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In This Edition

World Safety Organization

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Cover Photo

Some facts on wildfires

- According to federal data published by the National Park Service, people are responsible for 85 to 90 percent of all wildfires in the United States every year.
- According to the National Centers for Environmental Information's Annual 2021 Wildfires Report, fire consumed nearly 7 million acres of wild area during that year.
- According to the National Interagency Fire Center, California has the most wildfires and acres burned in the United States.
- In 1825, one of the greatest fires in recent history raged over Maine and New Brunswick, Canada, destroying 3 million acres of forest.
- Over 100,000 lightning strikes hit the planet every day; 10% to 20% of these lightning strikes result in a fire.
- Every year, an estimated 1.2 million acres of US woods burn.

Retrieved from:
https://www.iii.org/fact-statistic/facts-statistics-wildfires
https://www.dosomething.org/us/facts/11-facts-about-wildfires

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All articles shall be written in concise English and typed with a minimum font size of 12 point. Articles should have an abstract of not more than 300 words. Articles shall be submitted as Times New Roman print and presented in the form the writer wants published. On a separate page, the author should supply the author's name, contact details, professional qualifications, current employment position, a brief bio, and a photo of the author. This should be submitted with the article.

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The application of portable air cleaners in spaces occupied by vulnerable people during wildfire events

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KEYWORDS

Portable Air Cleaner
PurpleAir
Wildfire Event

ABSTRACT

In this study, PM2.5 concentrations were collected and documented during wildfire smoke impacted days using PurpleAir PA-II sensors at three different locations in a community located in the northwestern United States. Each location was comprised of three co-located sensors with one sensor positioned outdoors, one sensor indoors, and one sensor indoors with an air cleaner in the room. The relationship between both indoor and outdoor PM2.5 concentrations provided evidence on the effectiveness of sheltering indoors from wildfire smoke events with and without an air purification system.

1. INTRODUCTION

Increased wildfire frequency and severity throughout the western United States have led to increased human exposure to wildfire-induced fine particulate matter ≤ 2.5μm (PM2.5) (Lydersen, 2017). The mixture of pollutants in wildfire smoke can depend on the geographic location of the burn area (Liang, 2021). Wildfire smoke plumes can travel great distances and settle into surrounding communities (Preisler, 2015).

The Environmental Protection Agency (EPA) has established both a 24-hour and an annual standard for PM2.5 as a component of the National Ambient Air Quality Standards (NAAQS) under the Clean Air Act. These guidelines are designed to protect the general population from increased risk of negative health effects from long/short-term exposure (U.S. EPA, 2020). Most recently, the 24-hour and annual standards have been reviewed by the EPA at 35 $\mu g/m^3$ and 12 $\mu g/m^3$ respectively (U.S. EPA, 2020).

Air monitoring for wildfire smoke is formally conducted through each state, using criteria set forth by the Office of Air Quality Planning and Standards (OAQPS) (U.S. EPA, 2016). Air quality stations are strategically located to represent a large geographic area. Size-selective sampling for PM2.5 is conducted through various EPA reference and equivalent methods in accordance with 40 CFR Part 53 (U.S. EPA, 2016). Low-cost sensors (< $1000) use advancing technology to understand and

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communicate air quality on a consumer level, when compared to reference instruments (EPA, 2021). Consumer monitoring products can be used on an individual level to measure particulate matter concentrations in a variety of locations (EPA, 2021). These consumer devices are widely used across rural areas where formal monitoring does not occur (EPA, 2021).

The health effects of wildfire-induced PM2.5 exposure include coughing, trouble breathing, scratchy throat, headache, and much more (U.S. EPA, 2019). The most vulnerable populations in terms of harmful effects from PM2.5 exposure are the youth, older adults, and the transitory population (U.S. EPA, 2019). As PM2.5 concentrations rise, the common guidance from healthcare officials is to take shelter by staying indoors, keeping windows closed, and using a portable air cleaner (PAC) (Xing, 2016).

Portable Air Cleaners (PACs) aid in the filtration and removal of particulate matter inside buildings. Each PAC is rated for a given room volume, where it can effectively eliminate contaminants with the appropriate filter. The use of HEPA filters can provide the added benefit of reducing airborne particles like dust, mold, viruses, and bacteria. PACs have been demonstrated to significantly reduce indoor PM2.5 concentrations associated with wildfire smoke (Stauffer, 2020).

2. OBJECTIVE

The primary objective of this study was to evaluate the effectiveness of staying indoors during a wildfire event and staying indoors with a PAC operating during wildfire events in settings occupied by traditionally vulnerable groups. Indoor and outdoor air quality measurements were taken at three different sites in a community located in the northwestern United States. Previous research has shown the effectiveness of commercial and "do it yourself" (DIY) PACs at controlling PM2.5 concentrations for office workers exposed to wildfire smoke in this same community (Stauffer, 2020). Each site in this study was selected based on occupant designation (youth, older adult, transient), room size, and proximity to a DEQ county air monitoring station. Ideally, this study was intended to evaluate the effectiveness of each sheltering method, depending on wildfire-induced PM2.5 concentrations. Furthermore, a secondary objective of this study was to compare PM2.5 exposure at each location based on the time of day, and the time spent in each PM2.5 concentration level.

3. BACKGROUND

3.1 Background of PM2.5

The increase in frequency and severity of wildfires throughout the western United States has resulted in an increased average amount of wildfire-induced smoke exposure (Lydersen, 2017). Components of wildfire smoke include gaseous pollutants, water vapor, and particulate matter. PM represents the main component that poses a public health threat. PM2.5, commonly referred to as fine particulate matter, refers to particulates with an aerodynamic diameter ≤2.5µm. Particles of this size will tend to deposit throughout the respiratory tract. A smaller fraction can deposit into the alveolar region of the lungs, which may cause respiratory illness (Li, 2019). Common health effects associated with wildfire-induced PM2.5 can range from coughing and eye irritation to much more severe such as cardiovascular effects. The resultant smoke PM2.5 concentrations are measured by ambient air monitors and samplers located worldwide. The U.S. EPA must regularly update and revise national air quality standards for PM2.5, under the Clean Air Act.

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3.2 Wildfire Smoke Infiltration

The infiltration of wildfire smoke from outside to inside is a major factor that leads to human exposure to PM2.5 indoors during wildfire events (Pantelic, 2019). The infiltration of wildfire smoke has been studied in residential homes, as well as industrial buildings. Infiltration into larger industrial buildings largely depends on the type of ventilation system being used, and the building construction. Pantelic et al. (2019) compared two industrial buildings, one used a mechanical ventilation system with two-stage particle filtration, and one relied on natural ventilation during wildfire events. The particle filtration consisted of a first stage minimum efficiency reporting value (MERV) 8 pleated filter, and the final stage MERV 13 filter (Pantelic, 2019). The building with two-stage particle filtration had a mean indoor PM2.5 concentration of 21 $\mu g/m^3$, and an indoor/outdoor ratio of 0.27 (Pantelic, 2019). The building with natural ventilation had a mean indoor PM2.5 concentration of 36 $\mu g/m^3$, and an indoor/outdoor ratio of 0.67 (Pantelic, 2019). Wildfire smoke infiltration into residential homes is largely due to natural ventilation, and the opening of windows and doors (Barn, 2007). Barn et al. (2007) found that the infiltration factor for 17 homes in British Columbia, Canada during the wildfire season was 0.61 (Nguyen, 2021). Newly constructed homes built with central air conditioning systems were more effective at keeping wildfire smoke out, when compared to older homes in areas of lower socio-economic status (Liang, 2021). Compared to older homes, residences-built post 2000 had lower infiltration ratios during "fire days" (Liang, 2021).

Shrestha (2019) compared the impact of outdoor air pollution from wildfires to the air quality inside low-income housing to determine if indoor areas can be effectively used for PM2.5 protection. Twenty-eight homes were evaluated over two to seven days with air pollutants, including PM2.5, measured to characterize the relationship between indoor and outdoor concentrations. All the homes utilized natural ventilation, which was demonstrated to have a negative effect on indoor air pollutant concentrations due to infiltration of PM2.5 (Shrestha, 2019). The study also evaluated indoor factors such as exhaust stove hoods compared to recirculating hoods (Shrestha, 2019). Homes with exhaust stove hoods demonstrated an indoor/outdoor ratio of 49% less than homes using recirculating hoods and 55% less than homes using no stove hoods (Shrestha, 2019). This study revealed that low-income homes are significantly affected by environmental conditions, road proximity, and indoor behaviors (Shrestha, 2019).

3.3 Health Effects of PM2.5

Health effects of PM2.5 exposure from wildfire sources can range from relatively minor (respiratory irritation), to serious (asthma, heart failure, premature death) effects depending on the concentration, duration of exposure, and individual at risk (U.S. EPA, 2019). The youth (<18 years) are more sensitive to air pollution, and thus wildfire smoke (U.S. EPA, 2019). They spend more time outdoors, are typically more active, and consequently inhale more air during wildfire smoke season (Sacks et al. 2011). Older adults are more susceptible to short-term exposures to wildfire smoke due to an increased number of pre-existing conditions associated with age (U.S. EPA, 2009). Certain defense mechanisms decline with age, resulting in increased hospital admissions for older adults (U.S. EPA, 2009). The transitory population are those of lower socio-economic status at the community level. Transitory populations may not have consistent access to shelter within indoor environments.

Recently published studies on health outcomes in the northwest region of the United States associated with wildfire-sourced PM2.5 provide insight into the potential severity of wildfire exposure on public health. It is known that wildfire smoke can lead to increased hospital admissions for those with pre-existing respiratory health issues (Youssouf, 2014). Orr (2020) studied the long-term effects of wildfire smoke on the most susceptible population, the elderly. The study took place in Seeley Lake, MT, from July 31 to September 18, 2017, during heavy wildfire activity with a daily average PM2.5 concentration of 220.9 $\mu g/m^3$ (Orr, 2020). Health assessments were conducted in the community on 95 participants with an average age of 63 years (Orr, 2020). Follow-up assessments took place in 2018 and 2019 as well (Orr, 2020). The study revealed a significant decrease ($p < .05$) in lung function in 45.9% of the study population one year after the wildfire event, declining to 33.9% of the study participants two years after the wildfire event. (Orr, 2020). The study demonstrated that wildfire smoke has long-lasting effects on human health, and mitigation strategies are needed to reduce exposure (Orr, 2020).

Gan (2018) monitored the air quality from Washington wildfires to evaluate a potential association between adverse health outcomes and increased wildfire smoke exposure. The study was evaluated using a time-stratified case-crossover design and considered one wildfire season from July 1 to October 31, 2012 (Gan, 2018). Geographically weighted ridge regression, a spatial analysis technique that considers non-stationary variables (e.g., physical environmental factors, climate, etc.) and models the relationship between the non-stationary variables and an outcome of interest was used(Gan, 2018). The results showed that a 10 $\mu g/m^3$ increase in geographically weighted ridge regression smoke PM2.5 resulted in an 8% increased risk of asthma-related hospitalizations; however, chronic obstructive pulmonary disease (COPD) was not significantly associated with an increase in PM2.5 (Gan, 2018).

3.4 Low-Cost Air Quality Sensors

Low-cost sensors are used for monitoring atmospheric concentrations of particulate matter at relatively low costs when compared to NAAQS compliance EPA-approved monitors. Most of the low-cost sensors use optical particle counters or photoelectric sensors to detect particulate matter. Photoelectric sensors use infrared light and a photoelectric receiver to detect the presence of an object and to identify its size (AtGrating, 2022). The sensor is aligned with the light emitter, and a change in electrical signal will occur with any obstruction to the light (AtGrating, 2022). This is achieved with the photoelectric effect, where electrons of the passing particle absorb the photon energy (AtGrating, 2022). Optical sensors detect the state of the object and convert that into a light signal (AtGrating, 2022). When a particle passes through a beam of light, the light is scattered and can be measured to determine particle size (AtGrating, 2022). Low-cost sensors have become increasingly popular over recent years, with over 9,000 active PurpleAir aerosol monitors throughout the United States in 2020 (Tsai et al., 2020).

Correction factors for air quality monitoring equipment are essential for eliminating bias and improving the accuracy of the measurement. Barkjohn (2021) evaluated almost 12,000 24-hour averaged PM2.5 measurements collected from PurpleAir sensors, and Federal Reference Method (FRM) measurements from governmental stations across 16 states. This study revealed that PurpleAir sensors overestimate PM2.5 concentrations by an average of 40% (Barkjohn, 2021). A correction factor based on a simple linear regression and the addition of a factor to account for relative humidity reduced bias (Barkjohn, 2021). Overall, the root mean square error was reduced from 8 to 3 $\mu g/m^3$ (Barkjohn, 2021). The results show that the application of a correction factor may improve the accuracy of low cost sensors in air quality applications.

3.5 Portable Air Cleaner Effectiveness

Portable air cleaners (PACs) are designed to filter air in a room at a certain rate, as described by the clean air delivery rate (CADR). The CADR is the product of flow rate and filter efficiency. For example, a high-efficiency particulate air (HEPA) filter with 99.97% efficiency cleaning at 500 cubic

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feet per minute (cfm) would have a CADR of very close to 500 cfm. A HEPA filter in the portable air cleaner traps PM2.5 by drawing air through a high-efficiency filter.

The number of air changes per hour (ACH) represents how often the air is circulated in a specified room volume every hour. The greater the number of ACH, the greater the opportunity for particulate matter and other pollutants to be removed (AHM, 2021). The size of the room where the PAC is placed is an important variable and will influence the number of air exchanges made through the air cleaner. The Association of Home Appliance Manufacturers recommends the following equation for the largest room size that the PAC can be placed in during a wildfire event, depending on the number of air changes desired (AHAM, 2021):

$$Room\ Size\ (ft^2) = \frac{CADR\ (cfm)\ \times 60}{ACH\ \times Ceiling\ Height\ (ft)} \quad (1)$$

There have been several recent studies that evaluated the effectiveness of PACs in reducing indoor PM2.5 concentrations associated with wildfire events. Xiang (2021) studied the effectiveness of a PAC in apartment rooms, and a single-family home, by comparing the particulate matter concentration before and after the intervention of a PAC. The HEPA-PAC was left off for the first day of the study and then turned on in five out of the seven residences for the second day of the study (Xiang, 2021). A CADR of 116 cfm for dust, and 105 cfm for smoke was supplied by the manufacturer. Room sizes in the apartments and one house ranged from 581 ft^2 to 1905 ft^2, and year-built ranged from 1906 to 2019 (Xiang, 2021). The PAC was set to auto-mode, where it was able to switch speed settings (sleep, 1, 2, 3, turbo) based on measured concentrations (Xiang, 2021). Participants in this study were required to report indoor activities such as cooking, smoking, cleaning, candle burning, and window opening, along with the associated timeframe (Xiang, 2021). The study results revealed a 48%-78% decrease in the indoor PM2.5 concentration from using the PAC (Xiang, 2021). This study also suggests and gives relevant data to support the use of auto-mode PACs in the household (Xiang, 2021).

PACs have also been shown to control wildfire-sourced PM2.5 concentrations in the office setting (Stauffer, 2020). The effectiveness of a 3M Filtrete Ultra Clean PAC (FAP02-RS), with a MERV 13 rating, was evaluated by monitoring PM2.5 concentrations with two light scattering TSI Sidepack AM520 instruments each positioned in co-located offices; one with a PAC and one without (Stauffer, 2020). The indoor PM2.5 concentrations were compared with ambient PM2.5 mass concentrations obtained from a National Ambient Air Quality monitoring station located a few miles away (Stauffer, 2020). The results from this study revealed a 73% reduction in PM2.5 concentrations during working hours and a 92% reduction in PM2.5 concentrations during non-working hours (Stauffer, 2020). An office without a PAC was used as a matched control (Stauffer, 2020). The TSI Sidepacks overestimated the PM2.5 concentrations associated with wildfire smoke (Stauffer, 2020). A second outcome of this study was the publication of a ratio correction factor (Stauffer, 2020).

A summary of studies by Barn (2016) suggests that the application PACs should be considered a primary response mechanism to mitigate public exposures to wildfire smoke. The study evaluated health outcomes, such as endothelial function and inflammatory biomarker concentrations, in relation to the efficiency of particulate air filters to remove fine particulate matter from the indoor environment. Allen et al. found that indoor PM2.5 concentrations were reduced by 59% when using a HEPA-equipped PAC during landscape fire events. The 59% decrease in concentration, on average, was associated with improved endothelial function and decreased concentrations of inflammatory biomarkers (Allen, 2011). Correspondingly, research on residential air cleaner guidance shows that the best-documented health benefits come from reducing the amount of PM2.5 in homes (Harriman, 2019).

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Indoor exposures to PM2.5 particles of both indoor and outdoor origin account for about 70%, on average, of the total PM2.5 exposure throughout the United States (Fann, 2016). The study also supports the idea that portable air cleaners are the best way to reduce large amounts of PM2.5 if the central system does not use a MERV of 13 or higher filter efficiency (Harriman, 2019).

4. METHODS

4.1 Data Collection

4.1.1 Equipment

4.1.1.1 PurpleAir Sensors

Multiple PurpleAir-II-SD outdoor air quality sensors were used to measure real-time PM2.5 concentrations in this study. Although labeled as an outdoor sensor, the PurpleAir-II-SD is intended for outdoor and indoor use with an IP68 weather resistance rating. Built-in Wi-Fi allows for all data to be linked to an air quality map for easy data visualization across any smart device. An SD card is available in the instance of loss of connection or logging issues. The sensor utilizes two Plantower laser particle counters that are classified as class 1. Each particle counter stores particle sizes in five different bins: 0.3, 0.5, 2.5, 5.0, & 10µm (PurpleAir, 2022). For this study, we focused on the PM2.5 bin that includes particle sizes ~0.3µm to ~2.5µm. The counting efficiency of each particle counter is 50% at 0.3µm & 98% at 0.5µm (PurpleAir, 2022). The effective range of each particle counter is 0 to 500 $\mu g/m^3$, with a maximum range of 1000 $\mu g/m^3$ (PurpleAir, 2022). Each particle counter is independent of the other, with Channel A and Channel B. Each of the channels is then divided into two data sets, Primary and Secondary (PurpleAir, 2022).

In the PM2.5 bin, channel A & B Primary store mass concentration from count data for particles ~0.3µm to ~2.5µm for both "atmospheric" particles and "standard" particles (PurpleAir, 2022). The "atmospheric" and "standard" delineation is based on two different mass concentration conversion factors, to convert particle count to mass concentration. The "standard" particle entry data uses the "average particle density" of indoor particulate matter, while the "atmospheric" particle entry data uses the "average particle density" of outdoor particulate matter (PurpleAir, 2022). For this study, we used the Channel A Primary PM2.5 "atmospheric" particle entry data based on the characteristics of wildfire PM2.5 composition (PurpleAir, 2022).

4.1.1.2 UNbeaten Air Cleaner

Multiple UNbeaten Pet 300 PACs were also used for this study. This air cleaner is rated for an 800-square-foot room and can refresh air at 5x per hour on the high setting (UNbeatengroup, 2022). It is equipped with H13 True HEPA 5-stage filtration filters that remove 99.97% of airborne pollutants as small as 0.3 microns (UNbeatengroup, 2022). High-efficiency activated carbon accounts for roughly 80% of the filter, which has an estimated service life of 3-6 months (UNbeatengroup, 2022). For this study, each PAC was placed on setting 3 (high) and ran continuously for the length of the study. The clean air delivery rate (CADR), provided by the manufacturer, of the UNbeaten Pet 300 air cleaner is 177 cfm (UNbeatengroup, 2022).

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4.1.2 Sampling Setup

All wildfire smoke PM2.5 monitoring was conducted in a community located in the northwestern United States from August 27, 2021, through October 12, 2021. A total of nine PurpleAir-II-SD air quality sensors were strategically placed at three different facilities, identified by the local health department, and displayed in figure 1.

Figure 1. Facility Locations W/Elevation & Distance to NAAQS Air Station

Each facility was within four miles of the others and located less than three miles away from a NAAQS air station. Facility 1, Facility 2, and Facility 3 were equipped with three sensors each. The sensors were positioned close to standing head height (6 ft.) and attached to the wall. Two rooms were identified in each facility that were matched as close as possible based on volume, ventilation, occupancy, etc. One room in each of the facilities was equipped with an Unbeaten Pet 300 PAC. The PAC was placed on the opposite wall from the PurpleAir sensor, approximately 10 ft away at Facility 1, 15 ft away at Facility 2, and 40 ft away at Facility 3.

4.1.2.1 Facility 1

At Facility 1, a homeless shelter, two 124 ft^2 (992 ft^3) rooms with one window each were selected. A PurpleAir monitor was positioned on the wall furthest from the door to the hallway in each room. A portable air cleaner was placed 8 ft from the floor and 10 ft from the PurpleAir in room 2. Both rooms were located adjacent to each other, and were the furthest away from the indoor kitchen and cafeteria area. The third sensor was hung on the exterior of the building, directly outside of the two rooms and between their respective windows.

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Figure 2. PurpleAir Setup @ Facility 1

Figure 3. PAC Setup @ Facility 1

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Figure 4. Exterior Sensor Setup @ Facility 1

4.1.2.2 Facility 2

At Facility 2, a senior adult assisted living complex, two 460 ft^2 (3680 ft^3) rooms with two larger windows each were selected. Both rooms included a bedroom, bathroom, and closet space in the layout. A PurpleAir monitor was positioned on the wall between the bedroom and the bathroom, in each room. A portable air cleaner was placed on the ground level and 15 ft from the PurpleAir in room 2. The third sensor was placed directly outside the entrance to the building.

Figure 5. PurpleAir Setup @ Facility 2

Figure 6. PAC Setup @ Facility 2

Figure 7. Exterior Sensor Setup @ Facility 2

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4.1.2.3 Facility 3

At Facility 3, a school building, two 1,240 ft^2 (14,880 ft^3) rooms with multiple windows each were selected. A PurpleAir monitor was positioned on the wall midway between the room entrance and the windows, in each room. A portable air cleaner was placed 8 ft from the floor and 40ft from the PurpleAir in room 2. The third sensor was placed at an elevated level, on the exterior of the building. Each room was largely occupied (12 – 16 persons) during the weekdays, and empty on the weekends.

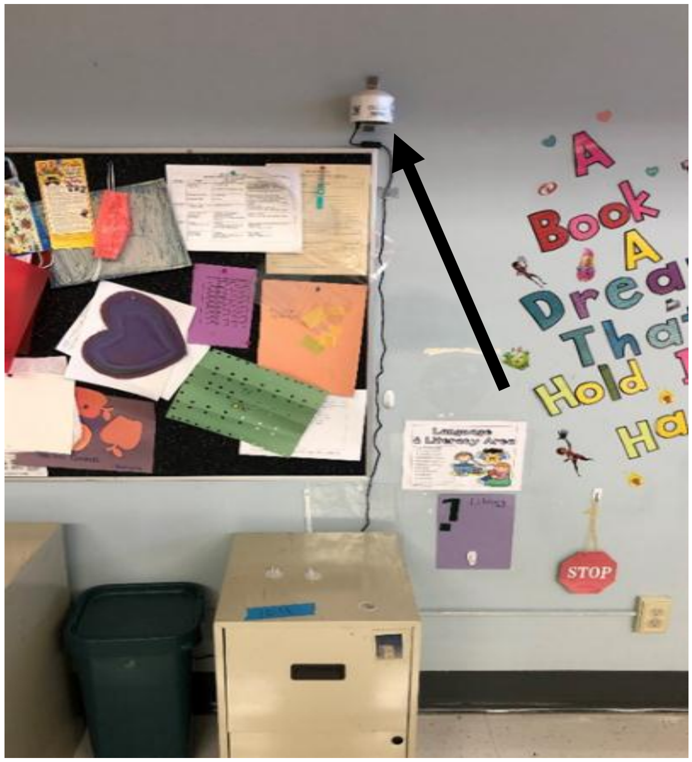

Figure 8. PurpleAir Setup @ Facility 3

Figure 9. PAC Setup @ Facility 3

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4.2 Data Analysis

4.2.1 Smoke Day Qualification

For this study, only data collected during wildfire events where the NAAQS Air Monitoring Station measured ambient PM2.5 concentrations of 50 $\mu g/m^3$ or greater during a 1-hour average, were considered. These were defined as "smoke days." For Facility 1, 11 "smoke days" were considered, corresponding to n=264 hourly concentrations at each sensor location. For Facility 2, 10 "smoke days" were considered, corresponding to n=240 hourly concentrations at each sensor location. For Facility 3, 11 "smoke days" were considered, corresponding to n=264 hourly concentrations at each sensor location. The PM2.5 concentrations measured at each facility were also compared to hourly data from the local NAAQS air monitoring station. A threshold was set to trim the data at ≥5 $\mu g/m^3$ according to the county air station. This threshold trimmed the data to n=234, n=215, and n=234 for Facility 1, Facility 2, and Facility 3, respectively.

4.2.2 Correction Factor

All data, either from the PurpleAir Map or SD cards, was downloaded as 1-hour averages measured in $\mu g/m^3$. After comparing concentration data from the exterior of each of the facilities to the local air monitoring station data, it was evident that the PurpleAir sensors were overestimating the ambient PM2.5 concentrations. A Bland-Altman Plot was used to visualize the difference in concentration measurements between the uncorrected outside measurements and the local air monitoring station measurements. Based on this overestimation, the correction factor equation from Barkjohn (2021) was applied to all data points, excluding the the local NAAQS air monitoring station data.

$$Corrected\ PM2.5\ \left(\frac{ug}{m^3}\right) = 0.524 * \left(PA\ PM2.5\ \left(\frac{ug}{m^3}\right)\right) - 0.0862 * (RH) + 5.75 \quad (2)$$

where PA is PurpleAir sensor data, and RH is relative humidity

4.2.3 Statistical Analysis

Descriptive statistics were used to summarize mean PM2.5 concentrations for each sensor location at each facility. A time series plot was generated at each of the facilities to visually compare the PM2.5 concentrations at each of the sensor locations. The average percent differences were then calculated for: outside vs. inside w/o filter, inside w/o filter vs. inside w/ filter, and outside vs. inside w/ filter at each of the facilities. The percent differences were further categorized based on their PM2.5 range and corresponding Air Quality Index (AQI) description. The total theoretical time spent (hours) in each of the PM2.5 ranges was then calculated for each monitoring location at each facility.

Since data were not normally distributed, a Levene's test was used to test for equal variances between sensor locations at each facility. The null hypothesis was that all variances are equal, and the level of statistical significance was set at $\alpha = 0.05$. A Welch's one-way ANOVA Test, and Games-Howell ANOVA with pairwise comparisons and simultaneous tests were performed for mean differences between indoor w/o PAC, indoor w/ PAC, and ambient PM2.5 concentrations. The null hypothesis was that all means are equal, and the level of statistical significance was set at $\alpha = 0.05$. Finally, Chi-Square Goodness-of-Fit tests were performed on concentration data from each sensor location at each of the three facilities. The expected counts are outdoor concentration data, and the observed counts are

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indoor "no filter" and indoor "yes filter", separately. The null hypothesis was that there was no difference between the expected counts and the observed counts.

5. RESULTS

The mean 1-hour averaged, trimmed, and corrected data for each of the "smoke days" were categorized based on facility and sensor location. These mean concentrations for each sensor location at each facility are summarized in Table 1, with raw 1-hour concentration data in Appendix A. As shown in the table, the average outdoor concentration at Facility 1 was 42.17 $\mu g/m^3$, the average indoor "no filter" concentration was 31.52 $\mu g/m^3$, and the average indoor "yes filter" concentration was 22.67 $\mu g/m^3$. The average outdoor concentration at Facility 2 was 44.79 $\mu g/m^3$, the average indoor "no filter" concentration was 35.88 $\mu g/m^3$, and the average indoor "yes filter" concentration was 21.95 $\mu g/m^3$. The average outdoor concentration at Facility 3 was 42.65 $\mu g/m^3$, the average indoor "no filter" concentration was 37.20 $\mu g/m^3$, and the average indoor "yes filter" concentration was 30.66 $\mu g/m^3$. The measured outdoor concentration differences between each of the facilities can be attributed to geographic location. The measured indoor concentration differences between each of the facilities can be attributed to room size (sqft.), smoke infiltration, occupancy, and other indoor particulate matter contributors. Time-series plots for each sensor location, at each of the three facilities, are provided in Appendix B.

The average percent difference between each 1-hour averaged concentration was calculated for: outdoors vs. indoors "no filter", inside "no filter" vs. inside "yes filter", and outside vs. inside "yes filter" at each of the facilities. Summary average percent difference data are provided in Table one.

Table 1. Summary Average Percent Differences at each Facility

Facility #	Outdoor vs. Indoor "no filter"	Indoor "no filter" vs. Indoor "yes filter"	Outdoor vs. Indoor "yes filter"
Facility 1	-22.12 %	-34.36 %	-50.03 %
Facility 2	-15.00 %	-35.92 %	-47.37 %
Facility 3	-1.45 %	-15.67 %	-21.25 %

The number of ACH were calculated using equation one above, and illustrated in table two below. A CADR of 176.57 cfm was given by the manufacturer, and used in the calculations. The ACH presented below ignore any mechanical or natural ventilation in the rooms.

Table 2. Summary ACH for Rooms at each Facility

Facility #	Room Volume (ft^3)	CADR (cfm)	ACH
Facility 1	992	176.57	10.68
Facility 2	3,680	176.57	2.88
Facility 3	14,880	176.57	0.71

The US EPA and Montana Department of Environmental Quality provide public health advisories or levels of concern based on measured PM2.5 concentrations in community airsheds. The color-coded advisories are illustrated below. The measured duration (in hours) at each of the EPA PM2.5 ranges is illustrated for each facility in Figures 10 - 12. Note that the total time is only based on applicable "smoke days" data.

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- 0 – 12.0 $\mu g/m^3$(Good)
- 12.01 – 35.5 $\mu g/m^3$ (Moderate)
- 35.51 – 55.5 $\mu g/m^3$ (Unhealthy for Sensitive Groups)
- 55.51 – 250.5 $\mu g/m^3$ (Unhealthy/Very Unhealthy)

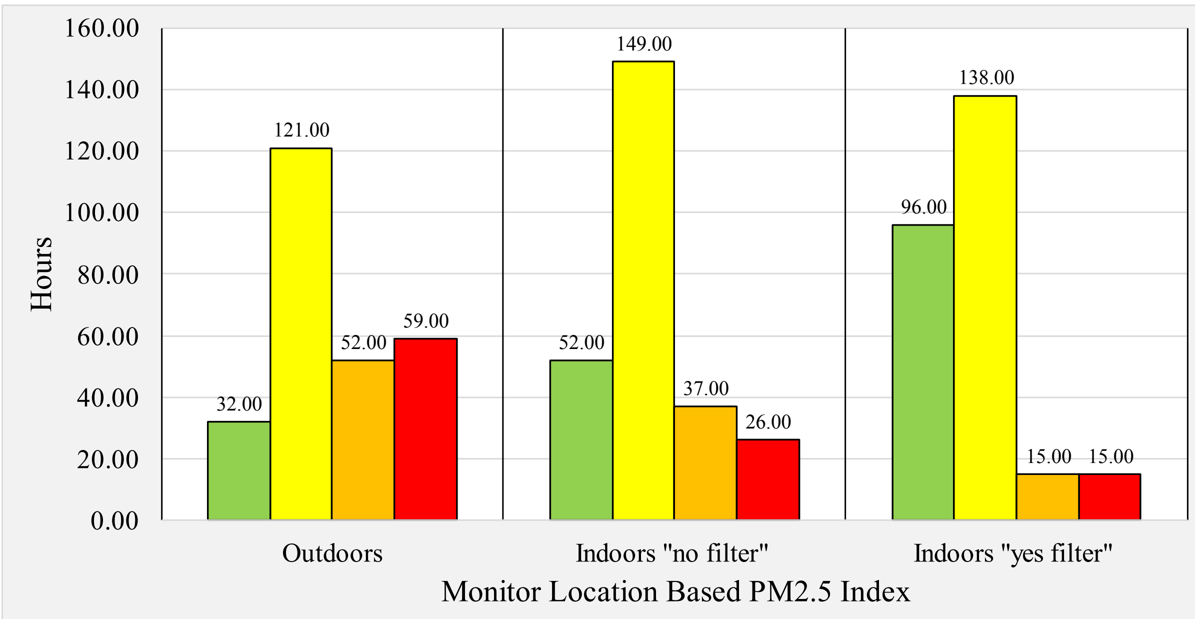

Figure 10. Facility 1 - Time Spent in Each AQI Description Based on Sensor Location

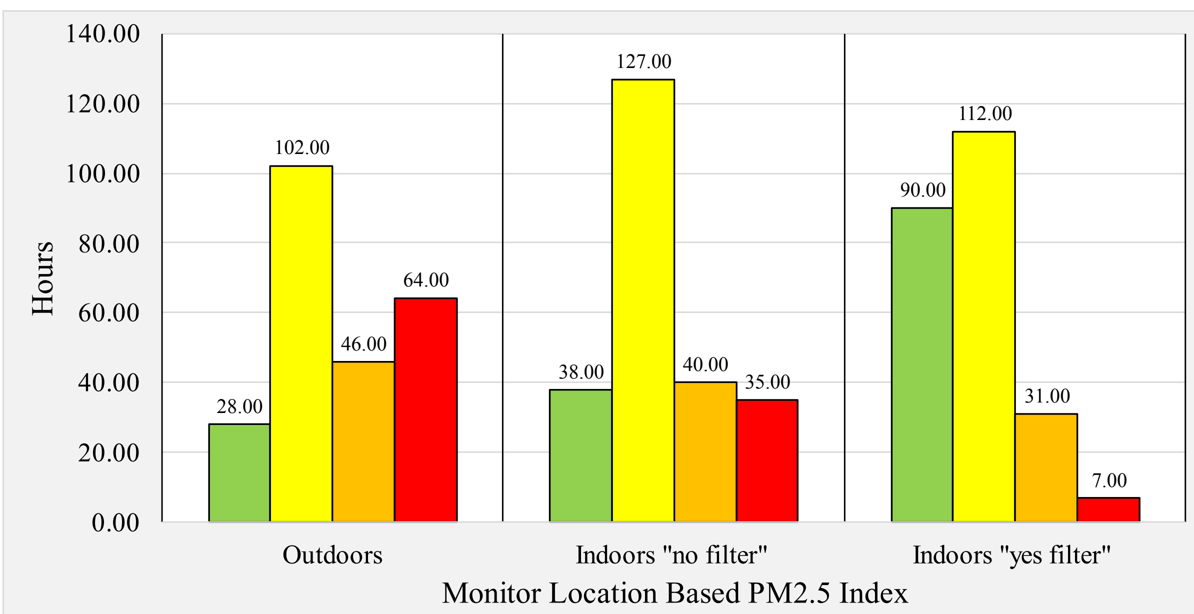

Figure 11. Facility 2 - Time Spent in Each AQI Description Based on Sensor Location

https://doi.org/10.5281/zenodo.8105756

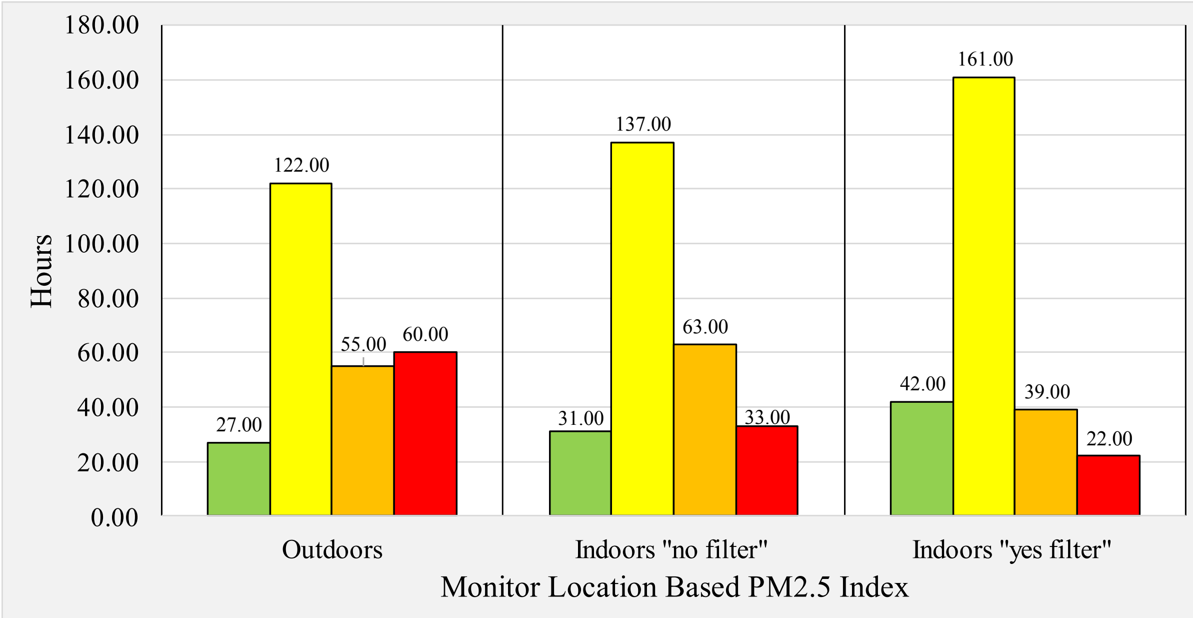

Figure 12. Facility 3 - Time Spent in Each AQI Description Based on Sensor Location

A Levene's test was used to determine if there was homogeneity of variance between the sensor locations at each of the three facility locations. At facility 1, the outdoor PM2.5 concentrations had a significantly different standard deviation ($p < .05$) than both indoor concentrations. At facility 2, the indoor "yes filter" concentrations had a significantly different standard deviation ($p < .05$) than the indoor "no filter" and outdoor concentrations. At facility 3, the outdoor PM2.5 concentrations had a significantly different standard deviation ($p < .05$) than both indoor concentrations.

At least one variance was different for each sensor location at each of the three locations. As a result, a one-way ANOVA was used along with the Games-Howell test to compare combicountries of statistical group differences between the sensor locations at each of the three facility locations. At facility 1, each sensor location was grouped separately, corresponding to PM2.5 concentration means that are all significantly different ($p < .05$). At facility 2, each sensor location was grouped separately, corresponding to PM2.5 concentration means that are all significantly different ($p < .05$). At facility 3, the outdoor sensor and indoor "no filter" sensor were grouped together, while the indoor "yes filter" sensor had a PM2.5 concentration mean that was significantly different ($p < .05$). Interval plots for Facility 1, Facility 2, and Facility 3 are provided below in Figure 13, Figure 14, and Figure 15 respectively.

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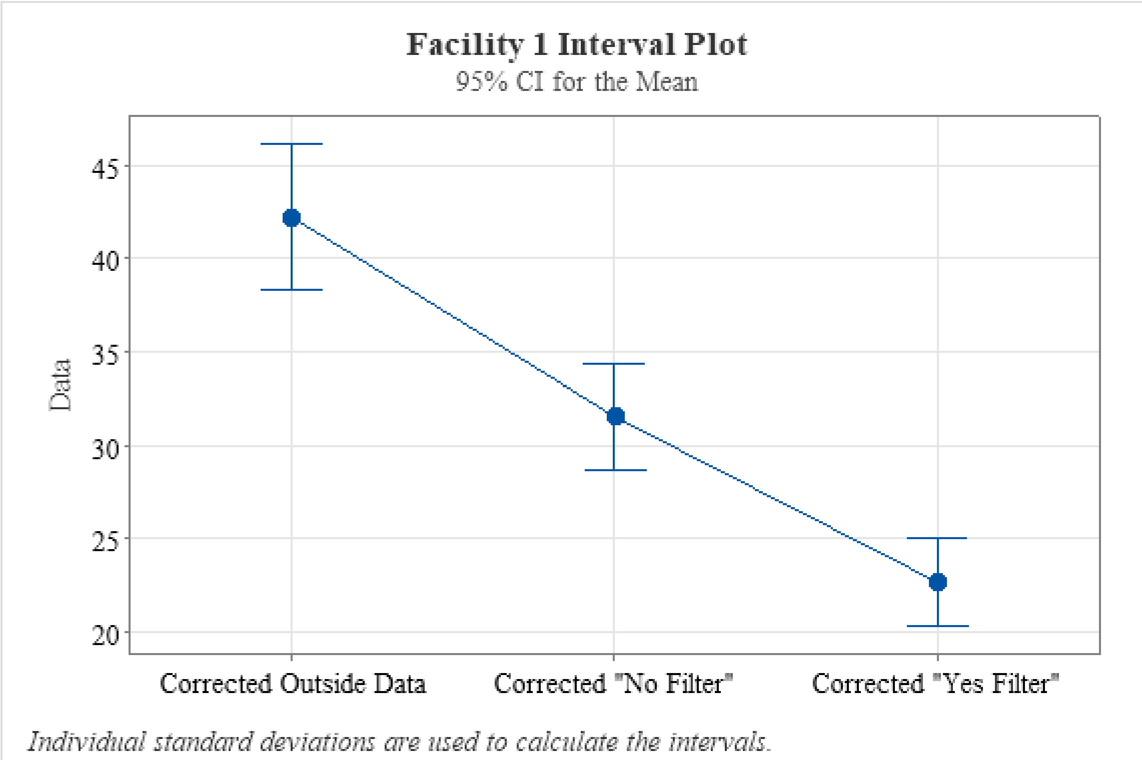

Figure 13. Facility 1 Interval Plot

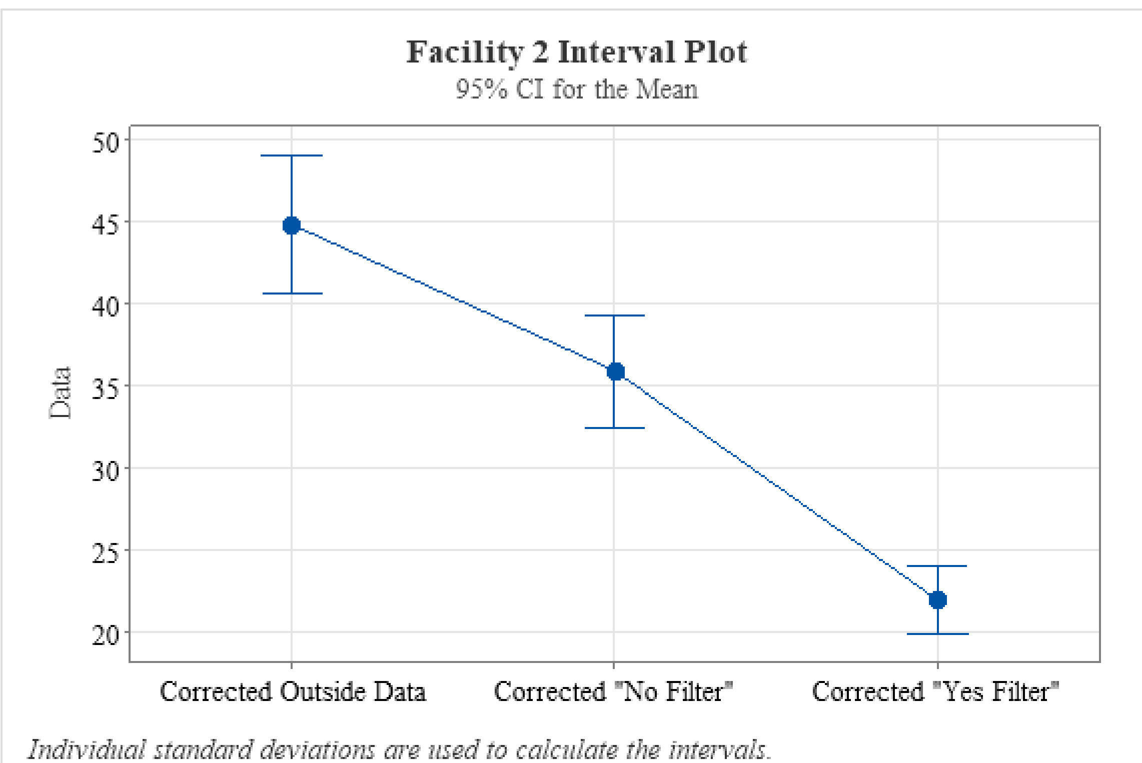

Figure 14. Facility 2 Interval Plot

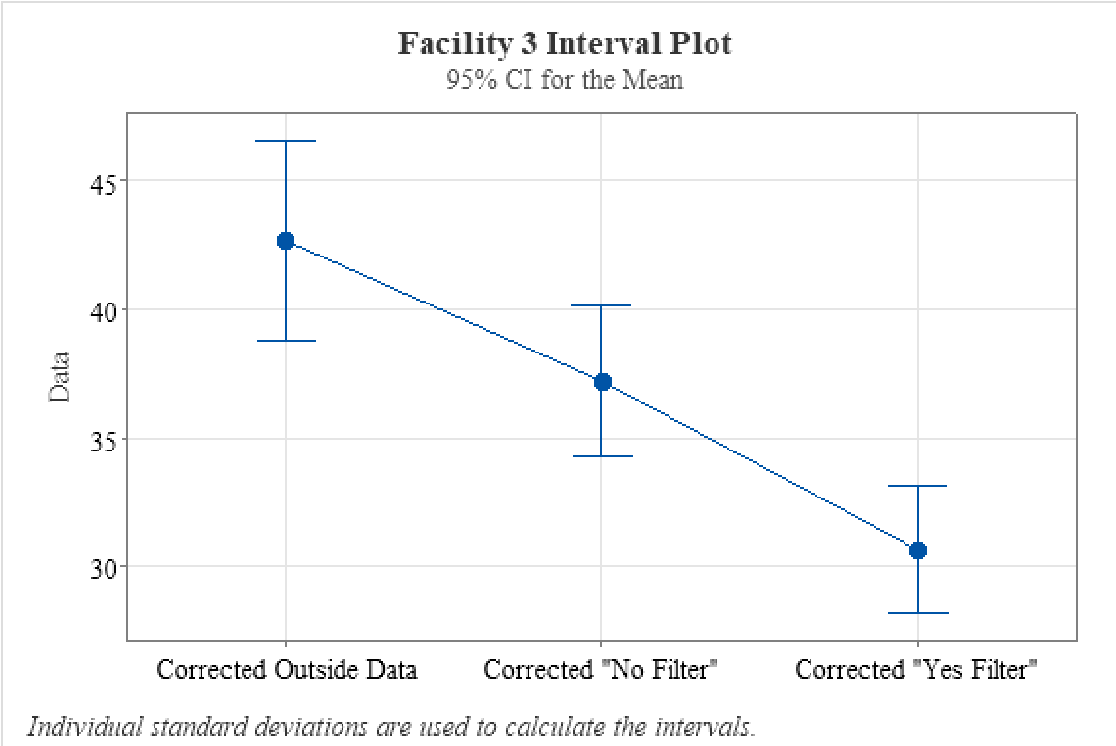

Figure 15. Facility 3 Interval Plot

A Chi-Square Goodness-of-Fit test was performed on concentration data from each sensor location at each of the three facilities. The expected counts at each of the facilities were outdoor concentration data, while the observed counts at each of the facilities were indoor concentration data from either "no filter" or "yes filter" designated rooms. Each test resulted in a significant discrepancy in fit between the observed and expected values. The plots for Facility 1, Facility 2, and Facility 3 are provided below in Figures 16 - 21.

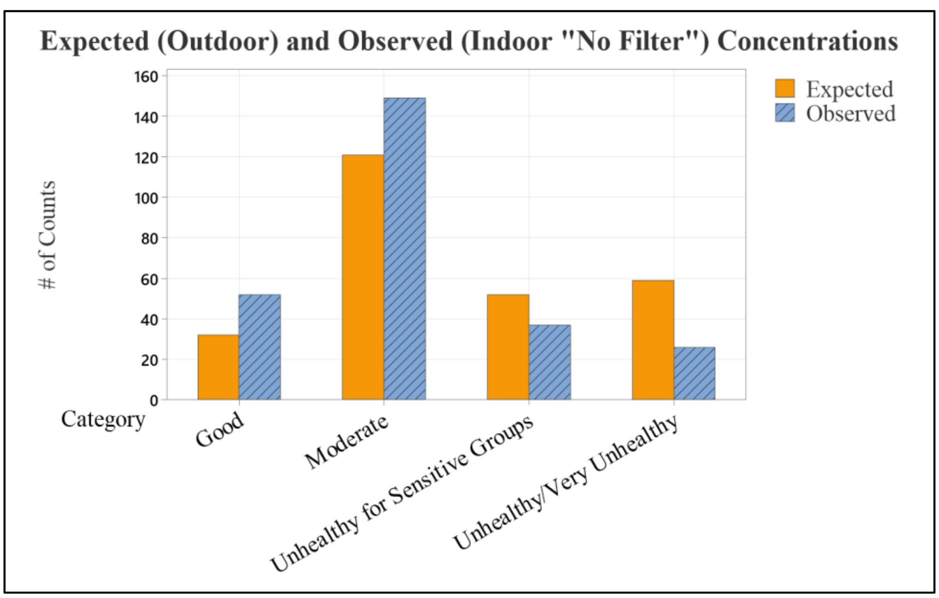

Figure 16. Facility 1 Expected (Outdoor) and Observed (Indoor "No Filter") Concentrations

https://doi.org/10.5281/zenodo.8105756

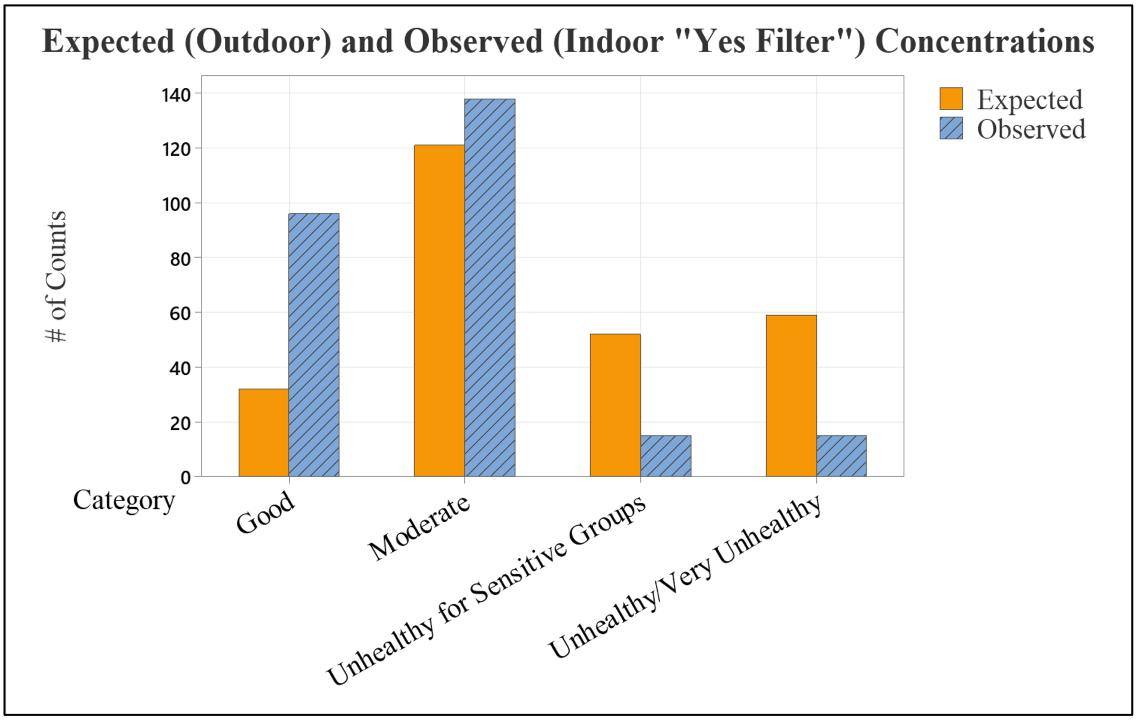

Figure 17. Facility 1 Expected (Outdoor) and Observed (Indoor "Yes Filter") Concentrations

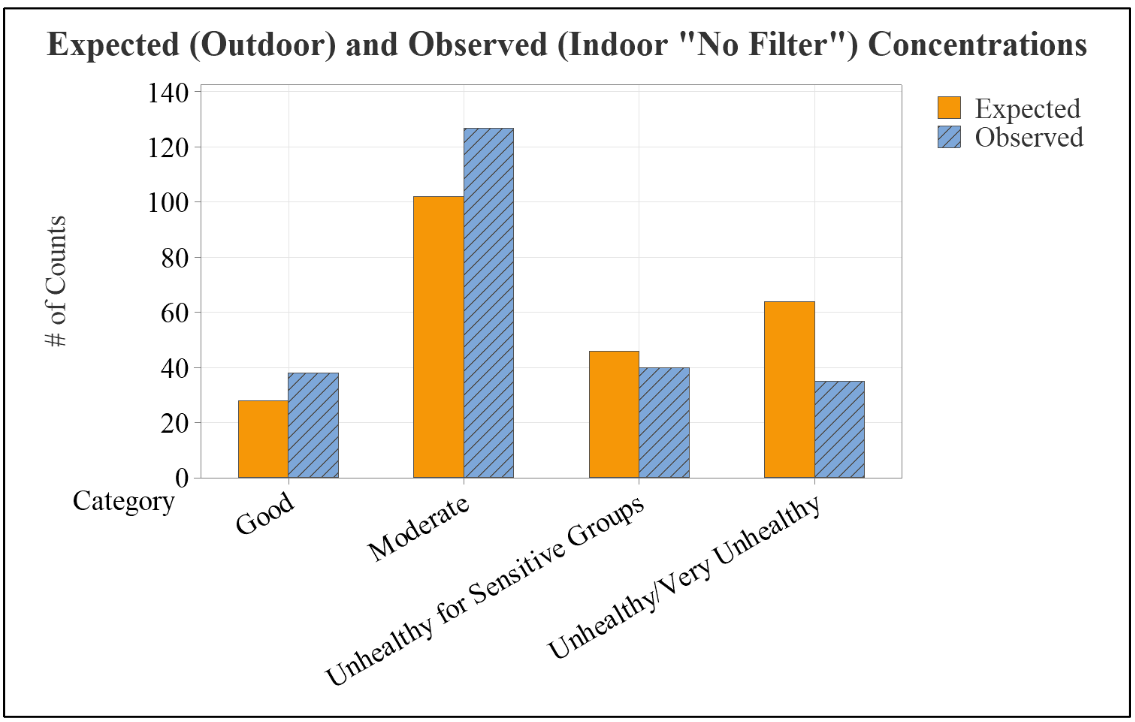

Figure 18. Facility 2 Expected (Outdoor) and Observed (Indoor "No Filter") Concentrations

https://doi.org/10.5281/zenodo.8105756

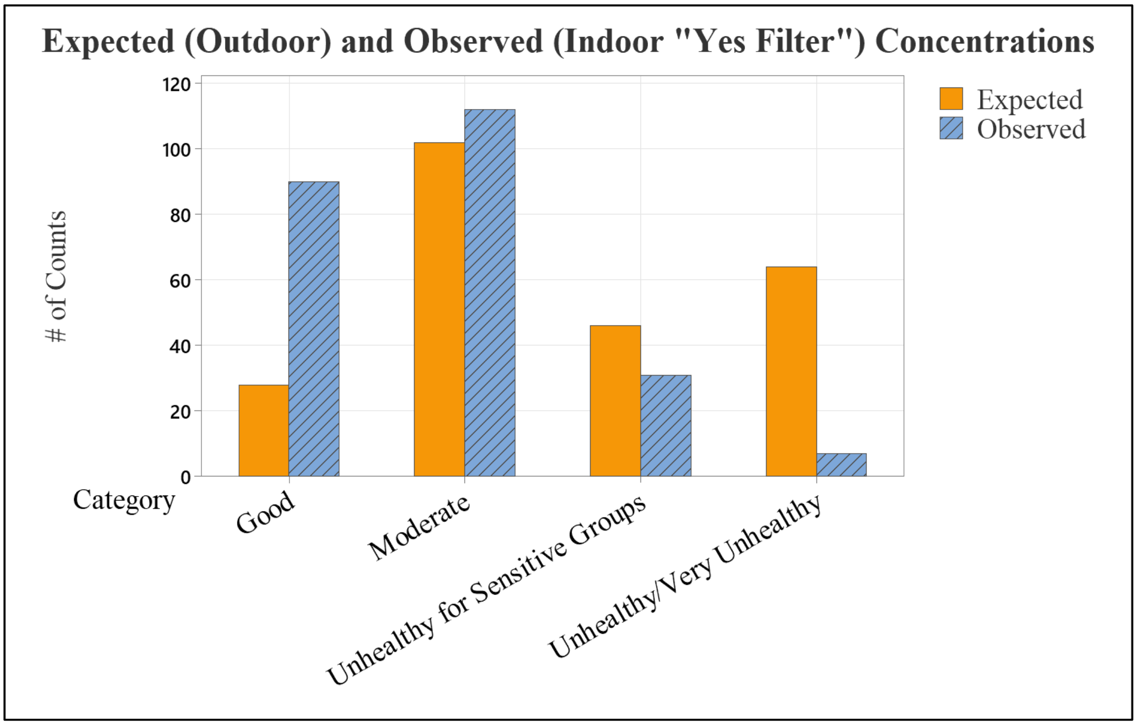

Figure 19. Facility 2 Expected (Outdoor) and Observed (Indoor "Yes Filter") Concentrations

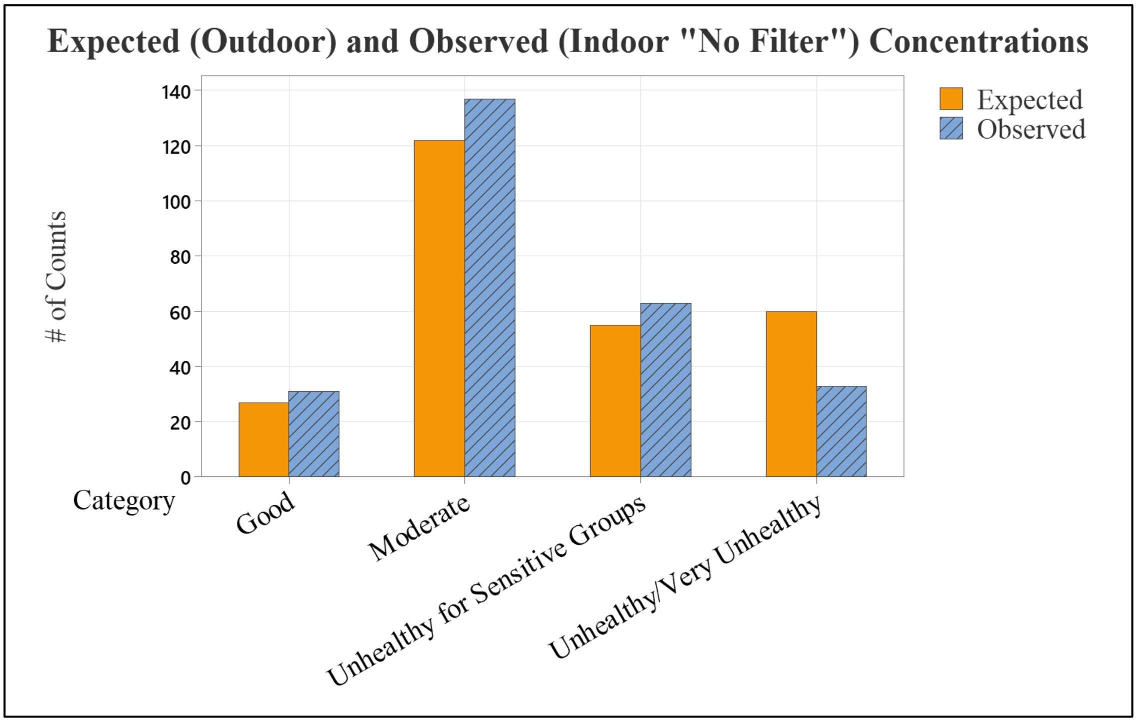

Figure 20. Facility 3 Expected (Outdoor) and Observed (Indoor "No Filter") Concentrations

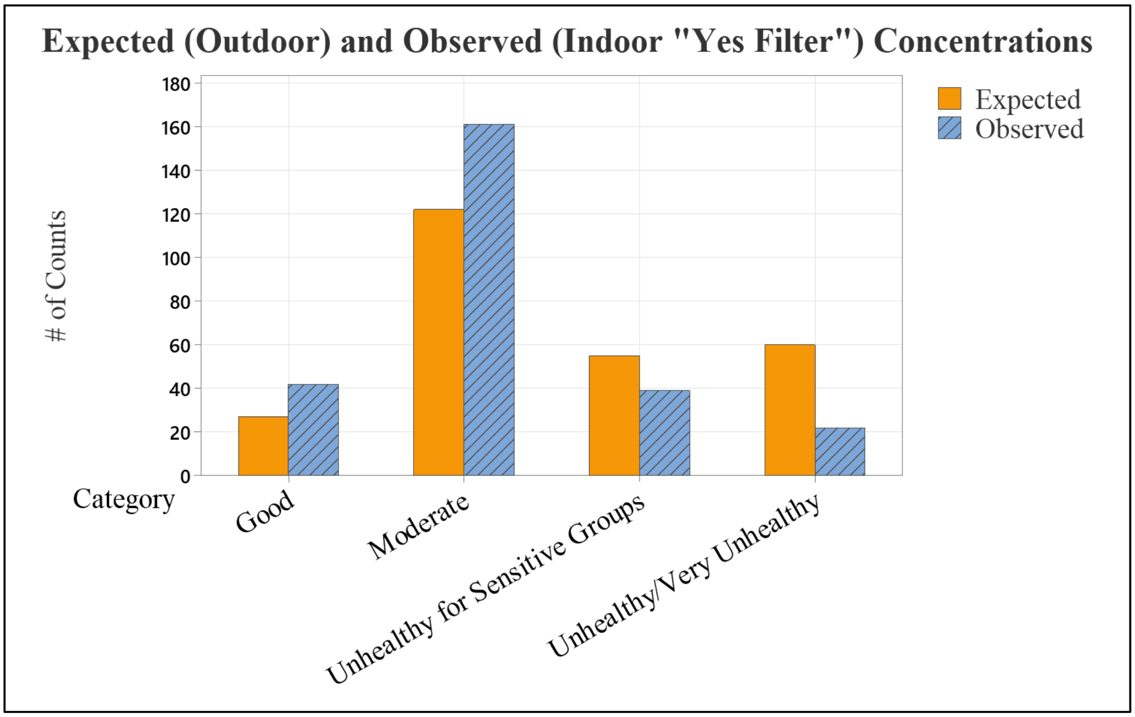

Figure 21. Facility 3 Expected (Outdoor) and Observed (Indoor "Yes Filter") Concentrations

6. DISCUSSION

The primary objective of this study was to evaluate the effectiveness of staying indoors during a wildfire event and staying indoors with a PAC during a wildfire event. The first aim was to compare the mean PM2.5 concentrations at each sensor location, at each of the three facilities. The results indicated that the average outdoor concentrations at each facility were within 6% of each other.

An assessment of the average percent differences between each facility, and corresponding sensor locations revealed that as room volume at each facility increased, the percent difference in PM2.5 concentrations between outdoor and indoor "no filter" sensor locations decreased. Similarly, as room volume at each facility increased, the percent difference in PM2.5 concentrations between outdoor and indoor "yes filter" sensor locations decreased. Overall, a decrease in PM2.5 concentrations was seen while being indoors with or without a PAC.

The second aim was to assess the total amount of time that each population group had spent in each EPA PM2.5 concentration range. Comparing the outdoor and indoor "yes filter" sensor locations at Facility 1, the number of hours spent in the unhealthy/very unhealthy range was decreased from 59 to 15 (74.58% decrease), while the number of hours spent in the good/moderate range was increased from 153 to 234 (52.94% increase). At facility 2, the number of hours spent in the unhealthy/very unhealthy was decreased from 64 to 7 (89.06% decrease), while the number of hours spent in the good/moderate range was increased from 130 to 202 (55.38% increase). At facility 3, the number of hours spent in the unhealthy/very unhealthy was decreased from 60 to 22 (63.33% decrease), while the number of hours spent in the good/moderate range was increased from 149 to 203 (36.24% increase).

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An assessment of the ACH for each room size at facility 1, facility 2, and facility 3 revealed that the UNbeaten PAC was only large enough for the rooms at facility 1 based on a recommendation of 5 ACH minimum (Salimifard, 2020). During wildfire events, the Association of Home Appliance Manufacturers recommends an ACH of 7.5 (AHAM, 2021). Having a higher ACH presents greater opportunities for air pollutants to be removed, resulting in cleaner indoor air (AHAM, 2021).

The relative risk of chronic obstructive pulmonary disease (COPD), lung cancer in adults (LC), ischemic heart disease (IHD), acute lower respiratory infection in children (ALRI), and stroke with PM2.5 exposure has been reported (Burnett, 2014). This information is useful when comparing the time spent in each EPA PM2.5 concentration range, with possible health outcomes. For example, reducing an exposure from 100 ug/m3 to 35.5 ug/ m3 would reduce the relative risk of lung cancer from 1.55 to 1.25 (Burnett, 2014).

6.1 Study Limitations

Each of the facilities are equipped with ventilation systems that are operated/maintained independently. A facility built in recent years with a well-maintained ventilation system will perform more favorable than an old facility with a poorly maintained ventilation system.

Similarly, the infiltration of wildfire-induced PM2.5 can depend on leaving doors and windows open, and the seal around the doors and windows. The occupants of each room at each facility were urged to keep the windows and doors to the exterior closed as much as possible. During regular check-ins, it was noted that the occupant in the indoor "no filter" room at Facility 2 was opening the window throughout the day. There were no other incidents for open windows at any of the other sensor location.

The number of occupants at each facility also differed, with 1-2 at Facility 1, 1-2 at Facility 2, and 12-16 at Facility 3. Facility 1 was only occupied during the night, Facility 2 was occupied during the day and night, and Facility 3 was only occupied during the day.

7. CONCLUSION

This study evaluated the effectiveness of staying indoors during a wildfire event and staying indoors with a PAC during a wildfire event. Previous studies have revealed that portable air cleaners are an effective intervention to decrease the concentration of wildfire-induced PM2.5 indoors. These results suggest that even if a portable air cleaner is not available, staying indoors is still an effective option to decrease wildfire PM2.5 exposure. The use of a PAC greatly reduces the amount of time an occupant is exposed to unhealthy/very unhealthy concentrations of wildfire-induced PM2.5. The PAC performed most efficient at or below its designed room square footage, but still offered a smaller decrease in PM2.5 for the larger square footage.

In terms of the vulnerable population, the indoor PM2.5 concentration should be at or below 35.5 $\mu g/m^3$, as to stay below concentrations that are unhealthy for sensitive groups. Further research should be performed to include a larger number of facilities and sensor locations, potentially including sensors in ventilation/HVAC systems. A potential limitation that may have influenced the PM2.5 concentrations reported is the amount of indoor PM2.5 that was produced during the study period.

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APPENDIX A

Raw 1-hour averaged, trimmed, and corrected concentration data for each sensor location at each facility during all "smoke days" are provided here: Appendix A - Raw Data

APPENDIX B

Time-series plots for each of the three facilities, each including 1-hour averaged, trimmed, and corrected concentration data for each sensor location during all "smoke days" are shown below:

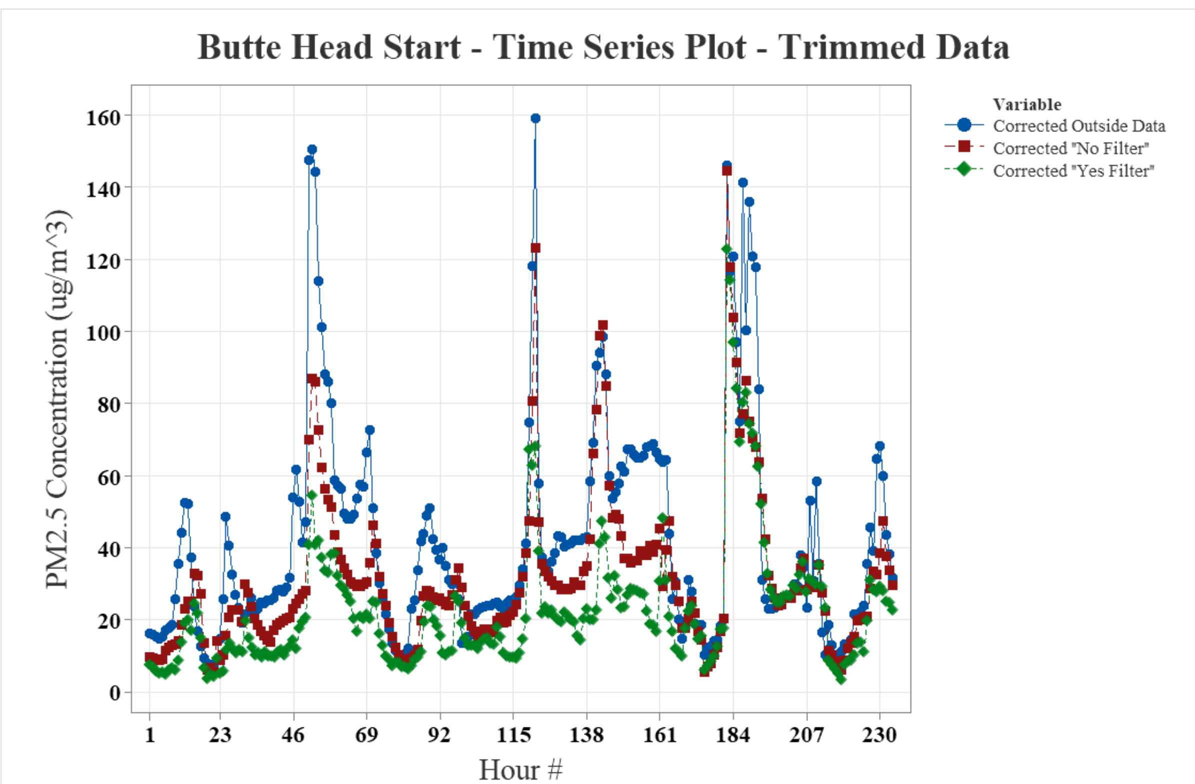

Figure 22. Time Series Plot - Facility 1 - Trimmed Data

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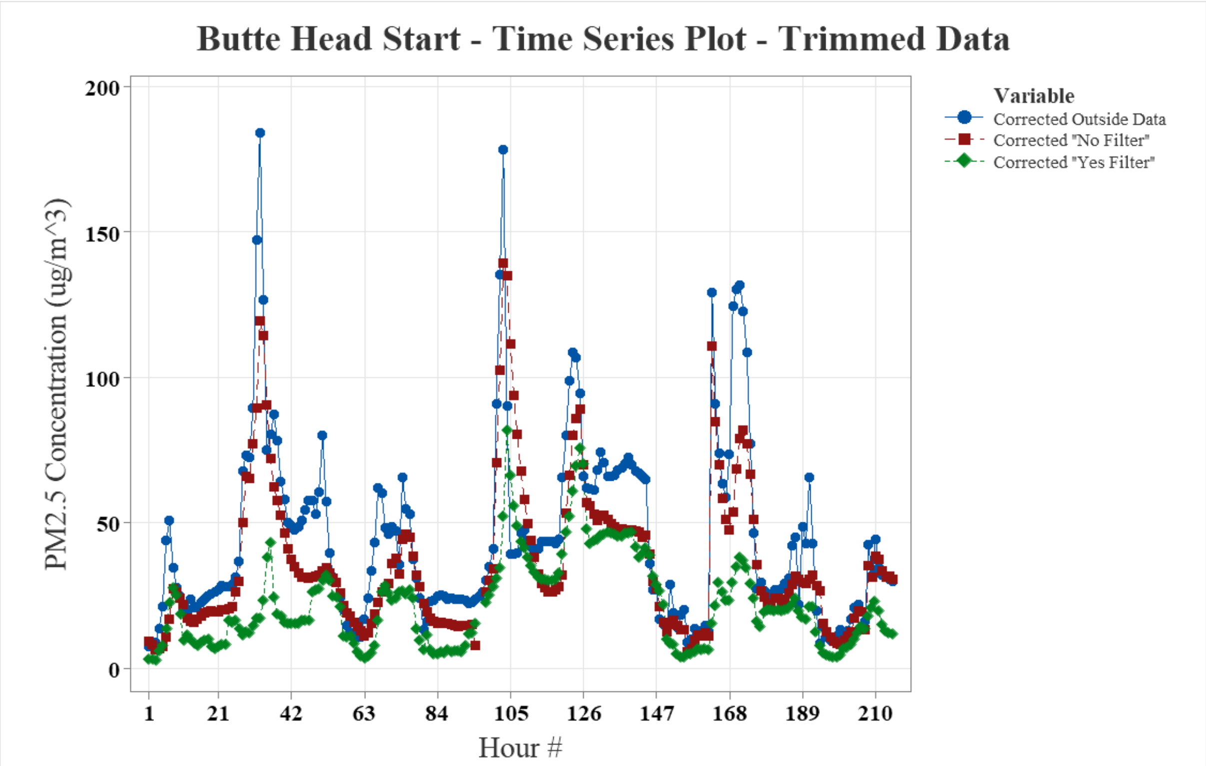

Figure 23. Time Series Plot - Facility 2 - Trimmed Data

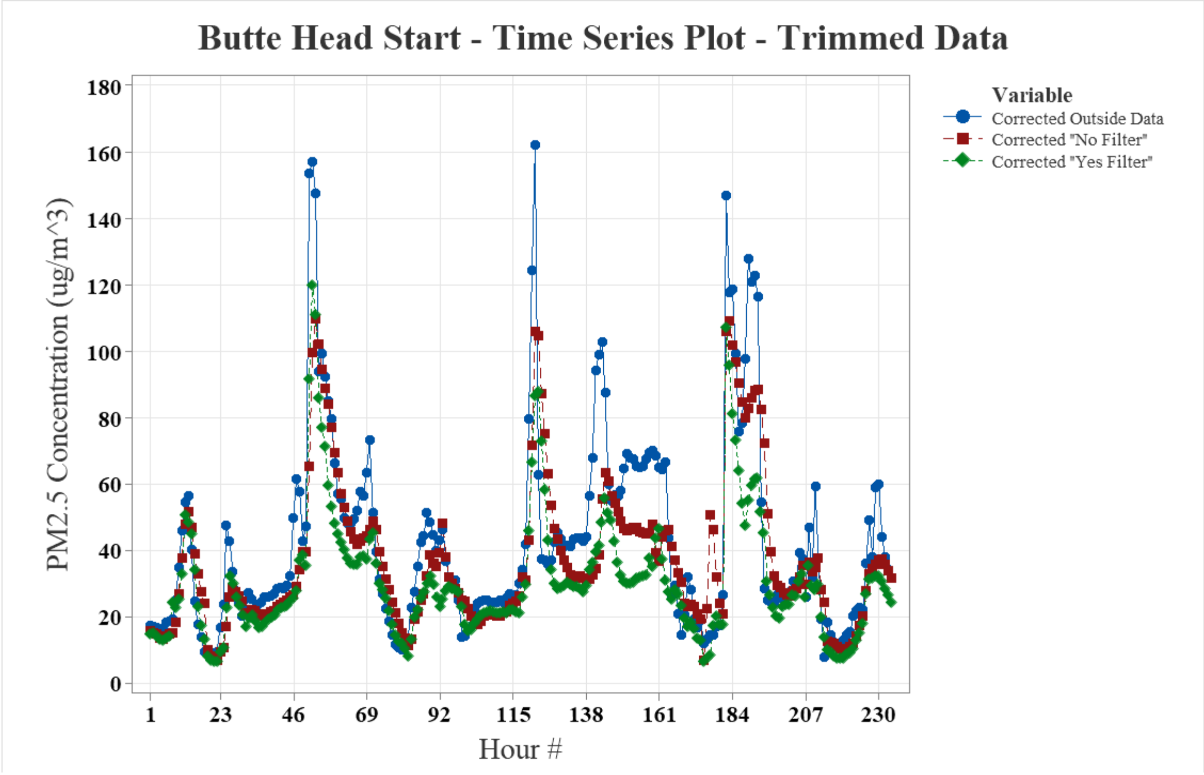

Figure 24. Time Series Plot - Facility 3 - Trimmed Data

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MAIN AUTHOR

Mr. Layne Willis is a graduate student at Montana Tech. Layne earned his bachelor's degree in civil engineering at MSU and, recently, his master's degree in industrial hygiene. Layne worked with Drs. Dan Autenrieth and Julie Hart in the Department of Safety, Health, and Industrial Hygiene. Layne completed his research on the effectiveness of low-tech, low-cost air purification systems for vulnerable populations in the Butte area during wildfire smoke events.

Working with the Bute Silver-Bow Health Department, the team identified three groups: senior citizens at the Springs, the young at Butte Head Start, and the underprivileged at the Butte Rescue Mission. Layne had to first meet his population on a personal level. He placed air monitors and air purifiers in specific locations for two months. Air quality measurements were taken during the two-month smoke season in residences with air purifiers. Findings revealed that staying indoors reduces exposure, and the air purifiers further reduced exposure to harmful air pollutants. The research provides evidence of effective and affordable interventions for disadvantaged and vulnerable citizens.

CITATION:

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Tactical exercises and verification of the effectiveness of crisis planning in the Moravian-Silesian Region. A case study from the Czech Republic

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KEYWORDS

Crisis preparedness
Tactical exercise
Trauma plans
Risk
Extraordinary event

ABSTRACT

Background: Crisis preparation in healthcare facilities should address and resolve both internal and external medical situations. This includes handling the admission of huge numbers of patients during catastrophic disasters, for example. Simultaneously, the management of accidents and disturbances within healthcare facilities, such as fires, power outages, lift functionality, evacuations, and so on, should be managed not only in collaboration with the integrated rescue system, but also in collaboration with higher territorial self-government units, namely regional authorities. The tactical exercises carried out by all components of the rescue system and their preparedness, which frequently show weak places, are one method of testing the efficacy of crisis planning.

Aim: Five tactical exercises were held in the Moravian-Silesian Region from 2015 to 2019 as part of the integrated rescue system's readiness, with the goal of testing the procedures of rescue work in road and rail accidents with a large number of injured people, and then testing the readiness of medical facilities to provide fast, effective, smooth, and well-organized medical care ("launch of the Traumatology Plan").

Datafile and Methods: For the tactical drills, five health care institutions created by the region were chosen. These were volunteer organizations that provided acute inpatient and outpatient care. After reviewing all tactical exercises, it was discovered that communication difficulties, insufficient marking of medical material, the medical team or interveners, and stations were the weak points. Human elements, as well as building and organizational measures in hospitals, proven to be troublesome.

Conclusion: The exercise tested the efficiency and coordination of the integrated rescue system's components, the ability of firefighters to provide first aid to affected people and carry out rescue and recovery work, and revealed the so-called weak points in the trauma plan's activation.

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1. INTRODUCTION

The world's population is constantly encountering, and will probably continue to encounter, extraordinary events that often have a negative impact not only on its activities but also on existence itself, and that includes the consequences of adverse effects on the environment, failure of technology, the economy, and, last but not least, human error. Companies try to prevent the occurrence of extraordinary events or minimize their consequences. The Ministry of the Interior of the Czech Republic has created the Population Protection Concept for 2020 with a view to 2050 (iHETA, 2019). A very important element in the protection of the population is also the level of health care provided by the given country, which is an indicator of its maturity and is determined according to the gross domestic product of the country.

Inpatient medical facilities prepare for emergencies and crisis situations as part of risk management and by creating plans such as trauma plans, pandemic plans, or evacuation plans. In the Czech Republic, after 1989, extensive trauma centers and emergency services were established, which are prepared for the occurrence of extraordinary events. Their task is to eliminate the medical consequences of a mass disaster in cooperation with the components of the integrated rescue system. Mastering the treatment of these serious conditions is ensured mainly by means of prepared trauma plans. These plans are developed for the mass admission of people with various types of disabilities, such as trauma, contamination (biological or chemical), substance intoxication, burns, and radiation effects. Traumatological plans define the tasks and methods of management in the healthcare sector with a focus on activities in the event of mass accidents, describe the activities of the operational centers of the medical rescue service, and provide contacts for healthcare services and facilities (hospitals). It also contains the impacts of selected extraordinary events on the health of the population, including the forces and means for ensuring health care (OSRI, 2019).

2. LEGAL REQUIREMENTS IN THE CZECH REPUBLIC

The obligation to prepare a trauma plan follows the current legislation of the Czech Republic. Inpatient medical facilities and facilities that provide one-day care are required to prepare a trauma plan, in which they adjust the set of measures that are applied in the event of a mass disaster, and to update it at least once every two years. The facility submits one copy of the plan to the relevant administrative authority (regional office, department of health) within 30 days from the date of its processing or updating. Processing is based on local conditions and possibilities and the results of discussing them (Act on Health Services 2011, 47, p. 4758).

2.1 The Trauma Plan

The content of the trauma plan is precisely defined by the applicable legislation and entails three parts: basic, operative, and auxiliary. The basic part defines, in addition to basic data about the organization (hospital), an overview and evaluation of possible internal and external sources of risks and threats to the medical facility and the definition of the provider's scope of activity. The operative part defines the procedures for the implementation of measures for the reception of a mass accident, cooperation with the medical rescue service, and individual workplaces in an inpatient medical facility. Part of the content is also an overview of connections and how to ensure the protection of workers' health. The auxiliary part contains overviews of, for example, concluded contracts with supplier institutions, a list of medical devices, medicines, and medical personnel, labeling principles, records, and other related documents.

However, it is possible to state succinctly that the trauma plans developed by inpatient medical facilities define potential external and internal risks that are present in or close to their organization and may pose a threat to the occurrence of extraordinary events or accidents. They define the contact points for communication with the integrated rescue system, including the characteristics of possible types of injuries and their treatment in the mentioned facility and the possible number of patient admissions in the time horizon. In the final part of the plans, personnel provision, material and technical equipment in the event of an emergency, and the contractual provision of companies in the event of a power outage are specified. Competences are also listed, whether from management to mini-trauma teams in operating and procedure rooms.

Prepared, regularly updated, and reviewed (e.g., tactical exercises) trauma plans must respect and fulfill the currently valid state legislation; however, some risks may still be underestimated. In most cases, existing emergency plans focus on mechanical risks, but it is also worth considering chemical, biological, and radiation risks, which can overload inpatient medical facilities. Threats with biological weapons began to appear in the world (e.g., the war conflict in Ukraine), and with them came preparations for a large intake of wounded contaminated with dangerous substances. An important project was, for example, TOXI-triage, which was based on the concept of dual use, namely multipurpose applications for our technologies within general emergency medicine (toxicity) and the environment. The Horizon 2020 project was also focused on the community and its rescue (Toxi-Triage, http://www.toxi-triage.eu/). The Fire and Rescue Service of the Moravian-Silesian Region took part in this international project.

2.2 Definition of an inpatient medical facility and its function for crisis planning

Medical facility means premises intended for the provision of medical services. Health services can be divided according to the form of health care provided in health facilities into ambulatory, one-day, inpatient, and health care provided in the patient's own social environment (e.g., visiting service, home care, artificial pulmonary ventilation, which can be provided as part of the provision of home care), and subsequently the type of care. Bedside care is understood as (Act on Health Services 2011, 9, p. 4734):

> *health care that cannot be provided on an outpatient basis and requires the hospitalization of the patient for its provision*.

This care must be provided as part of continuous operation. Accurate personnel security, including material and technical equipment for all fields and forms of health care provided, is clearly anchored by the legislation of the Czech Republic. Without compliance with applicable legislation and conditions, inpatient care in healthcare facilities, outpatient care, or home care cannot be provided.

2.3 Risk Management

Risk management in the healthcare sector focuses on preventing the occurrence of potential unwanted and negative consequences of a situation or event (Terje et al., 2018), which may threaten the functionality of an inpatient medical facility to the extent that the crisis situation deepens.

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A crisis is a situation (OSRI, 2019, p. 48):

> *in which the balance between the basic characteristics of the system (the mission, philosophy, values, goals, and style of functioning of the system) on the one hand and the attitude of the surrounding environment towards the system on the other hand is significantly disturbed.*

Currently, within the Czech Republic, medical facilities are constantly preparing to deal with extraordinary events and crisis situations through risk management activities and the creation of, for example, trauma plans, pandemic plans, or evacuation plans. The two basic concepts of all risk management include "danger" and "risk", when:

- Danger is understood as a source of potential harm.
- Risk is the effect of uncertainty on the achievement of goals.
    - The effect is understood as a deviation from the expected (requested), and in general, it can be not only negative but also positive.
    - The goals can then have different aspects (such as financial, health, and safety goals) and be applied at different levels (such as the strategic level or the level concerning the entire healthcare facility and its processes) (Standard Czech, 2010).

The risk management process according to ISO 31,000 is subsequently composed of two parts, namely, "risk assessment" and "risk treatment" (Danihelka et al., 2014). An extraordinary event is defined as:

> *harmful effects of forces and phenomena caused by human activity and natural influences, as well as accidents that threaten life, health, property, or the environment and require rescue and liquidation work. (The Law on the Integrated Rescue System 2000, 7, p. 3464)*

Extraordinary events, both external risks (which trigger a trauma plan or other action requiring a change in the functioning of the device) and internal risks (leading to device function failure, e.g., fire, power interruption), threaten inpatient medical facilities.

2.4 Population's Perception of Risk

Perceptions of risk and actual risks reveal a mismatch between the scenarios we fear and the ones that are really seriously harmful to us. The perception of risk and real danger are described in the work of Susanna Hertrichová (Bernstein, 2018). According to the illustration, the greatest danger for the population is a terrorist attack or air disaster (Fig. 1). At the same time, the real bigger threats are oncological diseases (Institute of Health Information and Statistics of the Czech Republic, https://www.uzis.cz/index-en.php), traffic accidents, the effects of environmental pollution, and even the impact of an asteroid.

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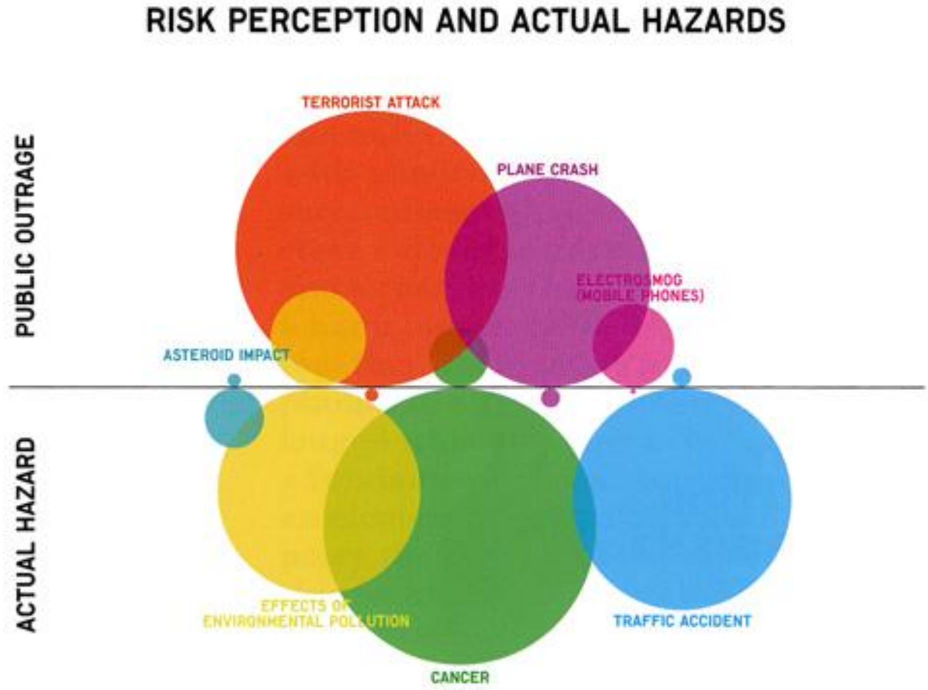

Figure 1. Perception of Risk and Actual Danger (Bernstein, Alison. Risk in Perspective, 2018)

3. VERIFICATION OF THE EFFECTIVENESS OF CRISIS PLANNING IN THE MORAVIAN-SILESIAN REGION

The integrated rescue system in the Czech Republic consists of the basic components, namely the Fire and Rescue Service, volunteer firefighting units, the medical rescue service, and the police. These emergency services are constantly preparing for emergency management, reviewing trauma plans from medical facilities, and conducting tactical exercises. The Health Department of the Moravian-Silesian Regional Authority is involved in the preparation and implementation of these large-scale tactical exercises.

3.1 Participants

The region chose five health facilities to participate in the tactical exercises as contributory organizations. The activity of all participating hospitals within the framework of tactical exercises is the provision and organization of inpatient and outpatient care, namely basic and specialized diagnostic, curative, and preventive care. The total capacity of beds in each hospital was around 450.

3.2 Procedure

As part of the readiness of the integrated rescue system, five tactical exercises took place in the Moravian-Silesian Region in the period 2015–2019, the aim of which was to check the procedures of rescue work in road and railway accidents with many injured people and subsequently the readiness of medical facilities to provide fast, efficient, smooth, and well-organized health care ("launching the Traumatology Plan"). The exercise tested the ability to act and the coordination of the components of the integrated rescue system, as well as the ability of firefighters to provide first aid to injured people and to carry out rescue and rescue work (Figs. 2–4). The aim of the exercise was to practice the method

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of sorting the injured. Among the important results of the exercise was the discovery of a number of possibilities for improvement in the organization of one's intervention and weaknesses, both technical and organizational. At the same time, shortcomings in the field of communication were also revealed.

3.3 Analysis and Results

Evaluation of tactical training and identified shortcomings

In all instances of tactical exercises, poor communication to medical facilities was the obvious cause of the trauma plan's problematic launch and delay. The Regional Operations and Information Center received information about the injured only after the first patients arrived at the medical facility, or the contact point was not informed at all about the launch of the trauma plan. Misinformation also occurred when the number of injured people brought in differed from the reported number and the actual admission to the medical facility, and in one case, the hospital was not informed about the termination of the trauma plan. The interveners who worked at the scene of the accident brought three injured people by themselves in private cars without being informed of the integrated rescue system or moving outside their designated areas in the medical facility, sometimes even complicating the work of the medical personnel. Their cooperation, as well as the cooperation of psychologists in the health sector and security workers who waited a long time for instructions or did not report to the Regional Operations and Information Center, was negatively evaluated. In the case of the first exercise, the telephone connection was overloaded. For other exercises, the medical staff did not report after activation, did not proceed according to the notification decree, but still managed to summon the medical staff after activating the trauma plan within 15 minutes.

Another problematic point was the designation not only of the medical team, including interventions, but also of the material used, which was part and parcel of the integrated rescue system during the initial intervention and was also handed over to the patients during their pre-hospital intervention. This situation resulted in the difficulty of determining the correct records of the used medical material. Among the problems were the lack of reflective vests and, in the first case of tactical training, the medical documentation and administration of the participants in the traffic accident. The masking of the mannequins and their injuries was very authentic, and during the transport there was an inappropriate marking that was insufficiently attached; there was a risk of it being lost during the transport, or the marking was illegible and therefore practically unusable.

The third problematic risk during the activation of the trauma plan included the construction-technical and organizational measures of medical facilities that created problematic areas, the failure to ensure smooth operation of the elevator with the injured, obstacles when handling the injured (e.g., flower pots, inappropriately placed benches, etc.), and very small spaces, for example, for relatives of the disabled.

The medical rescue service evaluated the insufficient marking of positions for the disabled as the most problematic part of the tactical exercise, and the leaders of the intervening functions (e.g., the intervention commander) were insufficiently marked. In two cases, the points of entry to the pre-hospital care station were also insufficiently marked. There was also an inappropriate placement of deceased patients who were close to affected and conscious patients. The shortage was also noted during the intervention in materials such as thermofoil or sorting tapes. In adverse climatic conditions, there is a need to ensure sufficient thermal comfort for patients waiting for triage.

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The failure of human factors occurred in the last case, when the dispatcher of the medical operation center of the medical emergency service did not realize the necessity of activating the traumatological plan of the medical facility and constantly verified the diagnoses that would be admitted to the medical facility as part of a tactical exercise. The dispatcher continuously verified the messages and notified the medical facility in advance of the upcoming exercise.

During the tactical exercises, the Fire Rescue Corps negatively assessed the confusing situation of marking which members of the integrated rescue system perform patient triage and its termination, as well as the interchangeability of the colors yellow and green in the first case of the exercise, resulting in non-marking and missing records of medical materials. There was also insufficient marking of the manhole covers, and the marking of the manhole location was made only by a sign on the tunnel wall at a height of about 3 meters. This marking is invisible to firefighters traveling near the ground when the tunnel is smoking.

For the Czech Republic Police, in two cases there were communication breakdowns between the commander of the intervention, the command of the units, cooperation with medical facilities, and their contact persons for providing data for the identification of people in a traffic accident.

Figure 2. Tactical Exercise: Mass Traffic Accident, 2017. (Fire Rescue Service of The Moravian-Silesian Region, 2017)

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Figure 3. Tactical Exercise: Collision Between A Bus and An Excavator (Kabarová, Ivana, 2018)

Figure 4. Tactical Exercise: Members of The Integrated Rescue System Triage Patients (Kabarová, I., 2018)

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Figure 5. Tactical Exercise: Train Accident in The Tunnel (Fire Rescue Service of The Moravian-Silesian Region, 2019)

At the same time, the Department of Health, Regional Office of the Moravian-Silesian Region, developed a graphic list of the capacities of providers of acute medical inpatient care based on the experience of tactical exercises and trauma plans of individual health service providers. The list consists of the data of health care facilities in the region that provide both inpatient and one-day care, with an indication of all contact points in individual facilities. The acute inpatient care provider is obliged to set up a contact point in order to ensure the patient's admission and the immediate continuation of the provision of health services. At the same time, there is an obligation to ensure continuous transmission of information on the number of available emergency beds to the contact point, information on restrictions on the provision of urgent care, and cooperation in rescue and liquidation work when dealing with extraordinary events and crisis situations when requested by the provider of emergency medical services (Law on Emergency Medical Services 2011, 6, p. 4841). Furthermore, the data in the table informs about the readiness to treat the injured (e.g., burns, trauma) and the number of immediately allocated beds in the event of an emergency in the Moravian-Silesian Region, with the expansion of the capacity of the bed pool within 2 hours and 24 hours. The data is regularly updated and accessible to members of the crisis teams.

4. CONCLUSION

The exercise tested the efficiency and coordination of the components of the integrated rescue system and the ability of firefighters to provide first aid to affected people and to carry out rescue and recovery work. It revealed the so-called weak points in the activation of the trauma plan. The Department of Health, Regional Office of the Moravian-Silesian Region, within the framework of current and still urgent challenges, constantly supports the electronic sharing of data and communication in the health sector and, at the same time, constantly develops projects to improve the quality and safety of the population for the health care provided in the region in cooperation with the integrated rescue system. The support includes financial subsidies for the integrated rescue system, especially for the ambulance service in the Moravian-Silesian Region. The support focuses on further training of health professionals, purchases of ambulances, support for IT systems, and telemedicine, including modernization and strengthening of the resilience of the backbone network of health care providers with regard to potential threats (focusing on acute care—disciplines that are linked to emergency admissions—in order to increase the resilience of the health system). Furthermore, the construction of other urgent incomes, the construction of exit bases and posts, and other important projects in the field of acute and follow-up care

Since November 2018, with the support of the regional authority, the Department of Health, another project, the First Responder System, has been put into operation in the Moravian-Silesian Region, i.e., a system that cooperates between the Moravian-Silesian Medical Rescue Service and volunteer rescuers. First responder is a globally recognized concept of informing and activating trained rescuers in the event of indications of a direct threat to the patient's life. In some cases, registered and trained volunteers can be informed by the operation center about the occurrence of a patient in a life-threatening condition in their vicinity, and the patient can be provided with basic first aid even before the arrival of the medical emergency crew. In conclusion, we also point out that inpatient medical facilities should prepare and rehearse their readiness for all real emergencies that may occur, such as criminal attacks (for example, terrorist attacks, attacks by mentally ill persons, cyber-attacks), interruption of the supply of commodities (energy crisis), migration waves, etc.

5. LIMITATIONS

Another tactical exercise in the Moravian-Silesian region was prepared for the year 2020 to check the trauma plan at the Ostrava University Hospital with the use of highly specialized centers (e.g., the Burn Center). The hospital's bed capacity was around 1,300. Due to other events that hit the Moravian-Silesian region in the period 2020–2022, including COVID-19, the migration wave of refugees from Ukraine, and an emergency that hit the University Hospital in Ostrava at the end of 2019 (the attack of an active shooter), a tactical exercise was held in April 2023. In the same month, another tactical exercise took place with the Integrated Rescue System in a smaller hospital in the Moravian-Silesian Region, the hospital in Blovec.

DEDICATION

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Emergencies, preparedness, and management: a case study of Nigeria

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ABSTRACT

Disasters, whether natural or man-made, have the same effect on society as a whole, causing unwelcome shifts and widespread panic among rescue workers and families who have lost loved ones. The consequences of these panics can only be affected by people's levels of preparedness and their responses to crisis management. The emergency management and preparedness infrastructure in Nigeria is the focus of this paper.

1. INTRODUCTION

Nigeria, like any other country, is subject to a variety of emergencies that necessitate planning and good management. These natural or man-made disasters include the following:

- Natural catastrophes: Nigeria is vulnerable to a variety of natural catastrophes, including floods, droughts, earthquakes, landslides, and extreme weather events such as hurricanes and storms. Flooding is a regular and recurring threat, especially in coastal and flood-prone areas.
- Disease Outbreaks: Like many other countries, Nigeria is vulnerable to disease outbreaks, including epidemics and pandemics. Infectious diseases like cholera, malaria, Lassa fever, and, most recently, the COVID-19 pandemic present substantial problems to public health and emergency management.
- Terrorism and Insurgency: Nigeria has faced terrorism and insurgency, notably in the northeastern region. Boko Haram and other extremist groups' attacks have led in humanitarian crises and population displacement, necessitating emergency response and management.
- Industrial and technological accidents: Nigeria has a diverse range of industries and infrastructure, including as oil and gas facilities, chemical plants, and transportation networks. Pipeline explosions, fires, and chemical spills can all result in situations that demand immediate response and management.
- Civil Unrest and disputes: Communal disputes, political unrest, and civil disturbances can all lead to emergencies that require a coordinated response. Security measures, humanitarian help, and efforts to restore peace and stability are frequently required in these situations.

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2. OBJECTIVE OF THE STUDY

The objective of investigating disaster preparedness and response in Nigeria is to obtain a complete understanding of the country's current state of readiness, identify strengths and shortcomings in existing systems, and suggest improvement measures. The study's goal is to provide a complete assessment of Nigeria's present state of emergency preparedness and response, as well as to offer evidence-based suggestions for strengthening the country's ability to manage catastrophes efficiently and protect lives and infrastructure.

3. EMERGENCIES, PREPAREDNESS AND MANAGEMENT: THE CONCEPTS

3.1 Emergency Management Laws and Policies

In Nigeria, emergency management is primarily governed by the National Emergency Management Agency (NEMA) Act of 1999, which established the National Emergency Management Agency as the legislative authority responsible for disaster and emergency management in the country. The NEMA Act defines the agency's authorities, functions, and organizational structure.

NEMA is responsible for organizing and facilitating disaster management actions throughout Nigeria under the NEMA Act. It works with state emergency management agencies and other stakeholders to plan for, prevent, mitigate, respond to, and recover from disasters and emergencies.

Other laws and policies in Nigeria that support emergency management activities, in addition to the NEMA Act, include:

- The Civil Defense legislation: This legislation created the Nigeria Security and Civil Defense Corps (NSCDC), which aids in disaster management, particularly in the areas of civil defense and key national infrastructure protection.
- The Fire Service Act: This act establishes and regulates fire departments in Nigeria. It defines the roles of fire departments in responding to fires and other situations involving hazardous chemicals.
- The Quarantine statute: This statute gives the Federal Ministry of Health the authority to take steps to prevent the introduction and spread of contagious illnesses in Nigeria. It establishes a legislative framework for dealing with public health crises and outbreaks.
- The Environmental Impact Assessment (EIA) Act: While not specifically aimed for crises, the EIA Act mandates project developers to conduct environmental effect assessments before engaging in certain operations. This aids in the identification of potential risks and the implementation of appropriate risk mitigation strategies.
- State-level laws and policies: To supplement the national framework, certain Nigerian states have implemented their own emergency management laws and policies. The scope and content of these laws may differ between states.

It is worth noting that, as a federal republic, Nigeria has a decentralized emergency management system. While NEMA serves as a national coordinator, state emergency management agencies are responsible for emergency management actions within their respective states.

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3.2 Entities involved in emergency preparedness and response

Emergency preparedness and response in Nigeria require the coordination and collaboration of multiple entities at the national, state, and local levels. These organizations perform distinct roles in the preparation, execution, and management of emergency operations. The following are the important entities in Nigeria involved in emergency preparedness and response:

- National Emergency Management Agency (NEMA): NEMA is the key agency in charge of national emergency management. Its mission is to coordinate and supervise disaster management activities such as preparedness, response, and recovery. To guarantee successful emergency response, NEMA works with other government agencies, non-governmental organizations, and foreign partners.
- State Emergency Management Agencies (SEMAs): In Nigeria, each state has its own State Emergency Management Agency in charge of emergency preparedness and response within their respective domains. SEMAs collaborate closely with NEMA and other relevant stakeholders to establish state-specific emergency response plans, coordinate resources, and put disaster management strategies into action.
- Local Government Emergency Management Committees (LGEMCs): These committees are formed at the local level to help with emergency planning and response operations. To achieve efficient emergency management within their territories, LGEMCs collaborate with SEMAs, community leaders, and local stakeholders.
- Nigerian Security and Civil Defense Corps (NSCDC): The NSCDC is critical in emergency response, particularly in security and civil protection crises. During an emergency, they provide security, crowd control, and support in maintaining law and order.
- Nigerian Police Force (NPF): The Nigerian Police Force is responsible for emergency response, law enforcement, and public safety during emergencies. They collaborate with other agencies to keep security and order in affected areas.
- The Nigerian Armed Forces, which include the Nigerian Army, Navy, and Air Force, are active in emergency response, notably in cases of terrorism, insurgency, and civil disturbance. They help to maintain security, execute rescue operations, and supply humanitarian supplies in disaster-stricken areas.
- Health and Medical Services: The Federal Ministry of Health, state health ministries, and healthcare facilities, among others, play critical roles in emergency response, notably in disease epidemics and public health emergencies. During an emergency, they provide medical help, disease surveillance, vaccination programs, and other healthcare services.
- Non-Governmental groups (NGOs) and Humanitarian Organizations: A number of NGOs and humanitarian groups operate in Nigeria, assisting with emergency planning and response. These organizations play an important role in delivering humanitarian aid, carrying out relief activities, and assisting affected communities.
- International Organizations and Donors: During emergencies, international organizations such as the United Nations, World Health Organization (WHO), International Red Cross and Red Crescent Movement, and numerous donor agencies contribute assistance, knowledge, and resources to Nigeria. They help with capacity building, resource mobilization, and coordination.

Effective emergency response and preparedness necessitate strong cooperation and collaboration across these agencies. They collaborate to ensure that emergency responses are well-coordinated, prompt, and efficient, thereby saving lives and reducing the impact on affected populations.

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3.3 Phases of Emergency Preparedness and Management

In Nigeria, emergency preparedness and management often take a multi-stage strategy with numerous stages. While nomenclature and classification may differ, the following are the frequently recognized phases of emergency preparedness and management:

- Prevention/Mitigation: This phase focuses on initiatives that try to prevent or mitigate the effects of disasters. It entails detecting potential hazards, assessing risks, putting mitigation measures in place, and increasing resilience in communities and key infrastructure. Land-use planning, construction standards, environmental protection, public awareness campaigns, and education initiatives are examples of mitigating strategies.
- Preparedness: The phase of preparation entails creating strategies, procedures, and resources to successfully respond to calamities. It entails tasks including developing disaster response plans, training and drills for emergency personnel, establishing communication systems, stockpiling necessary equipment and supplies, and coordinating with important parties. Preparedness programs attempt to improve reaction skills and provide a quick and coordinated response in the event of an emergency.
- Response: The initial activities done to address the effects of an emergency or disaster are referred to as the response phase. Its primary goals are to save lives, protect property, and stabilize the situation. Emergency evacuations, search and rescue operations, medical help, building up temporary shelters, delivering emergency supplies, establishing emergency operations centers, and coordinating the response efforts of multiple agencies and groups are examples of response activities.
- Recovery: After the urgent response activities are completed, the recovery phase begins. It entails attempts to reconstruct and repair damaged communities, infrastructure, and services. Debris removal, infrastructure repairs, psychological care for impacted individuals, community rehabilitation, economic recovery, and long-term planning to prevent repeat disasters are all examples of recovery operations. The goal is to return impacted areas to pre-disaster conditions or to increase resilience to future occurrences.
- Risk reduction and preparedness improvement: This phase entails analyzing the lessons learned from the emergency response and recovery operations and putting that knowledge to use in updating and improving mitigation and preparedness strategies. Implementing risk-reduction measures, upgrading response plans and systems, updating training programs, and incorporating new technology and best practices into emergency management processes are all part of it.

It is vital to notice that these phases are intertwined and frequently overlap. To create resilience and lessen the impact of future catastrophes, effective emergency management necessitates a continuous cycle of readiness, response, recovery, and mitigation.

In Nigeria, the National Emergency Management Agency (NEMA) is critical in coordinating and enabling various phases of national emergency preparedness and management. State emergency management agencies, local governments, and other stakeholders all help to implement these phases within their jurisdictions.

3.4 Long-Term Resources for Disaster Planning and Management

Long-term disaster planning and management resources in Nigeria include a variety of techniques, tools, and projects targeted at increasing resilience, readiness, and response capabilities. Here are some significant resources for long-term catastrophe preparation and management in Nigeria:

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- National Emergency Management Agency (NEMA): NEMA is Nigeria's major disaster management agency. It provides catastrophe risk reduction resources and skills, as well as emergency preparedness, response, and recovery. NEMA collaborates closely with state emergency management agencies to coordinate national and local actions.
- National Disaster Management Framework: Nigeria has created a National Disaster Management Framework including policies, plans, and activities for disaster risk reduction, emergency response, and recovery. This framework acts as a guide for all disaster management stakeholders and serves as a foundation for long-term planning.
- Risk Assessment and Mapping: Conducting risk assessments and mapping is critical for understanding Nigeria's vulnerability and exposure to various hazards. These assessments aid in identifying high-risk locations, demographics, vital infrastructure, and assets, allowing for improved resource planning and allocation.
- Early Warning Systems: Nigeria has worked to build and improve early warning systems in order to offer timely alerts and information about approaching disasters. These systems aid in proactive decision-making, evacuation planning, and catastrophe mitigation.
- Capacity Development and Training: Long-term catastrophe planning and management necessitate the use of a competent and knowledgeable personnel. Nigeria has engaged in capacity-building and training initiatives to improve the capacities of emergency responders, government officials, and community members. These programs concentrate on topics including risk assessment, emergency response, incident command systems, and community resilience.
- Emergency Management Legislation and Policies: As previously stated, Nigeria has emergency management legislation and policies. These legislative frameworks serve as the foundation for catastrophe planning, risk mitigation, and response efforts.
- International Assistance and Partnerships: Nigeria receives assistance from international organizations such as the United Nations, the World Bank, and regional organizations such as the Economic Community of West African States (ECOWAS). Through finance, technical help, and knowledge sharing, these collaborations contribute to long-term resources for disaster planning and management.
- Research and Data Collection: In Nigeria, research institutes and agencies conduct studies and gather data on many aspects of disaster management. These activities contribute to better knowledge, the development of evidence-based policies, and the implementation of effective initiatives.

It is crucial to note that the resources available for disaster planning and management may differ among Nigeria's states. Local governments and communities are also critical in formulating and implementing long-term strategies to address unique hazards and difficulties in their community.

3.5 Emergency Planning and Management Challenges

In Nigeria, emergency planning and management encounter a number of problems that might have an impact on the effectiveness of response activities. Among these difficulties are:

- Limited Resources: Inadequate money, insufficient infrastructure, and a scarcity of equipment and supplies can all impede emergency planning and management. The inability to design solid response plans, train staff, obtain appropriate equipment, and maintain emergency infrastructure is frequently hampered by a lack of financial resources.

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- Weak Institutional Capacity: Government entities, especially emergency management organizations, may have limited capacity to effectively coordinate and respond to emergencies. Inadequate training, limited staffing, obsolete procedures, and insufficient interagency collaboration can all contribute to this. Building institutional capacity is critical for effective emergency management.
- Communication and Information Sharing: During an emergency, timely and effective communication is crucial. However, communication infrastructure and information sharing issues might stymie coordinating attempts. Inadequate communication networks, particularly in rural places, can stymie the dissemination of critical information and coordination among emergency agencies.
- Urbanization and Population Density: Nigeria's rapid urbanization has resulted in increasing population density in cities, making them more vulnerable to disasters. The concentration of people and infrastructure in metropolitan settings creates obstacles for evacuation, emergency shelter, and the supply of key services during emergencies.
- Security Concerns: Nigeria experiences security issues such as terrorism, insurgency, and communal disputes, which can make emergency planning and response operations more difficult. These security concerns may restrict access to damaged areas, stymie relief efforts, and endanger emergency responders and affected communities.
- Climate Change and Environmental Degradation: Nigeria is vulnerable to a variety of climate-related hazards, including floods, droughts, and desertification. Climate change worsens these problems by increasing the frequency and severity of extreme weather occurrences. Environmental degradation, such as deforestation and erosion, increases catastrophe susceptibility.
- Community Engagement and understanding: Ineffective emergency management can be hampered by a lack of community engagement and understanding regarding disaster planning and response procedures. Promoting community engagement, informing the public about hazards, and fostering community-based projects are critical to increasing resilience and decreasing vulnerability.
- Political and administrative considerations: Political instability, bureaucratic processes, and inefficiencies in administration can all have an impact on disaster preparedness and response operations. Administration changes or a lack of political commitment to prioritize disaster management can undermine continuity and hamper effective coordination.

Addressing these issues would necessitate a multifaceted approach that includes increased finance and resource allocation, capacity building, improved communication systems, community involvement, and incorporating disaster risk reduction into development planning. Strengthening legal and institutional frameworks, boosting research and data gathering, and cultivating relationships with national and international stakeholders are also critical for overcoming these obstacles.

Nigeria must constantly analyze and address these difficulties in order to improve emergency planning and management capabilities and successfully respond to disasters and emergencies.

4. DISCUSSION AND RECOMMENDATIONS

In Nigeria, emergency preparedness is a major component of disaster management. Given the country's vulnerability to numerous hazards such as natural disasters, disease outbreaks, terrorism, and civil unrest, it is critical to have effective emergency preparedness mechanisms in place to reduce the impact of calamities and protect lives and infrastructure.

Several critical factors are required for effective emergency preparedness:

- Risk Assessment: Conducting comprehensive risk assessments aids in identifying and comprehending the dangers and vulnerabilities unique to Nigeria's various areas. This data informs the formulation of tailored preparedness programs and aids in the prioritization of resources and actions.
- Early Warning Systems: It is critical to establish and strengthen early warning systems in order to alert the public and relevant authorities about imminent emergencies in a timely manner. To deliver alerts and advisories, these systems rely on reliable monitoring, data processing, and communication networks, enabling proactive preparedness and response activities.
- Emergency Planning: It is critical to develop complete emergency response plans and practices. These plans define the roles and duties of numerous agencies and stakeholders, as well as coordination methods, communication protocols, and standard operating procedures for a variety of emergencies. To ensure their effectiveness, the plans should be evaluated, modified, and tested on a regular basis through exercises and drills.
- Training and Capacity Building: It is critical to build the capacity of emergency management employees, first responders, and other important stakeholders through training programs. Incident command systems, disaster response protocols, search and rescue techniques, medical triage, and public information management should all be covered in training. Continuous training and skill development ensure that the workforce is competent and well-prepared.
- Public Awareness and Education: It is critical to educate the public on potential risks, preparedness measures, and suitable response activities. Public awareness campaigns, community exercises, and the distribution of instructional materials all contribute to fostering a culture of readiness and empowering citizens to behave appropriately during emergencies.
- Interagency cooperation: Efficient disaster response requires effective cooperation among multiple government agencies, non-governmental organizations, and community groups. During an emergency, clear communication channels, coordination procedures, and information-sharing platforms promote collaborative decision-making and resource allocation.
- Infrastructure and Logistics: It is crucial for efficient disaster response to ensure the availability and functionality of critical infrastructure, such as communication systems, transportation networks, emergency shelters, and healthcare facilities. To satisfy the demands of affected populations, adequate logistical support, such as storing emergency supplies, equipment, and medical resources, is required.
- International Cooperation: Increasing Nigeria's emergency readiness through international cooperation, information sharing, and partnerships with neighboring countries, regional authorities, and international organizations. During an emergency, collaboration enables for resource mobilization, the exchange of best practices, and access to expertise and assistance.

Regular examination and modification of preparedness plans, learning from previous catastrophes, and incorporating new technology and best practices are critical for sustaining and improving Nigeria's emergency preparedness. Continuous efforts in this area help to increase resilience, reduce risks, and mitigate the impact of disasters on communities and infrastructure.

5. CONCLUSION AND RECOMMENDATIONS

Because of the country's vulnerability to numerous risks, emergency preparedness and response are critical in Nigeria. A multifaceted approach is required, integrating government agencies, community organizations, and foreign partners. Nigeria should prioritize the following in order to improve emergency preparedness and response:

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- Improving coordination and collaboration: It is critical to strengthen coordination mechanisms between national, state, and local institutions. A well-coordinated reaction requires effective communication, information exchange, and collaborative planning.
- Capacity building and training: It is critical to invest in training programs and capacity building initiatives for disaster management officials, first responders, and members of the community. This ensures that people have the skills and information they need to respond effectively in an emergency.
- Public awareness and education: It is vital to raise public knowledge and education regarding potential risks, preparedness measures, and reaction actions. Encouraging communities to play an active role in disaster preparedness can result in a more resilient and self-sufficient population.
- Infrastructure and resource investment: Adequate infrastructure, such as communication systems, transportation networks, and emergency response facilities, is critical for efficient emergency response. To satisfy the demands of affected populations, adequate resources for emergency supplies, equipment, and medical resources must be allocated.
- Integrating disaster risk reduction measures into development planning at all levels: Integrating disaster risk reduction measures into development planning at all levels can assist reduce vulnerabilities and improve resilience. This includes land-use planning, construction code enforcement, and promoting environmentally friendly practices.
- Continuous evaluation and improvement: It is critical to evaluate emergency response plans on a regular basis, conduct post-incident assessments, and incorporate lessons learned into future preparedness activities. This guarantees that emergency management plans are both adaptable and effective.
- International cooperation: Participating in international cooperation, exchanging best practices, and gaining access to resources and experience from international partners all help Nigeria's emergency preparedness and response capabilities.

Nigeria should increase its ability to effectively prepare for and respond to emergencies, alleviate the impact on impacted communities, and promote resilience in the face of future dangers by prioritizing these factors.

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The integration of behavior-based safety (BBS) as a company value is advocated!

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KEYWORDS

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ABSTRACT

Nearly all cases involving dangerous substances involve human error. Human error caused several disasters, including Bhopal and Chernobyl. The Health and Safety Executive (2023) states that human error management must be as rigorous as technical and engineering processes to prevent accidents and diseases. Human factors—positive or negative—influence employee behavior in a firm. Positive variables can improve safety culture, while reactive variables can hurt it. Restoring a strong safety culture depends on how top executives handle safety problems. A comprehensive safety culture framework integrates information from many conceptualizations to show how safety culture evolves and what variables influence it. This article summarizes qualitative or informal organizational behavior-based safety (BBS) deployment.

1. INTRODUCTION

An analysis of incidents and accidents indicates that human error is a contributing factor in nearly all instances involving exposure to hazardous substances. The primary factor behind numerous catastrophic incidents, such as those that occurred at Bhopal and Chernobyl, was attributed to human error. According to the Health and Safety Executive (2023), the efficacy of human error or mistake management is contingent upon its robustness being on par with the technical and engineering protocols implemented to avert accidents and illnesses. Human factors, whether negative or positive, refer to the elements within an organizational setting that impact the attitudes and conduct of employees. Positive variables have the potential to enhance the safety culture, whereas reactive variables may have a detrimental effect on it.

Lal (2023) posits that various factors such as limited time, fear, and inadequate resources can contribute to a mindset where safety decisions are not prioritized, safety culture is downplayed, and accidents gradually accrue, resulting in detrimental effects on individuals and assets. The response of top-level executives to safety-related incidents is considered a crucial determinant in reinstating a robust safety culture. Health, Safety, and Environment (HSE) experts emphasize the significance of

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maintaining equilibrium between challenges and concerns when incorporating behavior-based safety (BBS) and promoting a sound safety ethos.

2. BACKGROUND

BBS is a proactive method for encouraging safe behavior in a specific area. BBS is concerned with lowering dangers, risks, and events by observing a person's behavior and identifying what happens when that behavior occurs. It entails assessing the implications of a certain behavior and providing appropriate reinforcement for the desired behavior. BBS is dependent on total trust and collaboration between managers and employees. BBS is significant because it provides long-term solutions for risk and hazard elimination. This life-saving method promotes a safety culture in the workplace, which is critical for long-term success. According to the Health and Safety Authority (HSA), organizations strive to build a holistic safety culture within their area of responsibility. This is accomplished when each employee regards safety as a value and ensures the safety of coworkers. The BBS strategy is all about reducing risky behaviors and continuously improving safety performance (Safety Culture, 2023).

The micro-BBS strategy seeks to modify employee behavior in order to increase workplace safety. The behavioral safety procedure comprises the following seven steps:

- An identification of potentially problematic behaviors, such as hazardous or risky ones.
- A determination of the underlying causes of the observed behaviors.
- A creation of potential corrective measures.
- An assessment of corrective measures.
- A creation of the processes required to execute the BBS program.
- An execution of the BBS program.
- An evaluation of the BBS program's collected data to determine if it addressed the problem or increased safe behavior.

The macro-BBS approach seeks to effect lasting cultural change within an organization. This is the culture of safety that the majority of organizations strive to accomplish through their safety programs. Michael Topf designed a six-step procedure for achieving this long-term workplace safety solution. The six stages are as follows:

- Assess and analyze the workplace culture.
- Teach and instruct every employee about behavior-based workplace safety.
- Encourage the participation of all employees in the BBS program.
- Strengthen consciousness, accountability, self-observation, and self-management.
- Continuously support and dedicate oneself to employees.
- Provide evaluation and feedback.

Three factors—internal personal factors, external environmental factors, and behavior factors—reflect a complete safety culture, according to Geller (Safety Culture, 2023). These conditions must exist at all times. The integrated approach is fundamental to BBS and is founded on Geller's seven principles. This integrated approach employs both individual and organizational behavior to achieve a culture of total safety. Here are the seven principles:

- The behavior modification techniques should be observable.
- External factors that can aid in the comprehension and improvement of behavior should be determined.

- Antecedents should be utilized to direct behavior, whereas consequences should be utilized to motivate behavior.
- Positive outcomes to reinforce desirable conduct should be highlighted.
- An objective and measurable BBS program should be ensured.
- Hypotheses and combined BBS program data should be generated, in order not to limit the possibilities.
- A BBS program that takes into account the emotions and attitudes of employees should be created.

3. COMPONENTS OF THE BBS PROGRAM

The essential components of a BBS program for effective implementation are as follows (Safety Culture, 2023):

- **Standards for conduct and performance**, including the vision, mission, priorities, policies, processes, and methods, as well as everything else involved, must be communicated to all program participants.
- **Physical resources,** which consist of the tools, equipment, funds, and facilities that are required to implement a BBS system, while psychosocial resources include time, training, culture, and leadership.
- **A system of measurement** that ensures that behavioral observations are quantifiable by establishing criteria for evaluating performances and providing objective feedback.
- **Effective consequences** that can increase positive behavior. Positive reinforcements are one type of effective consequences.
- **Appropriate application**: The system must be equitable; in other words, it provides recognition and rewards when appropriate.
- **A continuous evaluation of the BBS program** enables the program to be continuously enhanced; this will also determine the effectiveness of the program.

The interdependence of work and safety implies that establishing and maintaining a safety culture requires a deliberate attention to multiple levels of impact on employee safety and welfare. Integrated interventions that are effective exhibit key attributes such as the development of interventions, their implementation, and the resultant outcomes.

4. ADVANTAGES AND DISADVANTAGES OF THE BBS PROGRAM

The following are some pros and cons of a BBS approach (Gould, 2019):

Pros:

- BBS programs encourage employee participation. BBS is advantageous in that it encourages the participation of all employees. The program attempts to provide a clear picture of what is working and what is not in terms of safety. In fact, a genuine BBS program cannot function without the participation and involvement of all employee levels.
- BBS programs utilize positive reinforcement. Regarding workplace safety, a small amount of optimism can go a long way. Workplace "safety" is not everyone's favorite topic. The majority of employees detest training sessions and safety meetings. Putting a positive spin on safety can enhance the workplace's overall safety culture.

Cons:

- BBS programs are challenging to maintain. To be effective, a BBS program requires the complete support of senior management. It must also be utilized and evaluated frequently. BBS will be ineffective if it is merely "implemented" without structure, commitment, and follow-up.
- Inadvertently, BBS programs assign "blame" to employees. Although assigning "blame" to employees is not the goal of a genuine BBS program, it is difficult to isolate its effects. After all, BBS is intended to emphasize individual actions and behaviors.
- BBS programs can lead to erroneous reporting. Due to the structure of the program, which rewards "good" conduct, accidents and injuries may go unreported. Nobody desires to be the one to end the "days without injury". When things go awry or unsafe behavior is observed, employees are also averse to investigations and in-depth conversations.
- BBS programs frequently identify the incorrect "root cause". BBS necessitates incident investigations when unsafe behaviors are observed or injuries occur. But frequently, these investigations focus on what occurred rather than the underlying cause or why it occurred.

5. BBS: IMPORTANT CONSIDERATIONS

BBS is not something that can be gradually implemented. Effective implementation requires meticulous planning, long-term commitment, and organization-wide support. How should one then proceed?

According to EHS Today, the six most common errors made by businesses when implementing a BBS program entail the following (Gould, 2019):

- Believing that participation and observation are the foundations of BBS.
- Failing to utilize positive reinforcement effectively and systematically.
- Only changing hourly employees.
- Making safety based on employee behavior the principal responsibility of employees.
- Not training managers, administrators, and hourly workers on the fundamental principles of behavior-change technology.
- Attempting to implement an activity-based "program" within the organization.

6. OBSTACLES THAT EMPEDE BBS EFFECTIVENESS

The development of a safety culture progresses from fundamental principles to fundamental values through the dedication of top-level management, ultimately leading to the realization of the advantages of BBS. Many businesses engage in thorough preparation of safety culture interventions, yet struggle to sustain them as enduring modifications due to insufficient attention to organizational variables. The issues identified by Lal (2023) include managers who persist in adhering to a culture of dependence on safety, a lack of motivation among lower-level workers to engage in mentally stimulating activities, insufficient support from relevant heads of departments and managers, and inadequate capacity to mobilize and engage all employees and associates.

To promote safe practices, it is recommended to implement measures such as modifying behavior, establishing structured infrastructure, monitoring and enforcing safety protocols, providing training and education, and utilizing positive and negative reinforcement techniques. Efficient implementation of safety measures can be achieved when it is considered a line-of-duty responsibility and integrated into daily activities. During regular meetings, it is recommended that the management team engage in

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discussions pertaining to safety metrics in addition to other operational parameters. The successful execution of any project necessitates the unwavering commitment and active participation of top-level management. In the absence of such involvement, the desired outcomes of such projects may not be realized (CPCL, 2021).

In order to establish a safe work environment, it is imperative to cultivate a fundamental need for safety practices, including the utilization of personal protective equipment (PPE) by all personnel, from the highest level of management to the lowest level of employees. It is essential that all individuals are cognizant of the safety policy and that top management is actively involved in all safety-related activities. Training is a crucial component in developing a safety culture, and it is recommended that at least 3% of man-hours be allocated to employee training.

The commitment of top management is an essential prerequisite for any action to be taken. The implementation of monitoring as a boardroom practice requires a dedicated commitment from management. The sustainability of a positive safety culture is contingent upon its integration into the boardroom and the level of discourse it receives therein. The efficacy of the system is contingent upon its integration into habitual behavior, which must be sustained over an extended period to effect lasting change. The reason for its failure can be attributed to the absence of a clear corporate vision or policy (Kaila, 2022, and 2022a).

One of the reasons businesses fail to maintain a positive safety culture is attributed to human error or organizational politics; this is often due to underlying conflicts and collective faults within the organization, which can impede the implementation of effective safety measures. BBS aims to address and resolve organizational concerns in tandem, with the goal of cultivating a positive work environment. The acquisition of knowledge and skills by employees through training is contingent upon their active engagement in the learning process, assimilation of information, and practical application of the acquired knowledge. According to Tata Steel (2021), achieving success in safety culture is not a static objective, but rather a dynamic process characterized by fluctuations and variations.

7. CONCLUSION AND RECOMMENDATIONS

Due to the challenges associated with long-term commitment, many businesses perceive the adoption of safety measures as a means of preserving their reputation. Consequently, they execute their assigned tasks and subsequently adopt a passive stance, anticipating unforeseen incidents. Certain enterprises have initiated a safety culture intervention but failed to follow through due to their predominant focus on individual behaviors rather than organizational behaviors. The exchange of ideas and perspectives at various levels within an organization pertaining to topics such as incentives, interpersonal connections, attitudes, and obstacles is believed to generate a novel model of organizational conduct, commonly known as BBS. BBS has evolved from a narrow emphasis on injury reduction (which, regrettably, involves victim blaming) to a comprehensive approach that considers not only behaviors but also the work environment, cultural factors, systems, and employee attitudes; this approach aims to enhance organizational cultures, values, and performance (Johnson, 2021).

The development of a favorable safety culture is a gradual process that necessitates ongoing scrutiny of its sustainability over an extended period. According to Wong et al. (2021), in order to effectively promote a culture of safety and encourage individuals to prioritize it, it is essential for management to consistently evaluate and analyze their strategies while implementing diverse interventions. ISO 45001:2018 (SEIL, 2023) stipulates that risk assessment should encompass human competence and behavioral factors, which should be regarded as internal concerns for risk management.

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BBS implementation in the workplace involves careful planning, participation, and commitment from all levels of the business. Here are a few suggestions for a smooth implementation:

- **Leadership Commitment**: Obtain senior management's commitment to prioritizing and supporting BBS efforts. Leaders must establish a clear vision for safety, allocate the required resources, and actively participate in BBS activities.
- **Employee Involvement**: Ensure that employees at all levels are involved in the BBS process. Seek their feedback, invite them to join safety committees or teams, and empower them to take responsibility for safety projects.
- **Training and Education**: Educate employees on BBS principles, safe work practices, danger identification, and the importance of their conduct in maintaining a safe workplace. Refresher courses and continuous education should be used to reinforce this training on a regular basis.
- **Observation and Feedback**: Create a method for observing and recording employee behaviors. Supervisors and designated observers should be trained to perform non-punitive observations, provide constructive criticism, and accurately document observations. Maintain confidentiality while emphasizing the importance of observations as a tool for progress.
- **Conduct Analysis**: Examine the collected data for trends, patterns, and the underlying causes of risky conduct. Utilize this data to prioritize specific behaviors for change and create tailored interventions.
- **Metrics and Goal Setting**: Establish measurable targets for corporate and individual safety performance. Define key performance indicators (KPIs) to monitor progress and assess the effectiveness of BBS activities. Employees should be kept up to date on progress, and milestones should be celebrated on a regular basis.
- **Reinforcement and Recognition**: Use a positive reinforcement system to identify and reward safe actions. To promote safe behaviors and encourage employees to participate actively, use a combination of verbal recognition, incentives, awards, and public gratitude.
- **Constant review and Improvement**: BBS is a continual process that necessitates continuing review and improvement. Review the efficacy of BBS initiatives on a regular basis, elicit employee input, and make appropriate program improvements.
- **Safety Culture Integration**: BBS should be integrated into the organization's broader safety culture. Align BBS with existing safety initiatives, rules and procedures, and foster a culture of shared responsibility for safety.
- **Communication and Engagement**: Create effective communication channels to keep employees up to date on BBS operations, progress, and results. Encourage open communication, create chances for input, and include employees in safety decision-making processes.

By many accounts, successful BBS installation takes time, effort, and a commitment to ongoing improvement. To accomplish long-term improvements in workplace safety, a supportive organizational culture, active employee participation, and continued leadership involvement are required.

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Introduction to STEM education and road safety: an overview

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KEYWORDS

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ABSTRACT

This paper looks at how a STEM (Science, Technology, Engineering, and Mathematics) background might help with road safety challenges. It emphasizes the importance of STEM education in equipping students with the tools they need to assess transportation safety issues, devise practical solutions, and improve existing transportation infrastructure. Incorporating STEM ideas into road safety education provides students with the knowledge they need to make informed decisions and contribute to improving road safety.

This paper also emphasizes the importance of real-world applications in STEM education. Through exercises, simulations, and real-world case studies, experience-based learning allows students to apply their theoretical knowledge to real-world road safety challenges. This strategy teaches children to think critically, solve issues, and make informed judgments, all of which are essential when confronted with difficult road safety concerns.

This paper also highlights the significance of STEM education in tackling various road safety challenges, covering a variety of topics, including road design, traffic analysis, ICT, and green transportation. Stakeholders would learn how to improve traffic operations, employ technology to make roads safer, promote healthy and active lifestyles, and much more. By incorporating STEM education into road safety programs, stakeholders may support a comprehensive approach to a wide range of challenges, from reducing the number of accidents and traffic congestion to safeguarding the most vulnerable road users.

This paper concludes that STEM education is applicable and beneficial to solving the challenges of road safety. It emphasizes the importance of hands-on experience, the potential benefit of STEM education in improving road safety outcomes, and the applicability of STEM education in dealing with a variety of road safety challenges. By promoting STEM education in road safety programs, stakeholders may help develop a more conscious and trained workforce for the future of transportation.

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1. INTRODUCTION

The term "STEM education" is used to describe a method of instruction that emphasizes the study of STEM fields. It is an interdisciplinary strategy that brings together these four areas of study to provide students with the knowledge and abilities they will need to thrive in the twenty-first century workplace. Focusing on developing students' abilities to apply scientific and mathematical ideas in real-world contexts, STEM education places a premium on problem-solving, critical thinking, creativity, and cooperation.

Exploration, experimentation, and discovery are fostered through the inquiry-based, hands-on learning activities emphasized in STEM education. Stakeholders are taught to reason logically, critically, and analytically. Since technology is so crucial to the advancement of science, engineering, and mathematics, STEM curricula place an emphasis on incorporating technological tools into the classroom experience.

2. BACKGROUND

The relevance of STEM education in fostering innovation, economic growth, and social advancement has garnered widespread attention around the world, as revealed in the following.

2.1 An International Perspective

- The United States is a leading supporter of STEM education. The government has launched a number of programs to encourage STEM education, such as the Educate to Innovate campaign and the incorporation of STEM principles into education policy.
- The European Union has made STEM education a top priority by launching programs like the European STEM Schools Alliance and the STEM Alliance. These initiatives seek to promote STEM education by encouraging a greater collaboration between educational institutions, corporations, and research organizations.
- Asia and the Pacific: Many governments have prioritized STEM education. As an example, China has released the "STEM Education Promotion Plan" to encourage more emphasis on STEM subjects in K-12 classrooms. South Korea has also instituted programs to promote STEM education, such as funding for students majoring in STEM fields and specialized schools.
- Australia: Because of the vital nature of STEM education, Australia has established initiatives like the National STEM School Education Strategy. The government has put an emphasis on teaching children STEM subjects, especially in areas like programming and robotics.
- Africa: In order to meet development difficulties and close the skills gap, many African countries are placing a premium on STEM education. The Rwanda Coding Academy is only one example of the country's extensive funding and support for STEM education. The Digital Literacy Program is only one of many STEM-oriented programs that Kenya has launched.
- Several countries in the Middle East, such as Saudi Arabia and the United Arab Emirates, have made it a priority to expand access to STEM education in recent years. To foster a talented workforce in areas like engineering and technology, they have set up schools, labs, and programs centered on the STEM disciplines.
- Several Latin American countries, including Brazil and Mexico, have come to appreciate the value of STEM education in fostering domestic prosperity and international innovation. There have been initiatives to strengthen STEM curricula, provide training for teachers, and encourage collaboration between schools, businesses, and research facilities.

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As a whole, the world places a high value on STEM education, and many countries have implemented programs and regulations to better facilitate this goal.

2.1 The MENA Region

The MENA (Middle East and North Africa) region shares global priorities with the rest of the world when it comes to STEM education. There are several different educational systems and STEM-focused projects and programs in the MENA region that have been undertaken to highlight the value of STEM education. These include:

- Several MENA countries have launched STEM-focused programs and projects because they understand the value of such an investment. Among these initiatives are:
    - Governments and schools at all levels—from elementary to university—are incorporating STEM topics into their curricula.
    - National Strategies: a number of nations now have comprehensive plans in place to promote STEM education at the national level. Teacher education, new courses, better facilities, and outreach to those interested in STEM fields are all possible goals.
    - Collaborations between the public and private sectors have been developed to assist STEM education. The goal of these collaborations is to improve schools by sharing resources like money and knowledge.
    - STEM contests, such as scientific fairs, and robotics competitions, are organized in many countries to get students interested in these fields and provide them with a platform to display their skills.
- Many countries in the MENA region place a premium on empowering women and girls to pursue careers in STEM. There is an ongoing movement to break down barriers and encourage women to study and work in STEM fields. To encourage more women to pursue careers in STEM fields, many organizations offer grants, mentorship opportunities, and educational sessions.
- STEM-related degree programs and research opportunities can be found in a number of MENA-region universities. The goal of these establishments is to develop future experts and enhance scientific knowledge.
- Some nations have built national or regional hubs of excellence in STEM. These facilities bring together students, professors, and business leaders to advance STEM education, research, and innovation.
- Collaboration in Industry: Collaboration between academic institutions and industries is essential for the growth of STEM education. Many businesses in the MENA region work to close the gap between classroom learning and real-world application through funding educational initiatives, offering internships, and collaborating on research.

It is worth noting that the resources, policies, and cultural backgrounds of the various countries in the MENA region may result in varying levels of progress and initiatives in STEM education. However, the value of STEM education in promoting MENA's economic growth, innovation, and development is becoming increasingly acknowledged.

2.2 Lebanon

The importance of STEM education in Lebanon in preparing students for success in the modern economy cannot be overstated. Because of its potential to help Lebanon produce a more highly skilled labor force and encourage technological progress, STEM education has risen in significance in the country in recent years. There have been public and private sector initiatives to advance STEM

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education from early childhood through higher education. A few important facts about Lebanon's STEM programs are as follows:

- Integration and Curriculum: To improve STEM education in Lebanon, the Ministry of Education and Higher Education has implemented new programs and policies. The goal is to promote active learning via inquiry and hands-on experience with STEM topics across subject areas.
- Several Lebanon-based educational institutions have taken up the STEM methodology, creating either specialized STEM programs or schools devoted only to the field. These schools offer a full STEM education package, complete with specialized facilities, resources, and certified educators.
- Supplemental STEM Programming: Many Lebanon-based organizations and projects provide after-school programming in the STEM disciplines. Robotics clubs, coding workshops, science competitions, and summer camps focused on STEM give children hands-on experience and encourage creativity.
- Training for Educators: Workshops and other forms of professional development are organized to instruct educators on how to best instruct students in the STEM subjects. These programs are designed to give teachers the resources they need to pique their students' interest in STEM disciplines and keep them actively engaged in the classroom.
- Cross-Sector Collaborations: Promoting STEM education in Lebanon requires close cooperation between public and business sectors, as well as academic institutions. The public and business sectors have joined forces to strengthen STEM programs by contributing money, materials, and expertise.
- Difficulties and Prospects: Despite the improvements, STEM education in Lebanon still faces several obstacles that must be overcome. These include closing the gender gap in STEM disciplines, encouraging more people to pursue careers in those fields, and increasing investment in infrastructure and other resources. However, there are also openings for multidisciplinary methods in STEM education, collaboration with foreign organizations, and the use of technology for distance learning.

Lebanon's efforts to improve STEM education are indicative of the country's dedication to providing its youth with the tools necessary to succeed in today's technologically advanced society. Lebanon hopes that through investing in STEM education, it can encourage creativity, find solutions to societal problems, and set up its young people for success in such sectors.

3. STEM EDUCATION AND LINKS TO SAFETY-RELATED FIELDS

STEM education includes many subdisciplines. Several STEM domains are dedicated to safeguarding people, places, and things from harm, and these are more important in today's world. Some examples of safe STEM specializations include:

- The term "**industrial safety**" refers to the practice of identifying and eliminating potential dangers in workplaces that produce goods or process chemicals. Accident, injury, and hazard prevention experts create and execute safety protocols, conduct risk assessments, and regulate workplace safety risks.
- The term "**environmental safety**" refers to the practice of minimizing threats to human and environmental health, such as those posed by pollution and hazardous waste. Compliance with environmental regulations, risk assessment, and pollution prevention all fall under this umbrella.

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- Professionals in the field of **occupational health and safety** are responsible for ensuring the safety of employees across a wide range of sectors. In order to reduce the number of work-related illnesses and injuries, they perform risk assessments, create and implement safety policies and procedures, train employees, and carry out inspections.
- The field of **fire safety** engineering applies engineering and scientific principles to the challenges of fire prevention, risk assessment, and mitigation. Engineers specializing in fire safety build fire suppression systems, evaluate fire hazards, create evacuation strategies, and check for regulatory compliance.
- Computer network, data, and system security (sometimes known as "**cybersecurity**") is an increasingly important area of study in today's interconnected digital world. Professionals in this field devise methods to monitor networks, identify security breaches when they occur, and respond appropriately.
- Risks from using genetically modified organisms (GMOs) and other **biotechnological** processes must be evaluated and mitigated in order to ensure biotechnology safety. Experts in this sector work to mitigate potential risks to human health and the environment associated with GMOs by ensuring their secure management and final disposal.

These are just a handful of the STEM disciplines that contribute to public safety. To effectively integrate safety measures across disciplines, a high level of specialized knowledge, skill, and experience is required. A solid grounding in STEM prepares students for work in the safety industry and helps them make the world a safer place for everyone.

In the following, we will only discuss traffic and transportation safety. Other safety-related topics will be tackled in future STEM papers.

3.1 Traffic and Transportation Engineering

Traffic and transportation safety engineering are domains where STEM education plays an important role. To ensure the safe, efficient, and sustainable flow of people and products, traffic and transportation engineers plan, develop, operate, and manage transportation systems.

Incorporating traffic and transportation engineering into STEM curricula can equip students with the background they need to tackle the issues plaguing this sector in the future. Important factors in traffic and transportation safety engineering include:

- The principles and methods used to study traffic flow can be introduced to students through STEM education. Things like traffic signals, road design, and driver behavior are just a few of the many elements that may be studied to better understand how to improve traffic flow.
- Students can gain knowledge about transportation planning by studying the steps taken to determine what services are needed, how they might be improved, and what effects transportation projects will have on people's lives and the environment. Land use planning, demand forecasting, and the feasibility of combining several modes of transportation are all examples of what this may entail.
- Designing highways and roads requires knowledge of geometry, paving, and where to place traffic lights and other controls, all of which can be taught in a STEM-based program. Taking into account aspects like sight distance, intersection design, and roadway safety features, students can learn how to build roads that allow for safe and efficient traffic movement.

- Safer, more efficient, and more mobile transportation is the goal of intelligent transportation systems (ITS), which employ various forms of technology and communication to achieve this end. Traffic signal coordination, dynamic message signs, traffic surveillance systems, and advanced driver assistance systems are only some of the ITS technologies that can be studied by students. Students who take the time to learn about ITS will be better equipped to help create and execute cutting-edge transportation systems.
- A focus on safety in traffic and transportation engineering can be promoted through exposure to STEM subjects in the classroom. Safety analysis methods such as crash data analysis, safety audits, and simulation modeling can be taught to students. Strategies for recognizing and reducing dangers, designing safer intersections and roads, and creating efficient traffic management mechanisms can all be investigated.

Schools and other educational institutions can do their part to improve STEM education in traffic and transportation safety engineering by implementing hands-on activities, simulations, case studies, and real-world projects. Students can benefit from working with transportation firms and professionals by gaining hands-on experience and networking opportunities. Students can be inspired to pursue careers in traffic and transportation safety engineering by being encouraged to participate in competitions or research projects in these areas.

3.2 Road Safety

When it comes to solving real-world problems like traffic accidents, a strong foundation in STEM is essential. While there are many factors that contribute to road accidents, STEM education can help make the roads safer in various ways:

- Individuals who have received a STEM education are better equipped to analyze and predict data. Researchers can learn more about what factors led to road accidents in the past by studying and interpreting the collected data. These results can be used to create predictive models, which in turn can be used to pinpoint locations with a high collision risk and implement specific measures to reduce that risk.
- Engineering is a crucial part of the STEM curriculum, as are traffic engineering and infrastructure planning. Engineers' expertise can be put to use in the development of safer transportation networks and physical structures. This includes installing safety features like guardrails, speed bumps, and roundabouts, as well as improving road layouts, implementing traffic management measures, developing efficient signaling systems, and so on. Professionals with STEM backgrounds can improve road safety and lower accident rates by applying engineering principles.
- Automation and technological advancements in vehicles could greatly increase travel safety. People who have received a solid education in STEM fields are better equipped to create cutting-edge automobile innovations. Anti-lock braking systems (ABS), electronic stability controls, collision avoidance systems, adaptive cruise controls, and driverless vehicles are all examples of such features. By boosting vehicle control, enhancing driver support systems, and lowering human error, these technical developments can aid in accident prevention.
- The ability to study driver behavior and create interventions to encourage safe driving can be gained through a STEM education. Researchers can analyze driver habits, pinpoint potentially dangerous actions, and create preventative measures with the use of data analytics and machine learning. Professionals with STEM backgrounds can help reduce dangerous driving and increase awareness of safe driving practices by delving into the psychology of motorists.

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- Improved road safety education programs can benefit from the incorporation of STEM disciplines. Educators may create interesting and interactive materials to promote safe driving by knowing the principles of pedagogy and instructional design. The significance of wearing safety equipment like seatbelts and helmets, as well as the risks of texting while driving, are all topics that should be covered. Professionals with backgrounds in STEM can be essential in creating and enforcing programs that teach children to be responsible road users from a young age.

To sum up, teaching children about STEM lays the groundwork for reducing traffic fatalities. Data analysis, technical solutions, technological advances, driver behavior analysis, and effective road safety education are all ways in which workers with STEM backgrounds may help bring about major improvements in road safety and the overall rate at which accidents can be prevented.

3.3 Pedestrian Safety

Safety for pedestrians is just one of many real-world issues that can be addressed through STEM education. Pedestrian safety is an issue that can be better understood and addressed if children are taught using a STEM approach. Pedestrian safety can benefit from STEM education in the following ways:

- Collecting and interpreting data is a fundamental part of any STEM curriculum. Pedestrian accidents, transportation patterns, and infrastructure are all areas where students can collect data. High-risk regions, prevalent accident causes, and trends can be identified through this analysis and used to guide the creation of robust safety protocols.
- Mechanical Methods: Learning about engineering is essential in the STEM fields. Students can apply engineering ideas to the problem of pedestrian safety by creating novel approaches to the problem. Better crossing designs, traffic light technologies that prioritize pedestrian safety, and sensor-based systems that identify and warn of impending threats are just a few examples.
- Integration of Technology: Technological progress is accelerating, and it plays a crucial role in ensuring the safety of pedestrians. By learning about GPS, sensors, and cameras in STEM classes, students can help make our streets safer for everyone. They can research the viability of making virtual simulations to teach people about safe pedestrian habits or smartphone apps that provide real-time updates regarding pedestrian-friendly routes.
- Education in the STEM fields can inspire students to take part in community service projects aimed at improving pedestrian safety. To improve pedestrian safety, students can work with government organizations, NGOs, and advocacy groups to host events, run workshops, and launch campaigns. Students may make a difference in their neighborhoods by taking part in such activities.
- Critical Thinking and Problem-Solving Abilities: The problem-solving and critical-thinking abilities fostered by STEM education are crucial for overcoming obstacles to pedestrian safety. Various classroom exercises and projects encourage students to think critically about problems, develop viable solutions, and assess the outcomes. With these abilities, students may address pedestrian safety concerns from a variety of angles.

Inspiring a love of learning and a desire to explore new ideas are two of the main goals of STEM education. In order to increase pedestrian safety, students might investigate current technology, research pertinent scientific literature, and offer original solutions. In addition, they can showcase their ingenuity and contribute to the subject by taking part in scientific fairs or competitions centered on pedestrian safety.

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Incorporating pedestrian safety into STEM curricula provides students with a more complete picture of the issues at play and helps them acquire the knowledge and abilities they would need to make their communities safer. It does more than teach them a trade; it instills in them a sense of responsibility and the motivation to make a positive difference in the world.

3.4 Motorcycle Safety

Motorcycle safety, as a topic that integrates a wide range of scientific and technological principles with engineering concepts to promote safe riding habits, is an integral part of STEM education. In the context of STEM education, the following are some essential factors to remember about motorcycle safety:

- Understanding the physics of motorcycle motion is essential for rider safety. There is a lot of weight placed on ideas like speed, acceleration, momentum, and inertia. Students can get an understanding of how these concepts affect motorcycle stability, braking, and maneuverability through hands-on exercises and simulations.
- The need to use safety equipment when riding a motorcycle can be emphasized through STEM education. Protective gear for motorcyclists includes helmets, gloves, jackets, pants, and boots. Students can get insight into the materials utilized to create these gears and the ways in which they serve to shield the wearer from collisions, abrasions, and other dangers.
- Dynamics and Stability: By delving into the engineering of motorcycles, students can gain an appreciation for how various design decisions influence the vehicle's overall dynamics and stability. Things to keep in mind include the vehicle's center of gravity (CG), weight distribution, suspension setup, and tire traction. Students interested in learning how various variables affect a motorcycle's stability and how those elements can be controlled can benefit from studying these fundamentals.
- In order to ride safely, one needs to have a firm grasp on the fundamentals of braking systems. Distances at which brakes are effective, how anti-lock braking systems (ABS) work, and the physics of tire-road friction are all possible subjects for STEM instruction. Students can learn how to efficiently brake in a variety of situations by experimenting with various braking strategies and surfaces.
- Decision-Making and Situational Awareness: Students can benefit from learning how to analyze and anticipate potential hazards on the road through STEM education. Statistics and data from the actual world can help teach students about the most common factors that lead to motorcycle accidents and how to avoid them. Investigating aspects like traffic flow, weather, and human behavior might be part of this process.
- Upgrades in Security and Technology: Improved motorcycle safety is in large part due to technological developments. Electronic stability control (ESC), collision avoidance systems, adaptive lighting, and smart helmets are just a few of the advances that students can learn about through STEM education. Appreciating the importance of technology in motorcycle safety can be facilitated by learning how these technologies function and the influence they have on minimizing accidents.

The value of rider training and education can be emphasized through STEM education as well. Motorcycle safety classes and programs to improve riders' abilities are only two examples of the types of training that could be promoted. Students have the option to learn more about the advantages of continuous training, such as enhanced riding skills, hazard recognition, and emergency responses.

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Students can learn the scientific, technological, and engineering foundations of safe motorcycling by including this topic in STEM instruction. They can use this information to become more cautious riders, make better choices, and help cut down on traffic accidents.

3.5 Vehicle Safety

Improving road safety is a major benefit of investing in STEM education. It includes a wide range of disciplines, from science and math to engineering and technology, that are all vital to making cars safer for drivers and passengers. Key contributions of STEM education to vehicle safety include:

- Engineering education in the STEM fields aids in the development and analysis of crashworthy vehicle structures. Professionals who have a solid understanding of material science, mechanics, and structural engineering can design safer car frames, crumple zones, and energy-absorbing materials.
- When it comes to building cutting-edge safety features like anti-lock braking systems (ABS), electronic stability controls (ESC), adaptive cruise controls (ACC), and collision avoidance systems, experts in the STEM fields of electronics and sensors are indispensable. To create these innovations, engineers draw on the fields of electrical engineering, computer science, and signal processing.
- Improved Vehicle Dynamics and Control through a Deeper Understanding of Physics and Mathematics. Engineers that are well-versed in STEM can improve a car's agility, stability, and handling, making them safer for drivers. Advanced driver assistance systems (ADAS) like traction control and electronic stability control are part of the picture.
- Psychology and ergonomics are parts of STEM education that can help make vehicles safer for their drivers and passengers. Engineers may improve overall safety and cut down on human errors by designing intuitive user interfaces, ergonomic seating, and driver aid systems that take into account human behavior, perception, and cognitive processes.
- STEM education in the field of materials science paves the way for the creation and use of cutting-edge materials in vehicle construction. Engineers may improve fuel efficiency without compromising safety by switching to lighter materials like carbon fiber composites, which have great strength-to-weight ratios. Materials with improved crash energy absorption capabilities can provide additional protection for passengers.
- Education in data analytics and machine learning is becoming increasingly crucial in the field of vehicular safety as more and more data is collected from vehicles. Engineers can improve safety systems by discovering patterns in massive datasets, which can then be used to create predictive models. It may be used for things like keeping tabs on drivers in real time, predicting when parts will break, and spotting possible dangers.

In conclusion, engineers are able to create cutting-edge safety systems and features for vehicles because of the widespread availability of STEM education. Crashworthiness, improved safety systems, vehicle dynamics, human aspects, sophisticated materials, and data analytics are all areas that benefit from this multidisciplinary approach.

3.6 Highway and Road Design

Because of the wide range of scientific, technological, engineering, and mathematical concepts involved, STEM education is crucial for the development of highways and roads. Let us take a look at how engineering, math, and other STEM fields play a role in the building of roads and highways:

- The scientific community has made significant contributions to our knowledge of the physical and natural factors that influence road layout. The analysis of soil composition and behavior, as well as the effects of roads on the surrounding environment, are all part of this field of study.
- Technology: Technology plays a crucial role in all phases of highway and road design, but especially in the preliminary stages of planning and modeling. Engineers can plan roads more precisely with the help of GIS, CAD software, and simulation tools, which allow them to examine traffic flows and optimize designs for efficiency and safety.
- Highway and road design and construction are based on engineering principles. Road alignments, width, slope, material selection, and structural integrity are all tasks civil engineers must complete. Transportation networks are designed using engineering principles and quantitative computations.
- Calculating road grades, pinpointing appropriate bends, and assessing traffic flow are just a few examples of how mathematics is integral to the road design process. Mathematical models help engineers anticipate traffic flows, evaluate road capacities, and determine the most effective times to activate traffic signals.
- Recent years have seen a rise in the importance placed on constructing roadways with environmental factors in mind. The environmental impact of road construction can be reduced with the help of STEM fields, especially environmental science and engineering. Management of storm water, noise abatement, and protection of wildlife habitat are all examples of such concerns.
- Transportation and safety planning: STEM Education helps make roads safer for drivers, pedestrians, and cyclists. In order to reduce traffic congestion and increase transportation efficiency, traffic engineers use statistical analysis and other principles to pinpoint locations prone to accidents and design intersections with suitable signalization.
- The creation of sustainable infrastructure solutions is aided by the study of STEM subjects. Intelligent transportation systems (ITS) can improve traffic flow and cut down on pollution, while renewable energy sources can be used for illumination. Environmentally friendly and energy-efficient road designs can be made possible with the knowledge and tools provided by the STEM fields.

By including highway and road design in STEM curricula, students can gain exposure to the practical uses of these disciplines. The interdisciplinary aspect of infrastructure development is one of the many topics covered. Inspiring future engineers and professionals in transportation planning, STEM education can aid in the development of transportation systems through student participation in road design projects.

3.7 Traffic Congestion

Congestion in today's metropolitan areas is a major problem that can only be alleviated with the help of STEM education. Understanding, analyzing, and developing novel approaches to reducing traffic congestion are all aided by the STEM disciplines' application of scientific, technological, engineering, and mathematical principles. Here is how teaching STEM subjects in schools can help fix this:

- Traffic flow statistics, vehicle counts, and travel patterns are just some of the types of information that students trained in STEM fields will be able to examine. Students can learn about congestion hotspots, peak traffic hours, and contributing causes by employing statistical analysis and data visualization tools.

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- The STEM fields provide the backbone of traffic engineering and transportation planning. In this respect, students can be taught transportation modeling, optimization methods, and traffic flow theories. This information is useful for reducing traffic congestion through better planning of road networks, signal timing, and traffic management systems.
- The term "intelligent transportation system" (ITS) refers to the incorporation of modern information and communication technology into existing modes of transportation. Adaptive traffic signal control, real-time traffic monitoring, and dynamic route assistance are just a few of the ITS solutions that students can learn about and work on with the help of STEM education. By providing drivers and authorities access to data in real time, these technologies help improve traffic flow and cut down on congestion.
- Through the use of computer simulations and modeling tools, students are encouraged to simulate traffic problems and test the efficacy of different treatments as part of STEM education. Students can learn about the efficacy of potential solutions to traffic management problems by trying them out in a simulated environment.
- Congestion-Reducing Transportation Infrastructure Creation: STEM fields are essential to creating efficient transportation infrastructure. Students can create novel infrastructure solutions that enhance traffic flow and decrease bottlenecks by thinking about issues including road capacity, geometric design, intersection design, and the integration of multi-modal transportation.
- Environmentally Friendly Commutes: STEM education promotes sustainable transportation options, such as public transportation, cycling infrastructure, and pedestrian-friendly layouts, which can help to reduce traffic congestion. Students may help reduce traffic congestion by studying alternative forms of transportation and how to integrate them.
- Road Safety STEM programs promote safe driving practices and policies. Students can create safer road conditions that reduce congestion-causing accidents by examining accident data, studying human variables, and using engineering principles.

Students obtain an all-encompassing awareness of the diverse factors involved in addressing traffic congestion when it is incorporated into STEM programs. They learn to think critically, solve problems, and be creative, all of which are essential for improving transportation systems and reducing traffic congestion.

4. PROS AND CONS

Recent years have seen a rise in interest and funding for STEM programs in schools. Some pros and cons of STEM education are listed below.

Pros:

- Developing students' capacity to analyze a situation, formulate a plan of action, and implement that plan is a central goal of STEM education. It encourages students to think critically, rationally, and creatively as they tackle real-world problems.
- Education in the STEM professions helps students develop marketable abilities that may be utilized in many different contexts. They will learn valuable technical skills like data analysis, programming, and computer literacy that are in high demand in the modern work market.
- Fosters teamwork and interpersonal skills: Through the use of group projects and collaborative exercises, students in STEM fields are encouraged to work together. Students develop the skills necessary to operate effectively in teams, including communication, negotiation, and cooperation, preparing them for careers in which these interpersonal skills will be vital.

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- Responds to the Needs of the Future Workforce: Careers in STEM are expected to expand rapidly along with the development of new technologies. STEM education provides students with the tools they need to enter these growing fields, enhancing their employability in a dynamic work market.
- Involving children in real-world experiments and discovery: STEM education ignites children's natural curiosity and a desire to learn more about the world around them. It inspires them to become inquisitive, persistent learners with a passion for discovery.

Cons:

- Lack of attention to other issues: An overemphasis on STEM programs could lead to a tunnel vision that ignores the significance of disciplines like the arts, humanities, and social sciences. An unbalanced curriculum can have a negative impact on students' ability to learn and grow in all areas.
- The underrepresentation of women and people of color in STEM areas is a historical result of a lack of diversity and inclusiveness. These inequalities may be perpetuated, and chances for underrepresented groups may be restricted, if STEM education does not take aggressive steps to promote diversity and inclusivity.
- While a STEM education does give useful skills, there is a danger of putting too much emphasis on theoretical understanding. Because of this, students may find it difficult to apply what they learn in the classroom to problems in the real world.
- Lack of funding and support for education: Teachers who have received extensive training and access to sufficient resources—including cutting-edge tools, equipment, and materials—are essential for successful STEM education implementation. However, not all schools have the resources or support to provide excellent STEM education, which leads to inequalities in both access and opportunity.
- The demanding nature of STEM curricula has the potential to heighten students' stress levels and stir up more healthy competition. Unchecked, this stress could lead to burnout, with a singular concentration on grades at the expense of a more well-rounded education.

The implementation and setting of STEM education can have a significant impact on pros and cons. In order to better prepare students for the future and encourage a holistic approach to learning, educators must address the problems and capitalize on the benefits of STEM education.

4. FUTURE PROSPECTS

Education in the STEM fields is essential for influencing the future and holds great promise in many fields. Some possible outcomes of STEM education are as follows:

- Employment Prospects: There will be a greater need for people educated in STEM fields as technology continues to improve rapidly. A solid grounding in STEM is essential for many fields today. Those who invest in their STEM education set themselves up for success in a variety of dynamic, high-paying fields.
- Education in the STEM fields helps students develop the critical thinking, problem-solving, and creative abilities they would need to be successful innovators and entrepreneurs. Students who major in STEM generally go on to be innovators and leaders in their fields. Individuals may launch businesses, invent innovative technologies, and boost economic growth if they have a solid grounding in STEM.

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- Climate change, healthcare, food security, and sustainable development are just some of the global concerns we face today. Education in STEM fields gives students the tools they need to successfully meet these issues. STEM graduates can help solve global challenges by applying their knowledge of scientific concepts and technologies.
- Innovations in technology will shape the future in significant ways. The goal of STEM education is to better equip students to appreciate and benefit from technological progress. Professions in the STEM disciplines are at the vanguard of fast-developing fields like AI/ML-based QC and genetic engineering.
- STEM education promotes interdisciplinary work, bringing together specialists from other disciplines to address intractable issues. As problems become more intertwined, multidisciplinary strategies will become more vital in the future. There will be a significant need for multidisciplinary team players with a background in the STEM fields.
- Diversity and Inclusion: It is important to encourage participation from underrepresented groups in the STEM industries. Progress can only be ensured if women and people of color are encouraged to pursue careers in STEM. Diversity in STEM fields is essential to fostering innovation and creativity and solving societal problems.
- STEM programs encourage students to continue their studies throughout their lives. Due to the ever-increasing speed of technological development, it is essential for people to regularly upgrade their knowledge and skill sets. Individuals with a solid foundation in the STEM fields are better prepared to learn about and adapt to new technologies and sectors as they progress in their careers.

In general, there are bright futures ahead for those who study STEM fields. Individuals who invest in their education in the STEM fields help drive innovation, find solutions to global problems, and create a better future for themselves and the world at large.

5. CONCLUDING REMARKS

STEM education has quickly become an integral part of today's curriculum due to the many advantages and prospects it provides students. It meets the demands of an innovative and technologically driven labor market by putting an emphasis on analytical thinking, problem-solving, hands-on experience, and teamwork. STEM education prepares students for success in a world that is constantly evolving by instilling in them a love of learning and a curiosity for the world around them.

However, it is critical to deal with STEM education's possible downsides. For children to grow in their imagination, compassion, and worldview, a curriculum that provides ample time for the arts, humanities, and social sciences is essential. To eliminate existing inequalities and enable all students to reach their full potential, it is essential to encourage participation from underrepresented groups in STEM disciplines.

Investment in teacher training and sufficient resources to conduct high-quality instruction are crucial for the successful implementation of STEM education. Connecting what one learns in the classroom with real-world challenges calls for a healthy mix of theoretical understanding and hands-on experience.

In conclusion, students greatly benefit from STEM education since it helps them acquire valuable skills and gets them ready for the job market of the future. By minimizing the risks and bolstering students' exposure to other disciplines, we can help students succeed in STEM fields while also encouraging their all-around growth and contributing to the formation of a more accepting and creative society.

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World Safety Organization (WSO)

The WSO was founded in 1975 in Manila, The Republic of the Philippines, as a result of a gathering of over 1,000 representatives of safety professionals from all continents at the First World Safety and Accident Prevention Congress. The WSO World Management Center was established in the United States of America in 1985 to be responsible for all WSO activities, the liaison with the United Countries, the co-operation with numerous Safety Councils, professional safety/environmental (and allied areas) organizations, WSO International Chapters/Offices, Member Corporations, companies, groups, societies, etc. The WSO is a non-profit, non-sectarian, non-political organization dedicated to: ***"Making Safety a Way of Life … Worldwide."***

World Safety Organization Activities

WSO publishes WSO Newsletters, World Safety Journal, and WSO Conference Proceedings.

WSO provides a network program linking various areas of professional expertise needed in today's international community.

WSO develops and accredits educational programs essential to national and international safety and establishes centers to support these programs.

WSO receives proposals from professional safety groups/ societies for review and, if applicable, submits them to the United Countries for adoption.

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WSO establishes and supports divisions and committees to assist members in maintaining and updating their professional qualifications and expertise.

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WSO organizes and provides professional support for inter- national and national groups of experts on all continents who are available to provide expertise and immediate help in times of emergencies.

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- [ ] Construction Safety (CS)
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By submitting this application, you are accepting that WSO will use the information provided to perform an independent verification of employer, credentials, etc.

Mail or email completed form, along with current résumé/CV:

WSO World Management Center

PO Box 518 | Warrensburg, Missouri 64093 USA

Phone 660-747-3132 | FAX 660-747-2647 | membership@worldsafety.org

Student Membership Application

WORLD SAFETY ORGANIZATION

Instructions | Complete all applicable fields and mail to **WSO World Management Center, PO Box 518, Warrensburg, MO 64093 USA**, email to **membership@worldsafety.org**, or fax to **1-660-747-2647**. For assistance completing this application, please call **1-660-747-3132**, or email questions to **membership@worldsafety.org**.

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Last Name/Family Name

First Name/Given Name ______ Initial ______ ❑ M ❑ F (Gender)

Birthdate MM / DD / YYYY *(Application must include exact birthdate with year to be processed.)*

Current Street Address ❑ On Campus ❑ Off Campus *(Attach separate sheet if you need more room for your address.)*

City ______ State/Province ______ Country ______

Zip/Postal Code ______ Telephone Number (including area code) ______ ❑ Landline ❑ Mobile (Type)

Permanent Street Address

City ______ State/Province ______ Country ______

Zip/Postal Code ______ Telephone Number (including area code) ______ ❑ Landline ❑ Mobile (Type)

Send mail to: ❑ Current Address ❑ Permanent Address

Email Address(es)

COLLEGE/UNIVERSITY STUDENT

Category: ❑ Undergraduate ❑ Graduate/Post-Graduate

Degree(s) Sought/Obtained

Name of College/University ______ Campus ______

MIDDLE / HIGH SCHOOL STUDENT

❑ I am a Middle Schooler in: ❑ 6th Grade ❑ 7th Grade ❑ 8th Grade

❑ I am a High School: ❑ Freshman ❑ Sophomore ❑ Junior ❑ Senior

Name of School

Approximate Date of Graduation (MM / YYYY)

(For High School and College/University students, application must include approximate date of graduation to be processed.)

If you were referred by someone, please list name(s), chapter, division, etc.:

WSO Member: ______

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Other: ______

What Interests You?

Please specify your area(s) of interest. These areas of interest will allow you to connect with others who share similar interests throughout the world.

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[ ] Construction Safety (CS)
[ ] Transportation Safety (TS)
[ ] Industrial Hygiene (IH)
[ ] Product Safety (PRO)
[ ] Risk Management (RM)
[ ] Hazardous (Toxic) Materials Management (HAZ)
[ ] Nuclear Safety (NS)
[ ] Aviation Safety (AS)
[ ] Ergonomics (ERG)
[ ] Petroleum (PS)
[ ] Oil Wells (OW)
[ ] Other: ______

Required Signatures & Permissions

I subscribe to the above record and when approved will be governed by the Constitution and By-Laws of WSO and its Code of Ethics as I continue as a member. I furthermore agree to promote the objectives of the WSO wherever and whenever possible.

X ______ ______

Applicant Signature ______ Date

FOR MID/HIGH SCHOOLERS ONY: WSO subscribes to the Family Educational Rights and Privacy Act (FERPA) philosophy in protecting student privacy and information. WSO may disclose "directory" information such as a student's name, WSO Student Chapter affiliation, name of school, grade in school, etc., along with group or individual photos in WSO NewsLetters, NewsFlashes, eNews, on WSO website, and on WSO's social media accounts.

❑ My student has permission to participate as outlined above.

❑ My student has permission to participate with exclusions:

______

X ______ ______

Parent/Guardian Signature (Mid/High Student) ______ Date

X ______ ______

WSO Student Chapter Mentor Signature ______ Date

[IF APPLICABALE]

WSO – National Offices

WSO National Office for Algeria
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contact: ferhatmohia@yahoo.fr

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binh.pt@safety.edu.vn
website: worldsafety.org.vn

World Safety Organization
Code of Ethics

Members of the WSO,
by virtue of their acceptance of membership
into the WSO,
are bound to the following Code of Ethics
regarding their activities associated with the WSO:

Members must be responsible for
ethical and professional conduct in relationships
with clients, employers, associates, and the public.

Members must be responsible for professional competence in
performance of all their professional activities.

Members must be responsible
for the protection of professional interest, reputation, and
good name of any deserving WSO member
or member of other professional organization involved in
safety or associate disciplines.

Members must be dedicated to professional development of new
members in the safety profession
and associated disciplines.

Members must be responsible
for their complete sincerity in professional service to the
world.

Members must be responsible for continuing improvement and
development of professional competencies
in safety and associated disciplines.

Members must be responsible
for their professional efforts to support the WSO motto:

"Making Safety a Way of Life…Worldwide."

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