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Risks to human, animal, and environmental health caused by fireworks

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ABSTRACT
The production of fireworks is old, but it has modernized over time and has new uses. However, the activity has always brought many inconveniences, from simple to serious accidents that can lead to death, besides the environmental damage related to its use. This work carries out a descriptive research on the damage caused by fireworks to man, animals and the environment. The data collection was carried out in the Scopus, medRXiv, MEDLINE, SciELO and Google Scholar and Google Scholar databases. The results showed that, in addition to noise pollution, the use of fireworks is also associated with non-auditory health damage, such as irritation, cardiovascular disease, damage to cognitive ability and sleep disorders. Noise affects many species of amphibians, arthropods, fish, mammals, mollusks and reptiles, and can affect the reproductive cycle of birds. The use of fireworks, in addition to being related to respiratory diseases, due to air pollution, can cause behavioral reactions such as stress and anxiety in animals, and noise-induced panic. In some cases, with pets, just the use of sedatives solves the problem. The handling of fireworks is related to many accidents that mainly affect the upper limbs and the face, causing burns and even amputations, whose main victims are children. Despite all the problems related to fireworks, the authorities are flexible with their use, mainly because they are associated with festivities around the world and, consequently, directly linked to tourism. Intense and continuous preventive education work is necessary.

Keywords: Fireworks; Pollution; Fauna; Flora; Health.

1 INTRODUÇÃO

Fireworks are not new and have been part of history for centuries. Today, their use is an important part and tradition of many festivities worldwide. Most of the population admires the extraordinary spectacles of light and sound fireworks provide. Therefore, they attract and enrich events, happenings, and celebrations. However, many people are unaware of the harms of using these artifacts.

Fireworks are associated with noise and air pollution, affecting humans and several animal species. Moreover, they also impact the environment with their toxic components, contaminating water and soil (SIJIMOL; MOHAN, 2014). Accidents from handling fireworks also impact human health. These can cause severe burns, amputations, vision damage, blindness, and death (SIQUEIRA et al., 2017).

Thus, through a bibliographical study, we aimed to identify and describe the possible damage fireworks can inflict on animals, humans, and the environment.

2 METHODOLOGY

This study comprised qualitative, descriptive, and literature-based research on fireworks damage to humans, animals, and the environment. The theme produced a hypothesis from which we defined the search terms "fireworks", "animals", "pollutants", "birds", "environment", and "burns". Data collection included Scopus, medRXiv, MEDLINE, SciELO, and Google Scholar databases.

3 RESULTADOS

3.1 Fireworks: Yesterday and today

Much of fireworks history has been lost. However, some researchers believe fireworks originated in China in the 2nd century BC, in ancient Liuyang (CLARO, 2019). Others claim fireworks originated between 600 and 900 BC. (APA, s/d), or in 200 AD (THOMPSON, 2014). The

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first natural "rockets" were believed to be made from bamboo stalks that exploded with a bang when thrown into the fire due to the overheating of the hollow air pockets in the bamboo. The Chinese believed that these natural fireworks warded off evil spirits. Thus, they used them at deaths, births, weddings, and many other events (AMERICAN PYROTECHNICS SAFETY & EDUCATION FOUNDATION, s/d; ZHANG et al., 2020). China still uses fireworks for New Year's celebrations, spring festivals, and weddings.

In earlier times, fireworks had a more limited color spectrum. However, with the French chemist Claude Louis Berthollet's (1748-1822) discoveries regarding potassium chloride, this reality changed to include more color spectra. Furthermore, fireworks that used to be ground-based are now aerial (MACHADO; PINTO, 2011).

Fireworks are made of different chemical compounds, in which the atoms accumulate energy when the electrons move around. This energy is released when the electrons return to their normal state, generating exothermic reactions. The varied colors presented by fireworks derive from the characteristics of certain chemical elements which emit the colors. For example, sodium chloride produces a yellow color; copper salts produce a blue color; calcium salts produce an orange color; lithium salts produce a red color; and barium salts produce a green color. Moreover, the mixture of strontium and copper salts produces a lilac color. On the other hand, aluminum and magnesium, both in metallic form and as salts, produce a white color (MACHADO; PINTO, 2011). Today, many metallic salts are mixed with the gunpowder of fireworks to obtain different colors: strontium (Sr) generates a red color; copper (Cu) generates a blue color; sodium (Na) generates a yellow color; calcium (Ca) generates an orange color; and barium (Ba) generates a green color, as shown in Figure 1. Purple can be obtained by mixing strontium and copper. Meanwhile, white can be obtained by mixing magnesium, aluminum, titanium, and silver. Unfortunately, all of these heavy metals and perchlorates released in the burning of the fires are highly toxic (SHI et al., 2011).

Figure 1 - Chemical elements used in making fireworks and their respective colors.

Source: Brunning (2013), adapted by the author.

Fireworks have been an important part of many celebrations for centuries. Festivals using fireworks occur all over the world. Some examples include the 'Lantern Festival' in China (YING et al., 2007); 'Bonfire Night' in the UK (POPE et al., 2016); 'Tihar' in Nepal (BUDHATHOKI; GURUNG, 2020); 'Bastille Day' in France and 'Sky Fest' in Ireland (AMBADE, 2018); 'Diwali' in India (GARAGA, KOTA, 2018); 'Independence Day' in the United States (PRUITT, 2019), and the New Year's Eve in Brazil. All these events are important and involve a large public, moving tourism. In addition, the fireworks display is one of the celebration's attractions.

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3.2 Fireworks: Impacts on human and animal health and the environment

Substances commonly used in fireworks composition include barium, aluminum, lead, salts of mercury, antimony, copper, and strontium. They are eliminated into the environment along with the smoke from fireworks, mainly comprising fine toxic dust that can easily enter the lungs (PALANEESWARI; MUTHULAKSHM, 2012). These substances are especially harmful to infants, children, pregnant women, the sick, and older people. Furthermore, precipitation from the particles produced by fireworks can contaminate water supplies and the soil and be carried into lakes, rivers, or oceans (PALANEESWARI; MUTHULAKSHM, 2012).

The perchlorate used in fireworks production can be released into the air. Then, as a result of precipitation, it gets deposited on land or water. Perchlorate is easily soluble in water and remains stable for a long time under natural environmental conditions. Furthermore, perchlorate deposited in the soil can leach into water or be absorbed by plants through soil moisture, accumulating in plant tissues. Several studies have detected perchlorate in groundwater, surface water, and drinking water after fireworks events (SIJIMOL; MOHAN, 2014).

Perchlorate is dangerous to many organisms because it is a potent thyroid disruptor. It actively inhibits iodide uptake by the thyroid gland, resulting in decreased thyroid hormone production (CHI-CHI, 2016). Therefore, it is dangerous for aquatic organisms that consume contaminated water and animals whose diet consists of aquatic organisms, such as waterfowl and some mammals.

Nitrate is another oxidizing component used to make fireworks. Even though we have not found any studies linking nitrate to environmental impacts, this compound is known to be potentially toxic to freshwater aquatic organisms at high concentrations. Some marine animals are also sensitive to it. In addition, nitrate impacts the conversion of oxygen-carrying pigments (CAMARGO *et al.*, 2005).

The health damage caused by fireworks is also related to noise pollution, which affects animals, children, older people, and the sick. Noise levels can reach 117 dBA, exceeding all noise codes. A 113% increase in respiratory illnesses treated during a fireworks episode was statistically significant (BACH *et al.*, 1975). Moreover, the health damage caused by noise worries authorities in Brazil (WESTIN, 2018).

An estimated 25% of the working population is exposed to Noise Induced Hearing Loss (NIHL). However, noise pollution is also associated with non-auditory health damage, such as irritation, cardiovascular disease, damage to cognitive ability, and sleep disorders (BASNER *et al.*, 2014).

Figure 1 shows the acceptable noise levels in different environments (Figure 1B) according to the NBR 10151 of the Brazilian Association of Technical Standards (ABNT, 2000). In addition, it shows the noise levels that can be reached by several noise sources, including fireworks (WESTIN, 2018). Individuals exposed to high noise levels for prolonged periods, which can occur in certain professions, can develop stress (Silva et al., 2014), despite using personal protective equipment (PPE). Furthermore, when the individual is exposed to other noise sources outside the work environment, such as events with fireworks, the situation becomes even more serious.

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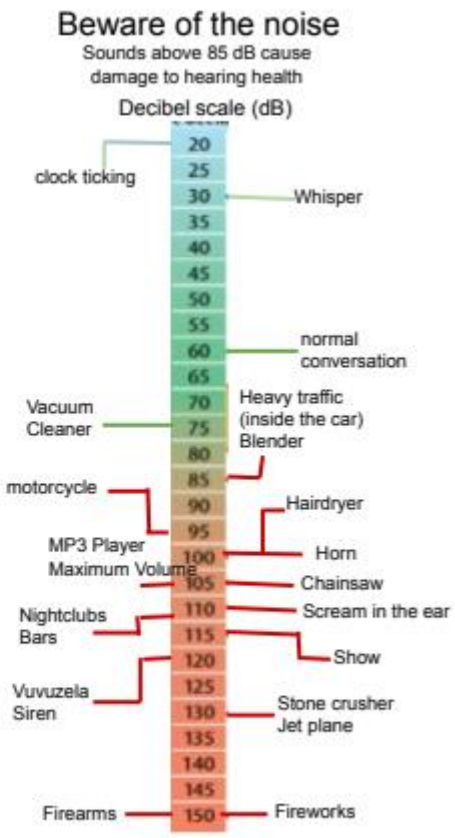
Figure 2 - Level of decibels considered acceptable in different environments and amount of decibels.

External environment*	Values in decibels (dB)	
	Dia	Noite
Rural	40	35
School or hospital	50	45
Only residential	50	45
Predominantly residential	55	50
Predominantly commercial	60	55
Predominantly recreational	65	55
Predominantly industrial	70	60

* Acceptable noise levels are lower indoors. With the windows open, you need to subtract 10 dB from the above values. With the windows closed, 15 dB.



Source: ABNT (2000), Figure 2A; Breaker (2019), Figure 2B. Adapted by the author.

As shown in Figure 2, the acceptable noise levels for the external environment are determined according to the human activity performed. For example, in urban areas with schools, hospitals, and residences, a maximum noise level of 50 decibels (dB) is recommended during the day and 45 dB at night. Meanwhile, acceptable noise levels increase in commercial, industrial, or recreational areas. On the other hand, in the rural environment, noise levels are lower, 40 dB during the day and 35 dB at night, mainly to protect livestock.

Even though humans generally regard fireworks as extraordinary artifacts, the loud noises and unexpected bright lights they produce represent a source of disturbance for many species of domestic and wild animals (SHAMOUN-BARANES et al., 2011). Studies have shown that fireworks represent traumatic events for dogs (LANDSBERG et al., 2003; LEVINE et al., 2007). Moreover, pyrotechnics and gas explosives are often used to disperse wildlife and are employed worldwide as an effective measure in preventing aircraft collisions with birds (GILSDORF et al., 2002; COOK et al., 2008).

Kunc and Schmidt (2019) studied the anthropogenic effect of noise pollution using a phylogenetically controlled multilevel meta-analysis method. They found that noise affects many species of amphibians, arthropods, birds, fish, mammals, mollusks, and reptiles. For example, studies by Gronqvist, Rogers, and Gee (2016) showed that about 80% of the horses evaluated demonstrated anxious or very anxious states at fireworks events. These events most

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commonly cause high-speed running, leading to fence breaking and injuries, including injuries caused by fireworks and injuries to people.

However, birds represent the animals that suffer the most from fireworks, which is demonstrated by several researchers (BERNAT-PONCE et al., 2021; KÖLZSCH et al., 2022; SHAMOUN-BARANES et al., 2011; STICKROTH, 2015). For example, a study conducted in Spain showed that festive activities with fireworks near sparrow breeding areas affect their reproductive capacity (BERNAT-PONCE et al., 2021). In addition, fireworks have been observed to cause a disordered flight of waterfowl, which can fly for up to 30 minutes, fleeing as a response to the noise generated by the fireworks' explosions (SHAMOUN-BARANES et al., 2011).

Disturbances caused by fireworks can be related to the sound or the light effect. However, the main damage is caused by the flash and light surprise effect (storm). Unlike the natural storm, whose environmental changes are perceived by birds, the sound and light of fireworks are associated with hunting, with waterfowl apparently being more sensitive than birds of prey and mammals (STICKROTH, 2015).

Kölzsch et al. (2022) state that birds experience long-term behavioral effects and describe potential consequences by analyzing the trail of migrating wild geese. Due to the noise pollution effect of the New Year's Eve festivities in New York City, USA, geese were observed to fly farther and higher. The behavior continued even during the pandemic period when the festivities were suspended.

In animals, fireworks can also cause behavioral reactions, such as stress, anxiety, and noise-induced panic (MCINTOSH, 2019). In some cases, only sedation solves the problem (CAPILÉ et al., 2014).

In addition to noise pollution, fireworks are related to respiratory diseases due to air pollution. Ambade (2018), in studies conducted during the Diwali festival in the city of Jamshedpur, India, found that these events are marked by a negative influence on ambient air quality due to the emission and accumulation of SO2, NO2, O3, trace metals, and PM10 (inhalable particles, less than 10 µm in diameter that constitute air pollution elements). It can lead to the development of respiratory diseases (BACH et al., 1975).

The June festivities in the Brazilian Northeast, as in all of Brazil, are important for their cultural beauty and typical foods. However, it is associated with several fireworks accidents. During this period, these accidents significantly increase. When people use fireworks improperly, they can suffer severe burns.

Table 1 presents the number of fireworks burn hospitalizations in Brazil between 2008 and 2016. The states of Bahia, São Paulo, and Minas Gerais had the highest number of cases. In addition, accidents with fireworks usually increase by about 10% during the June holiday period (BRASIL, 2022).

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Table 1 - Number of fireworks burn hospitalizations by state in Brazil between 2008 and 2016.

Brasil Hospitalizations for Fireworks Display by State and Year of Attendance										
Estado	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**Total**
Acre	3	1	2	1	2	1	-	3	-	13
Alagoas	-	2	2	4	3	4	5	5	7	32
Amapá	4	5	3	3	3	4	3	6	2	33
Amazonas	3	1	4	2	4	2	3	8	4	31
Bahia	78	75	130	100	118	105	139	112	104	961
Ceará	17	14	13	8	15	19	17	18	12	133
Distrito Federal	11	3	9	9	9	5	14	6	5	71
Espírito Santo	5	3	9	3	8	10	5	12	8	63
Goiás	17	10	11	14	6	7	3	7	7	82
Maranhão	11	2	12	6	9	7	9	13	4	73
Mato Grosso	5	5	5	13	9	15	10	6	18	86
Mato Grosso do Sul	1	1	2	3	5	2	3	6	3	26
Minas Gerais	49	45	58	81	54	105	93	46	109	640
Pará	13	6	14	15	20	18	30	41	42	199
Paraíba	13	14	31	103	9	12	4	7	9	202
Paraná	8	14	36	14	36	11	19	9	16	163
Pernambuco	-	4	10	3	13	15	19	10	10	84
Piauí	19	7	2	5	1	1	1	2	3	41
Rio de Janeiro	29	24	26	42	26	39	72	53	67	378
Rio Grande do Norte	2	1	1	6	7	13	10	14	20	74
Rio Grande do Sul	6	11	11	9	8	14	12	11	21	103
Rondônia	4	2	4	2	5	6	5	3	-	31
Roraima	-	2	3	1	3	-	3	1	3	16
Santa Catarina	9	13	17	15	17	10	18	23	15	137
São Paulo	71	81	87	121	142	84	102	100	62	850
Sergipe	7	5	1	7	6	5	1	8	2	42
Tocantins	-	-	-	1	2	2	2	2	4	13
Total	**385**	**351**	**503**	**591**	**540**	**516**	**602**	**532**	**557**	**4577**

Source: Brazilian Unified Health System (SUS) hospital information system (SIH/SUS). Data from January 2015 to March 2016, subject to rectification.

According to the Federal Council of Medicine (CFM, 2018), there were more than 5,000 hospitalizations due to fireworks accidents in Brazil between 2008 and 2017, which can lead to burns, injuries with lacerations and cuts, and limb amputations (SBCM, 2017).

Siqueira et al. (2017) showed that fireworks accidents are prevalent in the Southeast and Northeast regions, which recorded 38.94% and 38.66% of national cases, respectively. Furthermore, the accident victims are predominantly male (82.64%), and the fatal accidents involve children between one and four years old, where 35.48% are male (70.97%) and 54.84% are in the Northeast Region.

A study conducted in South Africa (SMITTENBERG, 2021) found that the average age of children treated for fireworks accidents is 8.8 years, with 78% being boys, a result similar to that obtained by Siqueira et al. (2017). Moreover, this study found that the body parts most affected are the hands (44%), the eyes (42%), and the face (31%) and that 47% suffer more than one injury. Another study conducted in India during the festival of lights, Diwali, showed that many patients in the hospital were people of all age groups with fireworks injuries. However, most were children between five and 14 years old, and 92% were not under parental supervision (PURI, 2008).

In Sergipe, during the June holiday period in 2019, the Sergipe Emergency Hospital (HUSE) treated 71 burn victims, 46 of whom were victims of fireworks burns. There was a 60% increase in the number of amputations compared to the previous year, 2018 (SERGIPE, 2019).

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4 DISCUSSION AND FINAL CONSIDERATIONS

According to the Statute of the Child and Adolescent (ECA) (BRASIL, 1990), selling fireworks to children, adolescents, and young people under 18 is prohibited, except for artifacts with a restricted capacity to cause physical harm (ECA, art. 81, item IV). However, firecrackers, which have been cleared for sale and are popular with younger children, can also cause harm (MPPR, s/d). According to Siqueira et al. (2017), accidents are related to the type of artifact being handled and how the handling occurs.

Regarding hearing loss, the damage occurs due to the explosion's loud noise. The sound hits the cochlea cells. When too loud, acoustic trauma destroys the hair cells, which are not regenerated.

A study by the World Health Organization (WHO) in 2014 showed that air pollution was responsible for the deaths of more than 7 million people worldwide in 2012, a rate higher than AIDS and malaria combined (PAHO, 2021). Furthermore, Bach et al. (1975), in research conducted in Oahu City, Hawaii, detected a 113% increase in respiratory illnesses treated during an event with fireworks.

In the current pandemic moment, the Sergipe State Department of Health published an alert about the airway damage smoke from fireworks can cause. This condition can facilitate the onset of respiratory infections, including SARS-CoV-2 (MAIA, 2021). In 2020, there was a significant reduction in fireworks accidents due to pandemic restrictions. However, in 2021, there has been a 36.8% increase in cases (SERGIPE, 2021). Even though it is lower than the rate recorded in 2019, the problem is still problematic since cases are underreported, according to the source used.

Public institutions, city halls, fire departments, health departments, and hospitals issue alerts to the population during festive periods. However, such measures are not enough to reduce the number of accidents with fireworks and the damage caused to health, the environment, and animals due to noise and air pollution. Therefore, it is necessary to have continuous and intense preventive education work in health and the environment. Furthermore, inspectors should be more rigorous, and the strictness of the laws should increase, especially regarding protecting children, teenagers, and young people.

In the current pandemic context, the Sergipe State Department of Health published an alert regarding the damage to the airways that can be caused by smoke from fireworks. This situation can favor the onset of respiratory infections, including SARS-CoV-2 (Maia, 2021). When studying fireworks restrictions on certain streets or parts of the city, Chen et al. (2022) found that although the measure has little impact on the air pollution rate, it improves public health by reducing respiratory and cardiovascular disease rates. These results demonstrate that low-cost measures can have an effect on controlling the damage caused by fireworks.

Regarding pets, the suffering is equivalent since they cannot understand and often need sedation on festive occasions. Even though the intention is only to celebrate, fireworks can cause irreparable damage to the affected flora, fauna, and pets. Ideally, fireworks should be handled only by professionals, but for those who still insist on using them, here are some recommendations: verify if the product has the Inmetro seal (National Institute of Metrology, Quality, and Technology); follow the safety instructions on the packaging; keep it away from

poles and electric wires; do not keep fireworks in your pockets or inside your home; do not set off fireworks near your face, or other people or animals; and handle fireworks in areas away from hospitals, homes, industries, and warehouses (ROMUALDO, 2020).

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