CZECH UNIVERSITY OF LIFE SCIENCES IN PRAGUE

Faculty of Environmental Sciences

BACHELOR THESIS

2024 Rozálie Slavíčková

CZECH UNIVERSITY OF LIFE SCIENCES IN PRAGUE
Faculty of Environmental Sciences

COMPARISON OF THE IMPACTS OF DUST STORMS AND WILDFIRES ON PEOPLE'S LIVES IN AUSTRALIA

BACHELOR THESIS

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2024 ČZU Prague

CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Environmental Sciences

BACHELOR THESIS ASSIGNMENT

Rozálie Slavíčková

Environmental Engineering

Thesis title

Comparison of the impacts of dust storms and wildfires on people's lives in Australia

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Objectives of thesis

The main aim is to compare various impacts of dust storms and wildfires on people's lives in Australia. Additionally, a review of the general impacts of dust storms and wild fires will be elaborated and the most severe events will be focused on in detail using latest online monitoring tools. Investigation on people living in more or less prone areas to these natural hazards will be conducted in terms to understand the impacts on their lives.

Methodology

In order to compare which of these two natural phenomena has more negative consequences for people, a questionnaire asking Australian citizens about their experiences and possible consequences was sent out. Results were statistically analysed and air pollution online monitoring tools used for selected events. Hybrid Single-Particle Lagrangian Integrated Trajectory (Hysplit) was used to find out where the air parcels and potential aerosols travelled. Additionally, the satellite Moderate Resolution Imaging Spectroradiometer (MODIS) was used to identify how selected dust storms moved across Australia. The Copernicus Atmosphere Monitoring Service (CAMS) was used to see where were the fires activated.

The proposed extent of the thesis

30

Keywords

wildfire, dust storm, Australia, population health, questionnaire, comparison

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Recommended information sources

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Authors statement:

I hereby declare that I have independently elaborated the bachelor thesis with the topic of: "Comparison of the Impacts of Dust Storms and Wildfires on People's Lives in Australia" and that I have cited all of the information sources that I used in the thesis as listed at the end of the thesis in the list of used information sources. I am aware that my bachelor thesis is subject to Act No. 121/2000 Coll., on copyright, on rights related to copyright and on amendments of certain acts, as amended by later regulations, particularly the provisions of Section 35(3) of the act on the use of the thesis. I am aware that by submitting the bachelor thesis I agree with its publication under Act No. 111/1998 Coll., on universities and on the change and amendments of certain acts, as amended, regardless of the result of its defense. With my own signature, I also declare that the electronic version is identical to the printed version and the data stated in the thesis has been processed in relation to the GDPR.

In Prague, Czechia

Signature: 

Rozálie Slavíčková

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Abstrakt

Znečištění ovzduší způsobené přírodními jevy ovlivňuje zvěř, přírodu i lidské zdraví. Prachové bouře a lesní požáry, ke kterým dochází v Austrálii, jsou dva fenomény, na které se tato práce zaměřuje. Zvýšené částice PM představují pro člověka obrovskou hrozbu. Čím menší PM částice jsou, tím hlouběji se mohou dostat do dýchacího a oběhového systému a způsobit zdravotní problémy, jako jsou respirační nebo kardiovaskulární onemocnění.

Hlavním cílem této práce je upozornit na prachové bouře a lesní požáry a porovnat jejich dopady na lidské zdraví. Pro tuto studii jsou zhodnoceny dvě velké události, jednou z nich je prachová bouře ve východní Austrálii v roce 2009 a druhá je sezóna lesních požárů v letech 2019–2020. Mezi nejčastější problémy způsobené prachovými bouřemi a lesními požáry, které vyžadují lékařskou péči, jsou dýchací potíže. Pro druhou část této práce byl obyvatelům Austrálie rozeslán dotazník mapující jejich zkušenosti s těmito dvěma jevy. Celkem 88 % účastníků mělo pocit, že jejich život více ovlivnily požáry než prachové bouře. Kolem 60 % z nich se s lesními požáry setkává častěji než s prachovými bouřemi.

Vzhledem k tomu, že výsledky dotazníku byly porovnány s informacemi z přehledu literatury, bylo zjištěno, že události lesních požárů ovlivňovaly životy lidí výrazněji než prachové bouře, ale vážnější zdravotní problémy s dlouhodobějšími následky způsobovaly převážně prachové bouře.

Klíčová slova: lesní požár, prachová bouře, Austrálie, zdraví populace, dotazník, porovnání

Abstract

Air pollution caused by natural phenomena affects wildlife, nature, as well as human health. Dust storms and wildfires in Australia are the two phenomena that this work focuses on. Elevated PM particles represent a huge threat to humans. The smaller the PM particles are, the deeper they can get into the respiratory and circulatory system and cause health issues such as respiratory or cardiovascular diseases.

The main goal of this work is to draw attention to dust storms and wildfires and compare their effects on human health. For this study, two big events are reviewed, one being the Eastern Australian dust storm in 2009 and the second being the wildfire season of the year 2019-2020. Respiratory problems are the most frequent impacts caused by dust storms and wildfires that need medical attention. For the second part of this work, a questionnaire was sent out to residents of Australia mapping their experience with the two phenomena. In total, 88% of participants felt that their life was more affected by wildfires than dust storms. About 60% of them encounter wildfires more often.

As the results of the questionnaire were compared with the review information, wildfire events were more significantly influencing the lives of people, but dust storms were more likely to cause more serious health problems with longer-lasting effects.

Keywords: wildfire, dust storm, Australia, population health, questionnaire, comparison

Table of Contents

1. Introduction

Living in an area with high air pollution is a serious environmental risk to human health. In 2022, the World Health Organization published that 99% of the global population lives in areas where the air that people breathe exceeds the quality limit (WHO 2022a). That is connected to premature deaths due to the surrounding air pollution, which is 4.2 million deaths yearly (WHO 2021a). Natural weather phenomena add more air pollution into the air that is later breathed by people.

For this work, Australia was chosen, where two phenomena occur side by side, namely dust storms and wildfires. They release huge amounts of dust particles, poisonous gasses, and ashes into the atmosphere. The population of Australia is often affected by dust storms and wildfires, which expose them to the health risks associated with them.

To assess the threat of phenomena such as the ones mentioned above, Particulate Matter (PM) is used. PM can be found in the air, in the form of droplets consisting of solid and liquid particles (Environmental Protection Agency 2023). WHO said that PM consists mainly of sulfates, nitrates, ammonia, sodium chloride, black carbon, mineral dust, and water (WHO 2022b). Lately PM with an aerodynamic diameter of equal to or less than 10µm (PM_{10}) and equal to or less than 2.5µm ($PM_{2.5}$) is getting extra attention (WHO 2021b). PM_{10} is one of the major indicators of air pollution and as a smog component, it reduces atmospheric visibility (Mukherjee and Agrawal. 2017).

Impacts from dust storms and wildfires affect human health and can lead to premature death. One of the health effects caused by wildfires is respiratory symptoms (Aditama 2000), with asthma also being proven to be one of them (Johnston et al. 2002). Due to wildfires, there can be an elevated increase in bronchitis and pneumonia cases (Delfino et al. 2009). Another health effect that is present during elevated PM values due to wildfires is cardiovascular problems (Delfino et al. 2009). The most common health outcome of dust storms is respiratory health issues, followed by cardiovascular problems, and among the less frequent issues are infectious diseases, allergic skin, and eye problems (Aghababaeian et al. 2021).

2. Objectives of the thesis

The aim of this work was to compare the various impacts of dust storms and wildfires on the population of Australia. Among the health effects that will be focused on are respiratory diseases (asthma, bronchitis), cardiovascular diseases, and mental health problems. Furthermore, the goal is to evaluate whether people are informed in time to prepare about the possible occurrence of these two phenomena and whether they are given recommendations for health protection. The final goal of this work is to evaluate which of these two natural phenomena has a more significant impact on the population of Australia, wildfires or dust storms.

3. Literature review

This section will discuss the two specific events for this paper. First, the timeline and effects of the 2009 Eastern Australian dust storm will be described. The second will be a focus on the Australian wildfires in 2019 - 2020. Last is a comparison of the impact of dust storms and wildfires on human health.

3.1 Eastern Australian dust storm 2009

The Eastern Australian dust storm so called “Red Dawn" swept across four states of Australia from September 21 to 24, 2009. From the years 2001 - 2010, there was an extremely dry period of time in Eastern Australia, especially in New South Wales, Queensland, and South Australia. These dry and hot seasons lead to a dry landscape, which had very low vegetation cover, so it was predisposed to wind erosion (Tozer and Leys 2013). According to the Recent and Historical maps of the Australian government (Figure 1), the rainfall in the year of 2009 was in the below average or very much below average range in the Lake Eyre Basin (Bureau of Meteorology 2021).

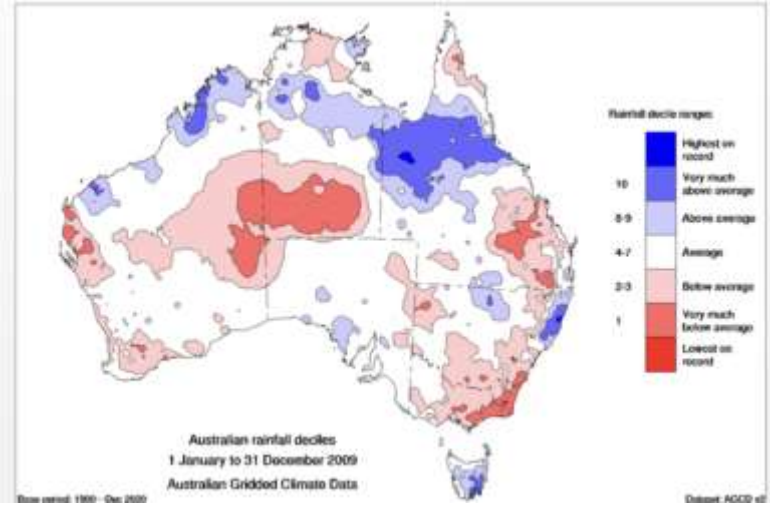

Figure 1: Rainfall for the year 2009 (The Bureau of Meteorology 2021)

Red Dawn began to form when a low pressure cell was over Adelaide, South Australia on 21 September 2009. That low pressure cell created a trough which reached central Australia, the main source of dust in the continent (Bullard et al. 2008). De Deckker et al. (2014) stated that the low pressure cell that reached that dry center of Australia, started whipping up the dust from the surroundings of the Lake Eyre Basin, the Simpson Desert, the South Australia's Strzelecki Desert, and western parts of New South Wales (De Deckker et al. 2014).

The South Australian dust traveled over central New South Wales toward the southern New South Wales and southeast coast of Victoria during the night from 21 to 22 September. Then, by noon of 22 September, the dust reached well into New South Wales and Queensland. In the city Broken Hill in New South Wales the measured visibility was only 10 to 20 meters and at 16:00 local time they experienced almost total darkness (De Deckker et al., 2014). During the night from the 22 to 23 September the Southern Australian dust settled into the frontal system and spread all over New South Wales and the southern half of Queensland. During that time, increased dust was pulled into the cyclonic vortex of the low pressure point. The dust then moved and swept across New South Wales toward Canberra (De Deckker et al. 2014). In the morning of 23 September, the dust storm reached Sydney (De Deckker at al. 2014). It reduced visibility, caused traffic chaos, and they had to close the airport and delay flights (Ramachandran 2009). The dust storm reached Brisbane at approximately 11 am on 23 September (Jayaratne et al. 2011). During the night from 23 to 24 September, the cyclonic vortex was moving toward New Zealand and the dust also spread over the Tasman Sea and was heading up to northern Queensland (De Deckker et al. 2014).

The PM_{10} concentrations of the Eastern Australian dust storm were the highest ever recorded since the 1950s when the Air Quality Monitoring Network was launched (Leys et al. 2011). According to the Australian government, Department of Climate Change, Energy, the Environment and Water, the air quality standard for PM_{10} are 50 $\mu g/m^3$ over 24 hours, and for the $PM_{2.5}$ are 25 $\mu g/m^3$, although, the typical hourly readings of PM_{10} in Sydney region is 20 $\mu g/m^3$ (Leys et al. 2011). The highest value measured in the Sydney area was in Bringelly, the suburb of Sydney, 45 km from the center, with the reading of PM_{10} at a value of 15,366 $\mu g/m^3$ at 8 pm on the 22 September (Leys et al. 2011), which was over 768 times higher than the typical Sydney amount. The wind speed in the morning of 23 September in the Sydney area was 8.7 m/s, with the PM_{10} concentrations below the air quality standard. As the morning progressed, the wind speed increased to 10 - 12 m/s, and the PM_{10} concentrations also increased until they exceeded 10,000 $\mu g/m^3$ in the Sydney area. Later that day, the wind speed increased to 10 - 14 m/s. The highest PM_{10} concentration measured across New South Wales was in Bathurst, which is approximately 200 km from Sydney, with a value of 15,388 $\mu g/m^3$ (Aryal et al. 2015).

In Brisbane (Queensland) the morning of the 23 September, the PM_{10} concentrations were at the typical level of 21μg/m^3. Although by 10 am with more sand being brought by the wind the PM_{10} concentrations exceeded 100 μg/m^3. The visibility started getting worse and by 1 pm the PM_{10} concentrations peaked to the 6,460 μg/m^3 value and $PM_{2.5}$ concentrations peaked to the value of 814 μg/m^3 (Jayaratne et al. 2011). Tozer and Leys (2013) stated that the total loss of soil on the East Coast was 2.54 tons.

In Queensland in the week of the dust storm from 22 September to 29 September, air medical interventions were mapped. In total, there were 332 of them, 13 being respiratory interventions, which in comparison to the same time period in the year 2008, is a 62.5% increase (Holyoak et al. 2011). In Brisbane on the 24th of September 2009, there was a 39% increase in admissions to hospital, but all the other days were met with no difference compared to the average (Barnett et al. 2012). In Sydney, there was no difference in hospital admissions due to a particulate matter increase observed (Merrifield et al. 2013).

3.2 Wildfires 2019 - 2020

At the beginning of December 2018 Australia started experiencing heatwaves, which continued into the year 2019 (The Bureau of Meteorology 2021). In January 2019, Filkov et al. (2020) stated that the monthly mean temperature was 2.90 ºC above average.

From the Recent and Historical rainfall maps of the Australian Government (Figure 2), the center of Australia and parts of the east coast experienced the lowest rainfall on record, and above average temperatures in 2019 (Bureau of Meteorology 2021). Moisture in live fuels, such as branches and leaves, decreased in 2019 which occurs during droughts (Nolan et al. 2020), due to the low rainfall and above average

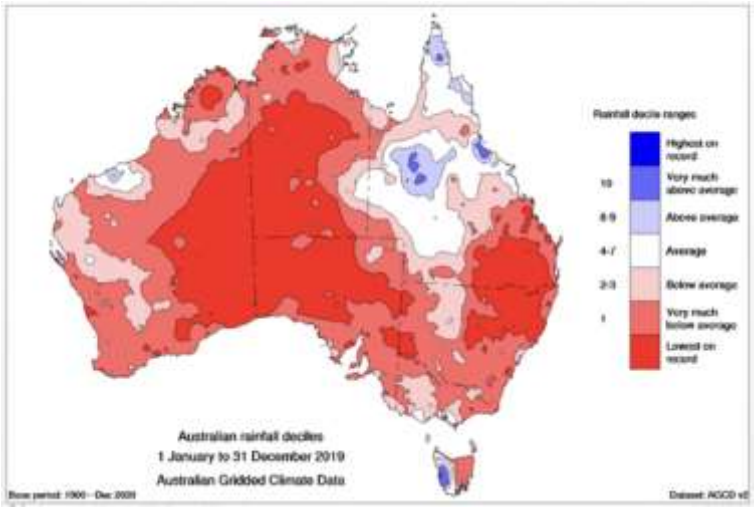

Figure 2: Rainfall for the year 2019 (The Bureau of Meteorology 2021)

temperatures. From this information, Australia was experiencing severe droughts leading up to the fire season.

For evaluating the scale of fire danger, Australia uses the Forest Fire Danger Index tool (Dowdy et al. 2019). During the spring of 2019 to the summer of 2020, large parts of Australia had the highest Forest Fire Danger Index since the start of recording in the 1950s (NSW government 2023). From those index ranges more than 95% of Australia amassed the very much above average value and from that percentage nearly 60% amassed the highest value on the record in the spring of 2019 (Filkov et al. 2020).

In south-eastern Australia, the combination of the extreme conditions, such as low rainfall, high temperatures, low humidity, and a large number of live fuels, led to a large-scale mega fire that lasted from early November 2019 to mid-January 2020 (Nguyen et al. 2021). In New South Wales, the fires started in the second half of October (Nguyen et al. 2021), specifically on the 26th of October 2019 in the Gosper Mountain which is a part of the Blue Mountains range (Flikov et al. 2020). The total area burned in this mega-fire was 512,626 hectares (Flikov et al. 2020). By January 11th, 2019, the second mega fire was created at the border of New South Wales and Victoria because the Dunns Road fire, East Ournie Creek fire and Riverinas Green Valley fire connected into one, which caused the burning of an area of 895,744 hectares (Filkov et al. 2020). Filkov et al. (2020) stated that the total burned area of New South Wales was 5,595,739 hectares due to 10,520 fires, which cost the lives of 20 people. In Queensland, there were around 50 fires monitored by December of 2019

(Davey and Sarre 2020). The state of Victoria experienced over 3,500 fires in the fire season of 2019 - 2020, which cost the lives of 5 people and burned a total area of 1,505,004 hectares, with the most destructive event being the fire of Mallacoota in east Victoria (Filkov et al. 2020).

In South Australia, the fires started on December 20, 2019, and were caused by lightning strikes. Three days later most of them were extinguished, but a few days later Filkov et al. (2020) also stated that there were more lightning strikes on the 30 December 2019 that started more fires, and those new fires connected with the existing ones. The total area burned during those fires was 286,845 hectares with 1,324 fires that caused the loss of 3 lives (Filkov et al. 2020). Although the total number of houses destroyed and loss of life was up to ten times higher than the average, the area burned, and the number of fires was below or average for South Australia (Filkov et al. 2020). Due to a rainfall event at the end of February of 2020, almost all fires were extinguished at the east coast of Australia (Davey and Sarre 2020).

$PM_{2.5}$ was measured in multiple states of Australia during the wildfire events. In New South Wales the $PM_{2.5}$ was measured in the period from December 29, 2019, to January 5, 2020, and had values mostly in the range of 75 - 500 $\mu g/m^3$ (Akdemir et al. 2022). The only exception was the event at North Wagga Wagga on January 5, 2020, where readings exceeded the standard (25 $\mu g/m^3$) 72 times (Akdemir et al. 2022). On January 6, 2020, at Port Macquarie (located on the Mid North coast of New South Wales), the peak concentrations of $PM_{2.5}$ were 273.7 $\mu g/m^3$ (Nguyen et al. 2021). On January 10, 2020, at 12:00 in Macquarie station in Sydney, the $PM_{2.5}$ value reached 610.6 $\mu g/m^3$, and another peak in the measurement happened on the 19 January 2020 in Sydney, when the $PM_{2.5}$ reached around 300 $\mu g/m^3$ and above (Nguyen et al. 2021). In Victoria the values from December 29 to January 5 were not particularly high, and the only peak value was recorded on January 3, 2020, being $PM_{2.5}$ 160 $\mu g/m^3$ (Akdemir et al. 2022).

In the Australian Capital Territory and Victoria, Ducket et al. (2020) compared data of hospital admissions when $PM_{2.5}$ was at the standard level of 25 $\mu g/m^3$ or less, to the $PM_{2.5}$ levels during the bushfires. They observed that there was a 27% increase in respiratory problem admissions on the days where $PM_{2.5}$ levels were between 50 - 100

μg/m^3, and a 70% increase in respiratory problem admissions on the days where $PM_{2.5}$ exceeded 200 μg/m^3 (Ducket et al. 2020).

Rodney et al. (2021) has also done a study about health problems due to the wildfire in the Australian Capital Territory. Their cross-sectional survey was completed by 2,084 people, from which 97.1% stated that they experienced at least one physical health problem. These problems were, in descending order from most common: watery eyes/eye irritation, dry throat/throat irritation, cough, headaches, breathlessness, sneezing and wheeze. They also asked about mental problems due to the bushfires, where over 55% of respondents stated experiencing a symptom of anxiety and/or depression. And 50% of respondents experienced worse sleep (Rodney et al. 2021).

Graham et al. (2021) stated that in the time period of October 2019 to February 2020, due to a short-term exposure to the $PM_{2.5}$ of the wildfires, there were 109 deaths in New South Wales, which was 38% of the total deaths due to exposure to $PM_{2.5}$. In Queensland, 15 deaths occurred, which was 13% of the total deaths due to exposure to $PM_{2.5}$, and in Victoria, 35 deaths occurred, which was 30% of the total deaths due to exposure to $PM_{2.5}$ (Graham et al. 2021).

3.3 Summary of the impacts from fires and dust storms

The highest risk of respiratory health effects from dust storms is for old people, whose immune system is weakened, for children, whose immune system is not developed fully (Schweitzer et al. 2018), and for people with chronic cardiopulmonary disorders (Yu et al. 2012).

As the dust storms move, they can take a lot of stuff from the surface with them, which can cause serious problems to human health. Bacteria, viruses, pollen, and fungi are some of them, which can survive for a long time in the dust and potentially cause health problems such as meningococcal disease (Goudie 2014). Griffin and Kellogg (2004) stated that allergic reactions can occur due to inhaling fungi and bacteria, contained in the dust. Derbyshire (2007) studied dust particles and came to an understanding that particles larger than 10 μm get stuck in the upper respiratory tract and are eliminated by respiration but can still be a potential risk to human health due to the toxicity of the particles.

Akba et al. (2013) studied dust samples collected during and after a dust storm near Anatolia in Turkey and found that the samples contained higher levels of heavy metals such as Al, As, Cd, Co, Pb, Zn, etc., than reported before the dust event. Goudie (2014) stated that dust storms can carry herbicides, pesticides, radioactive isotopes, and dioxins as well as heavy metals, all being potential risks to human health. Middleton (2017) said that inhalation of dust particles can trigger asthma, bronchitis, or chronic obstructive pulmonary disease. The World Health Organization stated that for people with chronic diseases or lung diseases, dust storms are a risk that can cause or worsen chronic obstructive pulmonary disease, heart disease or asthma (WHO 2021a). In Japan city of Toyama, Kanatani et al. (2010) found that in the period from the dust storm to 6 days after the dust storm, there was an increased risk of hospitalizations of pediatric patients (1-15 years) due to heavy metals in the air triggering asthma. The change in severity of asthma due to dust events, where the dust contained high amounts of fine particles was also observed by Rutherford et al. (1999) in Brisbane, Australia. According to Vestbo et al. (2013), chronic obstructive pulmonary disease, triggered by inhaling dust particles, was the main cause of morbidity and mortality worldwide in 2013.

Perez et al. (2008) did a study on the Saharan Dust Days event in Barcelona, with the results that during those days, with a 10 $\mu g/m^3$ increase in $PM_{10 - 2.5}$ the mortality increased by 8.4%, in comparison with 1.3% mortality during Non-Saharan Dust Days. The study also included a 10 $\mu g/m^3$ increase in $PM_{2.5}$, which ended up increasing the mortality by 5% during the Saharan Dust Days, in comparison to 3.5% mortality during Non-Saharan Dust Days (Perez et al. 2008). Middleton (2017) said that in extreme cases, people caught in a dust storm can suffocate. Silt-sized quartz is one of the most common dust storm materials, and it is known to cause non-occupational silicosis, also called “desert lung syndrome”, if inhaled for a long time (Goudie 2014). The same statement, that inhaling dust can cause silicosis, was made by Middleton (2017).

Chan et al. (2008) did a study in Taiwan, where they observed an increase in hospital visits of people with cardiopulmonary disease, due to PM_{10} levels being above 90 $\mu g/m^3$. They also observed an increase in hospital visits of people suffering from ischemic heart disease and chronic obstructive pulmonary disease (Chan et al. 2008).

Wildfires are dangerous to everything living and nonliving. More than others, however, it is dangerous for pregnant women who are in the third trimester (Amjad et al. 2021). And they are not the only ones. Zheng (2023) observed that exposure to wildfires has health risks for people older than 65. A predisposition to exposure for six or more days can be increased due to small airway size (Mirabelli et al. 2009). Due to that, children are also one of the vulnerable groups, and as the World Health Organization stated, people with chronic diseases are also in great danger (WHO 2024).

There are many health effects that can occur while being exposed to wildfire and smoke. One of them being asthma as already said. In Darwin Australia, a study was done during a dry season from April 1st to October 30th, 2000, which stated that with PM_{10} increasing by 10μg/m^3, asthma visits to the emergency department increased significantly (Johnston et al. 2002). The San Diego wildfires on October 22-26, 2007, also saw an increase in emergency room visits for asthma. During those fires, the $PM_{2.5}$ daily high reached 803 μg/m^3 (Hutchinson et al. 2018). $PM_{2.5}$ was also associated with asthma emergency visits in Northern California in the summer wildfires of 2008, among all age groups (Reid et al. 2016). Since children are one of the vulnerable age groups, many studies talk about asthma caused by wildfire smoke exposure. Hutchinson et al. (2018) stated that the most affected group of children, during wildfire smoke exposure in San Diego 2007 (United States), was the group aged 0-1, whose visits in the emergency department due to asthma increased the most. Leibel et al. (2020) later observed that the highest excess visits in the emergency department and clinics was among the children aged 0-5, during the San Diego (United States) wildfires in the years 2011-2017. The World Health Organization said that the exposure of pregnant women to the increased levels of $PM_{2.5}$ due to wildfires is risky for the fetus and the women (WHO 2024).

The year 2003 was one of the worst fire seasons in British Columbia. On August 16th in Okanagan Mountain Park, one of the most significant wildfires in British Columbian history started (Forest Protection Program of British Columbia 2004). During the first six days of the fire being active, the daily maximum of $PM_{2.5}$ and PM_{10} peaked at 200μg/m^3 and 250 μg/m^3 respectively (Moore et al. 2006). Those PM levels were associated with the increase of doctor visits due to respiratory diseases in British Columbia (Moore et al. 2006). In the 2007 San Diego wildfire, Hutchinson et al. (2018)

found an increase in bronchitis, pneumonia, and upper respiratory tract infections. In the years 2000 - 2016, there was a large study done by Chen et al. (2021) that covered 749 cities in 43 countries, detecting wildfire related increases of $PM_{2.5}$. They detected the highest daily $PM_{2.5}$ concentrations in North America and East Asia (Chen et al. 2021). Elevated levels of $PM_{2.5}$ were associated with the increase in respiratory and cardiovascular mortality which varied by country (Chen et al. 2021). The fact that cardiovascular problems are associated with increased $PM_{2.5}$ concentration caused by wildfires can be seen in another study focusing on cardiovascular health effects which was done in Melbourne (Victoria) from July 2006 - June 2007 (Dennekamp et al. 2015). They stated that the risk of out of hospital cardiac arrest increased with increasing $PM_{2.5}$ from the wildfires (Dennekamp et al. 2015).

There are many other types of health risk that can be associated with wildfires. Watery or itchy eyes and sore throat were found in Valencia (Spain) among children during wildfires in July 2012 (Vicedo-Cabrera et al. 2016). Instant health impacts such as diarrhea, eye irritation or acute respiratory infections were detected among eight provinces in Indonesia during fire events from September to November 1997 in Kalimantan and Sumatra islands (Aditama 2000).

Risk of worsening of mental health among people who are exposed to wildfires is also a big topic. In the United States a study across the whole country was done, focusing on people aged 57-85, who were exposed to wildfires in July 2005 - March 2006 and in August 2010 - May 2011 (Pun et al. 2017). The results of the study have shown an increase of moderate to severe anxiety symptoms in association with elevated $PM_{2.5}$ among the age group of 69-72 (Pun et al. 2017). Memory loss was also detected as one of the impacts of exposure to wildfire smoke (WHO 2024).

4. Methodology

4.1 Description of the area of interest

The territory from which the data originates is the federal state of Australia, which is located on the continent of the same name. With an area of approximately 7.7 million km², it is the sixth largest country in the world according to 2020 data (Ahmad et al. 2021). The water area occupies only 1% of the total area. Australia is the driest continent in the world, which leads to the frequent occurrence of forest fires and dust storms. The information for the questionnaire was sent out to six states and two territories (Figure 3). Tasmania was not included in the research.

Figure 3: States and territories of Australia with the capital cities (Google Maps, 2024)

4.2 Survey: Selection of the participants

The survey was conducted over three months from July 15th to September 15th, 2023. A link to the questionnaire was attached to an email. This email was sent to my

acquaintances and the professors I met in Australia. Several universities across Australia were subsequently selected. The email was sent to the randomly chosen professors from these universities. Among them are the University of Queensland, Charles Darwin University, and The University of Newcastle. In total 302 emails with questionnaires attached to it were sent.

4.3 Survey: Collecting Data

In the questionnaire, residents of Australia were asked about their experiences with dust storms and wildfires. The questions have been created in accordance with commonly known facts so that anyone could answer without prior education about the topic. Potential participants were sent an email containing a link to the survey, which was available in English and only in an online form. Consent by the participants was provided with submitting the form. Appendix 1 (Table 1, Table 2, Table 3, and Table 4) summarizes the questions and answers.

The survey collected: place of residence; gender; age; whether they experienced dust storm or wildfire in their place of residence; which one they encounter more often; how they were warned about dust storm; if they experienced health issues because of the dust storm; what health issues they experienced; how long these problems lasted; whether they had to go to the emergency room or not; what protective equipment they used during the dust storm; how they were warned about wildfire; if they experienced health issues because of the wildfire; what health issues they experienced; how long these problems lasted; whether they had to go to the emergency room or not; what protective equipment they used during the wildfire; which one (dust storms, wildfires) do they feel like impacts their lives more.

Due to a slight error, some participants who did not experience a dust storm or a wildfire were still directed to answer additional questions about them. This was not the original intention of the survey, so the error was fixed, and the responses submitted that skewed the data were removed.

5. Results

A total of 36 people completed the survey. This was a response rate of 11.9% to the survey invitation. One response was excluded because it was invalid. That resulted in the total number of responders 35.

5.1 Survey: Demographic parameters

Participant's demographics are summarized in graphs. A total of 17.1% of participants were from Queensland, 68.6% were from New South Wales, 2.9% were from the Australian Capital Territory, 8.6% were from Northern Territory and 2.9% were from Western Australia (see Figure 4). About 57.1% of the responders were male and 42.9% were female (see Figure 5). The ages of the participants differed. A total of 22.9% of respondents were in the 21-29 age group, 20% of participants responded in the 30-39 age group, 22.9% of participants responded in the 40-49 age group, 25.7% of respondents were in the 50-59 age group, and 8.6% of respondents were in the group of >60 (see Figure 6). The two youngest age groups (<17, 18-20) did not get any response. About 8.6% of participants said that they had experienced a dust storm, and 42.9% experienced a wildfire. Both dust storms and wildfires were experienced by 20% of respondents, and 28.6% said that they did not experience either a dust storm or a wildfire (see Figure 7). Percentages of responses sometimes have been rounded and therefore do not add up to 100%.

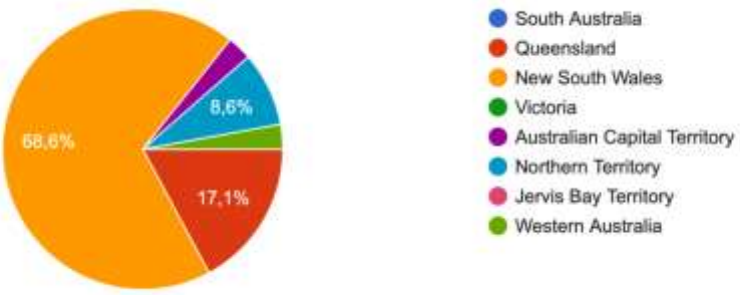

Figure 4: Place of residence of participants

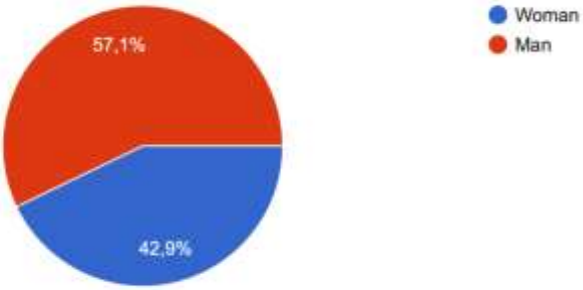

Figure 5: Gender of participants

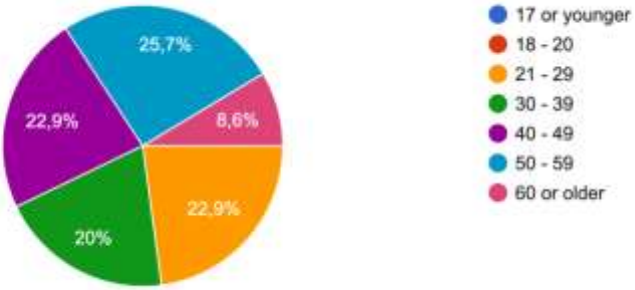

Figure 6: Age of participants

Figure 7: Dust storm and wildfire experience

5.2 Dust storm health issues

In total 10 participants (28.5%) reported experiencing a dust storm. Figures 8,9,10,11,12,13 summarize their answers.

The first question was “How were you warned about the dust storm?”. A total of 50% participants reported being warned that a storm would happen, 10% of participants were warned to avoid certain activities, and 50% of participants were not informed at all (see Figure 8). The next question asked about experiencing health issues. About 60% of participants did not report experiencing health issues, and 40% did report experiencing health issues caused by a dust storm (see Figure 9). The symptoms that participants experienced were: Asthma (75%), Coughing (75%), eye problems (25%) and hay fever/allergic rhinitis (25%). Hay Fever/allergic rhinitis was added from one of the participants (see Figure 10). A total of 75% of participants reported experiencing problems for less than 1 week, and 25% experienced health issues for 1-2 weeks (see Figure 11). None of the participants had to go to the emergency room (see Figure 12).

As a final question about dust storm health issues, participants were asked what personal protective equipment they used. A total of 75% of participants said “none”, and 25% of participants used a “mask or respirator” (see Figure 13).

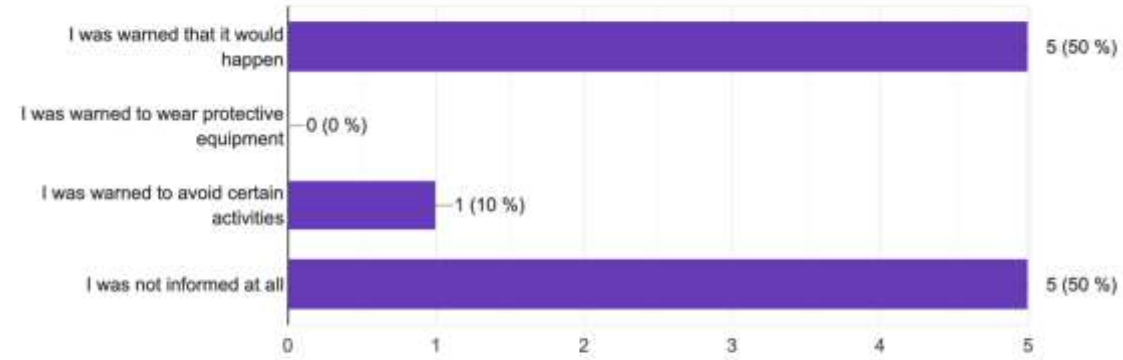

Figure 8: Availability of dust storm warning to citizens

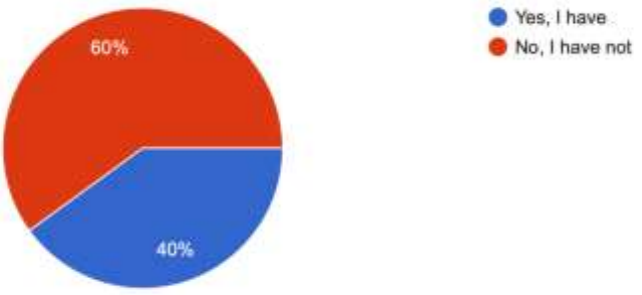

Figure 9: Experiencing dust storm health issues

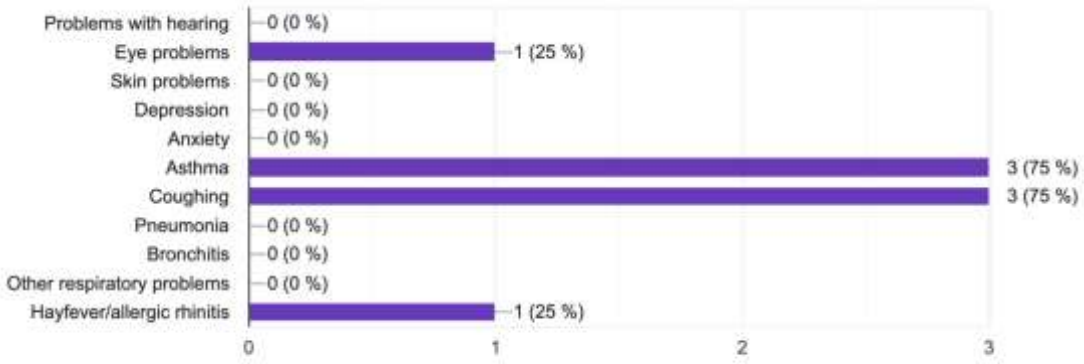

Figure 10: Types of dust storm health issues

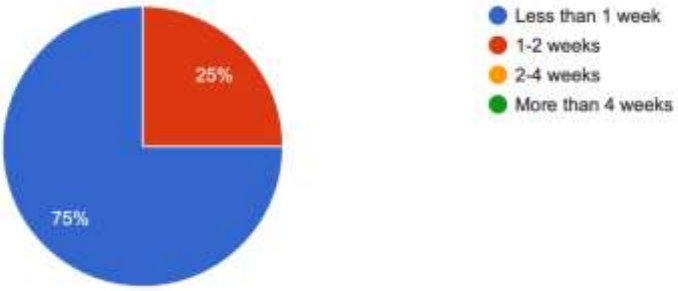

Figure 11: Period of time that dust storm health issues were active

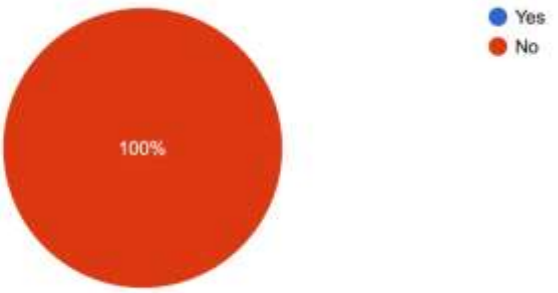

Figure 12: Emergency room visitation due to dust storm

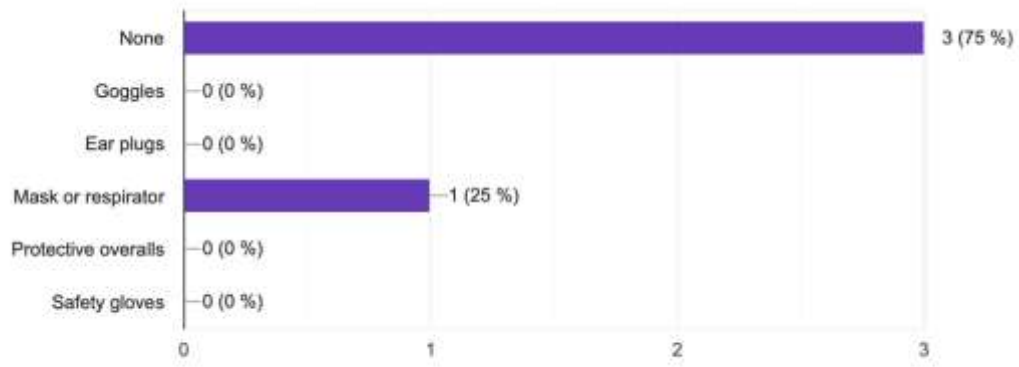

Figure 13: Protective equipment used during dust storm

5.3 Wildfire health issues

In total 22 participants (62.8%) reported experiencing wildfire. Figures 14,15,16,17,18,19 summarize their answers.

The first question was “How were you warned about the wildfire?”. A total of 77.3% of participants were warned that it would happen, 13.6% of participants were warned to wear protective equipment, 40.9% of participants were warned to avoid certain activities, and 13.6% were not informed at all (see Figure 14). The next question asked about experiencing health issues due to a wildfire. About 68.2% of participants reported not experiencing any health issues connected to the wildfires, and 31.8% reported experiencing health issues (see Figure 15). The symptoms that participants experienced were: Eye problems (42.9%), Asthma (57.1%) Coughing (85.7%), Anxiety (14.3%) and Hay Fever/allergic rhinitis (14.3%). Hay Fever/allergic rhinitis was added by one of the participants (see Figure 16). A total of 71.4 % of them reported experiencing those problems for less than 1 week, 14.3% experienced problems for 2-4 weeks, and 14.3% experiencing problems for more than 4 weeks (see Figure 17). None of the participants had to go to the emergency room (see Figure 18).

As a final question of the wildfire health issues, participants were asked what personal protective equipment they used. A total of 57.1% of participants reported that they used “none”, 28.6% used a “mask or respirator”, 14.3% used “protective overalls”, and 14.3% of participants added their own protective actions which were “staying indoors and acting in accordance with the general medical advice” (see Figure 19).

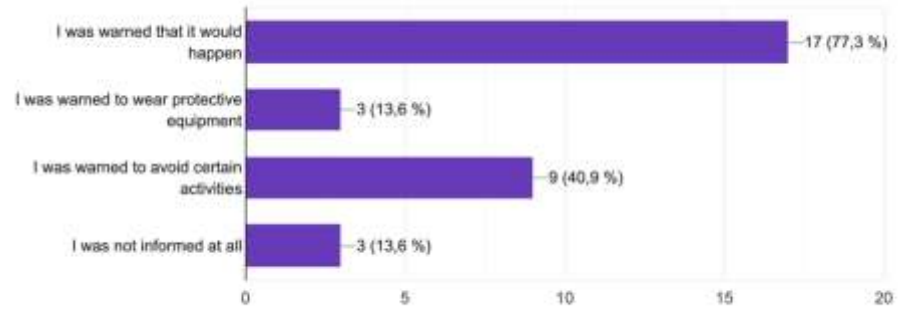

Figure 14: Availability of wildfire warning to citizens

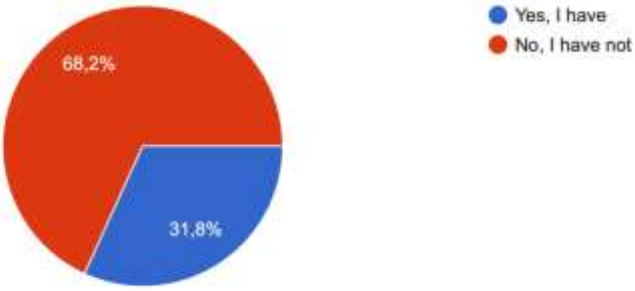

Figure 15: Experiencing wildfire health issues

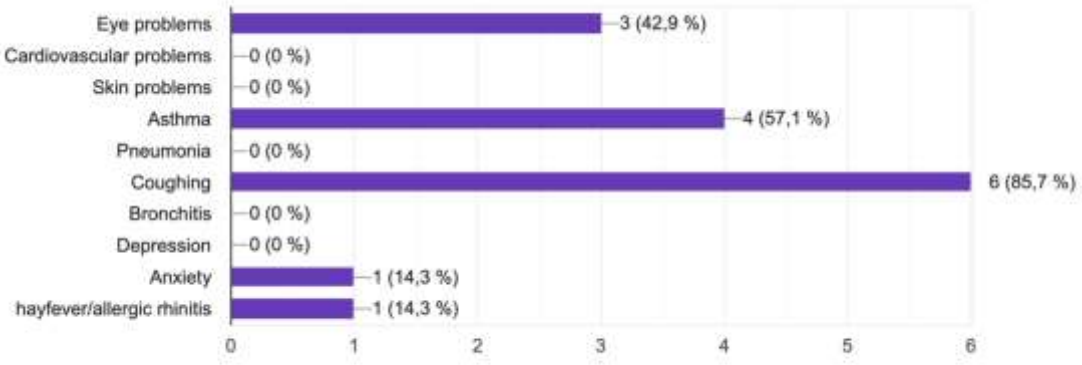

Figure 16: Type of wildfire health issues

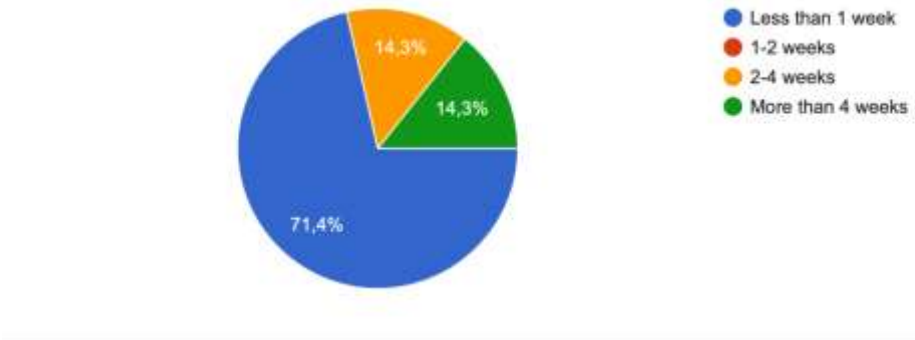

Figure 17: Period of time that wildfire health issues were active

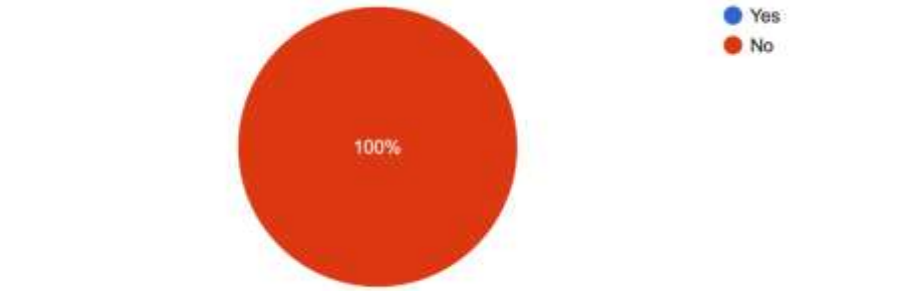

Figure 18: Emergency room visitation due to wildfire

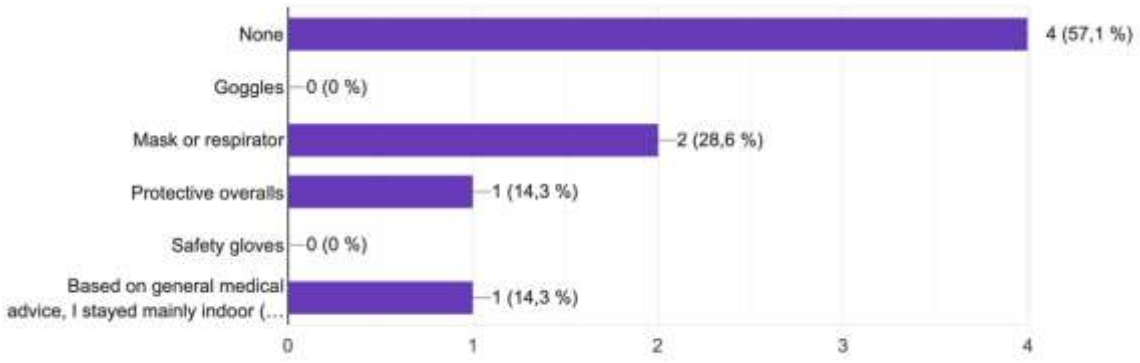

Figure 19: Protective equipment used during wildfire

5.4 Comparison of dust storm and wildfire effects

The first question was “Which do you encounter more often?”, in total 35 participants answered. A total of 8.6% of participants answered that they encounter dust storms more often, and 60% of participants said that they encounter wildfires more often. None of the participants reported that they would encounter both equally often. About 31.4% of participants said that they didn’t encounter anything (see Figure 20). The participants who answered that they didn't encounter either were not asked the final

question. To the question, which was “Which do you feel impacts your life more?”, 25 participants answered. A total of 4% of participants answered that dust storms impact their lives more, 88% of participants said that wildfires impact their lives more, and 8% of participants said that dust storms and wildfires have an equal impact on their lives (see Figure 21).

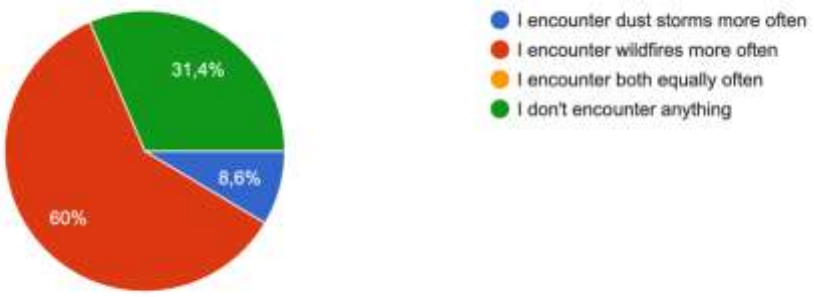

Figure 20: Dust storm and wildfire frequency

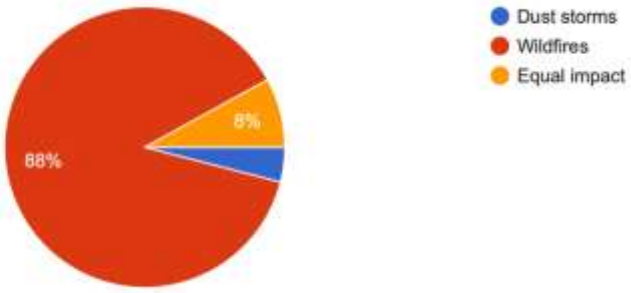

Figure 21: Greater perceived personal impact of dust storm and wildfire on citizens

6. Discussion

Human exposure to elevated concentrations of $PM_{2.5}$ and PM_{10} represents a major health risk worldwide, especially for vulnerable groups of people (Makri and Stilianakis. 2008). The air quality guidelines of the World Health Organization set the 24-hour average of $PM_{2.5}$ and PM_{10} concentrations to the limit of 15µg/m^3 and 45µg/m^3 respectively (WHO 2021). However, those limits are often exceeded during wildfires and dust storms. The largest reservoir of dust in the Southern Hemisphere is Australia (Ginoux et al. 2012).

The IPCC report of 2021 stated that there was significantly higher warming detected over land than in the ocean (IPCC 2023b) That tends to change the pattern of atmospheric circulation, and due to that the humidity on land is decreasing, leading to regional drying (IPCC 2023b). In Figure 22, IPCC (2023b) shows that in the future, all of Australia will experience a soil moisture decrease compared to the years 1995-2014. The soil moisture decreases ranges from 0 to 10% with approximately half of Australia in the 2 to 4% range. Unfortunately, much of Australia has a low model agreement (less than 80%), but the south-west of Australia which has a predicted soil moisture decrease of 6 to 10% has a high model agreement (greater than 80%) (IPCC 2023b).

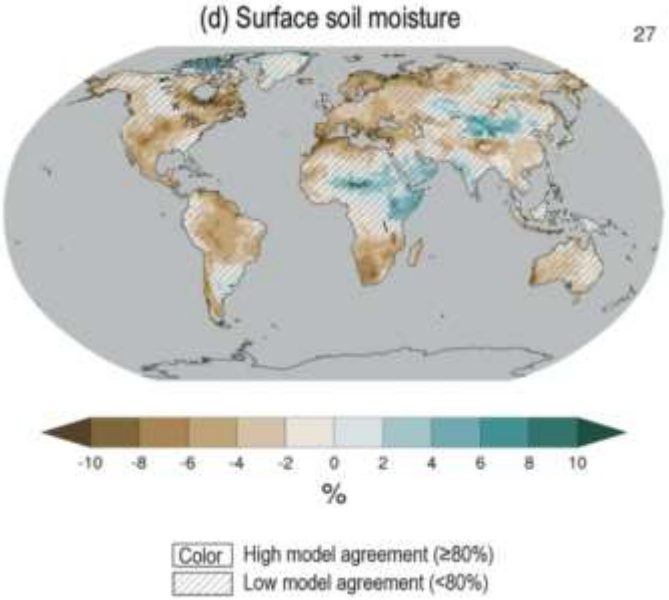

Figure 22: Surface soil moisture (IPCC 2023b)

Over the past decade (2011- 2022) the global surface temperature exceeded the 100 years scale (IPCC 2023b). In Figure 23, IPCC (2023b) shows that in the years 1981 to

2020 Australia experienced a significant warming trend in the range from 0.1 to 0.4°C. The south of Australia is in the range of 0.2 to 0.4°C increase trend. The graph also shows that the warming is more significant over land than ocean (IPCC 2023b). With the surface being that warm, IPCC (2023b) stated that due to the atmospheric circulation pattern being changed, there is much more evaporation process from the warm land cover. That process is making the droughts even worse (IPCC 2023b). The soil humidity will decrease also with the increasing evapotranspiration (IPCC 2023b).

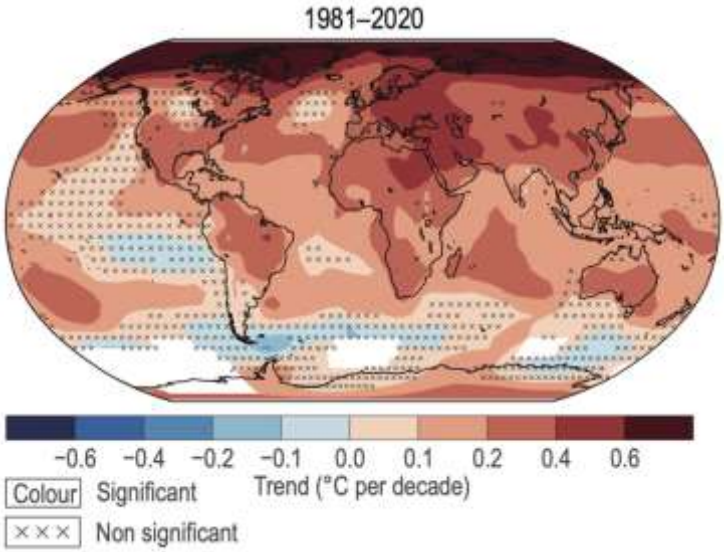

Figure 23: Surface temperature change in the years 1981-2020 (IPCC 2023b)

With the land surface being warmer and dryer, it is likely that in the future there will be more wildfire and dust storm events. Changes in the frequency of dust storms were found by Gouide et al. (2006), who stated that in some regions they observed an increase in frequency, and in other regions they observed a decrease in frequency. Recently the frequency had a sharp increase in some regions (United Nations Convention to Combat Desertification 2022). Figure 24 shows the backward trajectory of the 2009 dust storm on September 23 at an elevation of 100 meters. From the figure, it is visible that as De Deckker et al. (2014) stated that the low-pressure cell whipped the dust from the surroundings of Lake Eyre Basin, the Simpson desert, and other places after reaching the dry center of Australia.

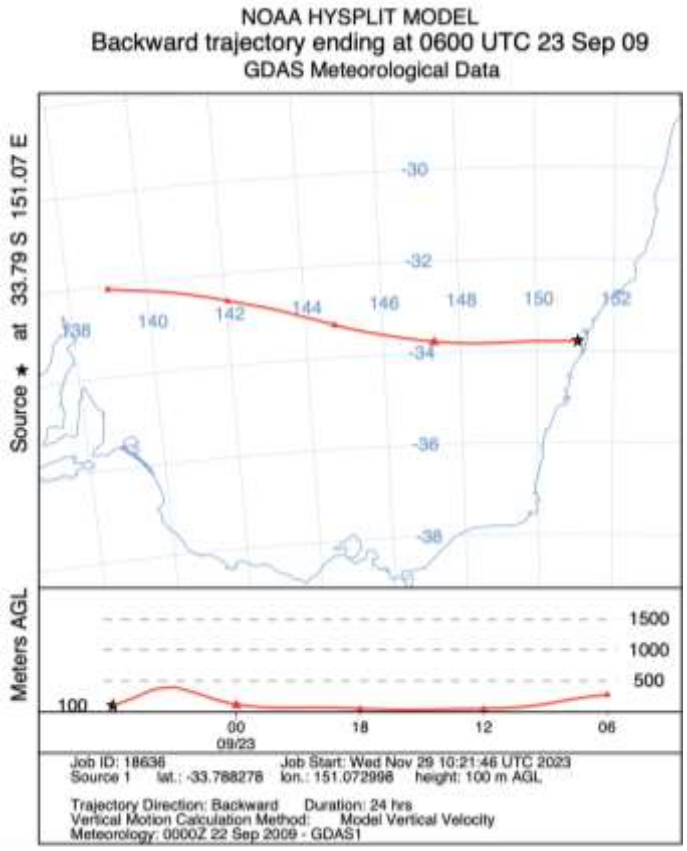

Figure 24: The backward trajectory of the 2009 dust storm (HYSPLIT)

Figure 25 shows the forward trajectories of the 2009 dust storm on September 23 at three elevation points (100 meters, 3000 meters, 5000 meters). De Deckker et al. (2014) stated that the cyclonic vortex moved toward New Zealand, spread across the Tasman Sea, and headed up to Queensland during the night from September 23 to September 24 (De Deckker et al. 2014). The same is shown on the Hysplit in Figure 25. De Deckker et al. (2010) presented an idea that the dry basins of Australia, such as Lake Eyre Basin, can be a source of airborne dust that gets to Antarctica, which is a very fragile and vulnerable continent (Siegert et al. 2023). This is in accordance with the elevation point of 5000 meters which traveled over New Zealand and continued to Antarctica.

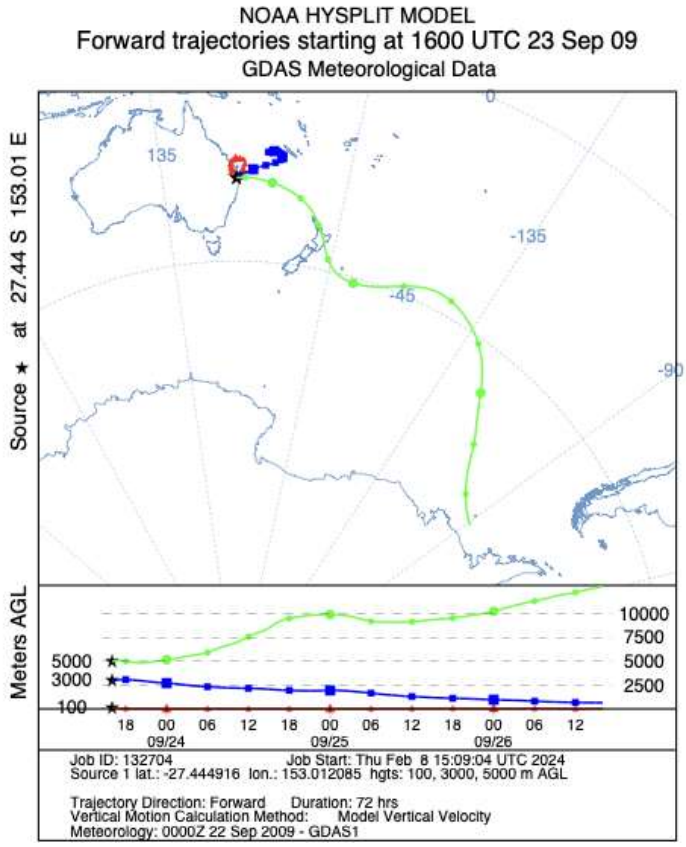

Figure 25: Forward trajectories of the 2009 dust storm (HYSPLIT)

This study focused on the health impacts on citizens of Australia as was said previously. The results from the questionnaire showed important data about the residents of Australia. In total 28.5% of participants experienced a dust storm and 62.8% of participants experienced a wildfire. From the 28.5% of participants experiencing a dust storm, 4 of them stated that they experienced health issues. One participant in the study said that they experienced eye problems which could be from the dust particles getting into their eyes and irritating them. Another health issue which the participants experienced was asthma. Rutherford et al. (1999), observed a change in severity of asthma. This study found a positive connection with that statement, where three participants experienced asthma health issues. Middleton's (2017) statement that dust particles can trigger asthma is also in accordance. Another health issue that three of the participants suffered from, was coughing. Luckily, none of the participants experienced bronchitis, unlike many other people who were traced by Middleton (2017). The reason for not proving this disease is probably the lack of participants who experienced such a health issue. Most of the study participants experienced the health issues from the dust storms for less than a week (3 participants) and one participant experienced the issues for 1-2 weeks.

The dust storm health issues overall were not as severe as the ones that were presented in the literature review. None of the participants had to visit the hospital. One participant wore a mask or respirator during the dust event, which could have made a difference on their health. The lack of noted severe health problems could be due to weak responses to the questionnaire, where the total number of participants that experienced a dust storm was ten. To get better results, the study would have to be done on a bigger sample of participants. Another improvement could come from additional questions, which were not considered previously. The questions could include, for example: In what year have you experienced the dust storm(s)?, Have you had any long-lasting problems due to the dust storm(s)?

The second natural phenomena that was within the objectives of this study, was wildfires. In the IPCC report of 2022, it is stated that Australia, North America, Amazon, and more regions are experiencing larger areas being burned (IPCC 2023a). In North America, it was analyzed that one of the reasons for wider areas being burned was due to human impacts toward climate change (IPCC 2023a). There is a large potential risk to human health when wildfires smoke is dispersed over big distances and the particulate matter originated by them is often $PM_{2.5}$. Figure 26 shows the active fires in New South Wales, Queensland, and Victoria on January 4th, 2020. In the Figure 26, there is a visible amount of fire smoke that was produced during the wildfires.

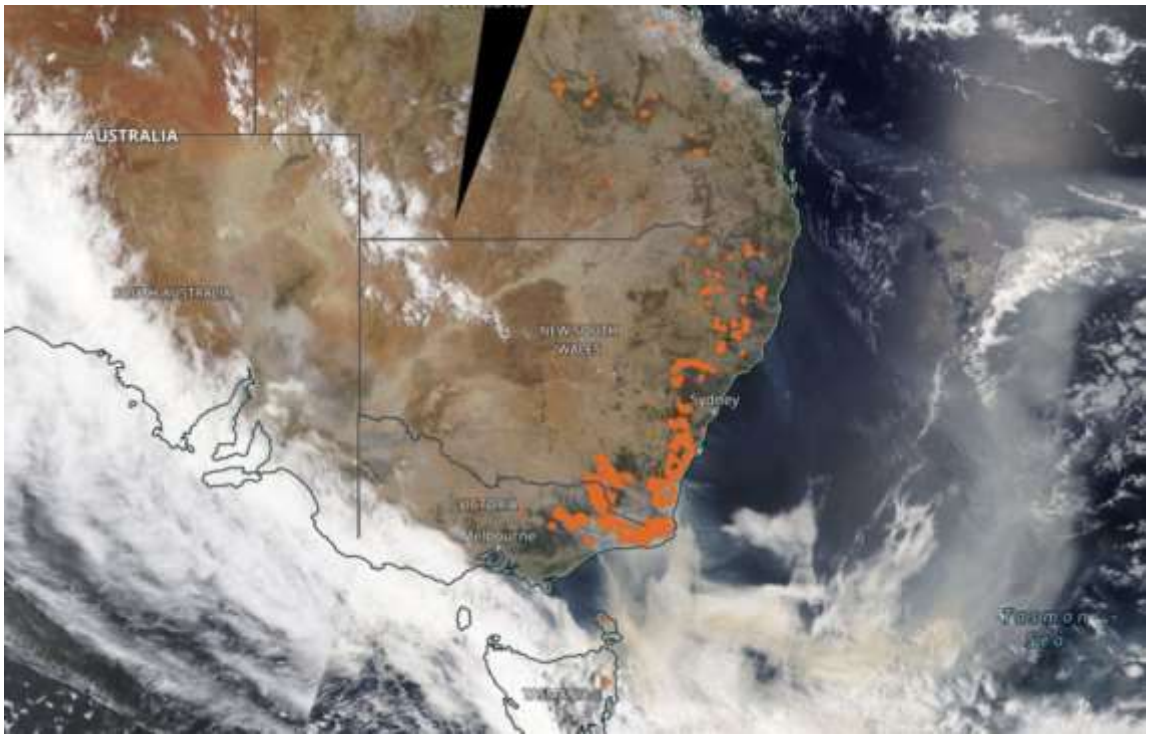

Figure 26: Active fires (MODIS Terra/Aqua January 4, 2020)

Figure 27 shows the aerosol depth of the active fire smoke and where it traveled on the 7th of January 2020. From the graph, it is visible that the smoke reached far behind New Zealand and continued into the South Pacific Ocean.

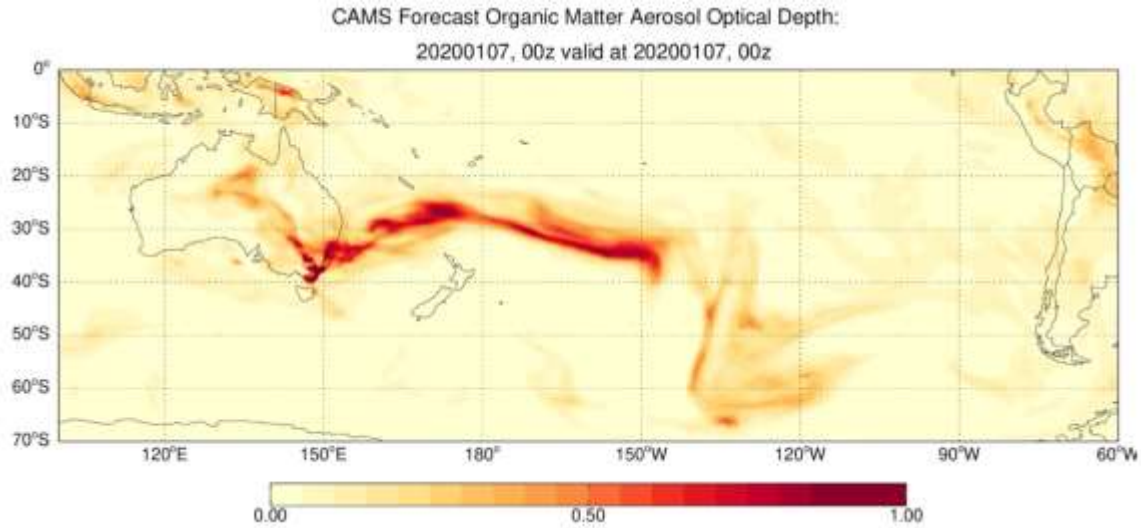

Figure 27: Transport of the smoke on January 7, 2020 (Copernicus Atmosphere Monitoring Service/ECMWF)

Figure 28 shows the same area of New South Wales, Queensland, and Victoria a week after January 4, 2020 (Figure 26). It is visible that the number of active fires is significantly reduced in Queensland and New South Wales. The state of Victoria has the largest amount of active fire, but still, it is less than the week before.

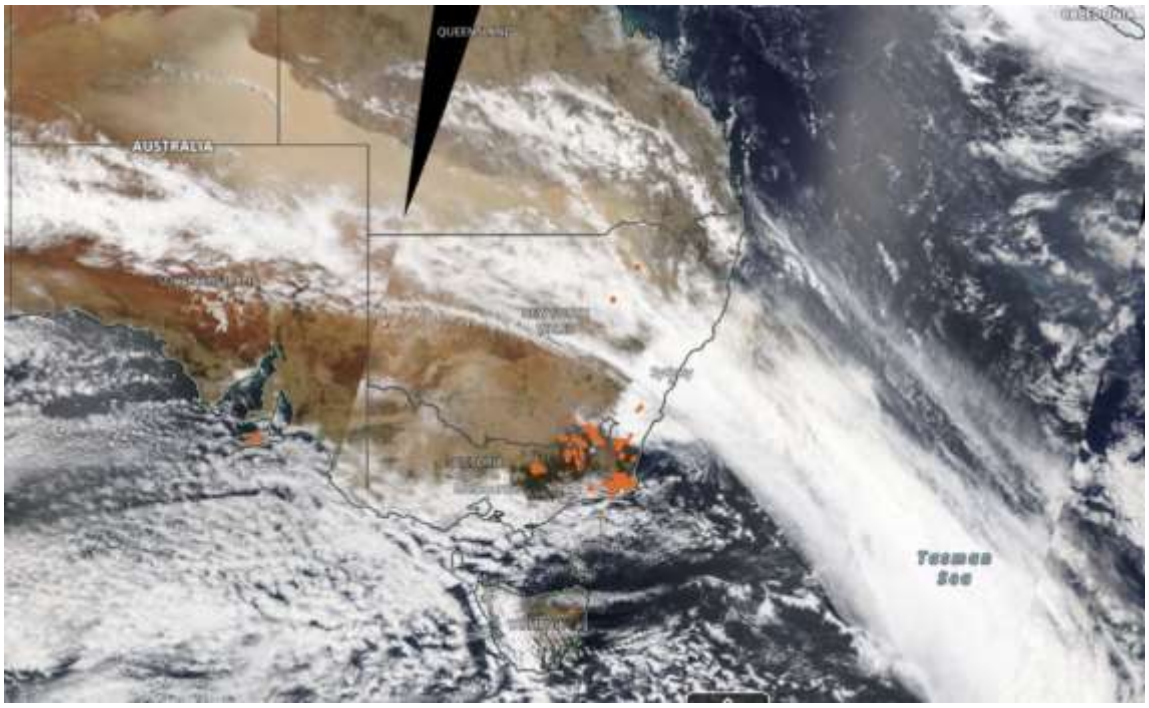

Figure 28: Active fires (MODIS Terra/Aqua January 11, 2020)

The questionnaire showed some important data about wildfire health issues. In total 7 participants experienced health issues caused by wildfires. Three of them experienced eye problems which were most likely directly connected to the smoke. The same was also observed by Vicedo-Cabrera et al. (2016), who did a study in Valencia (Spain) during wildfires in 2012 and Aditama (2000) who found cases of eye irritation in Sumatra islands in 1997. Another health problem was asthma. In total, four participants experienced asthma during wildfire events. Johnston et al. (2002) found a positive connection between increasing PM_{10} and increasing hospital admissions due to asthma in Darwin Australia. Another increase in emergency room visits due to asthma was found in San Diego by Hutchinson et al. (2018). Another symptom that was observed was coughing. In total six participants experienced that, which can be due to irritation of the throat. That was also in positive connection with Vicedo-Cabrera et al. (2016) and their study in Spain. The last health issue caused by wildfires that was noted in this study is anxiety. One participant stated experiencing anxiety symptoms during wildfire events. The same was observed in the United States among people in the age group from 69-72 (Pun et al. 2017). That study showed an increase in anxiety symptoms with increased $PM_{2.5}$ concentrations (Pun et al. 2017). The duration of the issues caused by wildfires was different from the dust storms. In total five participants experienced their issues for less than one week. One participant

experienced the issues for 2-4 weeks and one participant was experiencing the issues for more than four weeks.

Overall, the health issues caused by wildfires in this study were not as severe as the ones that were presented in the literature review. None of the participants had to visit the hospital, which could be due to the protective measures that they took. Two participants wore a mask or respirator during the wildfire events, and one wore protective overalls. The small number of severe health issues could be due to a weak response to the questionnaire, where the total number of participants experiencing wildfires was 22. A larger study would be needed for better results. In retrospect, choosing additional questions would have brought better and more specific results. These questions could include, for example: In which year(s) did you experience the wildfire? Can you describe your health problems? Have you had a long-term health problem?

This study collected various answers to the asked questions. From the comparing process, it was visible that more people have experienced wildfires over dust storms (61.1% over 27.7% respectively). A total of 88% of participants then reported wildfires as a bigger impact on their lives. Which leads us to think about people being more aware of wildfires than dust storms. There could be several factors to affect that. One of them might be the time period during which the wildfire lasts for, that is significantly longer than the time period of dust storms. Also, the risk of their homes being destroyed with the visible and active threat. The fear of those examples, plus the fear of experiencing health issues such as trouble with breathing, coughing, asthma, etc. can transform into anxiety or depression. World Health Organization stated that severe weather events like dust storms and wildfires can lead to people suffering from depression, anxiety, or post-traumatic stress (WHO 2023). The smaller awareness of dust storms could be due to the speed with which the event passes the people. Also, the amount of dust being spread can make a difference. It is possible that when the amount is minimal, the people might not encounter the dust storm at all. However, the health issues part of the study indicates something different. The percentage of participants reporting health issues caused by a dust storm was 40%. In contrast, only 31.8% of participants reported experiencing health issues caused by a wildfire. Which would point to dust storms as having a greater impact on human lives.

For a better understanding of this topic, a more extensive study would be needed in the future, using different methods to increase its power. With a larger sample size and a more detailed overview of wildfire and dust storm events, a unique and important study would be completed.

7. Conclusion

Dust storms and wildfires are part of the Australian nature and climate. Their impact on human health is a very important topic that more people could focus on in the future. This work aimed to compare these two phenomena and draw a conclusion. However, this cannot simply be said. Many factors suggest that wildfires have a greater impact on Australians than dust storms according to the questionnaire that was sent out. More participants have experienced wildfires over dust storms and more of them encounter wildfires in their lives. A total of 88% of participants reported that wildfires impact their lives more. Alternatively, 40% of people who experienced a dust storm reported at least one health issue, compared to wildfires, whereas from all the people experiencing them, only 31.8% reported at least one health issue. Therefore, it is difficult to announce a final comparison because even though more people are experiencing wildfires and feel more affected by them, the health impacts are stronger due to the dust storms. Dust storms were also found to be the ones, people are not warned about in time, with 50% warned and 50% not. Therefore, in the future, greater emphasis should be placed on informing the population in time.

The most common health problems caused by dust storms and wildfires include coughing, asthma, and eye irritation. Anxiety and depression are among the common health problems caused by wildfires. This study has shown that people do prepare themselves for wildfires and dust storms by using protective equipment such as masks, respirators, or protective overalls.

In the future, climate change is predicted to cause even more droughts and less precipitation in Australia, especially in the south. This increases the need for more studies about the topic. The change in weather will make phenomena like dust storms and wildfires more frequent, and that will put people at greater risk of health problems, or even threaten their lives. Greater focus on understanding the air trajectory movements of the air pollution produced by wildfires and dust storms is also needed. Polar Regions are affected by the pollution initiated from dust storms and wildfires. They are very vulnerable and fragile, so the two phenomena can cause huge environmental problems.

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List of Figures