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Particulate Pollution from New Year Fireworks in Honolulu

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Abstract: Fireworks have long been a problem in Hawaii despite restrictions on their use. They cause accidents and high levels of noise and air pollution and are accompanied by admissions to hospitals from accidents and breathing difficulties. There was some initial success in reducing injuries and particulate concentrations after the implementation of the permit requirements from New Year of 2012, but the recent years of 2022 and 2023 have witnessed elevated air pollution at New Year. It seems unlikely that this arises from weather conditions as a random forest analysis suggests that the effects of local climate are quite small, and particulate pollution at New Year arises from fireworks. The pollution does not seem related to the purchase of the permitted 5000 firecrackers. Locally, there is suspicion that injury and pollution more likely arises from illegally purchased aerial fireworks. Regulatory authorities have found it difficult to estimate the quantity of illegal fireworks, and preventing their import has proved a difficult task. Such problems mean that it is important to enhance our understanding of local environmental problems caused by fireworks and improve compliance with the regulations, without diminishing enjoyment of the New Year celebration.

Keywords: spring festival; Independence Day; regulation; illegal fireworks; pyrotechnic displays

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1. Introduction

The environmental impact of fireworks has become more apparent over recent decades. Where firework displays are frequent there are concerns about ecosystem impacts from accumulation of toxic metals [1,2] and perchlorate [3] that are components of fireworks. The explosive nature of fireworks also means that they can cause direct injury, but the possibility of high concentrations of pollutants released during displays has raised concerns. In some places this has led to public rather than private firework displays and the use of eco-friendly fireworks to reduce perchlorate and toxic metal deposits [4]. A shift to drone shows, laser displays, or lantern festivals is seen in Hong Kong and Taiwan [5]. Some studies have suggested health impacts from short exposures [6] to high concentrations of firework-related air pollution [7–10]. However, increases in daily mortality after celebrations are not easy to establish [11], although cyto-toxicological studies reveal potential risks [12]. Health burdens may be particularly relevant to pyrotechnic workers, performers, and athletes [6,13] who accumulate increased exposures because of their work.

Concern over problems with fireworks has led to increasing amounts of legislation. In China and India, despite the existence of regulations, their effectiveness is hard to guarantee as there are variations in their stringency and the rigidity of enforcement [14–16]. In the U.S. it has been Independence Day (4 July) that has been particularly noted as a time of elevated firework-derived air pollution [17]. In Hawaii, especially in Honolulu on Oahu, the situation is a little different as it is a diverse community with an East Asian influence that adds to that of its indigenous population. Here, there is a strong cultural attachment to fireworks; thus, the celebrations at New Year and Chinese New Year (Spring Festival) have

long been associated with displays, along with regular events for tourists. Past celebrations in Hawaii were dominated by the traditional strings of firecrackers that filled streets with smoke and red paper fragments. Today, they seem more characterised by extensive aerial displays and "bomb blasts" [18]. Poor air quality and the assoiated health risks have been part of New Year's Eve on Oahu for many years [19,20], and it remains a problem that continues to draw attention [21].

The State of Hawaii has established regulations and laws protecting the environment and public health and the control of fireworks [22] that reflect an increasing concern about reducing air pollution [23]. These concerns add to those that arise from stationary sources, vehicles, and a range of natural sources, most notably volcanic emissions that threaten the State's generally clean environment [24,25]. The State has established laws and regulations to control the use of fireworks to minimise the impact on the environment or reduce injury [26] and enhance public safety. Regulations restrict the sale, possession, and use of certain types of fireworks, such as aerial shells and large firecrackers, which are restricted to professional displays or are prohibited. Additionally, the use of fireworks may be subject to limits of time and location. In Hawaii, individuals require permits if they wish to purchase fireworks, which need to be obtained between 17 December and New Year's Eve. These allow a one-time purchase of up to 5000 firecrackers [27], but fountains, sparklers, aerial fireworks, and other consumer fireworks are illegal and not permitted. However, the enforcement of these regulations is typically the responsibility of the police department or fire department, and this has not been easy in Hawaii [23], as so often felt elsewhere [15].

Illegal fireworks often become a challenge as regulations tighten [15], which continues to be a problem in Hawaii as the government struggles to limit imports and enforce their sale and use [18,23]. It has been serious enough to see the creation of an Illegal Fireworks Task Force to develop strategies to address the problem in Hawaii [28,29]. Holidays and celebrations can shift the social dynamics such that otherwise law-abiding citizens feel freed from behavioural norms [30,31], which may explain the widespread use of illegal fireworks that has become such a problem in Hawaii. Private use of certain types of fireworks, including aerial fireworks and some firecrackers, is illegal in Hawaii [22] with strict penalties for violating these laws that can include fines and imprisonment. Despite tighter regulations, the situation has not greatly improved; hence, recent official documents have recognised that "the use of illegal fireworks has substantially increased in recent years" [32]. The government has drawn attention to the need for audits and "strict inventory and recordkeeping requirements to ensure that sales of fireworks" are regulated, along with a need to audit shipping containers to prevent the importation of illegal fireworks [33].

The study presented here examines particulate pollution concentrations in Honolulu at New Year and tries to assess the effectiveness of tightening legislative control. Assessing the contribution that fireworks make to air pollution can be difficult because meteorological conditions vary year to year. Sometimes, CO can be used as a marker of non-firework contributions, SO_2 the firework contribution [5], or through machine learning techniques [34]. The case for restrictions in Hawaii is likely to be supported by the public as they continue to draw attention to the issue in Honolulu's media. However, there are few scholarly studies [26] that contribute to the debate. Especially relevant to the current study is the contemporary concern that it is illegal fireworks that make the biggest contribution to the problem such that enforcement needs to be enhanced [23].

2. Materials and Methods

2.1. Data Sources

This study has largely focussed on $PM_{2.5}$ as ambient levels of particulate matter are elevated during intensive periods of firework use. The time windows are from 29 December to 3 January, the shorter period of 3 July to 6 July, the period starting two days before Chinese New Year, and the second day of the New Year. Weather data was extracted for hourly intervals over the years 2015–2023 (though not Independence Day 2023). The hours chosen

aligned with the legal allowances: from 9:00 p.m. on New Year's Eve to 1:00 a.m. on New Year's Day; from 7:00 a.m. to 7:00 p.m. on Chinese New Year's Day; and from 1:00 p.m. to 9:00 p.m. on the Fourth of July, although special permits may be organised for other periods, such as "9:00 a.m. to 9:00 p.m. as allowed by permit pursuant to Section 132D-10 if the proposed cultural use . . . ", but these are not considered here as they are likely site specific and probably represent restricted local uses. An example of regular local use is the pyrotechnic display for tourists in Waikiki on Friday nights just before 20:00 h (note that from here on we adopt the 24 h clock). There have been complaints about Waikiki fireworks in the past with common concerns including noise pollution, disruption of wildlife, and potential dangers posed by falling debris. Despite these complaints, the fireworks displays remain a popular attraction in Waikiki and continue to draw enthusiastic crowds.

Pollution observations were gathered as hourly measurements for the pollutants $PM_{2.5}$, PM_{10}, and CO, as extracted from the US Environmental Protection Agency website (http://www3.epa.gov/airquality/airdata/ad_data.html accessed on 15 March 2023) and the Hawaii Department of Health (https://air.doh.hawaii.gov/Report/AutomaticData accessed on 2 February 2023). The single urban monitoring site is located in the Capitol District, centered where there are many government buildings and landmarks, such as the Iolani Palace. Weather data for Honolulu was taken from Time and Date (https://www.timeanddate.com/weather/ accessed on 27 March 2023). A number of on-line sources for news and government reports are given in the reference list, but a most valuable site was that of the *Honolulu Star Advertiser* (https://www.staradvertiser.com/ accessed on 10 March 2023), which has a well-indexed database. Google Trends (https://trends.google.com accessed on 14 March 2023) was used to gain an impression of the search volume for queries about fireworks over time as a function of time and location.

2.2. Weather Effects and Random Forest Model

Air pollution during celebrations is related to the emissions from fireworks. However, particle and gaseous pollutant concentrations are both affected by weather conditions [35]. This makes it difficult to distinguish changes in particulate load that arise from weather events to those that are directly related to the quantity of fireworks used. In previous work [34], we adopted a random forest model described by Grange et al. [35] to resolve the effects of weather and changing emissions with the *rmweather* R package. This allowed us to estimate the concentrations of $PM_{2.5}$ under a business-as-usual scenario (i.e., pollutant levels without fireworks). The study of New Year particulate concentrations in Honolulu ustilised this model to establish the strength of various meteorological parameters (wind speed, atmospheric temperature, relative humidity, atmospheric pressure, and visibility) along with linear terms, such as the time of the observation (UNIX in seconds from New Year 1970) and the day number in each year and day-of-the-week, to account for regular changes associated with human activity. The random forest models were used without data transformation as the variables remained within their response scale. However, $PM_{2.5}$ was modelled only for cases where meteorological data was present. As with the previous study, 80% of the input data was used in a training set, retaining the remaining 20% for model validation. The random forest model was run around fifty times to assess the growth of hyperparameters. We set the number of variables to three, the minimum node size or depth to five, and within the forest the number of trees was set to 300.

The contribution to $PM_{2.5}$ concentration made by fireworks was determined by comparing the observations with the predictions for the particulate concentrations in the absence of fireworks (business as usual). A test set allowed the best-performing model to be selected. The training period used hourly observations from days with no fireworks. Five hours (21:00/02:00) across New Year's Eve to New Year's Day were defined as the firework period in Honolulu. The model was grown and tested for the three days before and after the New Year period with the trained model compared to observations [36]. As in previous work, fifty models were grown to allow uncertainty to be estimated; with model performance adopting four statistical parameters: Pearson's correlation coefficient

(r), mean bias (MB/μg m^{-3}), normalised mean bias (NMB), and normalised root-mean-square error (NRMSE), as tabulated in the Supplementary Materials. Statistical indicators and input variables, such as the importance values and the predicted concentrations, were determined in the fifty models (mean; the 2.5 and 97.5 percentiles). The models performed well with regression coefficients (r^2) typically ~0.35 (Table S2); the absolute value of most biases in the training set was usually less than unity, perhaps hinting at small errors in predicted concentrations.

2.3. Statistical Analysis

The data sets used in this project were not necessarily normally distributed and often small and contained integer values; thus, we frequently used non-parametric tests, most notably the Friedman test, which is a non-parametric equivalent to the ANOVA test. It was used to test differences in pollution on New Year and before and after. The Kendall rank correlation coefficient (τ) was used instead of the more common Pearson regression coefficient.

3. Results and Discussion

3.1. New Year, Spring Festival, and Independence Day

An overview of particulate concentration profiles over the holiday periods, New Year, Chinese New Year (Spring Festival), and Independence Day, is given in Figure 1. It shows the years from 2015 and reveals a sharp rise in the $PM_{2.5}$ concentration around midnight at the New Year. Peak values are typically recorded in the first hour of the New Year which is characteristic of firework-generated pollution in these celebrations [5]. The concentrations of $PM_{2.5}$ determined at 01:00 in the New Year were always higher than those collected at the same time of either 31 December or 2 January, which were significantly different with the Friedman test giving mean ranks to New Year's Eve, New Year's Day, and the day after New Year as 1.6, 3 and 1.4, respectively (p~0.0024). However, the absolute concentrations of $PM_{2.5}$ during the first hour of some new years were as low as 7 μg m^{-3} (2016 and 2017). Neither Chinese New Year (Spring Festival) nor Independence Day show such signatures, suggesting that fireworks have little influence on particulate load in Honolulu during these festivals as clear peaks in $PM_{2.5}$ are absent. Some fireworks are used, but celebrations may take place at more dispersed locations, and their use is not so intense across the short time window.

The importance of the New Year use of fireworks in Hawaii is supported by the search profiles extracted from Google Trends. The search term "fireworks" is relatively more common at New Year compared with the 4th of July in Hawaii than in the rest of the U.S. Outside Hawaii, the number of searches at New Year is proportionately rather small (Figure 1d). Furthermore, the Illegal Fireworks Task Force [28] notes the importance of New Year in Hawaii and suggests the need for additional resources to prevent the use of illegal fireworks at that time.

3.2. Trend in NewYear $PM_{2.5}$

High concentrations of firework-generated $PM_{2.5}$ are most apparent in the first hours of the New Year. Hints of this can be seen in Figure 1a, and although fireworks are permitted from 21:00 on New Year's Eve, quite understandably the highest concentrations are found close to midnight as seen in the profile of hourly concentrations over the New Years 2010/2023 (Figure 2), with the five measurements for each year covering the period 21:00 in the evening to 02:00 the following morning. Hourly data for the most recent celebration for a longer time period of 19:00 to 04:00 is shown as the inset to Figure 2.

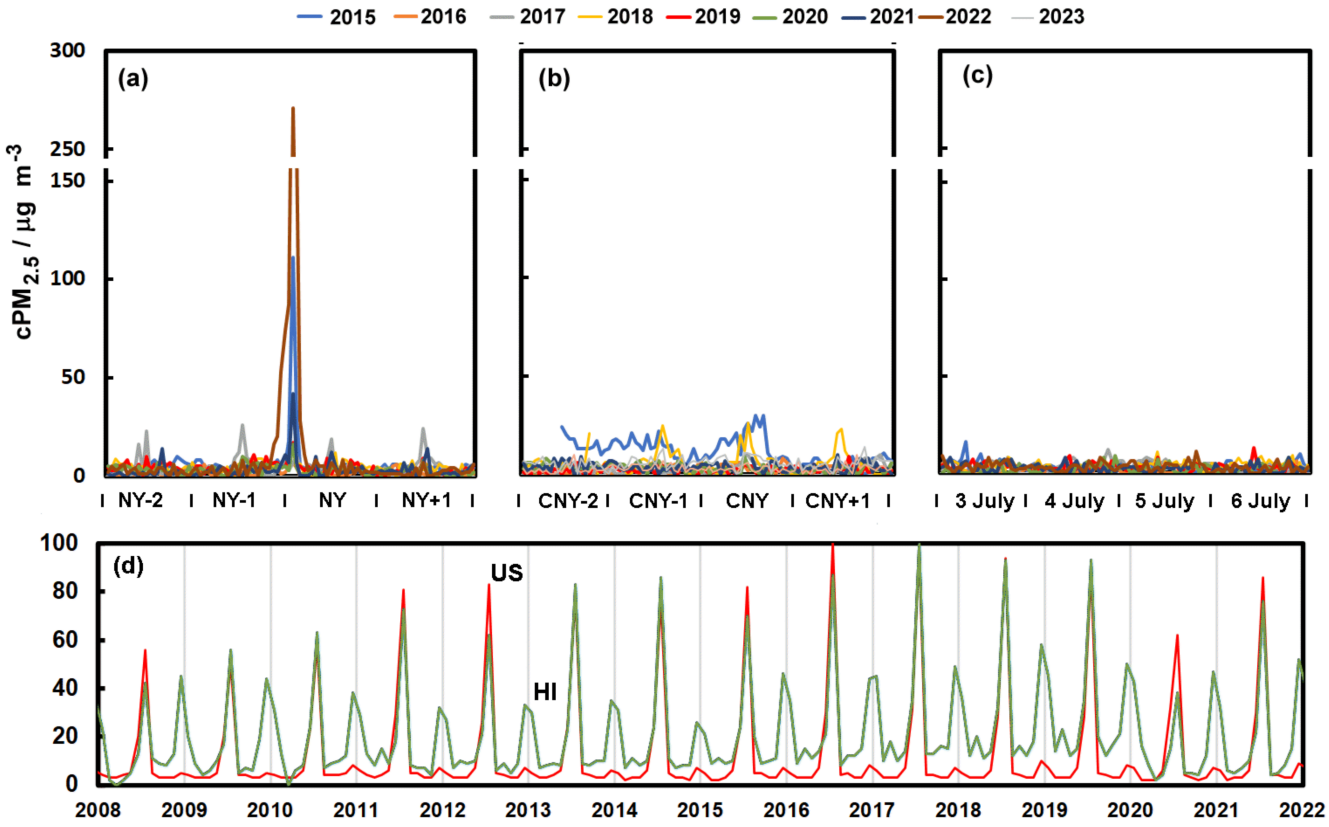

Figure 1. Hourly $PM_{2.5}$ concentrations in Honolulu before and after (across four-day windows): (**a**) New Year 2015–2022, (**b**) Spring Festival (Chinese New Year) 2015/2023, and (**c**) Independence Day 2015/2022. (**d**) The normalised search volume for "fireworks" in the U.S. and Hawaii (HI) 2004/2022 as recorded in Google Trends. Abbreviations NY−2 day before New Year's Eve, NY−1 New Year's Eve, NY New Year's Day, and NY+1 Day after New Year's Day. Chinese New Year follows this pattern, but Independence Day has the calendar dates. Note a rescaled version of Figure 1a–c appears as Supplementary Figure S1.

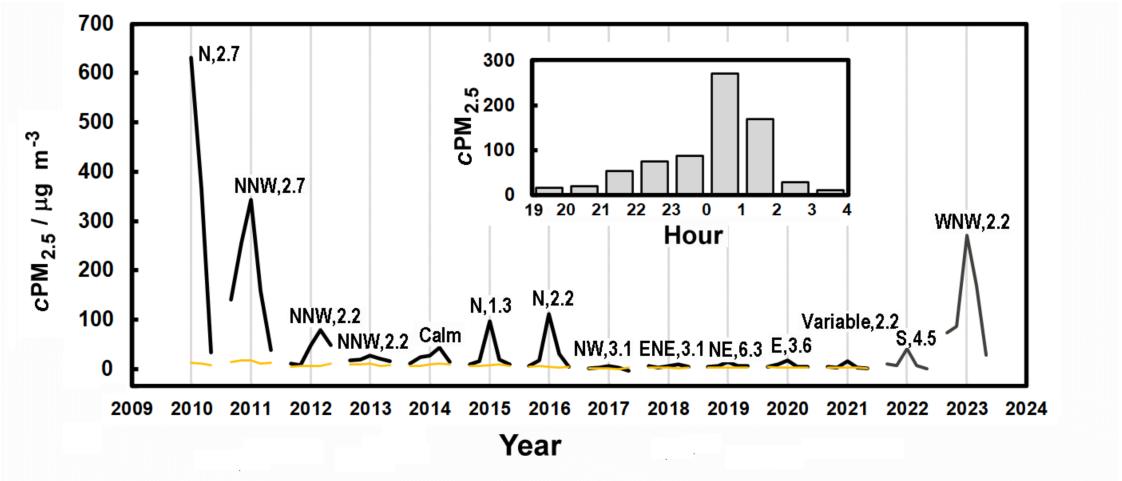

Figure 2. $PM_{2.5}$ concentrations across the time window 19:00 to 04:00 at New Year in Honolulu (dark broken line). Each peak is labelled with the wind direction and speed (m s^{-1}) from the hour after midnight. The inset shows the hourly values across a longer time window for the year 2023. The light-coloured line shows the random forest predictions of concentration based on weather and time parameters, which gives an indication of the concentrations in the absence of fireworks.

3.3. Weather and COVID-19 Effects on NewYear $PM_{2.5}$

There are always problems in attributing year-to-year variations in pollutants during periods of celebration with fireworks to changes in the amounts used. As mentioned earlier, enhanced pollutant concentrations could easily arise from other causes of which weather is likely to be especially important [15]. Hawaii is exposed to trade winds that tend to be fairly constant and anabatic and katabatic flows. Thus, winds blow upslope by day and downslope by night, though nocturnal windspeeds in Honolulu are low and typically from the north just after midnight (Figure 2). It is unlikely that wind direction plays a big role in concentrations measured within a homogeneous area source. In cases where fireworks are used widely across an urban area there are unlikely to be distinct plumes along specific wind directions; thus, wind speed or mixing height can be useful parameters to explore meteorological effects [15]. Here, we chose to apply the random forest approach, as described in the method section, to give an indication if the likely effect of weather. These weather-only effects on normal particulate concentrations are shown as the faint line in Figure 2, which suggests that changes in weather year by year are small and cannot convincingly explain the presence of peaks in firework pollutants. The weather-only effects on normal air pollution were driven by factors in the order UNIX date > temperature > Julian day > RH > pressure > windspeed > day of the week > visibility, as shown in Table S2.

The change in the New Year peak in observed $PM_{2.5}$ concentrations suggests a decline from 2010 (Figure 2). The sharp decrease in pollutant concentrations preempts the legislation, which took effect from the celebrations of 2012. It is possible that it reflects a social reaction as it is also evident that there was a decrease in Google searches for fireworks in Hawaii from 2010 through to 2013. The years 2013 and 2014 were also low in particulate concentrations, which was noted by the Hawaii Department of Health as reflecting success for the recent legislation [37,38]. However, concentrations became somewhat higher in 2015 and 2016. They were subsequently lower, and these conditions extended through the years of the COVID-19 pandemic to 2021. Social gatherings were less frequent in Hawaii as there was a strong sense of compliance with mask wearing and social distancing. Relaxation of COVID-19 rules and a renewed enthusiasm for pyrotechnic celebrations saw increased applications for firework permits, which rose to more than 20,000 on Oahu in late 2021. This may have been responsible for the slight elevation to $PM_{2.5}$ concentrations as the arrival of 2022 was welcomed (see Figure 3). However, it was the high particle concentrations during the 2023 celebrations that drew notable public ire, e.g., "The recent New Year's Eve brought the largest aerial show that we have ever seen on Oahu . . . ." [18].

3.4. Firework Permits

The number of fireworks permits issued each year could give an indication about the quantity of fireworks used. However, as seen in Figure 3, there does not appear to be a positive relationship with changes in the levels of particulate pollution suggested by Figure 2. Counterintuitively, a larger number of permits seems to be associated with years of low pollution, and there appears to be a negative relationship between the pollution and permits issued (Kendall $\tau = -0.45$; $p < 0.03$). A reason for this may be that permits are only for firecrackers; thus, they do not account for the pollution that arises from aerial and other illegal fireworks. Overall permits increased for nearly a decade, suggesting that many individuals recognised the importance in obtaining these. In December 2016, the *Honolulu Star Advertiser* [39] asked "Did you get a permit to buy and use fireworks for New Year's Eve?" and collected the responses which were: (i) no, not using fireworks (779 votes), (ii) no, but might use fireworks anyway (120 votes), and (iii) yes, enjoy popping (83 votes). Although not a controlled survey of its readers, the results show that rather few felt the need to get a permit, and a substantial fraction were willing to buy fireworks illegally. There was a decline in permits from 2017 associated with an attendant drop in firework sales observed by Wu [40], but the cause was not identified. However, by 2020, social distancing imposed because of COVID-19 pandemic restrictions limited a wide

range of public activities in Hawaii. Permits increased in 2022 as the pandemic ended, as noted elsewhere, as firework displays could be seen as celebrating a victory over the virus [41]. However, permit applications were down a little in 2023, but as often noted in the media, this was not accompanied by lower pollution concentrations: "The significant drop in firecracker permits . . . wasn't a good predictor of actual pyrotechnic activity or fireworks-related injuries." [42]. New Year 2023 proved to be the noisiest and most polluted celebration for more than a decade. Worries about the environmental burden fuelled public concern over the expanding use of illegal aerial fireworks, a matter that drew much comment in local media [18,23,42].

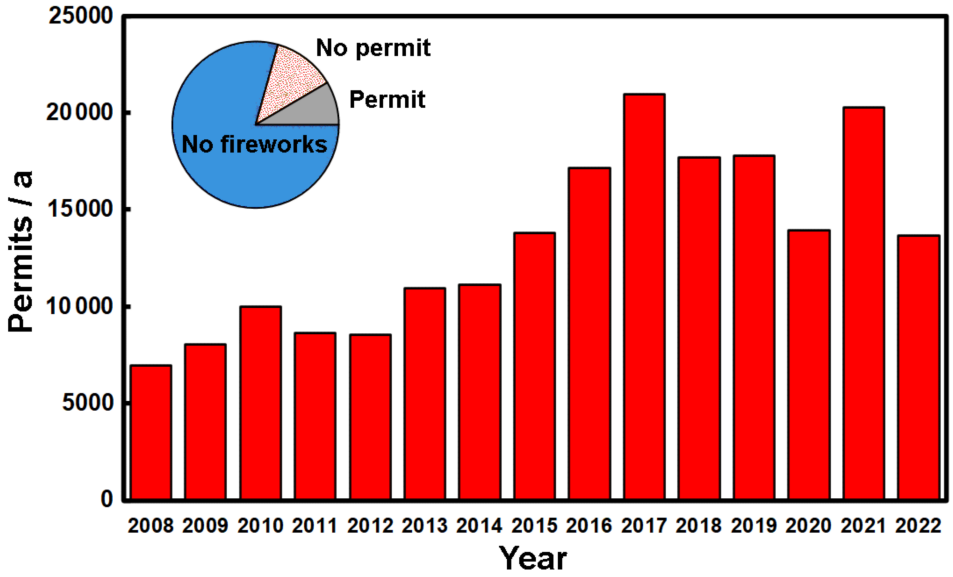

Figure 3. The number of fireworks permits issued before New Year [26]. The inset pie diagram shows the proportions of respondents who asked about obtaining a permit to buy and use fireworks for New Year's Eve [39], which relates to the purchases for the celebrations of New Year 2009/2023.

3.5. New Year Fireworks and Air Pollution

Figure 4 summarises changes of $PM_{2.5}$ concentrations averaged across the period from New Year's Eve at 21:00 to 02:00 the following morning. The concentrations, shown as line-joining averages, are corrected by subtracting the weather-only estimates for hourly particulate concentrations (shown in Figure 2). We note that the value for 2010 cannot be estimated exactly as the two hours between 21:00 to 23:00 are absent; hence, a symmetric profile around the midnight maximum was assumed. The $PM_{2.5}$ concentrations each year are compared with other factors related to firework use. The number of permits issued was discussed in the last section and if anything shows a negative relationship with the particulate concentrations observed.

The high concentrations found in 2023 amplified concerns that firework problems are caused by the illegal use of aerial fireworks. These were reflected in media headlines, such as "Honolulu EMS [Emergency Medical Service] reports long list of fireworks-related injuries in a 'brutal' start to new year" with at least eight people seriously injured by illegal fireworks [43]. It is certainly possible that illegal fireworks make a major contribution to air pollution, but this is difficult to assess because the quantities of these fireworks cannot be readily estimated. Record keeping over the years has been inconsistent, and government reports reveal that the statistics provided to support the Illegal Fireworks Task Force are inadequate [29].

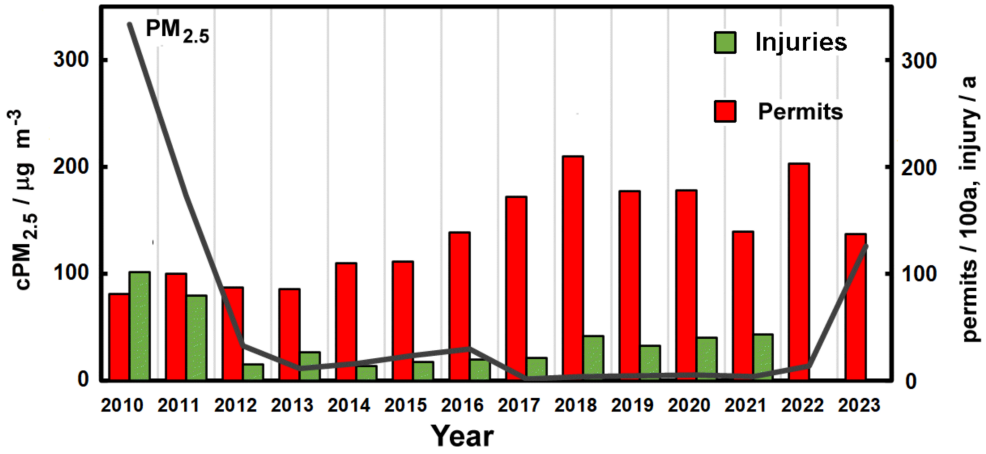

Figure 4. Average $PM_{2.5}$ concentrations 21:00 to 02:00 during New Year celebrations as a line. The number of permits (as hundreds) granted prior to New Year (red bars) and the number of injuries at New Year [26]. Note: 2022 and 2023 have no data for injury, and the concentrations are not corrected for weather effects.

Injury is often seen as related to illegal aerial displays; thus, it might seem that the record of accidents could provide evidence that air pollution was derived from these fireworks. However, as shown in Figure 4, there is no relationship between injury and $PM_{2.5}$ concentrations during the New Year celebrations; the Kendal τ is almost zero. In line with the high concentrations observed in 2023, Malcolm Medrano (the Honolulu Fire Department Captain) commented on their response to emergency incidents: "For us we've seen a significant increase this year," although he thought some of the rise may have been due to the relaxation of pandemic restrictions in Asia [42]. However, as another media outlet noted, it was likely that illegal fireworks were especially prominent in 2023 [44]. Although there are some early studies of fireworks and asthma in Hawaii [19,20] more recent evidence is not systematic, though reported in the media [18,23].

3.6. Social and Environmental Management

There are many problems in managing the use of fireworks and the resultant environmental pollution. In Hawaii, as in China and India, strong cultural associations with the celebratory use of fireworks complicates regulation. Additionally, tourism is extremely important to the State; therefore, public firework displays have been seen as important in encouraging the return of visitors in a post-COVID world. Nevertheless, articles in local media and surveys (Figure 5) reveal a public that has continuing concerns about the use of fireworks to welcome the New Year. In each of the ad hoc surveys, the dominant response (blue sectors of the pie diagrams) seems to indicate a resistance to New Year fireworks. However, these surveys address a particular segment of society which reads the local newspaper and may also be biased towards being especially concerned with firework use.

Illegal fireworks are of particular concern to the public as seen in the survey of 31 December 2016 (Figure 5a) where 599 responses suggested that fireworks should be banned, but 436 believed that the situation was fine except for the illegal fireworks. A more recent survey in the *Honolulu Star Advertiser* New Year's Day 2019 saw 358 of 627 respondents arguing that the situation was bad and that there were too many illegal fireworks (not displayed in Figure 5). This is also a concern within the government as enforcement agencies find it difficult to prevent access to illegal fireworks. There appears to be no easy way to curb sales, such as confiscating unlicensed imports as they enter Hawaii. Vivian Gonzalez, a Petty Officer with the Coast Guard, explained there were only 75 inspectors to examine the 1.5 million shipping containers that passed through Hawaii ports of entry in 2020 [44]. Enforcement is hampered by a willingness to use illegal fireworks at New Year, which comes as part of an increase in anti-social behaviour in the carnival-like atmosphere;

such times can create a sense that there is a "moral holiday" [31]. In Hawaii, the New Year is accompanied by an increase in criminal behaviour, particularly related to alcohol consumption, drunk driving, disorderly conduct, and assaults [42], which adds to the burden of regulating fireworks.

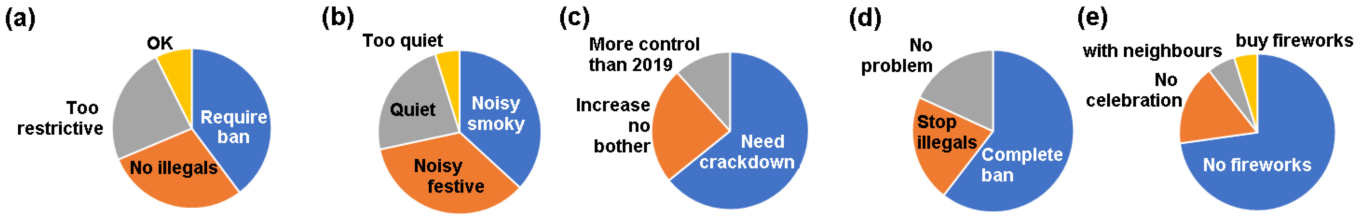

Figure 5. Results of ad hoc surveys in the *Honolulu Star Advertiser* asking a range of questions over the years (**a**) 31 December 2016: What do you think about the use of fireworks on New Year's Eve? (**b**) 1 January 2018: How was the fireworks situation in your neighbourhood (or where you were) on New Year's Eve? (**c**) 3 January 2020: What's your general reaction to the fireworks in neighbourhoods on New Year's Eve? (**d**) 5 January 2021: What do you think about how the New Year's Eve/Day fireworks played out? (**e**) 27 December 2021: Are you celebrating New Year's Eve with fireworks? Note: Survey data *Honolulu Star Advertiser* at dates listed.

Initially, the introduction of the permit system in Hawaii from 2012 seems to have been successful, but changes over the last two years have been worrisome. Other places have faced similar difficulties. In China and India, for example, some elements of the public remained resistant to bans on the use of fireworks that encouraged the development of illegal trading. However, in China, this has been accompanied by rising public concern over the effectiveness of pollution control [45] and enhanced government education and awareness campaigns along with a need to balance with community issues [46,47]. This has led to a wider acceptance of the need to control fireworks [15]. The Hawaian situation suggests that many already feel there is a need to limit the use of fireworks (Figure 5), but legislation continus to stall [48].

4. Conclusions

Comparisons of broad changes in air pollution from firework celebrations on a year-to-year basis can be difficult to assess because of changing meteorology. Nevertheless, the concentration of night-time particulate pollutants during New Year celebrations in Honolulu can be assigned to firework emissions rather than meteorology. The New Year period increases injury and respiratory problems from fireworks and related pollutants, but the long-term accumulated exposure is probably small as Oahu has fairly low particulate loads. The regular weekly displays for tourists in Waikiki are of limited duration (~10 min). Public and legislative concern remains high, especially after enhanced levels of pollution at New Year 2023 and an excessive use of illegal fireworks. Future research needs to look more closely at the role played by such fireworks in increasing particulate pollution but also their effect on injury and fires. More complete analyses of toxic metals, ultrafine particles, and ion clusters could give further insight. The Illegal Fireworks Task Force aims to collect better statistics, likely to improve future assessments. The Coast Guard hopes for improved discovery of illegal imports, and the public wishes to see stronger enforcement of the regulations. Eco-friendly fireworks might also help, but these tend to address the problems of perchlorate and toxic metals rather than airborne $PM_{2.5}$ concentrations. Approaches seen elsewhere, lasers and drone light shows and festivals with electric lanterns might provide alternative festive solutions.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/environments10040068/s1; Figure S1: Hourly $PM_{2.5}$ concentrations in Honolulu; Table S1: The statistical performance of 50 models was evaluated using four indicators: Pearson's correlation coefficient (r), mean bias (MB; in $\mu g\ m^{-3}$), normalised mean bias (NMB), and normalised root-mean-square error (NRMSE); Table S2: Variable importance for the chronological and meteorological variables.

Author Contributions: Conceptualization, P.B.; statistics, P.B.; machine learning, Y.L.; data curation, Y.L.; formal analysis, Y.L. and P.B.; writing—original draft preparation, Y.L. and P.B.; writing—review and editing, P.B.; visualization, P.B. All authors have read and agreed to the published version of the manuscript.

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