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The Environmental Impact of Fireworks in the City of Dubrovnik

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Abstract

Fireworks have a long history of commemorating special occasions around the world. What is not often acknowledged is the harmful health and environmental effects that are produced from firework usage. Inhalation of particulate matter (PM) 2.5 μm and release of perchlorate into soil and surface water can cause serious short and long-term issues. The lack of education surrounding firework pollution makes them a silent environmental hazard, causing more harm than realized. A case study was conducted in the city of Dubrovnik, Croatia to better understand both the public's and city's awareness surrounding firework pollution. An interview with a senior maritime advisor of the city of Dubrovnik along with a media content analysis on local media archives were conducted to gain a better grasp of the current awareness. Both the interview and media content analysis revealed that the city of Dubrovnik is unaware of potential firework pollution and the harm presented towards the environment and human health. While noise pollution was a concern regarding animals, no definitive actions were taken to prevent this issue. While the environmental effects of fireworks were not a concern of the city, there are still actions that can be taken to reduce future harm. The first step is conducting primary research to gauge the extent of pollution in Dubrovnik after firework displays. Once this is established as a baseline, solutions can be implemented such as using eco-friendly firework alternatives to reduce the amount of environmental harm.

Keywords: firework pollution, environmental impact, particulate matter, Dubrovnik, eco-friendly fireworks

The Environmental Impact of Fireworks in the City of Dubrovnik

Fireworks are often used to commemorate special occasions; we see fireworks on New Year Eve, on national independence days, and even wedding ceremonies. Some countries have firework festivals, in which tourists travel far distances to see exuberant displays that span hours. Modern fireworks have existed since approximately 1733 and have been used as a form of entertainment from the dawn of their existence. More recently, fireworks have been incorporated into events of all kinds. What is not commonly considered is the aftermath of firework displays, which release various pollutants that can harm the environment, humans, and animals.

This research investigates the potential harm that comes with firework use as a form of entertainment. Continuous use of fireworks may cause long term damage and the extent of it is unknown. One of the main purposes is to better understand the environmental impact of fireworks and possible alternatives to reduce the harmful effects.

Background Information

Fireworks, sometimes referred to as pyrotechnics, are chemical explosions that result in a release of smoke, light, sound, and other tangible and intangible elements. Using a mixture of blackpowder (potassium nitrate, charcoal, sulfur), metallic salts to produce colors, and oxidizing agents such as perchlorate (Russell, 2008), fireworks produce vibrant colors of light in various patterns. Fireworks have fuel and an oxidizing agent interact and propel the shell into the sky, allowing the chemical explosion to take place (Brockmeier, 2019).

Size and Scope of the Firework Industry

The largest manufacturer of fireworks is China, providing around 90% of the global firework supply. The city of Liuyang in the Hunan region of China is a leader in firework production, with more than 1,000 factories that export to over 100 countries (Veverka, 2017). While China exported \$843 million worth of fireworks in 2019, the largest importer of fireworks in the world is the United States, consuming \$368 million worth of fireworks that same year (The Observatory of Economic Complexity, 2019). Some of the largest fireworks displays in the United States happen during Independence Day on July 4th and during New Year's celebrations. Some laws prohibit the use of fireworks for personal consumption in certain U.S. states, though personal fireworks are still commonly used within the country. In 2020, 404.5 million pounds (183.5 million kilograms) of fireworks were consumed within the United States. Of that amount, 18.7 million pounds (8.5 million kilograms) were purchased for personal use. Comparing the consumption of fireworks in 2020 to the year previous, we see an increase of approximately 48% based on the weight consumed in pounds (American Pyrotechnic Association, 2020).

Use of Fireworks in Hospitality and Events

Increasing economic mobility has led to a boom in tourism, hospitality, and travel among most demographics across the globe. The increase in tourism activity has led destinations to prioritize experience and the creation of long-lasting memories as a form of marketing. Fireworks have become a part of the tourism package and serve the purpose of leaving a lasting impression on the viewer. “Through an astonishing pyro spectacle, a memorable way, the traveler learns history, immerses himself in the destination and becomes part of it in an indelible way” (Charoupa, 2017). Destinations with a rich history of using pyrotechnics can profit off of such history. Alternatively, fireworks can be used as a way to commemorate events for a more interactive spectacle.

Health Effects of Fireworks on Humans and Animals

When fireworks are set off, they release particulate matter (PM) that can be ingested and absorbed by humans and animals alike. A majority of the PM released by firework pollution is 2.5 μm (micrometers), which is dangerous due to its ability to enter the bloodstream and deep crevices within the lungs. One element that is commonly used and released in the combustion of fireworks is an oxidizer called perchlorate, which has been found to harm the endocrine system in animals. Perchlorate is known to adversely impact the thyroid gland and its intake of iodine, which is necessary to ensure hormonal regularity. Perchlorate is also known to affect other systems in the body such as the nervous and vascular systems (Li et al., 2014).

When assessing the risk posed to humans, the body weight and height are relevant to the amount of PM considered non-harmful, putting children at the highest risk. A study conducted in Central London tested the PM in the air during the day and night to see changes in potentially toxic elements (PTEs) during and after fireworks displays. It was found that “50% of the inhaled and ingested fine particulate PTEs was found to be harmful to children at night time” and the noncancerous hazardous index (HI) was higher for both children and adults (Hamad et al., 2016).

There is an added risk, as PM can travel through the air, and eventually enter the soil and drinking water. The main concern here is perchlorate, which was detected in 89% of drinking water samples collected in Malta (Debono, 2019) while firework displays were consistently happening. There were high levels of perchlorate in runoff water, which is heavily consumed by wild animals. Along with a PM of 2.5 μm , animals may be at higher risk of inhalation and ingestion. It was found that mice exposed to PM over a short period of time have adverse health effects such as inflammation of the hypothalamus, decreases in oxygen intake, and obesity after a longer period of time (Campolim et al., 2020).

Environmental Impact (Land, Water, and Air Pollution)

Fireworks contain a variety of metals that when interacting with each other produce certain colors. For example, sodium nitrate creates a vibrant yellow color and barium chloride produces a green color. When set on fire and expelled into the night sky, these metal elements get released into the air. Smoke from the fireworks can travel and affect the overall air quality. In the city of Żejtun in Malta, metals from fireworks were found up to ten kilometers away and were present even two-months after the fireworks displays were over (Camilleri and Vela, 2010). These chemicals stay in the soil and seep into groundwater, impacting locally grown produce and drinking water supplies.

To reduce the likelihood of fires, fireworks are often launched over bodies of water. While this reduces the risk of fire damage, this presents a larger risk that debris will contaminate surface water. “The chemicals and heavy metals used in fireworks also take their toll on the environment, sometimes contributing to water supply contamination and even acid rain” (Earth Talk, 2021). There may be risks towards aquatic life and other animals relying on surface water as a drinking source or to sustain life.

Other Impacts (Light and Noise)

Pollutants do not have to be tangible elements such as particulate matter. Both light and noise pollution are present in fireworks and can be detrimental to humans and animals alike. Noise pollution describes harmful levels of unwanted noises that are present and measured in decibels. If a noise reaches 85 decibels or over, it can cause harm to human eardrums which can lead to hearing loss and to partial or total deafness. Additional risks include increased blood pressure, stress levels, irregular sleeping patterns, and heart disease. In animals, it can impact their heart rate, ability to reproduce, and their spatial awareness (National Geographic Society, 2019). Fireworks and firecrackers can produce a significant amount of noise pollution. In order to better understand the harm produced from the yearly Diwali fireworks in India, “a green-cracker lit by Awaaz Foundation and the Maharashtra Pollution Control Board (MPCB) tested 127.6 decibels. It crossed the threshold of pain” (Abdulali, 2021). Sounds above 120 decibels have the ability to immediately cause pain and hearing loss, and repeated exposure to fireworks would then increase the likelihood of prolonged damage to the body.

Light pollution refers to artificial light sources used in the dark that may disrupt the natural patterns of humans and animals. Artificial light can disrupt the circadian rhythm of humans which controls sleep patterns. If disrupted, it can lead to poor sleep, can result in serious health issues, and has been linked to cancer. In nocturnal animals, light pollution affects the visibility of stars and the moon, which many of these animals rely on for navigation (National Geographic Society, 2019). While fireworks may not seem significant enough to alter circadian

rhythm or migration patterns, some firework festivals span hours or are lit consecutively over a period of days, weeks, or months. More research is needed to discover the extent to which fireworks alter the circadian rhythm, migration patterns, and living conditions of both humans and animals.

Eco-Friendly Alternatives

Increased awareness of environmental impacts associated with pyrotechnic pollution has sparked discussion of possible alternatives that may be less harmful to nature as well as humans and animals. Some of the solutions to produce more environmentally friendly fireworks include halting use of perchlorate as an oxidizing agent, no longer using sulfur to propel the fireworks, no longer using chlorine and strontium, as well as smokeless fireworks (Herrer, 2021). There is evidence that shows that the plume size of environmentally conscious fireworks is lower and the amount of PM of 2.5 μm is reduced (Fan et al., 2021). There may be further alternatives that can reduce PM and the release of metals into the atmosphere, though a reduction of the amount of fireworks and duration of the display may be a more effective option.

More modern alternatives to fireworks include laser projections and aerial drone light shows. The advancement of technology and the availability of computer programmed drones makes it a viable alternative to firework displays. In recent years, aerial drone light shows were used for singer Lady Gaga's 2017 Superbowl performance and in the opening of the 2020 Olympic Games (Roets, 2021). While both of these drone performances were put on by Intel Corporation, dozens of similar companies offer drone light shows for weddings, parties, or other events. Aerial drone light shows do not produce smoke and are less harmful to the environment. Laser shows are also a more environmentally friendly alternative to fireworks, producing no tangible pollutants.

Fireworks in Dubrovnik

The city of Dubrovnik in Croatia is one of the top seasonal tourist destinations in Southern Europe. There are a variety of event agencies within the city and region that include firework shows as part of their offer for events, specifically weddings and MICE (meeting, incentives, conferences, exhibitions). The city puts on two official fireworks displays a year, the first being the Opening of the Summer Festival beginning in July, and second being New Year's celebration on January 1st. These long standing traditional events include firework shows as part of their main offer and have for decades.

Prior to the emergence of the COVID-19 pandemic in 2020, use of fireworks for private events was a common occurrence. Starting at the beginning of the tourist season in May, frequent firework displays were visible in various parts of the city. While this may have been from

organized private fireworks displays, some displays were put on by private citizens and unregulated. After January 2021, Croatia enacted a law that prohibited use of category F2 and F3 firecrackers and fireworks for public consumption. This limited unregulated use of fireworks and contributed to stricter safety regulations (Smilović, 2020). This may have contributed to fewer displays post-2020, though the pandemic may have lowered these numbers as well.

The primary goal of my research is to better understand how the city of Dubrovnik processes fireworks, beginning with permitting and regulations to putting on displays and finally any procedures post-event. The main purpose of this research is to understand if there are any environmental regulations put on fireworks by the city of Dubrovnik or other agencies.

Method

The primary goal of conducting qualitative research is to understand the role of the city and other stakeholders in holding firework displays in the city of Dubrovnik. The two methods chosen, interview and media content analysis, are meant to delve deeper and find nuances in both the way the public and city officials regard firework displays.

The first form of qualitative research was an interview with Jelena Dadić, senior maritime advisor of the Department of Tourism, Economy and Sea in Dubrovnik. An informal phone interview was the predecessor to sending 14 written questions, first written in English and then translated into Croatian. These questions specified important information regarding permitting, organizations involved, and post-firework cleanup procedures.

A media content analysis was conducted using local newspapers as a primary source to understand media and community perceptions of fireworks in the city of Dubrovnik. “Media content analysis is a non-intrusive research method that allows examination of a wide range of data over an extensive period to identify popular discourses and their likely meanings” (Macnamara, 2005). For this particular research, understanding the local dialogue happening within Dubrovnik is relevant to the perceived environmental impact, particularly noise and light pollution. An archive search was conducted on four media websites by searching the term ‘vatromet’ (Croatian for ‘firework’). These outlets were Dubrovački Dnevnik, Dubrovački Vjesnik, DubrovnikNet, and DuList, which are all based out of the city of Dubrovnik in Croatia. The search returned 29 articles spanning from 2014 to 2022. These articles were then categorized by content and date.

Results

The articles (n=29) found via media content analysis were categorized by content. The first category is “announcements” which was made up of articles that were announcing a specific

firework display happening in the future. Some of the announcements also included agencies putting on the event, the location, and approximate timing and duration. The second category is “reporting of an event” which reported on a past firework event. This category was broader, including articles in which the fireworks were only a small portion of the text and a larger event was the main topic. The last category was “other” due to the various topics that could fit under a larger categorization. Some of these articles warned about hazards, while other articles promoted a specific company putting on the firework displays. The results of this categorization found 10 articles categorized as “announcements”, 13 articles categorized as “reporting of an event”, and 6 articles categorized as “other”.

The majority of the discourse found during my media content analysis was positive. The words “spectacular fireworks” were mentioned in 5 separate articles. Other terms such as “magnificent” and “impressive” were used to describe the writer’s impression of the firework displays put on in Dubrovnik. There was a sense that fireworks can be alarming and 5 of the articles categorized under “announcements” used the phrase “don’t be surprised” in an effort to warn citizens of upcoming firework events and to not be surprised when they hear the sudden loud booms associated with fireworks.

The aim of this research was to find further information on the local perception of fireworks pollution. Out of the 29 articles, only one article in the “other” category mentioned pollution in regards to fireworks. The main topic of this article discussed the banning of certain types of fireworks in Croatia and the relief for dogs due to noise pollution emitted from fireworks and firecrackers. This sentiment was expressed in the sentence “pyrotechnic devices disturb people and animals and pollute the air and the environment” (Dubrovnik Net, 2021). The extent to which the environment was mentioned ended in this sentence. Another article mentioned the potential fire hazards and risk of bodily harm that fireworks pose to children. All in all, my results were indicative that there is very little to almost no awareness or discussion on the environmental impacts of fireworks in the Dubrovnik area.

The phone interview and written responses from Dubrovnik's senior maritime advisor of the Department of Tourism, Economy and Sea, Jelena Dadić, gave insight to the processes associated with putting on a firework display over the sea. In order for permits to be issued, the microlocation, timing, and reason needs to be adequately proposed to the council for concession approvals, which consists of 3 city or municipality representatives, 1 representative of maritime affairs from within the county, and 1 representative from the port authority. The two agencies responsible for fireworks over the sea are the City of Dubrovnik along with the Administrative Department of Tourism, Economy, and the Sea. For firework displays over land, the Dubrovnik Police Department would need to be contacted for further information. Fireworks displays, both private and public, cannot be longer than 5 minutes in duration. The only exception is during the opening of Dubrovnik’s Summer Festival and New Year’s celebrations, which still cannot exceed

10 minutes in duration. There have been no reported injuries due to fireworks and no official complaints, though some anonymous complaints have mentioned the noise discomfort for animals, mostly dogs. Lastly, there was no information about environmental cleanup or concern for the environment mentioned during both the phone interview or later in a written response.

A short phone interview was later conducted with a spokesperson for the Public Health Department in Dubrovnik. It was confirmed that there is no water testing for pollutants. The local water source is only tested for bacteria, such as e.coli, that cause immediate illness to those who consume it.

Discussion

Due to the nature of my research, there were various limitations that need to be addressed. The first limitation being the time constraints on this research. In order to properly assess the impacts of fireworks in Dubrovnik, I would need more information to paint a clearer picture. This information could have been accessed through public records of permit holders, information from pyrotechnic companies in the area, as well as in-depth interviews with each department involved with the approving firework displays. Gathering such information would have been time consuming, and given the limited time allowed for the completion of this research, I was unable to obtain all relevant information.

The second limitation of my research was the language barrier. Using the Common European Framework of Reference (CEFR), my level of proficiency in the Croatian language is about an A2 (pre-intermediate), while the ability to understand such articles used in my research would need a B2 (upper-intermediate) level or higher. I had to undergo translating articles using online tools, which often cannot express certain phrases or nuances in text with full accuracy.

My last limitation is in regards to my research methods. My research was highly investigative and there was no prior information published on the topic in the Dubrovnik area. When it came to environmental impacts, the research pool became significantly smaller.

After conducting both a media content analysis and an interview with the senior maritime advisor, it is clear that there is a lack of knowledge or awareness of the potentially negative impacts associated with firework displays. There is a small emphasis put on the safety hazards associated with children being around fireworks and the noise pollution that harms dogs, though these seem to be the only concerns. In the city of Dubrovnik, people are deeply connected to fireworks as a way to commemorate events such as the opening of the Summer Festival and New Year's celebration, and the positives seem to outweigh any negatives that the general public is aware of.

It is important to inform the public about these harmful impacts, specifically that of perchlorate as well as the dangerous metals that travel in the plumes of smoke. While firework shows tend to be sporadic, it is important to inform the public about possible health risks, especially towards children, that occur during and post-firework events. To help inform the public of potential dangers, cities can implement campaigns or simply post articles in local newspapers. Increased awareness is the ultimate goal and informing people about the dangers may prompt people to stay home or watch displays from afar.

The research conducted in this paper shows that cities such as Dubrovnik are blissfully unaware of any environmental impact associated with setting off fireworks. One of the first steps that should be conducted is testing the air quality, water sources (both drinking and sea), and soil before and after firework displays to see if there is a significant difference. If there is evidence of elevated levels of the chemicals tested, then eco-friendly alternatives should be considered as an immediate solution. Since Dubrovnik is situated on the Adriatic sea, there is also possible harm that may be happening to aquatic life. Many firework displays in Dubrovnik are put on directly over or near the sea, alluding to the fact that debris and particulate matter is entering the water. While my research did not talk about sea pollution, there may be a significant risk in this area that has gone unnoticed. Sampling of marine animals for common firework pollutants would give insight into whether or not this is a larger issue. Along with this, the local fish that is caught and served for consumption may be impacted by chemicals and pollutants, which is concerning to those who will consume it.

Regarding the overall organization of fireworks in Dubrovnik, the departments involved with both displays over sea and land need to be in better communication with each other. While there seemed to be both concern for fire safety and bodily safety, environmental and health concerns were disregarded. The local Department of Public Health and a local or regional environmental agency should be involved with approving firework displays.

While it is infeasible to get rid of firework shows as a whole, some of the alternatives mentioned in this research paper are viable options. At the moment, drones are costly and not readily available, though they can be used to enhance visual performances. Laser lights and spatial mapping have become more advanced, and create unique visuals using the architecture in its vicinity. While the laser light shows are not a replacement for fireworks, they can be used as an alternative to commemorate events. The last and most realistic alternative is eco-friendly or “green” fireworks. These fireworks use alternatives that are less harmful to the environment and health, as well as produce less smoke. While eco-friendly fireworks do not reduce pollution completely, they are still better than the current fireworks in use. Many of the alternatives used make eco-friendly fireworks more expensive than ordinary fireworks but this is a cost worth paying the price for. The environment and our health is worth a few extra cents in the grand scheme of it all.

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