captive green turtles have shown that they develop more tumors during the warmer months. Therefore, the environmental temperature probably impacts fibropapillomatosis occurrence in sea turtles, similar to what occurs in other herpesviruses in other populations [16].

5. Conclusions

Sea turtles should be considered sentinels of ecosystem health, given that they depend directly on the environment for reproduction and development, and the slightest change can have a considerable impact on wild populations [7]. Even if not fully understood, there is a relationship between the development of sea turtle fibropapilomatosis and environmental factors. In the future, better fibropapiloma monitoring is necessary and could serve as a tool for monitoring ecosystem health in nearshore marine habitats and the impact of climate change.

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Occupational and Environmental Chemical Risk Assessment in a Changing Climate: A Critical Analysis of the Current Discourse and Future Perspectives †

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Abstract: Global climate change (GCC) models predict direct changes in region-specific rainfall patterns, floods, sea levels, infectious and heat-related disease patterns. The indirect effects of GCC on chemical risk assessment (CRA) have not received adequate attention. This study presents a synopsis of the implications of GCC on CRA, which forms the basis for both occupational and environmental health. GCC can make organisms more sensitive to chemical stressors, and chemical exposures can make organisms more sensitive to GCC. Consequently, occupational and environmental chemical RA will need mechanistic understanding and analytical tools to predict outcomes of multiple stressors and their combined effects.

Keywords: climate change; greenhouse gases; toxicology; risk assessment; adverse outcome pathways

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1. Introduction

Expanding human activities increase the variety and intensity of stressors, whose effects are exacerbated by accelerating climate change [1–5]. For example, the increase in the concentration of greenhouse gases (GHGs) such as carbon dioxide, methane and dinitrogen oxide is resulting in global warming and climate change [6].

Global climate change (GCC) can make organisms more sensitive to chemical stressors, and chemical exposures can make organisms more sensitive to GCC. Since stressors are heterogeneous and can affect individuals, populations, communities, and their habitats, many disciplines investigate their combined effects, e.g., pharmacology and epidemiology, toxicology, environmental science, conservation biology, and ecology [1]. The common challenge, irrespective of the discipline, is that combined effects cannot be predicted reliably from the individual effect of each stressor, where the way in which each stressor operates in isolation may change or be modified in the presence of other stressors [1,7–9].

This study presents a synopsis of implications of climate change on occupational and environmental chemical risk assessment (CRA). After analysing all the pertinent issues on the topic, the study also makes suggestions for incorporating climate change into occupational and environmental CRA of chemicals.

2. Direct Effects of Climate Change

GCC may influence a variety of environmental variables, including temperature, precipitation, salinity, pH, and insolation of ultraviolet (UV) radiation. Overall, climate change is expected to result in more frequent and intense heat waves, precipitation and storm events. These changes are expected to have an impact on the behaviour and fate of pollutants as well as changes in interactions of pollutants with living organisms, especially thresholds that might trigger adverse events.

2.1. Temperature

Differences in temperatures may alter the physicochemical properties, bioavailability and toxicokinetics of chemicals resulting in different toxicity profiles. Biological rates depend on temperature, where physiological dose–response functions can be used to represent variation (of biological rates) in response to environmental stressors [10]. For example, juvenile *Penaeus semisulcatus* were reported to exhibit significantly higher toxicity to ammonia at 14 °C than at 26 °C [11]. Similarly, the toxicities of two commonly used biocides, chlorothalonil and copper pyrithione (CuPT), to marine copepod *Tigriopus japonicus* and dinoflagellate *Pyrocystis lunulaf*, were highly temperature-dependent, although the temperature dependency varied between the two chemicals [12]. Kwok and Leung [13] also reported temperature-dependent toxicities for tributyltin chloride antifouling biocides to *T japonicas,* while Li et al. [14] reported temperature-dependent toxicities of copper sulphate pentahydrate triphenyltin chloride, dichlorophenyltrichloroethane and copper pyrithione (to marine medaka fish *Oryzias melastigma* and the copepod *T japonicus*).

Temperature has also been shown to affect the toxicity of pollutants to terrestrial organisms. For example, the effect of temperature on the reproductive toxicity of mercury affecting swallows [15] and the effects of temperature on the toxicity of many pollutants affecting herbivores [16] has been reported. Most notably, for several different chemicals, a difference in ambient of 10 °C from 26 to 36 °C produced an effect in rodents that was similar to increasing the dose two- to eight-fold, while the lethal dose of caffeine in mice at 36 °C is one-fifth the lethal dose for mice at 26 or 8 °C [16].

Changes in temperature have an effect on the bioavailability of persistent organic pollutants and their subsequent uptake and bioaccumulation. For example, increased temperatures are expected to reduce the overall bioaccumulation of organic contaminants in the Arctic marine food web [17], but increase the bioavailability of metals (Cd, Pb and Zn) in soil [18].

2.2. Preciptation, Rainfall Patterns, Floods, Sea Levels

GCC will influence water availability and quality. Increased precipitation has been predicted for some regions such as northern Europe, North and South America as well as northern and central Asia, while substantial droughts have been predicted for other regions such as southern Africa, Asia and the Mediterranean, i.e., the impacts are area- or region-specific [19]. Although the mean total quantity of water resources is likely to increase for Africa as a whole, substantial variations are expected for individual sub-basins and countries, along with increases in the drought events and their duration, i.e., variations exist for regions and sub-regions [20]. In that regard, IPCC models predict rainfall increases over most part of West Africa with the exception of the coastline where a little decrease in amount of rainfall was estimated [21]. This stressor does not necessarily act in isolation, where the effects of precipitation and temperature on vegetation index have also been modelled and should be considered [22].

2.3. Water and Soil Salinity

The effects of climate change on water availability and quality will in turn affect water and soil salinity [23,24]. Salinity has been reported to enhance the toxicity of many pollutants to many aquatic organisms, including L-selenomethionine to Japanese medaka (*Oryzias latipes*) embryos [25], polyvinylpyrrolidone (PVP) coated silver nanoparticles to

Tisbe battagliai (Tb) and *Ceramium tenuicorne (Ct)* [26]. Interaction between salinity and pollutants has been reported not only in aquatic organisms, but also terrestrial organisms. For example, salinity increased the toxicity, as indicated in changes in weight and mortality, of Zn^{2+} to the earthworm *Eisenia fetida* [27]. Salinity also increased soil Cd availability and toxicity to microbial organisms, as indicated in the decreased soil microbial respiration rate, microbial biomass and enzyme activity [28]. Similarly, salinity reduced tolerance of conocarpus (*Conocarpus erectus* L.) against Cd stress due to increased uptake of toxic ions and intensification of oxidative stress [29]. In some cases, increasing salinity reduced the toxicity of some pollutants. For example, increased salinity reduced the acute toxicity to *T japonicus* due to precipitation of the dissolved concentrations of the ions [30]. Similarly, salinity was reported to be protective against acute Ni toxicity in the crustacean species *Litopenaeus vannamei* and *Excirolana armata* [31].

3. Indirect Effects of Climate Change

The impacts of GCC are numerous, including changes in human migration as a result of rainfall patterns or sea level rise, heat-related mortality and mutation in infectious disease vectors [32]. Furthermore, predictive models indicate that GCC will affect the geographic distribution and annual number of generations of agricultural pests, which will in turn change pesticide use patterns [33–35]. This will increase the usage and sources of pesticides [36–38].

Following release from primary sources, pollutants are stored on various compartments from where they are subject to various secondary release processes. According to UNEP/AMAP [39], climate change will affect the rate of mobilization from materials and stockpiles, volatilization as well as partitioning between air and soil and air and water. Indeed, changes in climate variables such as temperature, winds, precipitation, currents, and snow will in turn change transport, deposition and fate of contaminants. Soil properties that control pollutants adsorption and mobility such as temperature, moisture, organic matter, mineral fractions, and microbial activities are affected by climate change. Consequently, exposure to contaminants could be increased because of desorption and remobilization of soil contaminants [40]. This is important for both environmental exposure to chemicals (e.g., pesticides) and occupational exposure to chemicals, especially exposure of workers to agricultural pesticides on re-entry.

4. Influence on (Toxic) Action or Interactions between Chemicals and Target Molecules

GCC can influence physiochemical properties of chemicals (toxicokinetics), i.e., absorption, distribution, metabolism, and excretion (ADME), or mode of action or interactions between chemicals and target molecules (toxicodymanics), e.g., various transport, degradation, dissipation and fate processes which can in turn influence the internal dose. Chemical, biological and ecological information is used to define the pathways that link stressor exposure to potential adverse outcomes at different organisational levels [41], e.g., adverse outcome pathways (AOPs) in ecotoxicology [42]. AOPs have been used to predict that toxicants may alter the ability of organisms to respond to climate change and, in turn, climate stressors may affect chemical toxicity [43]. AOPs depict links starting from a mechanism-based molecular initiating event (MIE), followed by biological key events (KE) that are connected via key event relationships (KER) and result in an adverse outcome (AO). Chemical and climate-specific stressors can influence the MIE, KE, or KER and ultimately change the AO.

5. Implications on the Validity of Occupational and Environmental Chemical Risk Assessment

GCC may cause more frequent and intense heat waves, precipitation and storm events where these changes impact on the behaviour and fate of pollutants, interactions of pollutants with living organisms, and thresholds that trigger adverse events. The impacts of climate change on the transport, fate and exposure to pollutants have been thoroughly examined and discussed [19,40,44–50]. Occupational and environmental CRA requires an understanding of these kinds of relationships between exposure and effects.

The exposure to chemicals in occupational and environmental settings depends on the dissipation, fate and behaviour of the chemical, which are in turn affected by a number of physical, biological, and ecological processes in the environment that include microbial degradation, volatilization, adsorption, uptake by plants and animals, surface runoff, and leaching [51,52]. These processes are interrelated, where the governing factors for each of these processes are complicated. Hence, it is difficult to interrogate each process in isolation.

The dependencies of toxicity of many pollutants on temperature and salinity are crucial for toxicology and RA. It is predicted that anthropogenically-driven GCC may increase salinity and incidents of extreme temperature events, which may have significant effects on the toxicity of chemical pollutants and lead to adverse effects [43]. Occupational and environmental CRA are based on toxicity data on model organisms obtained under standard test conditions, which may not reflect actual environmental conditions that may change how organisms respond to chemical insults. Indeed, after exposing larval and adult grass shrimp to the fungicide chlorothalonil and the insecticide Scourge under various test conditions of (i) standard toxicity test conditions, (ii) a 10 °C increase in temperature, (iii) a 10 ppt increase in salinity, and (iv) a combined increased temperature and salinity exposure, DeLorenzo et al. [53] reported that standard toxicity bioassays may not be predictive of actual pesticide toxicity under variable environmental conditions.

For ecological CRA, Landis et al. [54] proposed critical changes that involve use of conceptual cause–effect diagrams that include both direct and indirect effects of climate change. In order to consider effects of climate change in standard toxicity testing of pollutants, DeLorenzo et al. [53] recommended toxicity testing under a wider range of exposure conditions to improve the accuracy of CRA.

GCC will trigger multiple stressors and impact a myriad of contaminants in different ways. Under these circumstances, CRA, which often assesses effects of one stressor at time, will have to concomitantly consider interactions among contaminant and non-contaminant stressors. This will include new temperature and precipitation regimes, new ecosystems and hydrologic processes that are likely to result in new responses to lethal and sub-lethal doses of pollutants [54]. Hooper et al. [43] proposed the use of mechanistic toxicological tools such as AOPs in assessing climate change risks.

6. Conclusions

Rapid modifications occur in the environment resulting from climate change and encroachment of human activities on all ecosystems. However, some stressors cannot be mitigated rapidly. GCC will have implications on the validity of occupational and environmental CRA through space and time. Consequently, occupational and environmental CRA will need mechanistic understanding and analytical tools to predict outcomes of multiple stressors and their combined effects. For example, conceptual cause–effect diagrams at spatial and temporal scales can be used in order to account for both direct and indirect effects of climate change, whose magnitude will depend on the extent to which current conditions are altered.

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environmental sciences proceedings

Proceeding Paper

Air Pollution Derivatives Linked to Changes in Urban Mobility Patterns during COVID-19: The Cartagena Case Study †

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Abstract: The impact of the pandemic caused by COVID-19 on air pollution in our cities is a proven fact, although its mechanisms are not known in detail. The change in urban mobility patterns due to the restrictions imposed on the population during lockdown is a phenomenon that can be parameterized and studied from the perspective of spatial analysis. This study proposes an analysis of the guiding parameters of these changes from the perspective of spatial analysis. To do so, the case study of the city of Cartagena, a medium-sized city in Spain, has been analyzed throughout the period of mobility restrictions due to COVID-19. By means of a geostatistical analysis, changes in urban mobility patterns and the modal distribution of transport have been correlated with the evolution of environmental air quality indicators in the city. The results show that despite the positive effect of the pandemic in its beginnings on the environmental impact of urban mobility, the changes generated in the behavior patterns of current mobility users favor the most polluting modes of travel in cities.

Keywords: air pollution; urban mobility; environmental impact; Cartagena; COVID-19

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1. Introduction

Air pollution in cities causes seven million premature deaths each year, with more than 400,000 in Europe alone [1,2]. In this context, transport accounts for 25% of greenhouse gases of the planet, with 70% of these gases produced by urban mobility in the form of cars, buses, vans, etc. [3,4]. Most experts agree that pollution from urban mobility is currently the greatest challenge in relation to the future of air quality in cities [5,6] and its analysis through the indicator PM 2.5 the most effective way for its investigation [7–9].

In the last two years, the pandemic caused by the SARS-CoV-2 virus has brought about a very profound change in our society's way of life. One of the aspects on which the pandemic has had a greater impact was urban mobility, due to the restrictions imposed in many countries. This has caused a temporary transformation of mobility patterns in cities, the impact of which is only partially known. The first studies on the matter highlighted that, during the time of the greatest restrictions on mobility in cities, pollution levels fell by 50% in developed countries [10,11].

Nevertheless, these first figures are only part of the phenomenon, since the subsequent changes caused by the pandemic in the behavior patterns of urban mobility are not limited to the transitory impact of the initial reduction of polluting gases caused by people remaining at home due to lockdown. The capacity restrictions in public transport, the greater use of private vehicles because of the psychological effect of the possibility of contagion, or the change in the lifestyle habits of users throughout this past and present period have had effects that should also be analyzed from a broader perspective at the environmental level.

However, this issue is far from simple to analyze as it implies knowledge of the details of the COVID-19 pandemic's impact in the areas related to the behavior patterns of urban mobility and application to the field of environmental impact. To address this, we have studied the urban mobility patterns in the city of Cartagena (southeast Spain) during the pandemic from the perspective of spatial statistical analysis. These patterns have been statistically correlated using geostatistical analysis tools to infer the evolution of the different environmental impacts caused by the pandemic.

2. Methodology

2.1. Area of Study and Data Source

The study area is located in Cartagena, a medium-sized city in the southeast of Spain. Assessment of this phenomenon in a city of this category is not a random decision. Cartagena is a city that, due to its size, allows access to a critical mass of data on key pertinent variables, thus enabling robust statistical analysis without having to address the difficulty of handling large numbers of variables and data that would surely be involved in the context of a similar analysis in major European or American capital cities [12]. The analysis focuses on the urban perimeter shown in Figure 1.

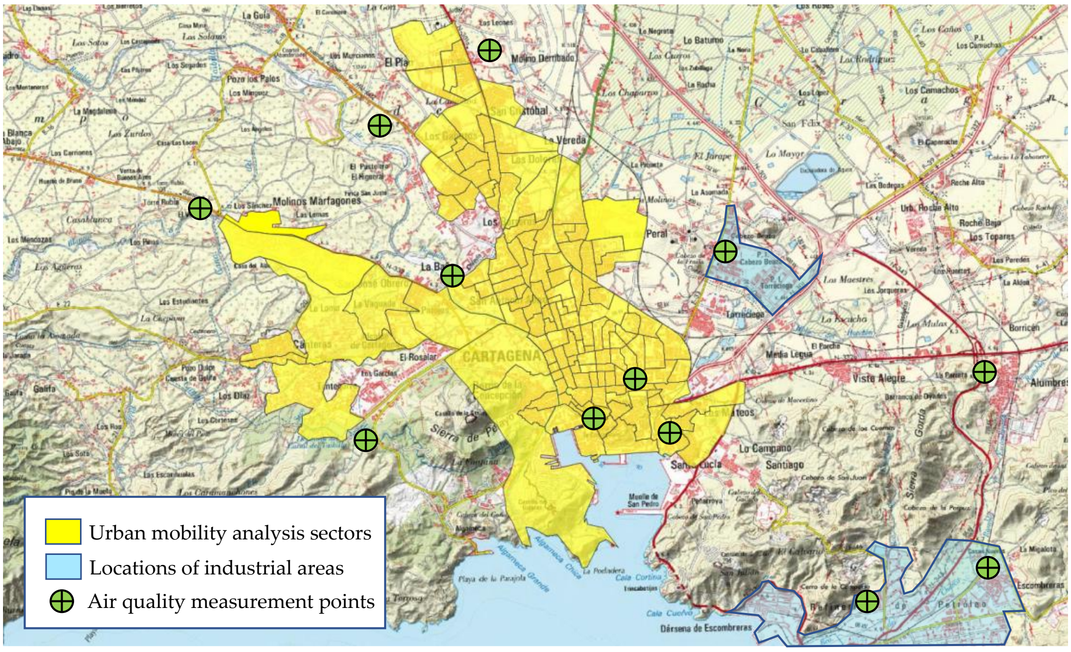

Figure 1. Air quality measurement points and division of the city of Cartagena into sectors for analysis.

2.2. GIS Indicators of Urban Mobility Spatial Patterns and Environmental Impact Assessment

In the urban sectors generated in Figure 1, indicators related to the evolution of the different modal alternatives for urban mobility during the pandemic, as well as an indicator related to the air quality in the city, have been computed and spatially analyzed. The indicators used are described below.

2.2.1. Private Vehicle Use Density Index (PVUD)

This indicator assesses the evolution of the density of private vehicle use in a sector. Through the measurements and gauges of the City Council's traffic control center in the different streets of the city, the level of traffic density in each of the sectors has been evaluated, comparing the existing values for the years 2019, 2020, and 2021, with this formula:

$$PVUD^{t_2-t_1} = \frac{\sum_n a_i^{t_2-t_1}}{\sum_z d_j^{t_2-t_1}} \quad (1)$$

with a_i being the estimate of the number of daily trips in private vehicles in a sector during a period of time between t_1 and t_2 and d_j the total set of z displacements produced in that sector between t_1 and t_2.

2.2.2. Index of the Evolution of Public Transport Use (IPTU)

This indicator assesses the evolution of the density of public transport use in a sector. Through the measurements provided by the municipal public transport concession companies on the different lines and bus stops in the city, the level of density of public transport use in each of the sectors has been evaluated by comparing the existing values for the years 2019, 2020, and 2021. The indicator is formulated as follows:

$$IPTU^{t_2-t_1} = \frac{\sum_n b_i^{t_2-t_1}}{\sum_z d_j^{t_2-t_1}} \tag{2}$$

with b_i being the estimate of the number of daily trips by public transport in a sector during a period of time between t_1 and t_2 and d_j the total set of z displacements produced in that sector between t_1 and t_2.

2.2.3. Healthy Mobility Density Index (HMD)

This indicator assesses the evolution of the density of use of mobility modalities classified as healthy (pedestrian movements and bicycle use) in a sector. By means of the data obtained from the surveys carried out through the municipal app, the level of density of use of these mobility modalities has been evaluated in each of the sectors, comparing the existing values for the years 2019, 2020, and 2021. The indicator is formulated as follows:

$$HMD^{t_2-t_1} = \frac{\sum_n c_i^{t_2-t_1}}{\sum_z S_j^{t_2-t_1}} \tag{3}$$

with c_i being the estimate of the number of daily pedestrian or bicycle trips in a sector during a period of time between t_1 and t_2 and d_j the total set of z displacements produced in that sector between t_1 and t_2.

2.2.4. Evolution of Air Quality Index (EAQI)

In the urban area of Cartagena, twelve air quality measurement stations measure the Air Quality Index (AQI) parameters PM2.5, PM10, O3, NO2, and SO2. In this study, for the analysis of the air quality, the values of PM 2.5 have been taken as a reference for AQI. This parameter has been contrasted for the years 2019, 2020, and 2021 for a period of several days, to ensure that the readings were not merely due to weather phenomena, punctual pollution episodes, or anomalous measurements. Thus, an evolution indicator is established according to the following formula:

$$EAQI^{t_2-t_1} = \frac{\sum_n AQI_i^{t_2-t_1}}{N} \tag{4}$$

with AQI_i being the estimated AQI daily value for a sector during a period of time between t_1 and t_2 and N the total number of days measured between t_1 and t_2. In this case, it would be the mean value of the PM2.5 parameter over a period of N days.

3. Results

The bivariate statistical correlation existing from a spatial point of view between the distribution pattern of each of the modal mobility indicators and the level of air quality have been analyzed using Anselin's Local Moran's I statistic (see Table 1). This analysis has been complemented in an aggregate way with a numerical OLS analysis and with a spatial analysis of hot spots with the Getis–Ord Gi * statistic to understand, in a two-dimensional way, the patterns of clustering behavior and the outliers of the existing relationship between the different modal alternatives for mobility and environmental pollution in the city (see Table 2 and Figure 2).

Table 1. Bivariate Global Moran's I statistics for spatial correlation between mobility indicators and EQI index (data order: 2019/2020/2021).

GIS Indicators	*PUVD—EAQI*	*IPTU—EAQI*	*HMD—EAQI*
	Bivariate Global Moran's I		
Global Moran's Index	0.59/0.66/0.65	0.61/0.71/0.75	0.60/0.71/0.18
z-score	55.2/68.7/70.1	37.0/44.6/43.5	38.8/60.2/15.5
p-value	0.01/0.01/0.01	0.01/0.01/0.01	0.01/0.01/0.01

Table 2. Detailed multiple regression models (OLS) for LISA bidimensional analysis of the different levels of air quality index.

Mobility Indicators	**Low EAQI Values (<10)**				**Low—Intermediate EAQI Values (11–25)**			
	B	**Std. Error**	***t***	**Sign.**	**B**	**Std. Error**	***t***	**Sign.**
PUVD	−0.265	0.003	−1.454	0.000 *	−0.196	0.005	−2.316	0.000 *
IPTU	0.067	0.004	1.255	0.000 *	0.260	0.005	5.521	0.000 *
HDM	0.249	0.003	2.286	0.000 *	0.117	0.006	3.090	0.000 *
Akaike's information criterion (AIC): 25,287.6 Multiple R-squared: 0.43 Adjusted R-squared: 0.42 F-statistic: 70.78 Prob (>F) (3,3) degrees of freedom: 0					AIC: 20,180.9 Multiple R-squared: 0.18 Adjusted R-squared: 0.17 F-statistic: 126.32 Prob (>F) (3,3) DF: 0			
Mobility indicators	**Intermediate—High EAQI values (26–40)**				**High values EAQI values (>40)**			
	B	**Std. error**	***t***	**Sign.**	**B**	**Std. Error**	***t***	**Sign.**
PUVD	0.176	0.005	1.218	0.000 *	0.337	0.004	3.120	0.000 *
IPTU	0.107	0.006	2.144	0.000 *	−0.053	0.003	−4.631	0.000 *
HDM	−0.127	0.003	−4.713	0.000 *	−0.301	0.007	−5.355	0.000 *
Akaike's information criterion (AIC): 19,573.0 Multiple R-squared: 0.19 Adjusted R-squared: 0.18 F-statistic: 148.55 Prob (>F) (3,3) degrees of freedom: 0					AIC: 24,745.6 Multiple R-squared: 0.41 Adjusted R-squared: 0.41 F-statistic: 66.71 Prob (>F) (3,3) DF: 0			

* Significant at the 0.01 level.

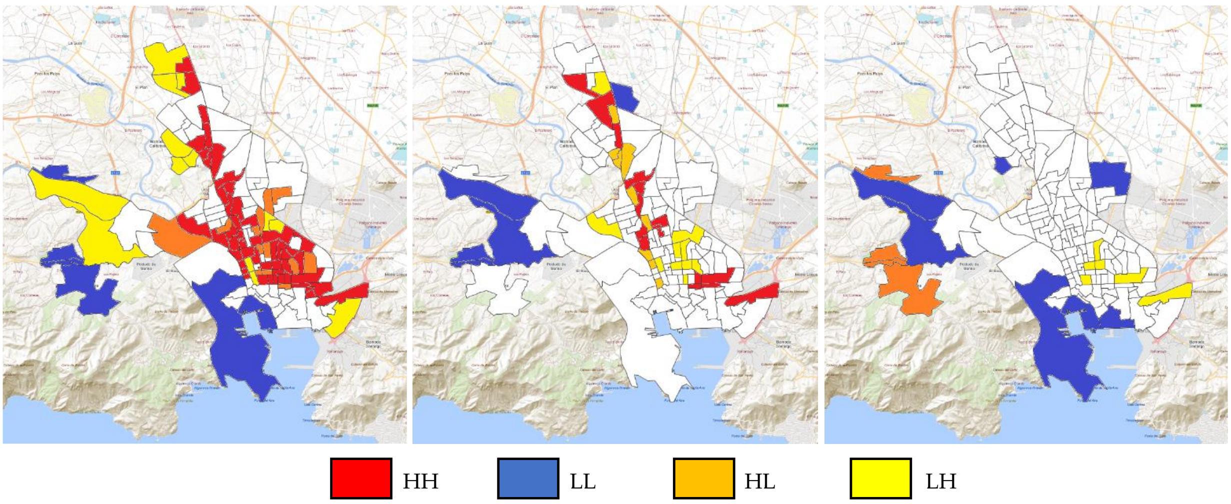

Figure 2. Current trend of LISA hot spots maps between mobility indicators and AQI for March and April 2021 (case order: PVUD-EAQI/IPTU-EAQI/HMD-EAQI).

Based on the results, we can verify that there is a clear spatial correlation between the areas with the greatest increases in private vehicles and the areas of consolidation with a high level of environmental pollution. This is verified both at the numerical aggregate level in the analysis and in the spatial distribution of the behavior patterns of the modal alternatives linked to private vehicles (HH cases in Figure 2). We also note that the increase in walking and cycling due to the pandemic is not enough to compensate for the increase in the level of pollution derived from the decline of public transport in most sectors. In any case, as shown by the numerical analysis of the Akaike's information criterion and the adjusted R^2 value, the model behaves better in extreme situations (e.g., high or very low values of pollution levels in 2020) but is less reliable and robust in intermediate or transitional situations, such as in 2021, so these results cannot be taken as definitive.

4. Discussion and Conclusions

The results obtained reflect a more complex reality than that currently inferred on many occasions in relation to the effects of the pandemic in the context of urban mobility in cities, and consequently of the environmental impact of this phenomenon. It is evident that the general paralysis of economic activity, as a result of the inability of developed countries to cope with the spread of the SARS-CoV-2 virus during the first months after the declaration of the worldwide pandemic situation, led to a planet-wide reduction in greenhouse gas emissions, as confirmed by numerous studies [13].

In the case of transport, the reduction in its environmental impact has been prolonged over time in various sectors because of restrictions being maintained on international mobility between countries, as has happened, for example, in the sector of international aviation (which represents one of the most polluting means of transport). However, in the case of urban mobility, this analysis is more complex. The tougher restrictions on mobility in the initial phase of the pandemic led to a reduction in all trips in all modes of transport in cities, contributing to a global reduction in pollution in these areas, which usually represents a significant percentage (>70%) of all greenhouse gas emissions from transport. However, once this initial stage of confusion in the face of the virus that forced administrations to resort to more drastic measures had been overcome, the subsequent re-establishment of the usual activity of the cities has opened a new scenario that is possibly less favorable to the environment and human health.

In the case study presented in this work, maintaining certain mobility limitations, such as capacity restrictions in public transport, has led to an inevitable loss of modal share in the distribution of urban mobility alternatives, assuming a clear decrease in several of the most efficient alternatives at an environmental level. On the other hand, an increase in the use of private vehicles in municipal gauges once restrictions on mobility were relaxed has been found in the city of Cartagena. This growth is partially fueled by those users who have abandoned public transport due to the capacity restrictions imposed in this modality, but also by the changes in the behavioral habits of the users because of the psychological effect generated by the risk of contagion of the virus.

This therefore reflects a dual situation in which, after an initial phase of general reduction in mobility and thus its environmental impacts, the effects of the pandemic did not result in a reduction in greenhouse gases, but rather a change in the behavioral patterns of urban mobility that favors a trend of higher environmental impact (but still not higher in total numbers) than the one that existed before the pandemic.

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Proceeding Paper

Temperature Changes and Ischemic Heart Disease Mortality: Global Trends, 1990–2019 †

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† Presented at the 4th International Electronic Conference on Environmental Research and Public Health—Climate Change and Health in a Broad Perspective, 15–30 October 2022; Available online: https://ecerph-4.sciforum.net/.

Abstract: Joinpoint regression analysis was applied to calculate the average annual percent change (AAPC), with 95% confidence interval (CI), to evaluate global ischemic heart disease (IHD) mortality trends in 1990–2019. In 2019, there were disparities by sex in terms of the contribution of non-optimal temperature to global IHD mortality: for low temperature (5.99% in males and 6.19% in females, respectively) and high temperature (0.50% in males and 0.44% in females, respectively). A decreasing trend for global IHD mortality attributed to low temperature was observed in males (AAPC = −1.7%; 95% CI = −1.8 to −1.6) and females (AAPC = −2.1%; 95% CI = −2.1 to −2.0).

Keywords: ischemic heart disease; global mortality; temperature changes

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1. Introduction

Ischemic heart disease is the top leading single cause of death worldwide [1–3]. The World Health Organization estimated that ischemic heart disease (IHD) was responsible for 16% of the world's total deaths, i.e., IHD caused 8.9 million deaths in 2019 globally [2]. The burden of IHD, in number of deaths, continues to increase globally [1,2]. A large increase in mortality has been reported for IHD, and this disease was responsible for over 2 million deaths (more in 2019 compared to 2000) [2]. The increasing number of IHD cases and deaths are partly due to population growth and aging [4].

On the other hand, trends in IHD mortality rates in the last decade showed a progressive decline, especially in the Western countries, in contrast to a rapid increase in IHD burden in developing countries [5,6]. An overall decreasing trend in IHD mortality may be explained by improvements in therapy and prevention of cardiovascular disease, as well as by better health care access [5].

The Global Burden of Disease 2019 study showed that a newly included determinant, i.e., non-optimal temperature, accounted for 1.01 million deaths in males and 0.946 million deaths in females [6]. Some previous studies have indicated that non-optimal temperature is an important environmental risk factor for IHD, with both high and low temperature associated with risk of mortality from IHD [7,8].

Climate change, including non-optimal temperature, is a large health issue humanity faces. There have only been a few studies that examined the impact of temperature variations on the global and regional variations in IHD mortality [9,10]. The purpose of this study was to assess the association between global ischemic heart disease (IHD) mortality and temperature changes.

2. Materials and Methods

2.1. Study Design

A descriptive epidemiological study design was used.

2.2. Data Source

Data on deaths of IHD were extracted from the Global Burden of Disease (GBD) 2019 database [11]. The GBD 2019 database contains data for 204 countries and territories. Data for global and regional level were extracted and analyzed for the years from 1990 to 2019. Ischemic heart disease as a cause of death was defined according to the International Classification of Disease (X revision) codes I20–I25. Age-standardized rates (ASRs, per 100,000) of IHD mortality were calculated by the direct method using the GBD standard population. Additionally, data on contribution (%) of high and low non-optimal temperatures to IHD mortality were extracted from the GBD 2019 study [11].

2.3. Statistical Analysis

Joinpoint regression analysis was applied to identify magnitude and direction in temporal trends of IHD mortality rates in 1990–2019 [12]. The Monte Carlo permutation method was used. The average annual percentage change (AAPC) with corresponding 95% confidence interval (95% CI) was calculated. Additionally, to evaluate pairwise differences, the comparability test (test of parallelism) was used to determine whether two regression mean functions were parallel. A two-sided significance level set at $p < 0.05$ for all tests was used.

3. Results

The contribution of non-optimal temperature to global IHD mortality in both sexes together in 2019 was 6.53% (for low temperature it was 6.08% and for high temperature 0.47%) (Figure 1). There were disparities by sex in terms of the contribution of non-optimal temperature to global IHD mortality in 2019: for low temperature (5.99% in males and 6.19% in females, respectively) and high temperature (0.50% in males and 0.44% in females, respectively) (data not shown).

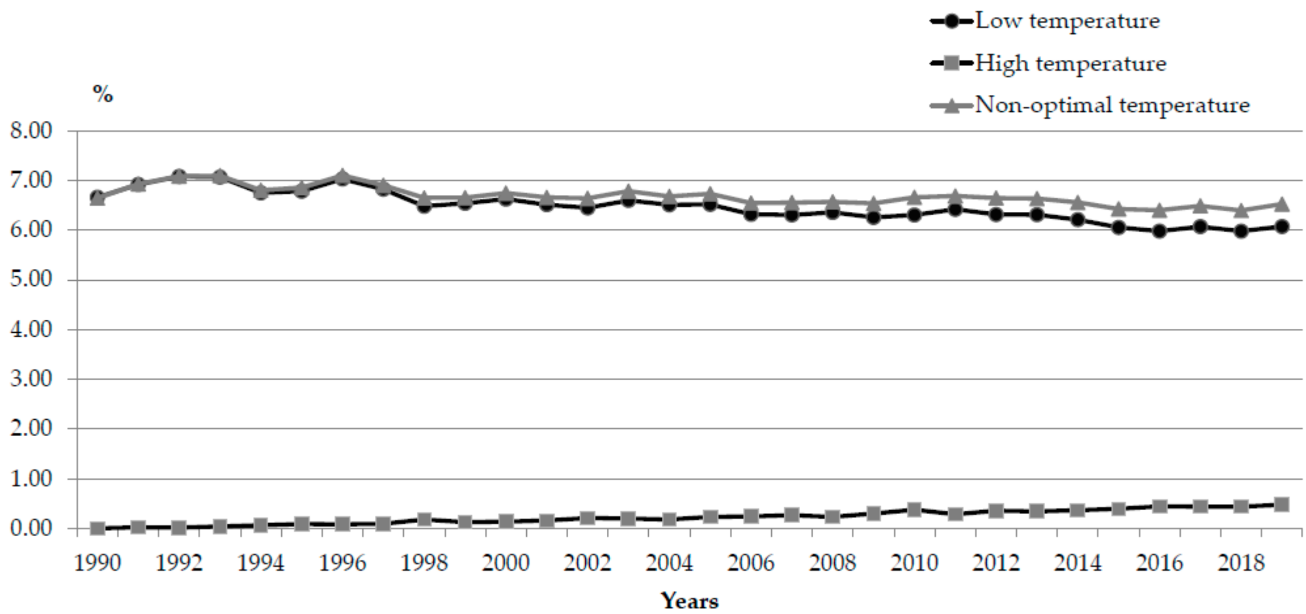

Figure 1. The contribution (%) of non-optimal temperature to global ischemic heart disease mortality in both sexes together, 1990–2019.

Trend from global IHD mortality rates attributable to high temperature significantly increased both in males (AAPC = +10.9%; 95% CI = 8.2 to 13.7) and females (AAPC = +9.3%; 95% CI = 7.1 to 11.5) (Figure 2).

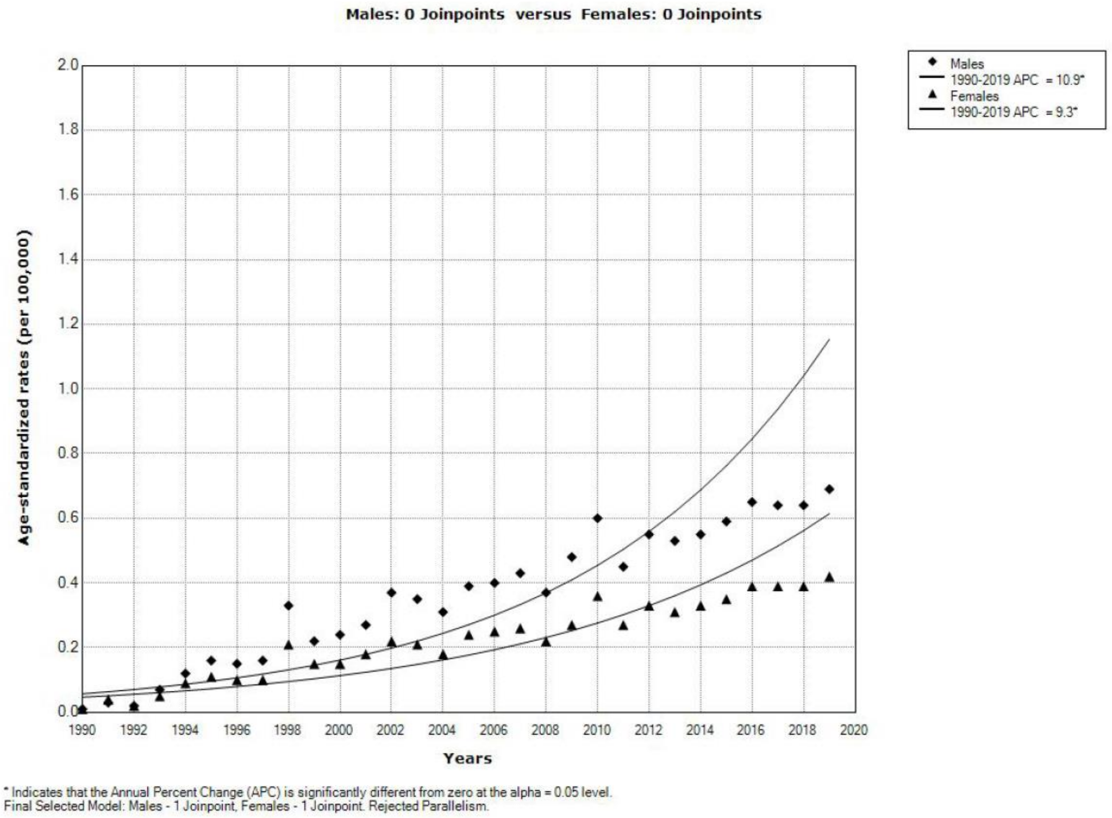

Figure 2. Global ischemic heart disease mortality rates (per 100,000 person) attributed to high temperature, by sex, 1990–2019; a joinpoint regression analysis.

There were disparities by sexes in terms of the global IHD mortality rates that attributed to non-optimal temperature in 2019: for high temperature, ASR was 0.69 per 100,000 in males and 0.41 per 100,000 in females, while for low temperature ASR in males was 8.78 per 100,000 person, and in females was 5.88 per 100,000 person (Figures 2 and 3).

A significantly decreasing trend for global IHD mortality attributable to low temperature was observed both in males (AAPC = −1.7%; 95% CI = −1.8 to −1.6) and females (AAPC = −2.1%; 95% CI = −2.1 to −2.0) in 1990–2019 (Figure 3).

According to the comparability test, trends in mortality of IHD by each mode of temperature change in males and females were not parallel (final selected model rejected parallelism, $p < 0.05$).

In both sexes together, a significant increase in age-standardized rates of IHD mortality attributed to high temperature was described in all regions in 1990–2019, whereby the highest rise was seen in the Southeast Asia (by +13.8% per year) and the African region (by 13.3% per year), followed by the Western Pacific region (by 11.9% per year) (Figure 4). A significant decrease in age-standardized rates of IHD mortality attributed to low temperature was described in almost all regions, while the only exception was the Western Pacific region where a non-significant increase was reported. The highest decline was reported in region of the Americas (by −3.2% per year) and European region (by −2.4% per year).

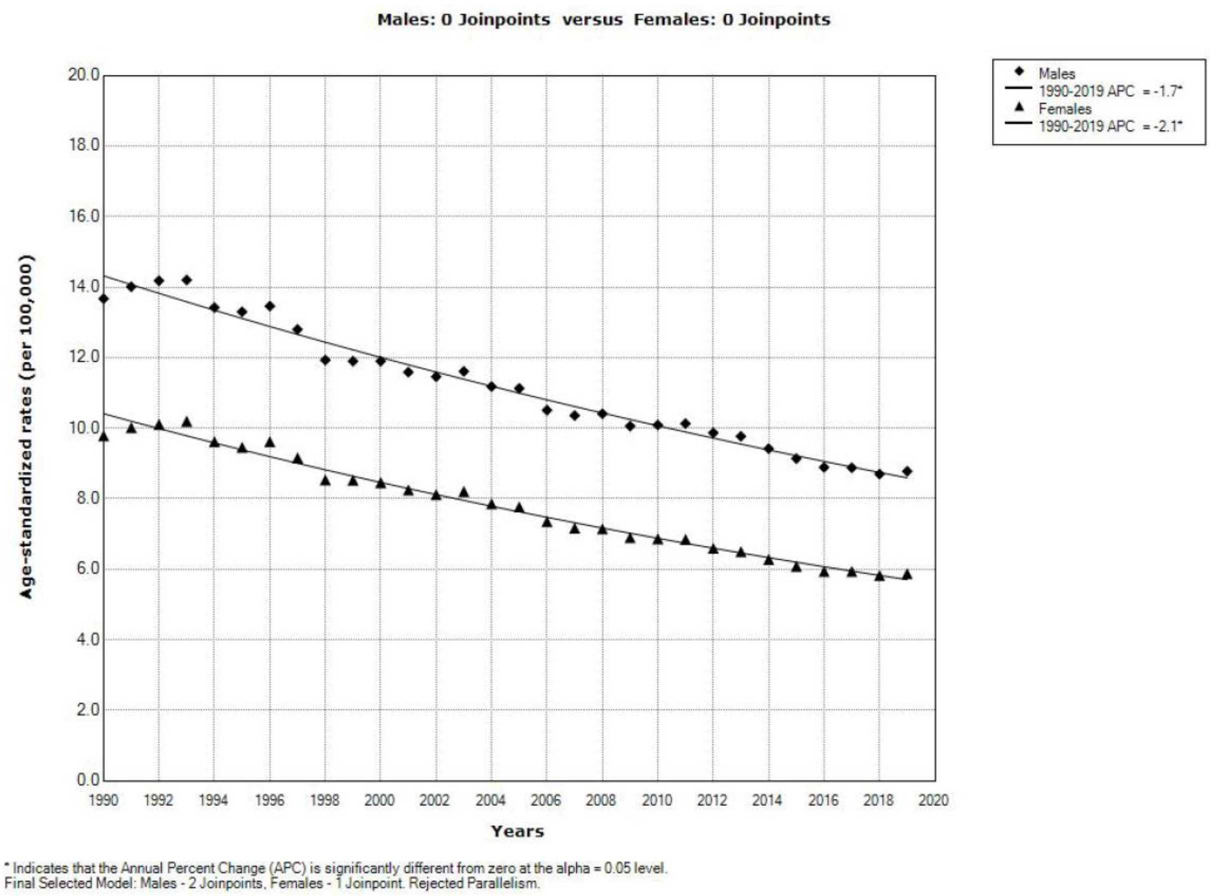

Figure 3. Global ischemic heart disease mortality rates (per 100,000) attributed to low temperature, by sex, 1990–2019; a joinpoint regression analysis.

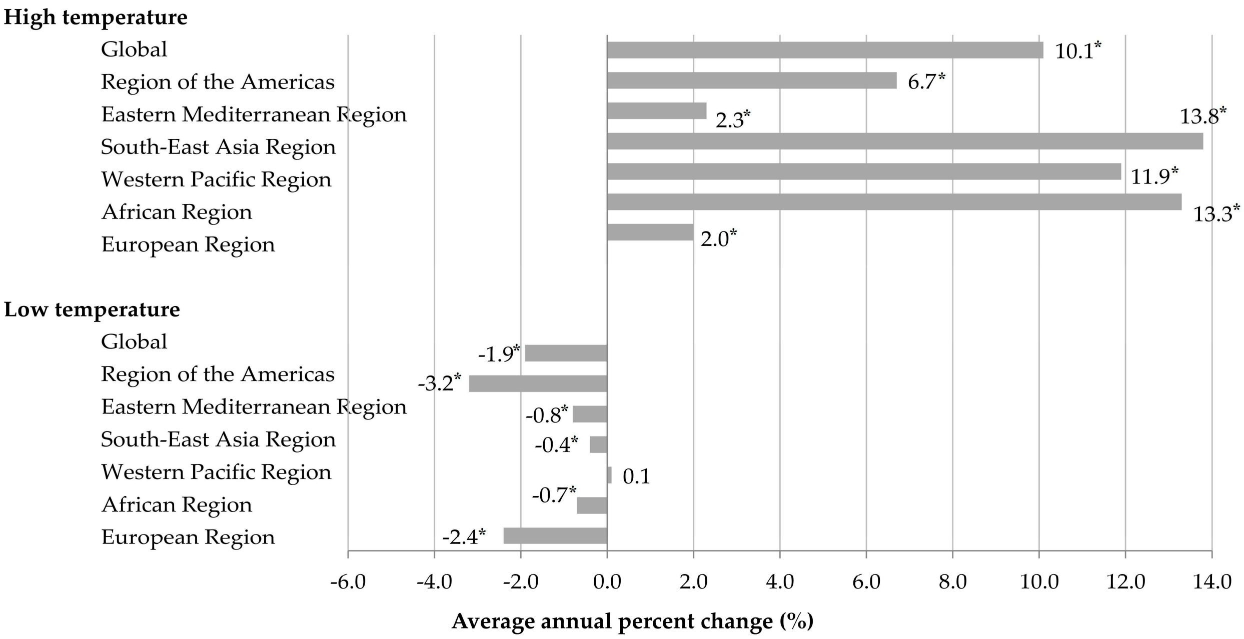

Figure 4. Global and regional trends of ischemic heart disease mortality rates (per 100,000) attributed to non-optimal temperature, in both sexes together, 1990–2019; a joinpoint regression analysis. * statistically significant, $p < 0.05$.

4. Discussion

IHD due to non-optimal temperature remains a large concern to public health because, despite a decline in the last three decades, it still contributes to a share of over 6% to the global burden of IHD in both sexes together. At the global level in 1990–2019, substantially higher ASRs of IHD mortality due to non-optimal temperature were experienced by men than women, both for high and low temperatures.

Similar to our results, several reports indicated that both low and high temperatures were associated with increases in cardiovascular disease mortality and constituted among the largest global environmental risk factors for premature mortality [6–8,13]. A previous study suggested that, globally, 596.8 thousand deaths from IHD were attributable to suboptimal temperature (including 555.5 thousand deaths attributed to low temperature and 43.300 thousand deaths attributed to high temperature) [7]. Using a tool from the GBD 2019 study for comparative risk assessment, Wang and coauthors assessed that the IHD deaths attributable to high temperature ranked 26th and mortality attributable to exposure to low temperature ranked 12th among all risk factors for the IHD deaths globally from 2000 to 2019 [7].

Our study showed that regional trends in IHD mortality attributable to high and low temperature were consistent with global patterns in trends, which were found in some other studies [7,8,14]. Certain disparities in regional trends could be partly due to differences in incidence of IHD, implementation of prevention measures, and availability of health care, but also regional differences in socio-economic status, technical adaptation to cold and heat influence across countries, and other climate factors influence via negative effects of non-optimal temperature on air pollution, etc. [1,3].

Our findings show that global IHD mortality attributed to exposure to high and low temperature among males and females significantly differs by magnitude of trends, although the trends showed similar direction. The gender disparities in IHD mortality attributed to temperature changes in the observed period could be partly linked to differences in exposure to the well established cardiovascular risk factors, incidence of IHD, diabetes mellitus, arterial hypertension, other comorbidities, biological differences between the sexes, and professional exposure, especially in developing countries [1,3]. In conclusion, the effects of non-optimal temperature on IHD mortality need to be further elucidated in longitudinal research.

Author Contributions: Conceptualization, I.I. and M.I.; methodology, I.I. and M.I.; software, I.I. and M.I.; validation, I.I. and M.I.; formal analysis, I.I. and M.I.; investigation, I.I. and M.I.; resources, I.I. and M.I.; data curation, I.I. and M.I.; writing—original draft preparation, I.I.; writing—review and editing, I.I. and M.I.; visualization, I.I. and M.I.; supervision, M.I.; project administration, M.I.; funding acquisition, M.I. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Ethics Committee of the Faculty of Medical Sciences, University of Kragujevac (Ref. No.: 01-14321, 13 November 2017), entitled "Epidemiology of the most common health disorders".

Informed Consent Statement: Not applicable. No patient approvals were sought nor required for this study. Namely, as our model-based analysis used aggregated data, patients were not involved in the research.

Data Availability Statement: Data are contained within the article.

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Conflicts of Interest: The authors declare no conflict of interest.

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Proceeding Paper

The Impact of Temperature Changes on Global Stroke Mortality—Ischemic Stroke, Intracerebral and Subarachnoid Hemorrhage †

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† Presented at the 4th International Electronic Conference on Environmental Research and Public Health—Climate Change and Health in a Broad Perspective, 15–30 October 2022; Available online: https://ecerph-4.sciforum.net/.

Abstract: The percentage of stroke deaths attributable to low temperature was 7.23% in 2019, accounting for 474,002 stroke deaths globally, while about 48,030 of the stroke deaths were attributed to high temperature. Joinpoint regression analysis was applied to calculate the average annual percent change (AAPC) with 95% confidence interval (CI) to evaluate stroke mortality trends in 1990–2019. Trends from global stroke mortality attributed to low temperature significantly declined (AAPC = −2.5%; 95%CI = −2.6 to −2.3) in both sexes together. A significantly increased trend for stroke mortality attributed to high temperature was observed in both sexes together (AAPC = +1.0%; 95%CI = 0.6 to 1.3).

Keywords: stroke; global mortality; temperature changes

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1. Introduction

Strokes are the second most common cause of death worldwide, after ischemic heart disease [1–3]. Strokes are responsible for approximately 11% of the world's total deaths in 2019 [1,2]. The Global Burden of Disease (GBD) 2019 study estimated that the total number of stroke deaths increased between 1990 and 2019 by 43.5% (or 2.0 million deaths, i.e., from 4.6 million to 6.6 million deaths, respectively) [1,3]. Ischemic stroke constituted 50.0% of all stroke deaths in 2019 (3.3 million), while intracerebral hemorrhage constituted 43.9% (2.9 million) and subarachnoid hemorrhage constituted 6.1% (0.4 million) [3]. The tremendous increasing number of stroke deaths could be due to ageing and increase of global populations, as well as the exposure to cardiovascular risk factors [3,4].

On the other hand, the age-standardized rates of global stroke mortality decreased sharply from 1990 to 2019 (by 36.0%) [1,3]. The percentage change of age-standardized rates of deaths from stroke globally in the same period by pathological types of stroke were −34.0% for ischemic stroke, −36.0% for intracerebral hemorrhage and −57.0% for subarachnoid hemorrhage [1,3]. A decreasing trend in global stroke mortality may be explained by better accessibility to improved treatment and implementation of strategies for prevention of non-communicable diseases (that led to decreasing prevalence of certain environmental, occupational, behavioral and metabolic risk factors for stroke) [4–6].

Some previous studies have indicated that the large increase in the global burden of stroke can be due to the increase in exposure not only to well-established risk factors, but perhaps also to some still insufficiently known risk factors, and suggested potential role of the effects of ambient temperature on the risk of stroke [3,7–9]. This study aimed to assess the link between stroke mortality and non-optimal temperature at the global level.

2. Materials and Methods

2.1. Study Design

An ecological trend study was conducted.

2.2. Data Source

Data on deaths due to overall stroke and stroke subtypes (ischemic stroke, intracerebral and subarachnoid hemorrhage) were derived from the GBD 2019 study database for the years 1990 to 2019 [10]. Age-standardized rates (ASRs) for stroke mortality were calculated by method of direct standardization and expressed per 100,000 persons. In addition, data about the effects of non-optimal temperature on stroke mortality were extracted from the GBD 2019 study: non-optimal temperature included low temperature (daily temperatures below the theoretical minimum risk exposure level) and high temperature (daily temperatures above the theoretical minimum risk exposure level).

2.3. Statistical Analysis

Changes in stroke mortality between 1990 and 2019 were determined by using joinpoint regression analysis software [11]. Joinpoint regression analysis was applied to calculate the average annual percentage change (AAPC) with 95% confidence interval (CI) to evaluate trends in 1990–2019. The joinpoint regression model is consisting of segments joining at points (i.e., joinpoints) where a significant change in the trend occurs. The changes in temporal trends include changes in intensity and/or direction of stroke mortality trends. As the statistically significant level, $p < 0.05$ was taken.

3. Results

Globally, the percentage of stroke deaths attributable to non-optimal temperature was 7.95% in 2019, accounting for 521,031 stroke deaths in both sexes together (Figure 1). Globally, 401,624 stroke deaths (8.78% of total stroke deaths in the world) were attributed to non-optimal temperature in 1990.

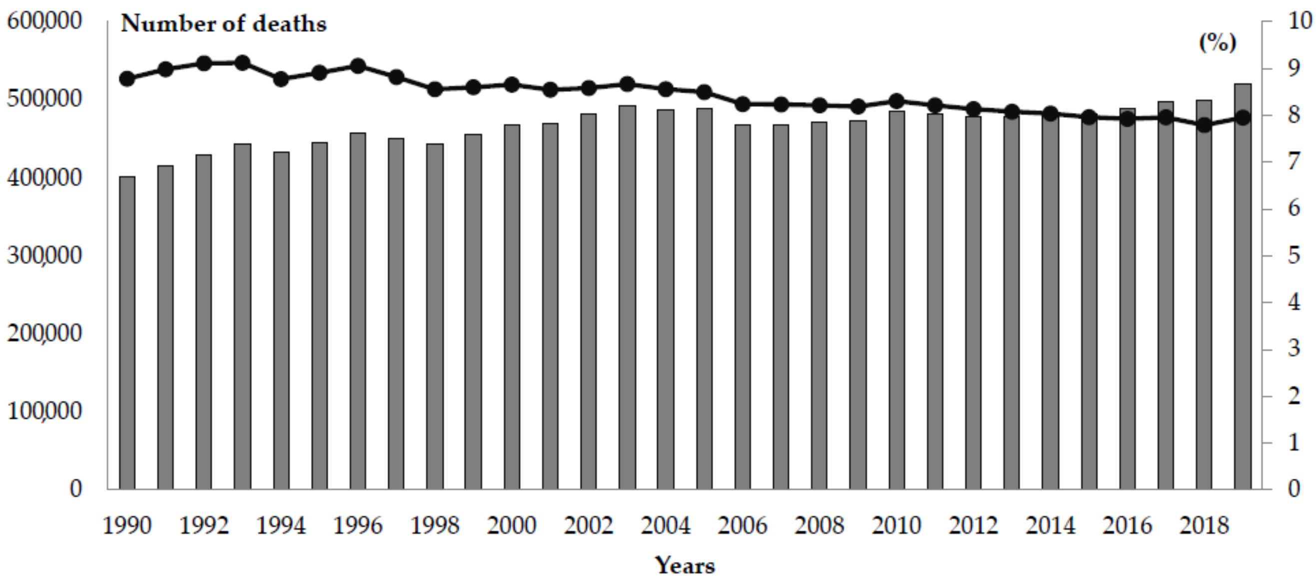

Figure 1. The global stroke deaths attributed to non-optimal temperature (number of deaths and percentage contribution in total stroke) in both sexes together, 1990–2019.

In both sexes together, the number of deaths for ischemic stroke, intracerebral hemorrhage and subarachnoid hemorrhage attributable to non-optimal temperature was 279.644, 212.194 and 29.194, respectively (Figure 2).

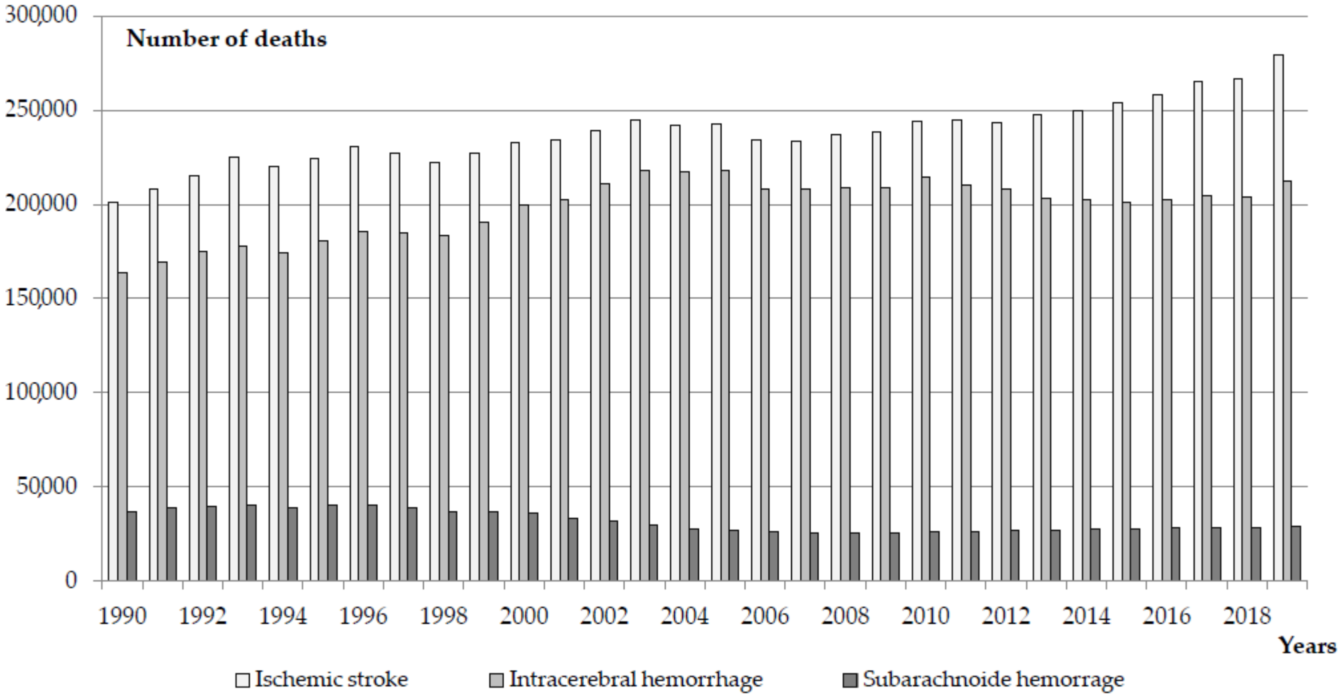

Figure 2. Number of global stroke deaths attributed to non-optimal temperature in both sexes together, by stroke types, 1990–2019.

Trend from global stroke mortality attributed to low temperature significantly declined (AAPC = −2.5%; 95%CI = −2.6 to −2.3) in both sexes together, with five joinpoints (Figures 3 and 4). A significantly increasing trend for stroke mortality attributed to high temperature was observed in both sexes together (AAPC = +1.0%; 95%CI = 0.6 to 1.3).

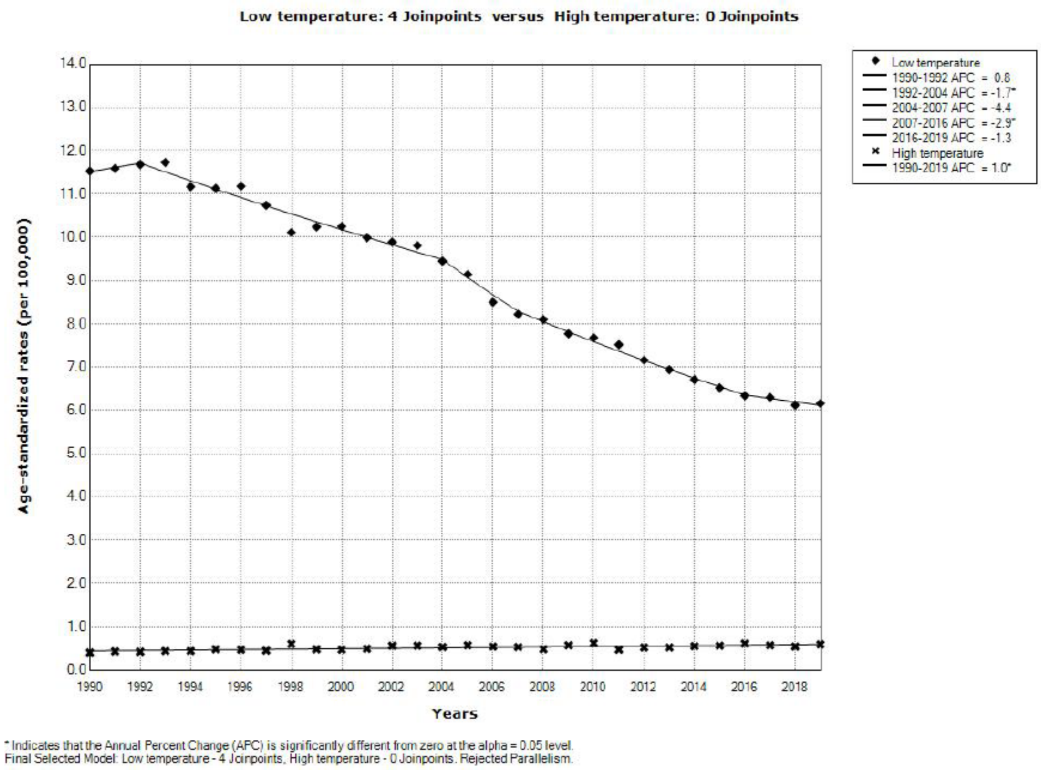

Figure 3. The global stroke mortality attributed to non-optimal temperature, in both sexes together, 1990–2019; a joinpoint regression analysis.

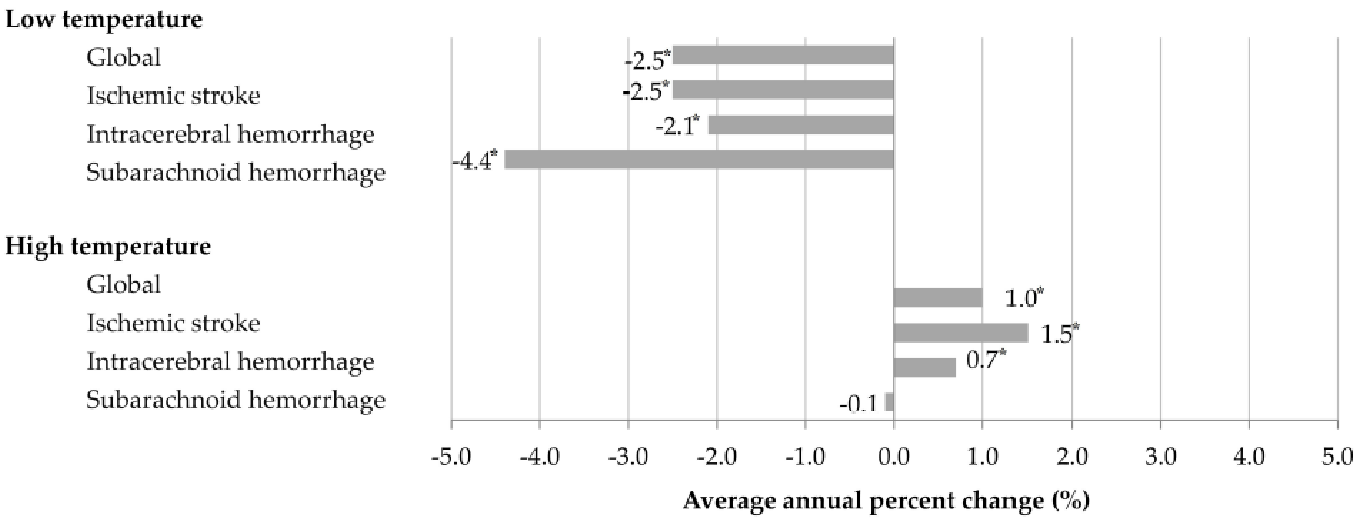

Figure 4. The global trends of stroke mortality attributed to low and high temperatute in both sexes together, by stroke types, 1990–2019; a joinpoint regression analysis. * statistically significant, $p < 0.05$.

Globally, a significantly decreasing trend for total stroke mortality attributed to low temperature was observed in both sexes together in 1990–2019 (by −2.5% per year), as well as decreasing trends that were observed for all stroke types, those being ischemic stroke (by −2.5% per year), intracerebral hemorrhage (by −2.1% per year), and subarachnoid hemorrhage (by −4.4% per year) (Figure 4). Globally, a significantly increasing trend for total stroke mortality attributed to high temperature was observed in both sexes together in 1990–2019 (by +1.0% per year); increasing trends were observed for ischemic stroke (by +1.5% per year) and intracerebral hemorrhage (by +0.7% per year), but not for subarachnoid hemorrhage, where a stable trend was observed.

4. Discussion

Stroke deaths attributed to the non-optimal temperature are a substantial issue worldwide, because they contribute by participation to about 8% to the global stroke mortality in the last decades. Rising temperature showed a substantial effect on total stroke mortality at the global level in 1990–2019, with a substantial increase in ASRs of mortality due to high temperature described for ischemic stroke and intracerebral hemorrhage.

Similar to our results, some other ecological studies suggested association between non-optimal temperature and stroke burden [7,12,13]. However, to the best of our knowledge, the GBD 2019 study is the first systematic analysis to estimate the global effect of non-optimal temperature on stroke burden and its subtypes and added high and low non-optimal temperatures as risk factors [3,5]. Some previous studies indicated that low temperature was one of the top ten risks in the oldest age group [13] and that older age seems to increase vulnerability to low temperature for both ischemic stroke and intracerebral hemorrhage [7]. Our results showed that the global burden of stroke (as measured by ASRs of mortality) attributable to low temperature was 10 times greater than the burden attributable to high temperature in 2019. On the other hand, a rise of temperature had a substantial effect in populations with a lesser ability to adapt to temperature changes, especially in countries with limited socio-economic resources, which can worsen health inequalities in the world [14,15]. Among others, based on the link between non-optimal temperature and stroke mortality, the Lancet Countdown on health and climate change concluded that the response to climate change could be "the greatest global health opportunity of the 21st century" [16].

Author Contributions: Conceptualization, I.I. and M.I.; methodology, I.I. and M.I.; software, I.I. and M.I.; validation, I.I. and M.I.; formal analysis, I.I. and M.I.; investigation, I.I. and M.I.; resources, I.I. and M.I.; data curation, I.I. and M.I.; writing—original draft preparation, I.I.; writing—review and editing, I.I. and M.I.; visualization, I.I. and M.I.; supervision, M.I.; project administration, M.I.; funding acquisition, M.I. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Ethics Committee of the Faculty of Medical Sciences, University of Kragujevac (Ref. No.: 01-14321, 13 November 2017), entitled "Epidemiology of the most common health disorders".

Informed Consent Statement: Not applicable. No patient approvals were sought nor required for this study. Namely, as our model-based analysis used aggregated publicly available data, and patients were not involved in the research.

Data Availability Statement: Data is contained within the article.

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Conflicts of Interest: The authors declare no conflict of interest.

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Proceeding Paper

Socio-Environmental Risk Management of the COVID-19 Pandemic in Central America: Unity Became Strength Even in Times of Uncertainty †

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Abstract: This brief note discusses the articulation of Central American countries in the fight against the pandemic from a socio-environmental perspective. Central America is one of the most disaster-prone regions in the world; hurricanes, earthquakes, droughts, floods, and volcanic eruptions are the main threats to the nations. The emergence of SARS-CoV-2 exacerbated the socio-environmental risks, demanding the emergency action of joint management within the framework of the Central American Integration Scheme (CAIS). Thus, technical meetings of the Coordination Center for Disaster Prevention in Central America sought to maintain a synergy to reduce social vulnerability and the environmental impacts of the pandemic. The region adopted intersectorality as a mechanism of articulation among all CAIS-derived bodies, allowing for more comprehensive humanitarian assistance to groups at higher risk (involving all human life cycles). The joint negotiation between the countries sought to provide technical support for estimates and projections for the calculation of needs, as well as to adjust health measures in each country according to the following scenarios recommended by WHO: (i) no cases, (ii) sporadic cases, (iii) clusters of cases, and (iv) sustained transmission. Therefore, the countries promoted the participation of the population in the prevention and mitigation phases, which helped to mitigate the pent-up demand in the health sector and strengthened community-based interventions. Thus, the region managed to keep the case fatality rate below 3% and reinforce compliance with local sanitary measures in the first two pandemic years due to the multi-systemic approach to risk management. The role of the community led to the development of social groups more aware of socio-environmental and public health responsibilities, besides the benefits of working as a collective.

Keywords: Central American Integration Scheme; public health; community-based medicine; pandemics

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1. Initial Notes on Central American Regional Integration and Environmental Profiles

Geographically speaking, continental Central America is conformed of seven countries, Belize, Costa Rica, El Salvador, Honduras, Guatemala, Nicaragua, and Panama [1]. These countries are located in the region bordering Mexico to the south and Colombia to the north, bordering the Pacific Ocean and the Caribbean Sea. The Spanish language is predominant, with Belize being the only English-speaking country. The countries share historical and cultural aspects that date back to the processes of emancipation from the Kingdom of Spain, which ruled the region for more than two hundred years [2]. Even with very close distances, the countries have divergent socioeconomic profiles (Table 1).

Table 1. Socioeconomic parameters for Central American countries.

Country	GDP/Capita (2020)	Pop. (Total, 2020)	Surface Area (sq.km, 2020)	Pop. Density (inh/sq.km, 2020)	Urban Pop. (% of Pop., 2020)	HDI (2019)	Poverty Lines (% Total Pop., 2019)
Belize	4435.6	397,621	22,970	17	46	0.716	52
Costa Rica	12,076.8	5,094,114	5100	100	81	0.810	30
El Salvador	3798.6	6,486,201	21,040	313	73	0.673	26
Guatemala	4603.3	16,858,333	108,890	157	52	0.663	59
Honduras	2405.7	9,904,608	112,490	89	58	0.634	48
Nicaragua	1905.3	6,624,554	130,370	55	59	0.660	25
Panama	12,269	4,314,768	75,320	58	68	0.815	22

Source: Adapted with permission from Quesada-Román and Campos-Durán (p. 3) [3].

Central America is one of the most disaster-prone regions in the world; hurricanes, earthquakes, droughts, floods, and volcanic eruptions are the main threats to the nations. A recent study observed the number of disaster occurrences classified by extensive, intensive, and combined risks in Central American countries between 1960 and 2015. Of a total of 23,727, the majority were combined (n = 20,683; 87%), followed by extensive (n = 1922; 8%) and intense (n = 1122; 5%), respectively. Costa Rica was the country with the most disasters (n = 11,750; 49.5%) and Belize the least (n = 113; 0.5%) [3].

Historically, Central American countries have shown a sense of brotherhood and unity that, over the last hundred years, have helped forge the paths of regional integration, despite the ups and downs generated by some individual interests. In the socio-environmental field, the countries have more than thirty years of team experience (Figure 1), establishing solid frameworks for the protection of environmental wealth and addressing regional threats (Figure 2). A brief contextualizing is given below.

With the creation in 1987 of the Coordination Center for the Prevention of Natural Disasters in Central America (CEPREDENAC, from the Spanish acronym), and the entry into force of its Constitutive Agreement in 2007, it contributes to the reduction of vulnerability and the impact of disasters, which have been causing severe human and material losses in the region, and to the pursuit of Sustainable Development in accordance with the Tegucigalpa Protocol, the Alliance for Sustainable Development (ALIDES, from the Spanish acronym), and the Sustainable Development Goals 2030. In line with the integral development process and in view of the need to address the constant threats of recurrent disasters in Central America, the Heads of State and Heads of State of the SICA region, at their XXV meeting on 29–30 June 2010, approved the Central American Policy on Comprehensive Disaster Risk Management, with the aim of providing the region with a guiding framework for comprehensive disaster risk management intertwined with economic management, social cohesion management, and environmental management through a systemic approach [4] (p. 6).

Figure 1. Governing Body Members of the Coordination Center for Disaster Prevention in Central America [5]. The entities act individually in their countries of origin, but during emergencies they weave regional support networks, involving the availability of human resources and physical assets to counter socio-environmental challenges.

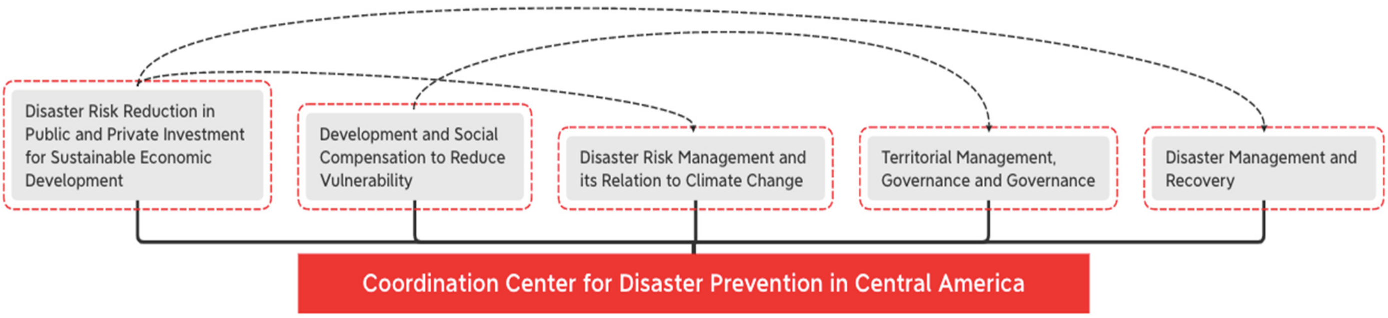

Figure 2. Coordination Center for Disaster Prevention in Central America Central Axes [5]. These central axes are inseparably integrated, and seek to contribute to the reduction of vulnerability and the impact of disasters, as an integral part of the transformation and development process of Central American integration.

2. The COVID-19 Pandemic and Its Socio-Environmental Implications

The disproportionate and irresponsible management of ecosystems was reflected in the Millennium Ecosystem Assessment, 2005, indicating that, since the second half of the 20th century, humans have been causing changes (some irreparable) in their habitat [6]. In human health, the urgency of addressing social vulnerability was stressed, given that the populations or subgroups with the least adaptive capacity tend to be the most affected. It is a first-degree equation of simple interpretation but with a high degree of practicality.

Thus, the pandemic came at an iconic moment, as countries set out to launch the Sustainable Development Agenda for the new decade as early as 2020. Ironically, studies have shown that, during the months of social isolation and lockdown, the rates of environmental air and water pollution, especially in metropolitan cities, suffered drastic reductions [7,8]. Notwithstanding, the unprecedented production of medical and personal protective equipment (such as testing kits, disposable masks, eye protection items, and surgical gloves) brought up the challenge of providing responsible purposes for biomedical waste in hospital settings and the community [9,10].

Authors such as Salazar-Galán and colleagues [11] draw attention to the urban–rural relationship in contemporary societies since the current potential for transmission and expansion of "infectious diseases such as COVID-19 in crowded urban environments is due to causes such as high social connectivity, mobility patterns, and daily work and social routines that favor contagion by air, or through direct or indirect contact" (2). Thus, the effects seen during the pandemic invite us to think about health beyond hospital corridors. It becomes necessary to reinforce the understanding of planetary health, in which equally relevant roles are attributed to human, environmental, and animal health. Alterations in any of these domains generate inward changes in their peers [12].

3. Central American Socio-Environmental Regional Approach during the Pandemic

The emergence of SARS-CoV-2 exacerbated the socio-environmental risks, demanding the emergency action of joint management within the framework of the Central American Integration Scheme (CAIS). Thus, technical meetings between the Coordination Center for Disaster Prevention in Central America and the Council of Central American Ministers of Health (COMISCA, from the Spanish) sought to maintain a synergy to reduce socio-health vulnerability and the environmental impacts of the pandemic. It was necessary to activate alert mechanisms in areas with more difficult access that could be more affected by cuts in basic services such as electricity, drinking water, and the transfer of patients with aggravated clinical conditions. The countries used risk flags, a generic categorization already used on other occasions. During the red activation, special efforts were deployed among health professionals, firefighters, and police forces, and there was also a leading role for organized civilian groups.

The region adopted intersectorality as a mechanism of articulation among all CAIS-derived bodies, allowing for more comprehensive humanitarian assistance to groups at higher risk (involving all human life cycles). The joint negotiation between the countries sought to provide technical support for estimates and projections for the calculation of needs, as well as to adjust health measures in each country according to the following scenarios recommended by WHO: (i) no cases, (ii) sporadic cases, (iii) clusters of cases, and (iv) sustained transmission. The assignment of tasks to monitor compliance with health measures in border and conurbation areas made it possible to reduce the pressure on the demand for hospitalization, combat misinformation, strengthen national vaccination campaigns, and support community interventions to combat malnutrition and hunger during the most chaotic months. The "Regional Contingency Plan aimed oriented to implement national efforts for the prevention, containment and treatment of COVID-19" [13] structured the approach to the pandemic along five axes. Axis 1 corresponded to health and risk management, with the following components:

- Component 1.1. Prevention and Containment Measures;
- Component 1.2. Patient management measures in each case type;
- Component 1.3. Harmonization of informative, preventive, and educational messages;
- Component 1.4. Access to medicines, medical devices, and other goods of health interest through the COMISCA® Joint Negotiation;
- Component 1.5. Regional Mechanism for strengthening preparedness, mitigation, response, and humanitarian assistance capacity.

Overall, the countries promoted the participation of the population in the prevention and mitigation phases, which helped to mitigate the pent-up demand in the health sector and strengthened community-based interventions. Thus, the region managed to keep the case fatality rate below 3% and reinforce compliance with local sanitary measures in the first two pandemic years due to the multi-systemic approach to risk management [14]. The role of the community led to the development of social groups more aware of socio-environmental and public health responsibilities, besides the benefits of working as a collective, as the nations acted on vulnerabilities, their causes, and increasing capacities in order to build a safer and more resilient region.

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Potential Hazard to Human and Animal Health from Bacterial and Fungal Contaminants in Small Freshwater Reservoirs †

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Abstract: In general, the assessment of microbiological quality in aquatic systems focuses on the presence of some bacterial groups or species. Although quantification of fungi presence is not a mandatory parameter, recently the WHO advises its detection/quantification. Its concentration and diversity varies greatly among the various types of aquatic systems. Fungi are mesophilic, dependent on organic matter to grow and their presence can be associated with pollution. Depending on their concentration and diversity, fungi may pose a risk to human and animal health. The objective of the present work was to evaluate the presence of some bacterial indicators (*Escherichia coli*, fecal enterococci, among others) and fungi (total yeasts and molds) in freshwater reservoirs (water tanks) with different sources, sun exposures and anthropogenic and animal influences. Additionally, it was intended to assess the diversity of molds. For this, filamentous colonies were isolated, purified, and morphologically identified (whenever possible to the genus). The three tanks differed in bacterial (presence of *Escherichia coli*, fecal enterococci, *Proteus* sp. and *Staphylococcus aureus*) and fungal (total and mold) presence. Regarding molds, 16 different taxa were identified and, depending on the water tank, the *Penicillium*, *Aspergillus* and *Fusarium* genera and the Chytridiomycota phylum were the most representative. Some of the taxa isolated may pose a risk to human and animal health (*Trichophyton*, *Aspergillus fumigatus* and some dematiaceous). The water reservoirs presented different fungal communities. Although preliminary, the results show that freshwater tanks can be a source of potentially pathogenic bacteria and fungi to humans and animals that use them.

Keywords: freshwater tanks; molds; *E. coli*; enterococci; *Proteus*; *S. aureus*; dematiaceous; dermatophyte

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1. Introduction

Fresh water has high microbial diversity, as microorganisms play a fundamental role in the nutrient cycle and in the purification of aquatic ecosystems. However, they can also cause disorders and be pathogenic for humans, animals and other organisms. The classic parameters used are fecal indicator organisms (FIO) associated to pollution of fecal origin are fecal coliforms from the *Enterobacteriaceae* family, fecal enterococci and clostridia, although there are other organisms such as helminths or protozoa can also pose health risks to humans [1,2]. Among these indicators, fecal coliforms are widely used, being associated with a high number of human intestinal infections, and involved or being participants in pathologies such as meningitis, urinary tract infections and nosocomial pneumonias [3]. However, recent studies pointed out that these organisms may not be sufficient as indicator organisms, and it may be necessary to assess the presence of others such as filamentous fungi and yeasts. It is therefore important to know the presence of these organisms in their counts, distribution, diversity and behavior, in different aquatic environments [4,5]. Fungi are heterotrophic eukaryotes widely distributed in nature. They are present in soil, air, organic matter and water, especially in untreated water, reservoirs and distribution systems. Several authors have reported the presence of yeasts and molds in the aquatic environment, the latter being found in greater numbers [6,7]. Among many different taxa of fungi found in aquatic environments, several species are opportunistic or pathogenic, produce toxins and are allergenic. Most of these species belong to the phyla Ascomycota, Zygomycota and Chytridiomycota. The fungi with the most significant presence are *Aspergillus*, *Penicillium*, *Fusarium, Clasdosporium* and *Curvularia*, and some of them increase the risk of diseases in humans and animals [7,8]. Although most of the time fungal infections or mycoses do not result in the death of patients, they can be a public health problem. The most common mycoses are caused by dermatophytes that affect the skin, hair and nails, and are very contagious [9,10]. Hyaline, dematiaceous and dimorphic fungi can affect various tissues and organs causing severe mycoses [11,12]. Systemic mycoses are difficult to treat and have an unpredictable prognosis, especially in immuno-incompetent populations.

The main objective of the present work was to evaluate the presence of FIO (*E. coli*, fecal enterococci), other bacterial species associated to humans and animals and fungi (mainly molds) in freshwater reservoirs from three different sources, sun exposures, and anthropogenic and animal influences.

2. Materials and Methods

2.1. Localization of Water Tanks

The present study was carried out between April and June 2022. All the tanks are located on the *Campus* of the University of Trás-os-Montes e Alto Douro (UTAD), in Vila Real (Latitude: 41.2885° N; Longitude: 7.7391° W; Altitude: 462 m), and are close to each other (115 to 270 m apart). Tanks 1 and 2 are mostly fed by natural founts and are nearby foot paths and pastures, while tank 3 is fed by rainwater, and in an inner courtyard with restricted access (Figure 1).

Figure 1. Visual aspect of the three tanks in the University *Campus* UTAD. Tanks 1 and 3 are oriented to the north and northeast, and tank 2 to the east.

Tank 1 water was cloudy with cherry blossoms, and although surrounded by vegetation, it had the cleanest water compared to the other tanks. In tank 2, the water was covered with macroalgae, filamentous microalgae and aquatic plants such as *Lemna* sp. Tank 3 had very turbid water, green in color due to the massive growth of microalgae, it was surrounded by vegetation and did not get direct sunlight.

2.2. Culture Media

In the evaluation of the water samples microbiology the following culture media were used: (a) for bacteria: Slanetz & Bartley Agar (Slanetz, Oxoid, Hants, UK) for fecal enterococci, Chromogenic Coliform Agar (Chromo, Oxoid) for *Escherichia coli* and other fecal coliforms; Cysteine Lactose Electrolyte-Deficient Agar with Andrade indicator (C.L.E.D., Liofilchem, Roseto, Italy) for bacteria that cause urinary infections (*S. aureus*, *E. coli* and

Proteus vulgaris); (b) for fungi: Yeast Malt agar (YMA, Liofilchem), Yeast Glucose Chloramphenicol Agar (YGCA, Himedia, Mumbai, India), Mycosel Agar (Mycosel, Liofilchem) for dermatophytes; and Potato Dextrose Agar (PDA, Liofilchem), for molds isolation and maintenance. All media were prepared according to the manufacturers' specifications.

2.3. Water Sampling and Microbiological Analyses

For each tank, three independent water samples were collected using 500 mL sterilized plastic bottles. Each bottle was quickly submerged approximately 30 cm deep, except for tank 3 which was shallower. The samples were taken on 20 April (tanks 1 and 2, air temperature 12 °C, water temperature 8 °C) and 9 May (tank 3, air temperature 21 °C; water temperature 10 °C), between 10:30 and 11:00 a.m. For the detection of bacteria, the membrane filtration technique was used, filtering 100 mL of water per filter (0.45 µm pore). For the quantification of fungi, in addition to the membrane filtration technique, the spread of a small volume (100 or 200 µL per plate) of the sample on a Petri dish surface was used. The media were incubated at 37 °C (bacteria and fungi) and 25 °C (fungi). After 24–48 h of incubation (bacteria) or 2, 5 and 7 days (fungi) the colony forming units (UFC) were counted and expressed as UFC/100 mL or UFC/mL, respectively, for the membrane and the spread techniques. In the case of fungi, all morphologically distinct colonies were quantified, isolated, purified and maintained (in PDA) until their identification.

3. Results and Discussion

3.1. Water Samples Bacterial Load

In the Chromo medium, large numbers of total coliforms (uncountable, (>300 CFU/100 mL), *E. coli*, and other colonies of yellow and white color that probably correspond to Actinobacteria and yeasts were detected. In Slanetz medium, only red colonies were detected, which indicate the presence of fecal enterococci. The maximum concentration of *E. coli* and fecal enterococci was obtained in tank 3, with respectively, 191 and 282 CFU/100 mL of water (Table 1), values above the recommended guideline for recreational water (the European Union threshold 100 CFU/mL for *E. coli* and the WHO guideline 200 CFU/100 mL for fecal enterococci [10]). The simultaneous presence of *E. coli* and fecal enterococci may indicate recent fecal contamination, as fecal enterococci are able to survive in water longer than *E. coli* [13,14]. In C.L.E.D. medium used in the clinic, the presence of *S. aureus*, *Proteus* spp., yeasts and Actinobacteria was detected.

Table 1. Presumptive bacteria counting, at 37 °C, by membrane filtration (UFC/100 mL) on the differential media Slanetz and Chromo media, or by spread techniques (UFC/100 mL) on C.L.E.D. medium. Mean values (n = 3) ± standard deviation).

Presumptive Bacteria	Tank 1	Tank 2	Tank 3
E. coli (UFC/100 mL) [1]	4 ± 2	43 ± 6	133 ± 58
Fecal coliforms (UFC/100 mL) [2]	>300	>300	>300
Fecal enterococci (UFC/100 mL) [1]	8 ± 3	3 ± 1	167 ± 115
S. aureus (UFC/mL)	23 ± 15	3 ± 6	77 ± 45
Proteus sp. (UFC/mL)	2690 ± 279	260 ± 46	740 ± 426
Other (UFC/mL) [3]	0	0	27 ± 25

[1] fecal indicator organisms (FIO). [2] Other than *E. coli*. [3] such as Actinobacteria and yeasts.

It would be expected, due to their locations and easy access for people and animals, that tanks 1 and 2 would present higher values of FIO than tank 3, located in an interior courtyard. Additionally, tanks 1 and 2 collect water from founts and rain, unlike tank 3 fed exclusively by rainwater. However, the results point out a higher bacterial load in tank 3 than can be explained by the many bird droppings observed on site, a lower volume of water and a lower rate of water renewal (high retention time).

S. aureus indicates human presence (the inner courtyard is surround by offices, a museum and a laboratory). In all the three tanks, *Proteus* was the most represented bacteria. This *Enterobacteriaceae* is a saprophytic mostly associated with animal organic matter, and is present in the mammalian gastrointestinal tract. Additionally, it is often associated or responsible for infections in the urinary tract [15].

3.2. Water Samples Fungal Load

Overall, the total fungi concentrations were low [0–100 UFC/100 mL] and [0–100 UFC/mL], depending on the incubation temperature and the quantification method, and highly variable within the sampling replicas. In general, the highest fungal loads were obtained by the inoculum spreading method, compared to the membrane filtration method. Furthermore, and on average, at 25 °C more colonies of yeasts and molds grew than at 37 °C. In addition, with YGCA, more fungi were recovered, both at 25 °C and 37 °C. At 37 °C, there was no growth of yeasts in any of the tanks and there was only growth of molds in tanks 1 and 3. In Mycosel, it showed more growth at 25 °C, while at 37 °C there was only growth of molds in tank 3.

In all media molds dominate over yeasts. Yeasts were not recovered from tank 3. This pattern is generally observed in waters from different sources [16,17].

The analysis of the frequency of molds found in the ponds is shown in Figure 2. Clearly, the diversity of fungi and the prevalence of taxa varied among the three water reservoirs. Tank 1 presented higher diversity than tank 3 and tank 2. Among the identified genera, the ones common to the three reservoirs were also the most frequently observed: *Penicillium* (14.3–28.6%), *Aspergillus* (9.5–21.4%) and *Fusarium* (3.6–33.3%). These results are in agreement with previous works in fresh water [10,18]. *Aspergillus*, the second most abundant genus in this work, was reported as the most frequent in other studies [19].

The genera *Penicillium* and *Aspergillus* were particularly isolated and include species that can be allergenic or cause human infections. These two genera can be found in environmental samples (soil, water, rhizosphere and air) and produce large amounts of spores [20].

The dematiaceous group had an expressive prevalence in water tanks (21, 24 and 15%, respectively for tanks 1, 2 and 3) with several genera identified: *Phialophora*, *Fonsecaea*, *Rhinocladiella*, *Ulocladium* and *Stachybotrys*. Some taxa were isolated only in one of the tanks: Chytridiomycota, *Basidiobolus* sp., *Scopulariopsis* sp. and Oomycota (tank 1), *Rhizopus* sp. (tank 2) and *Acremonium* sp. (tank 3). Dermatophytes were isolated only from tanks 1 (11%) and 3 (14%).

It is important to note that several of the identified taxa are of clinical interest: *Basidiobolus* sp. and several dermatophyte species are pathogens [21], and although *Aspergillus* spp. are opportunistic fungi, *A. fumigatus* is responsible for approximately 90% of diagnosed invasive aspergillosis [22].

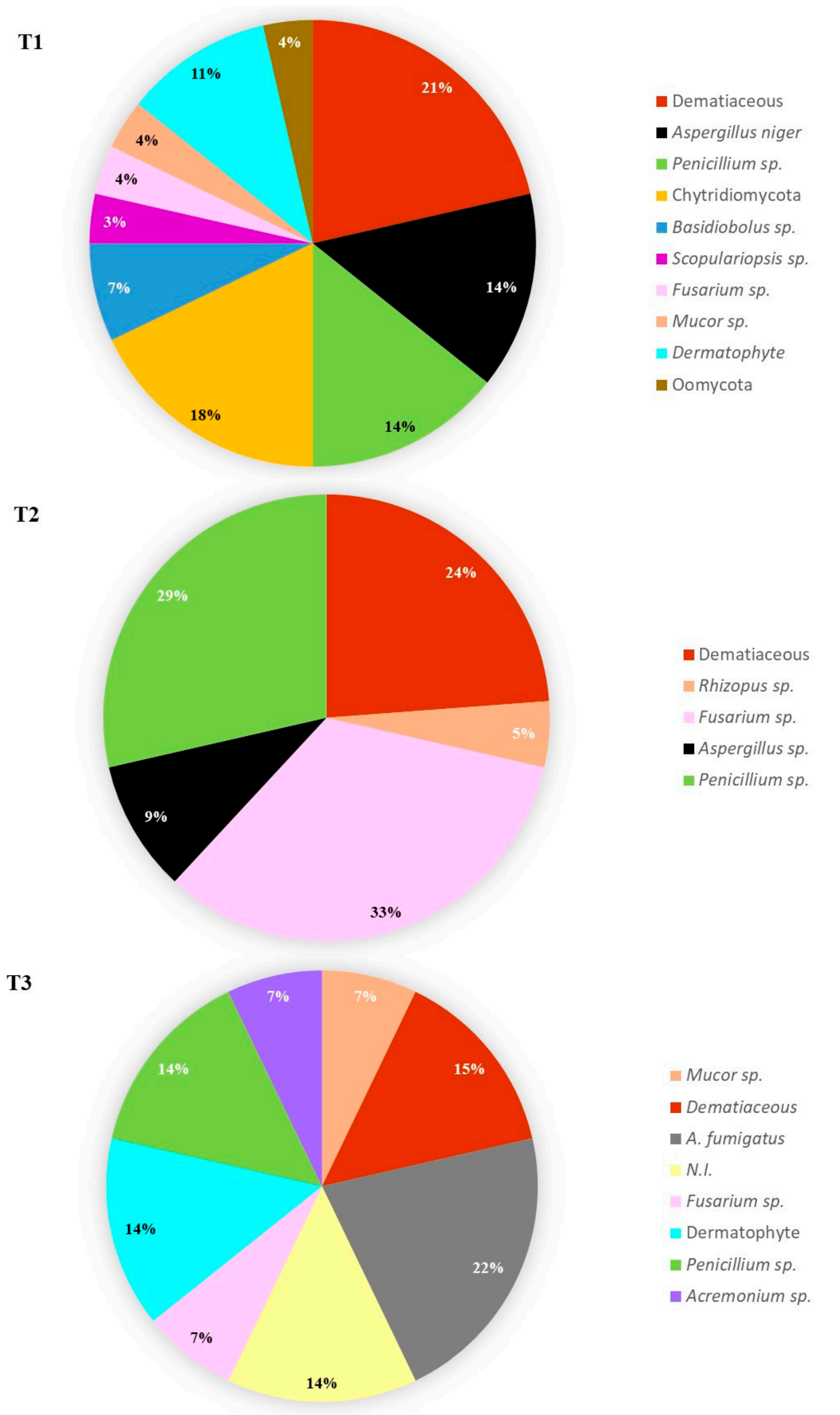

Figure 2. Fungal taxa frequency (%) in tanks (T) 1, 2 and 3. N.I.—Not identified.

4. Conclusions

Small freshwater constructions such as tanks are very frequent in green spaces managed by man, due to their useful, recreational, pleasant and aesthetic values. However, their microbiology is poorly understood. Our results point to the presence of potential hazard microorganisms in freshwater tanks. The relationship between FIO/other bacteria and bacteria/fungi should be further studied to better understand their significance and potential risks in these largely ignored constructions.

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Proceeding Paper

Indoor Air Quality ($PM_{2.5}$ and PM_{10}) and Toxicity Potential at a Commercial Environment in Akure, Nigeria †

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Abstract: According to studies, indoor air quality is a major concern because of the health risks it poses. In Nigeria, little is done to improve indoor air quality and the toxicity potentials (TP) of $PM_{2.5}$ and PM_{10}. We assessed the levels of $PM_{2.5}$, PM_{10}, the $PM_{2.5}/PM_{10}$ ratio, and the toxicity potential of a commercial area in Akure, Ondo State, Nigeria, in this study. For the three-month assessment of the study area (March to May 2022), a low-cost sensor (Canāree A1) was used. The results depict the following: 73.23 ± 53.94 µg/m^3 ($PM_{2.5}$), 68.58 ± 50.64 µg/m^3 (PM_{10}), 0.93 ± 0.02 ($PM_{2.5}/PM_{10}$ ratio), and toxicity potentials ($PM_{2.5}$—2.74 ± 0.04 and PM_{10}—1.47 ± 0.02). Both PM values exceed the WHO standard limits. The PM values differ significantly. The average ratio value indicates that anthropogenic activities in the area contribute significantly to the high $PM_{2.5}$ levels. It should be noted that TP greater than 1 indicates a potential health risk. The TP values obtained in this study are greater than 1, indicating that the environment may be harmful to the vulnerable. Based on these findings, efforts should be directed toward continuous monitoring of this study area and Akure as a whole.

Keywords: indoor; health risks; low-cost sensor; WHO standard; Nigeria

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1. Introduction

In general, neither developing nor developed countries take the effects of air pollution for granted. Attempts are being made to reduce or entirely eliminate it. Pollutant gases (O_3, NO_2, SO_2, and CO) and particulate matter (PM—PM_{10} and $PM_{2.5}$) are the main culprits of air pollution. The size of particles in PM is directly related to their likelihood of triggering health problems [1] Small particles less than 10 µm in diameter cause the most issues because they can penetrate deep into lungs and, in some cases, enter into the bloodstream. Exposure to such particles can harm the lungs and the heart. Various studies have shown the connection of particle pollution exposure to a variety of health problems, including premature death in people with heart or lung disease, nonfatal heart attacks, irregular heartbeat, aggravated asthma, decreased lung function, and increased respiratory symptoms, such as airway irritation, coughing, or difficulty breathing. Particle pollution exposure is most likely to affect vulnerable people (the sick, children, and the elderly).

Researchers have discovered that human activity is a major source of heavy metals and fine particulate matter contaminants in the air [2–4]. Industrial activities in both developed and developing nations are documented to contribute significantly to human-induced air pollution, with particulate matter and gaseous pollutants being produced at mostly undesirable levels. Heavy metal air pollution is a worldwide issue because most metals are inextinguishable and can endanger human health, plants, animals, ecosystems, or other media [4]. The studies on pollutant toxicity potential have been motivated by growing human health concerns about PM inhalation [3]. Particulate matter toxicities are known to pose serious health risks, and a calculated toxicity potential value that exceeds unity when using the threshold limits is concerning. The objective of this study was to assess the levels of $PM_{2.5}$, PM_{10}, the $PM_{2.5}/PM_{10}$ ratio, and the toxicity potential of a commercial area in Akure, Ondo State, Nigeria.

2. Materials and Methods

Akure is the capital city of Nigeria's Ondo state. Every year, the city experiences dry (November to March) and wet (April to October) seasons. The dry season (harmattan) is typically cold (9–16 °C), with dusty northeasterly trade winds from the Sahara desert transporting large amounts of dust for several days. The season is typically distinguished by high solar radiation and clear skies, moderate air temperatures, and no precipitation. Between April and mid-October, southwesterly winds from the Atlantic Ocean predominate. The research was carried out at the Federal College of Agriculture, Akure, REC campus commercial area (5°14′23.94″ E 7°5′49.34″ N). There are motorcycle mechanics, shoe-making workshops, and a commercial shop (typing, bookbinding, etc.) in the campus commercial area. A lot of generator usage occurs in these places. A low-cost Canāree A1 sensor an Intelligent Particle Sensor was used for the three-month monitoring (March to May 2022) of PM_{10} and $PM_{2.5}$ in the study for 6 h each day. The manufacturer's standard protocols were strictly followed. The generated data were statistically manipulated using Minitab and Excel 2013 software, producing basic summary reports and a bar chart, respectively.

Toxicity Potential

Toxicity potential (TP) is the ratio of evaluated ambient PM mass to the standard limit of ambient concentration [5]. It is useful in determining the harmful effects of pollutants on human health. It was calculated using Equation (1), in consideration of the World Health Organization 2021 Guidelines for PM_{10} and $PM_{2.5}$ ambient air quality standards: PM_{10} (24 h-45 μg/m^3 and Annual-15 μg/m^3) $PM_{2.5}$ (24 h-5 μg/m^3 and Annual-5 μg/m^3) [6].

$$\text{Toxicity Potential} = \frac{MPM}{SPM} \tag{1}$$

where *MPM* is the measured particulate matter, and *SPM* is the guideline limit set for PM_{10} and $PM_{2.5}$.

3. Results and Discussion

Figure 1 depicts the summary reports for PM_{10}, $PM_{2.5}$, and their respective ratios. The recorded $PM_{2.5}$ and PM_{10} levels for the study periods ranged from 1.26 to 469.80 μg/m^3, $PM_{2.5}$—1.26 to 419.13 μg/m^3, and their ratios were observed as 0.49 and 1.00. It should be noted that the WHO 2021 guidelines assert that annual average $PM_{2.5}$ and PM_{10} concentrations must not exceed 5 and 15 μg/m^3, respectively, while 24-h average risks must not surpass 15 and 45 μg/m^3, respectively. The majority of the 24-h PM_{10} and $PM_{2.5}$ values in the commercial area were discovered to be greater than the WHO recommendations in this study. Figure 1 depicts the summary reports for PM_{10}, $PM_{2.5}$, and their respective ratios. The high Particulate matter levels are expected due to the many anthropogenic activities within the study area, including the use of perfumes by people (customers and shop owners) within the surroundings, generator fumes, and the center's proximity to a high-traffic location, i.e., vehicular movements on the airport road. During this time, there were also many land preparations for the start of the new planting season. There was a lot of bush burning and soil dust movement.

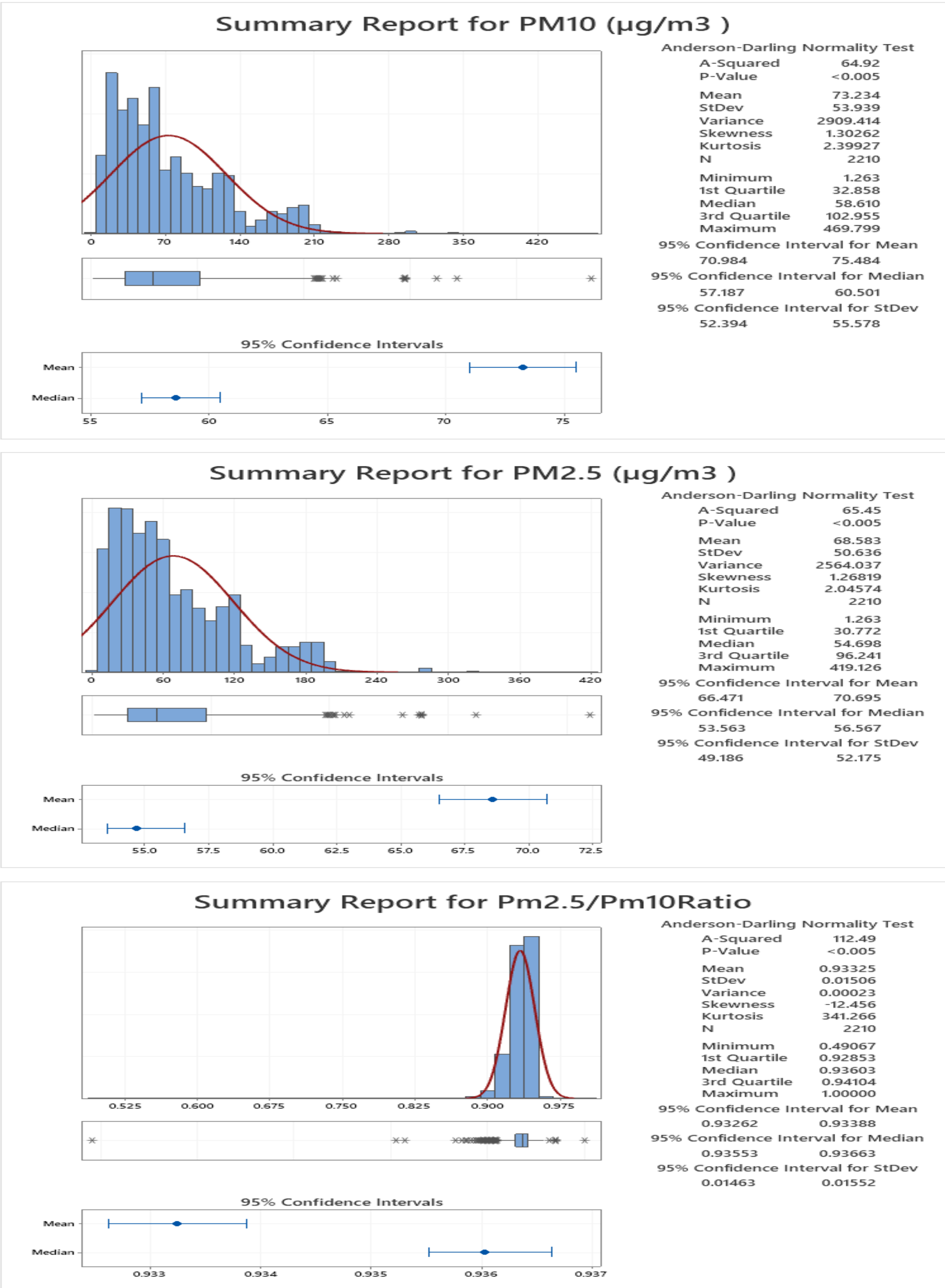

Figure 1. The Summary Report of PM_{10}, $PM_{2.5}$, and Their Ratios.

In addition, forest fires could also have contributed to mass concentrations during this time period. Table 1 compares our findings to previous research in Nigeria and other countries. Figure 1 depicts the summary reports for PM_{10}, $PM_{2.5}$, and their respective ratios. The average $PM_{2.5}/PM_{10}$ ratios in other countries were consistent with our studies, which range from 0.3 to 0.85 in the winter, spring, and summer seasons. The consistency could be explained by the fact that traffic-related sources are dominated by particle emissions and the constituents of $PM_{2.5}$ and PM_{10}.

Table 1. Comparison of the results of our study with previous ones in Nigeria and Other countries.

S/N	Location	PM_{10} (μg/m^3)	$PM_{2.5}$ (μg/m^3)	$PM_{2.5}/PM_{10}$	Toxicity Potential	References
1.	FECA, Akure, Nigeria	73.23 ± 53.94	68.58 ± 50.64	0.93 ± 0.02	PM_{10}—1.47 $PM_{2.5}$—2.74	This Study
2.	Kano, Nigeria	22.70–57.00	11.71–25.30	-	PM_{10}: 0.45–1.14 $PM_{2.5}$: 0.45–1.08	Ayua et al. [7]
3.	Chelyabinsk, Russia	6 and 64	5 to 56	0.85	-	Krupnova et al. [8]
4.	Helsinki and Stockholm	-		0.30–0.80	-	Adães and Pires [9]
5.	Tianjin, China	40.09 to 746	13.03 to 309	Average 0.41 ± 0.22 (Spring) – 0.43 ± 0.19 (winter),	-	Zhang et al. [10]
6.	China mainland	74.37–85.13	38.08–48.63	0.54–0.57	-	Fan et al. [11]
7.	Omu-Aran, Nigeria	59.32–473.52	11.42–32.40	-	PM_{10}: 0.13–0.36, $PM_{2.5}$: 0.33–2.64	Fakinle et al. [12]
8.	Idiroko Road, Nigeria	-	43.0 ± 1.0 to 91.0 ± 5.0 (day) 42.0 ± 2.0 to 53.0 ± 3.0 (evening)	-	$PM_{2.5}$: 1.36–3.64	Oghenovo et al. [13]

Figure 2 depicts the mean values of PM_{10} and $PM_{2.5}$ Toxicity Potentials 1.47 and 1.47 and 2.74. Our results were similar to those of Fakinle et al. [12]—$PM_{2.5}$: 0.13–0.36, and PM_{10}: 0.33–2.64—but Oghenovo et al. [13] obtained a higher maximum level (3.64). The similarities in TP results revealed that the sources of particulate matter may not differ between locations. A TP value greater than one indicates that PM_{10} and $PM_{2.5}$ in a location pose a health risk to people in the area. Several epidemiologic studies and toxicity research studies have found that a variety of chemical components and sources can have a negative impact on people's health. It is crucial to mention that the area surrounding this study is healthy, but good tracking of the environment in terms of PM should be done on a regular basis.

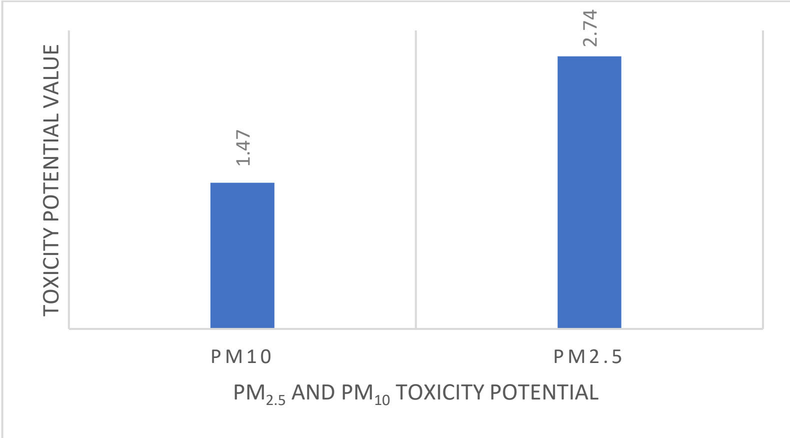

Figure 2. The PM_{10} and $PM_{2.5}$ Toxicity Potentials.

4. Conclusions

The $PM_{2.5}$, PM_{10}, $PM_{2.5}/PM_{10}$ ratios, and TP of a commercial area in Akure, Ondo State, Nigeria were measured for three months using a Canāree A1 low-cost sensor. The findings revealed that the WHO 2021 guidelines were exceeded. The $PM_{2.5}/PM_{10}$ ratios revealed that the presence of PM could be attributed to fumes from the generator and vehicles in the study area. A TP greater than one is a health concern, especially for the vulnerable (the sick, children, and the elderly). Constant monitoring is advised.

Author Contributions: Conceptualization, F.O.A.; methodology, F.O.A., A.M.K. and A.A. (Ademola Adamu); investigation and formal analysis, A.A. (Akinyinka Akinnusotu), S.D.O. and S.A.; data curation, A.A. (Akinyinka Akinnusotu) and S.D.O.; writing—original draft preparation, F.O.A.; writing—review and editing, S.A. and K.M.A.; visualization, F.O.A. and A.A. (Ademola Adamu). All authors have read and agreed to the published version of the manuscript.

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Proceeding Paper

Ambient Temperature Effect on Pregnancy Outcomes: Single Center Experience from Belgrade †

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Abstract: *Background*: Climate change with global warming and frequent summer heatwaves could negatively impact pregnancy outcome; however, this is still not well understood. *Objective*: To assess the association between ambient temperatures of the last 4 weeks of pregnancy with higher risk for preterm stillbirth. *Material and Methods*: Study included all pregnant women with preterm stillbirth (20 to 37 weeks of gestation) treated in the Clinic for Ob/Gyn University Clinical Center of Serbia during a ten-year period (2010 to 2019). We used meteorological data (minimal, mean and maximal temperatures) per year and month for the city of Belgrade which were provided by Republic Hydrometeorological Society of Serbia and are freely available. *Results*: During the study period, 409 stillbirths occurred in our clinic (1.02% of all deliveries). Gestational week of stillbirth ranged from 18 to 33 (mean ± SD = 23.8 ± 2.9). Mean temperatures ranged from −3.3 °C (January 2017) to 27 (July 2012). Rates of stillbirths were similar in spring and summer compared to autumn and winter months (233 vs. 186; $p = 0.317$), as well as if temperatures were <15 °C and ≥15 °C (200 vs. 209, $p = 0.854$). Moreover, there was no trend in stillbirth rates in relation to ambient temperatures of the last 4 weeks of pregnancy ($p = 0.435$). *Conclusion*: Risk for preterm stillbirth was not associated with ambient temperatures of the last 4 weeks of pregnancy.

Keywords: ambient temperature; pregnancy outcome; premature stillbirth

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1. Introduction

Climate change is the long-term change in the average weather patterns that define local, regional, and global climates. Numerous literature data have confirmed that global warming is currently occurring, which might lead to more frequent and intense environmental disasters, such as heatwaves, wildfires and hurricanes [1,2]. This climate change can also have short and long-term effects on human health ranging from dehydration to heatstroke, respiratory diseases, infectious diseases, mental health complications, cardiovascular disease and even death. A changing climate is a key factor in increasing the intensity, duration, and frequency of heatwaves, which can especially be exacerbated for people with chronic diseases, the elderly and young children, newborn babies and pregnant women [3,4].

During pregnancy, women and their fetuses experience a range of tightly regulated physical and psychologic changes. Pregnant women and the fetus in development present a vulnerable group as numerous factors including environmental ones can disturb the fine metabolic balance of pregnancy and cause different complications for the mother and fetus [5,6]. Any environmental perturbations such as heat or air and water pollution during this sensitive period could have both immediate and life-long consequences for both mother and the child. Some studies showed that adverse pregnancy outcomes especially occur if pregnant women are exposed to heat during the last week of pregnancy. Exposure to heat toward the end of the gestational period can trigger labor soon after. However, research on the health impacts of climate change on pregnancy outcomes is still limited [7,8].

2. Objective

The study aim was to assess the association between ambient temperatures of the last four weeks of pregnancy with the risk for having a preterm stillbirth.

3. Materials and Methods

This retrospective study was performed at the Clinic for Gynecology and Obstetrics University Clinical Center of Serbia, incorporating a period of ten years (2010 to 2019 year). The study included all pregnant women who had delivered a stillbirth child before term, i.e., before the 37th week of gestation in our clinic. Patient data were obtained from medical records (histories of illness and delivery protocols). To prevent the confounding effects of other different pathologies on study findings, all cases with a known reason for stillbirth were excluded (fetal malformations, infections, etc.).

Meteorological parameters regarding minimal, maximal and average daily temperature were obtained from the website of the Republic Hydrometeorological Society of Serbia, where these data are freely available. Temperatures per year and per month for the city of Belgrade during the examined ten-year period were noted. We assessed the impact of the average temperature during the last month of pregnancy with the pregnancy outcome.

Serbia is a country with a mild continental climate. Measurements of the temperature in Belgrade are performed 2 m above ground at the grass field of the main meteorological station. Measurements are performed three times per day (morning, noon, and evening); based on these findings, the minimal, maximal and average daily temperatures are reported.

Obtained data of patients and temperatures were compared and analyzed using methods of descriptive (number, percent, mean, standard deviation–SD) and analytical statistics. Differences and comparisons between groups were tested using the Hi square test and ANOVA. To analyze trends in temperature and stillbirths, a time series analysis was applied. All analyses were performed using SPSS 20 software.

4. Results

During the study period, 409 stillbirths occurred in our clinic (1.02% of all deliveries). Women who had preterm stillbirths were from 17 to 46 years of age (mean $\pm$ SD = 30.93 $\pm$ 5.99 years) and were mostly primiparous (54.5%; $p = 0.001$). There were no significant differences regarding the gender of stillbirth children (males = 51.8%; females = 48.2%; $p = 0.458$). The gestational week of stillbirth ranged from 18 to 33 (mean $\pm$ SD = 23.8 $\pm$ 2.9); at the time of delivery, children weighed 549.30 $\pm$ 214.75 g on average (range 50 to 980 g). We present the rates of stillbirths per month during the examined ten years in Figure 1.

In the examined ten-year period, mean temperatures ranged from −3.3 °C (January 2017) to 27 (July 2012). The coldest month was January every year, while July and August were generally the hottest months ($p = 0.001$). April to September are considered as summer and spring months with an average temperature of $\geq$ 15 °C. The hottest years were 2012, 2013 and 2018, with average yearly temperatures of $\geq$ 15.5 °C. However, there were no significant differences in average yearly temperatures in Belgrade during the examined ten years ($p = 0.738$). The mean temperatures per year in Belgrade, Serbia, between the years 2010 and 2019 are presented in Figure 2.

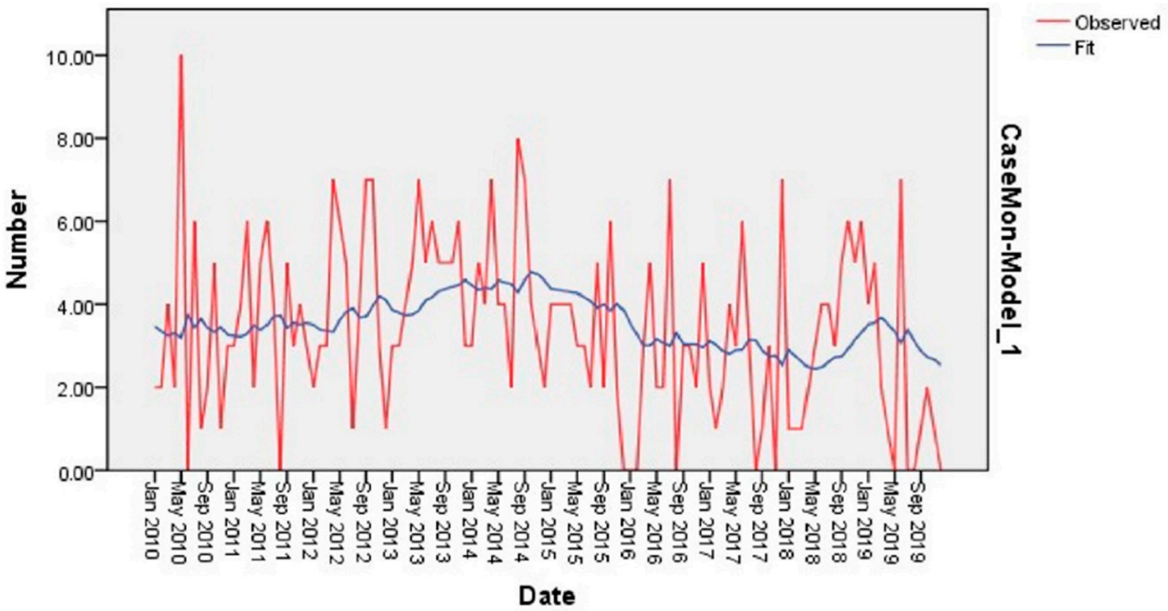

Figure 1. Rates of stillbirths per month during the examined ten years (2010–2019).

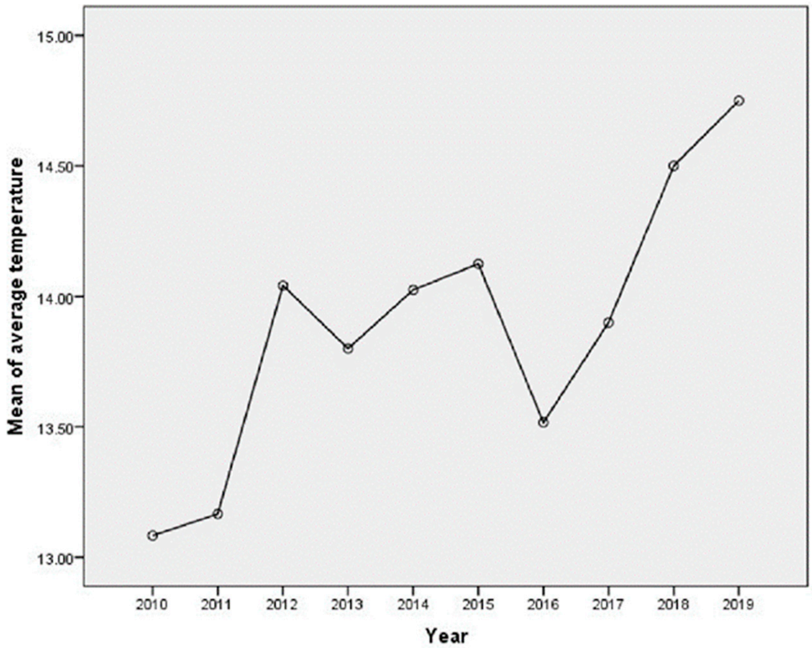

Figure 2. Mean temperatures per year in Belgrade, Serbia between the years 2010 and 2019.

Rates of stillbirths were similar in spring and summer compared to autumn and winter months (233 vs. 186; $p = 0.317$) as well as if temperatures were <15 °C and ≥15 °C (200 vs. 209, $p = 0.854$). Moreover, there was no trend in stillbirth rates in relation to ambient temperatures of the last four weeks of pregnancy ($p = 0.435$).

5. Discussion

Numerous studies undertaken worldwide found that exposure to heat is associated with a higher risk of adverse pregnancy outcomes such as preterm birth, low birthweight, and congenital anomalies—especially of the heart—and stillbirth. Some authors found a correlation between prenatal heat exposure and decreased cognitive ability in later life [5,7]. Maternal health is also at risk with heat exposure, with studies identifying increased incidence of maternal hypertensive disease, gestational diabetes and bleeding due to placental abruption. No critical period of maternal exposure to heat has yet been definitively identified, but data suggest that heat exposure earlier in a warm season is more harmful than later due to lack of acclimatization [9,10].

Environmental heat can present a health risk for pregnant women by causing an increase in core body temperature. This occurs through a few mechanisms [11,12]. Increased body weight and fat during pregnancy increase core body temperature and heat production. The decreased ratio of surface area to body mass of pregnant women reduces the heat-loss capacity of sweating. Finally, the fetal metabolism also increases maternal body temperature. When environmental temperature exceeds the maternal core body temperature, the physiological reaction is cutaneous vasodilation and sweating along with decreased uterine and umbilical cord blood flow. If heat-loss mechanisms are unable to disperse heat effectively, the body becomes dehydrated which is a hazard for both mother and fetus. In such conditions, the endocrine system activates and releases the antidiuretic hormone and oxytocin, further decreasing uterine blood flow to the fetus which may cause transient asphyxia or even death. The hormonal response to dehydration may even trigger labor regardless of the expected term. In addition, heat exposure can cause acute heat stress. If stress occurs, heat-shock protein is released into maternal circulation. The heat-shock protein is known to damage placental cells and reduce placental efficiency, thereby decreasing adequate oxygen and nutrition supply to the fetus. Consequently, frequent heat shocks during pregnancy can lead to intrauterine growth restriction of the fetus. Moreover, heat stress can interrupt the typical sequence of gene activity, causing congenital anomalies or stillbirths [11,12].

Data from California indicate that the risk of stillbirth increases 10.4% for every 5.6 °C increase in ambient temperature. This risk is even higher for younger and less educated mothers, as well as male fetuses. The highest risks were observed during gestational weeks 20–25 and 31–33 [13]. Authors from Brisbane, Australia, found that risk of stillbirth increased with exposures during the prior week up to temperatures of 21 °C, but that there was no increased risk at the highest temperatures. Still, the peak of stillbirth rates in Australia is during the summer [14]. On the other hand, studies performed in Nordic countries revealed that stillbirth rates did not show a linear trend during the last century, but had a peak in the 1930s, in particular among boys. Trends differed also by region and per year. No clear effect of temperature on stillbirths across the entire year was found in Sweden. However, stillbirth risk was highest in spring and summer, both at low and high temperatures [15,16]. In contrast, some authors found a link between high stillbirth rates and winter and spring months in New York, Minnesota, and Switzerland [13]. We did not find any significant differences in rates of stillbirths throughout the ten-year period regardless of the season.

The delivery of a stillbirth has been shown to occur significantly more often as a response to ambient temperature in a couple of days to up to a week after exposure [7,8]. When we analyzed the impact of average temperature one month before the adverse pregnancy outcome, no correlation was found.

The novelty of our study is the fact that it is the first to examine the link between acute exposure to heat and risk of preterm stillbirth is Serbia. The major study limitation is not testing for other different environmental or gynecological risk factors (use of air conditioning, etc.). Therefore, further research with a greater number of parameters regarding the examined pregnancies as well as environmental factors during longer periods of time is needed to fully understand the mechanisms of interaction between environment and pregnancy health.

6. Conclusions

According to the results of our study, the risk for preterm stillbirth was not associated with ambient temperatures in the last four weeks of pregnancy of women in Serbia.

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Editorial

Statement of Peer Review †

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