Post-Diwali Air Pollution in New Delhi
The Tragedy of the Commons

Asra Ishfaq, Aruma Khan, Khansa Riaz and Adiba Talmiz
M.A. Economics
Department of Economics, Jamia Millia Islamia, New Delhi

Abstract

Most of the ecological crises of shared common resources are a result of the conflicting self-interests of individuals with that of social interests. More than often, self-interests seem to overpower the latter. This is known as the Tragedy of the Commons. One example of such a tragedy is the pressing issue of air pollution in New Delhi which gets severe in the winter months, especially after the festival of Diwali. The existing literature shows the causal relationship between firecrackers and increased air pollution. This study approaches post-Diwali air pollution using the apparatus of the theory of the tragedy of the commons. In this paper, we use PM2.5 AQI levels, at 20:00 hours, in Delhi for a thirteen-day period that includes Diwali in 2017, 2018 and 2019. We have applied paired t-test on our data to analyse the impact of Supreme Court orders that regulate the use of firecrackers. The results suggest that these orders have had a statistically significant role in reducing the level of air pollution after Diwali. The impact also depends upon the efficacy with which the orders are implemented.

Keywords: Tragedy of the commons; air pollution; Diwali; New Delhi

Post-Diwali Air pollution in New Delhi: The Tragedy of the Commons

'The Tragedy of the Commons', a phrase coined by Garrett Hardin, is now a theory popularly used to explain the environmental hazard of resources collectively owned. The Tragedy of the Commons (Hardin 1968) became the hot topic for debates and discussion soon after its publication. Hardin differs from the renowned classical economist Adam Smith in his views. The Wealth of Nations (1776) by Adam Smith had popularized the idea of the 'invisible hand', which implied that when the rational individuals try to maximise their self-interests, they automatically promote the public interest. But what if the self-interests of individuals are in conflict with the public interest? Smith's idea rests upon the assumption of coinciding personal and social interests, which isn't necessarily always true; for instance, take the case of commons, the collectively owned resources.

The rationale behind this theory is fairly intuitive and closely reliant on the human behavior. Its acknowledgement can be traced back to Aristotle's philosophy in his concept of the distribution of care; who takes care of what and how.

"What is common to the greatest number gets least amount of care. Men pay most attention to what is their own; they care less for what is common; or at any rate, care for it only to the extent to which each is individually concerned" (Aristotle, Politics, Book 2, Part 3).

When individuals are allowed to use the commons freely, they end up overexploiting it and imposing mutual externalities upon each other. They end up depleting the shared common resources. This happens because there is only the desire to gratify self-interests and a lack of obligation to regenerate the resources. Hardin had come up with what looked like a catchall explanation for various ecological crises. One such crisis is that of air pollution. This paper aims to approach the problem of worsening air pollution of New Delhi as a Tragedy of the Common.

New Delhi topped the list of the most polluted capital cities in the world in 2019 for the second time in a row. According to a report by IQAir, a Swiss-based company that monitors air quality data globally, Delhi recorded an average 98.6 Particulate Matter (PM 2.5) concentration. Delhi is often beyond the daily mean threshold set by the Indian Central Pollution Control Board (CPCB, 60 µg / m3) and the threshold for unhealthy air given by the World Health Organization (WHO, a 24-hour average of 25 µg / m3).

In 2019, Delhi experienced one of the severest and longest spells of air pollution during late October and early November. The gravity of the situation compelled the government to declare a health emergency, temporarily suspend classes at schools, and limit construction activities. Late October also witnessed the festival of Diwali, a major religious festival lasting four to five days, celebrated extensively in India. Diwali is considered to be the festival of light, and hence, earthen lamps are lit, and houses are decorated with lights.

The burning of firecrackers is a very common practice and has become the main highlight of the festival and the major source of enthusiasm. The aftermath of Diwali is not so pleasant. Air pollution naturally becomes more prominent in cold weather. The coinciding of Diwali with the cold months is an unfortunate event for the air of Delhi.

In response to the spike in toxic air pollutants in the aftermath of Diwali, the Supreme court has passed numerous orders. In 2016, Delhi's pollution levels reached alarming levels a day after Diwali. Smoke caused by fireworks, as part of Diwali festivities, had enveloped the NCR in a thick layer of smog for weeks. This forced the Supreme Court to impose a blanket ban on the bursting of firecrackers on Diwali in its October 2017 judgement. This ban was temporary and was described as an experiment to observe its impact on pollution levels. While instances of violation of order were reported, the Central Pollution Control Board (CPCB) recorded better air quality than the preceding year.

However, citing concerns over the rising unemployment of those engaged in the manufacturing of firecrackers, SC, in its 2018 judgement, ruled out a blanket ban but laid down stringent conditions to control pollution in Delhi and NCR. These included fixing time slots, switching over to green crackers and ban on their online sale. Despite these measures, CPCB reported higher pollution levels than in 2017 due to higher fireworks and unfavourable weather conditions. This also highlights failure in the proper execution of the order, and massive violations were reported. In 2019, SC emphasised the regulation of crackers and suggested exploring an alternative to deal with pollution such as community bursting of crackers, etc.

In this paper, we have used PM2.5 AQI levels, at 20:00 hours, in Delhi for a thirteen-day period (including Diwali) each in the years 2017, 2018 and 2019. We use the paired t-test technique to observe whether the SC rulings have significantly impacted air pollution levels around Diwali time.

LITERATURE REVIEW

1. The Tragedy of the Commons (Garrett Hardin,1968)

The 'tragedy of the commons' is a theory formulated by ecologist Garrett Hardin. He has explained the concept by using William F. Lloyd's example of a pasture shared among herdsmen to graze their cattle (Lloyd, 1833). He states that a rational herdsman would prefer to increase another animal to his herd because the marginal utility of increasing another animal is greater than the marginal cost incurred due to another animal increased in the herd. This is because the cost of increasing the animal due to overgrazing would be shared by all the herdsmen, although he alone would bear only a fraction of this cost. Similarly, all the herdsmen would arrive at the same conclusion and increase their animals in order to gain proceeds from the sale of the animal and therein lies the tragedy.

'Each man is locked into a system that compels him to increase his herd without limit- in a world that is limited. Ruin is the destination toward which all men rush, each pursuing his own interest in a society that believes in the freedom of the commons'. (Hardin, 1968)

Hardin realised that this concept could be applied in a broader sense to understand several environmental catastrophes such as overgrazing of federal land, overpopulation, water pollution, air pollution, ocean dumping, acid precipitation, overfishing etc. However, for the tragedy of the commons to occur, there are certain necessary conditions. Firstly, we need to differentiate between the term commons and public goods. They can be distinguished from each other because the public good is non-consumptive in nature (one's use of the good does not reduce its availability for others). In contrast, the commons are subtractable in nature and are capable of being overused. Secondly, the resource needs to be open access resource because it would then be impractical and impossible to restrain its usage. Hence the conditions include the resource needs to be subtractable, can be overused and have unrestricted open access.

To prevent this tragedy, there are solutions offered by several ecologists, they include:

- **Transfer ownership of resources to the government or private owners**: It is considered one of the most effective ways to restrain the use of common resources. However, it can be argued that centralised forced coercion to regulate the use of resources could motivate people to disobey the rules and act in defiance. Also, privatisation of resources does not ensure sustainability because the short term gain could tempt private owners to exhaust resources.

- **Punitive measures**: They are also weighed as one of the competent measures of restraining and regulating the use of resources. Penalising environmental criminals is imperative for curbing overexploitation of resources. Heavy taxes and fines on corporates act as a deterrent against the exhaustion of resources.

- **Output shared within subgroups**: It involves the sharing of proceeds earned among members of a subgroup. The collective sharing of gains would make the overuse of resources comparatively less attractive.

- **Self-governing common systems**: E. Ostrom, in her paper ' Governing the Commons: The Evolution of Institutions for Collective Action' (1990), has stressed on self-governing common systems that coordinate and manage the common resource without any external intervention. She was awarded Nobel Memorial Prize for Economic Sciences for this work in 2009. The paper specifies several examples such as forest

institutions in Switzerland and Japan, irrigation systems in Spain and the Philippines and fisheries maintained sustainably. However, these institutions need regular assistance and funding.

Apart from these, monitoring, sanctioning, communication, and awareness are some of the measures that can be conducive to averting the tragedy of the commons.

2. Estimates of Air pollution in Delhi from burning of firecrackers during the festival of Diwali (Dhananjay Ghei & Renuka Sane, 2018)

The paper studied the aftermath of Diwali in order to look for the existence of a causal relationship between firecracker burning and air pollution. Although the date of Diwali moves according to the Hindu lunar calendar, it always falls in the cold winter months of October and November. In winters, particles remain suspended in the air for a longer duration. This also happens to be when the farmers of Haryana and Punjab, the neighboring states, engage in stubble burning to prime the land for sowing for the next season. It goes without saying, this time of the year is dismal for the air of Delhi with or without Diwali. The question is whether or not the firecrackers exacerbate the air pollution.

The research made use of the PM 2.5 concentration records of multiple places in Delhi to measure the quality of air since PM 2.5 is severely harmful to health. It is small enough to enter the respiratory tract and reach the lungs causing hazardous short term and long term effects. After using the event study technique and the difference-in-difference regression, the results suggested that firecracker burning has a small but statistically significant contribution in deteriorating the already poor air quality.

We improve upon the existing research by studying the problem of air pollution in Delhi as a dilemma of the tragedy of the commons. When the people of Delhi individually yet simultaneously try to gratify their own desire to celebrate Diwali with firecrackers, they end up making the air of Delhi the common, unfit to breathe for all. To our knowledge, this might be the first attempt at approaching this issue as a tragedy of the commons. The existing literature supports and establishes that firecrackers exacerbate air pollution but do not put forward a corrective framework or some administrative laws to resolve this tragedy. In this paper, we attempt to come up with feasible and plausible measures to do so. The paper also aims at collecting and studying data to gauge the effectiveness of the Supreme Court orders addressing post-Diwali air pollution using the paired t-test technique.

METHODOLOGY

Ethical Declaration

All the data collected at the four monitoring sites used in this study is publicly available on the internet, and no specific permissions are required to access these sites.

PM 2.5 AQI as Pollution Level Indicator

Combustion releases many pollutants, including carbon monoxide (CO), oxides of nitrogen (NOx), ozone (O3) and fine particles, into the atmosphere. The term fine particles or particulate matter(PM2.5) refers to particles or droplets that are 2.5 microns in diameter. These are considered the most harmful of all pollutants.

Particles in the PM 2.5 range are able to penetrate deeply into the respiratory tract. Prolonged exposure to PM 2.5 has been associated with conditions like asthma, lung cancer, respiratory diseases, cardiovascular disease, congenital disabilities, and premature death.

Indiscriminate use of firecrackers each Diwali increases the PM 2.5 level at an alarming level. We, therefore, restrict our study to the measure of PM 2.5 AQI. The air quality index (AQI) is a number used to report the air quality on any given day and ranges from 0-500. AQI level from 0-50 is considered good, 51-100 is satisfactory, 101-200 is moderate, 201-300 is poor, 301-400 is very poor, and 401 and above is severe.

Data Source

We collected data related to PM 2.5 values in Delhi from Central Pollution Control Board(CPCB) from four locations:

1) ITO in Central Delhi
2) NSIT Dwarka in South West Delhi
3) Dilshad Garden in East Delhi
4) DTU in North West Delhi.

We use 20:00 hours, PM 2.5 level from the locations mentioned above for a period of thirteen days, including Diwali for years 2017, 2018 and 2019. It should be noted that certain values are missing from certain sections of the data. These missing observations are excluded from our analysis.

The Festival of Diwali

Diwali does not fall on the same date every year as it is based on the Hindu lunar calendar. In the years under consideration, Diwali occurred on 19th October 2017, 7th November 2018 and 27th October 2019.

The Supreme Court Rulings

On 9th October 2017, The Supreme Court of India banned the sale of fireworks till 1st November 2017 in Delhi and NCR. This was an attempt to limit air pollution during Diwali season. The Court had said it wanted to examine the effect of cracker-free Diwali on the quality of air. Licenses given by Delhi police to wholesalers and retailers of firecrackers were cancelled. The order had come after Delhi-NCR experienced its worst case of smog in 17 years in 2016, and pollution from crackers was cited as the main cause.

On 23rd October 2018, The Supreme Court ruled out imposing a complete ban on the sale of firecrackers during Diwali but put certain conditions in place for the sale and use of firecrackers.

The court ordered that the bursting of firecrackers on Diwali and other festivals would be only from 8 PM to 10 PM.

It directed that only green firecrackers be manufactured and sold in Delhi and NCR. However, firecrackers already produced were allowed to be sold in that festival season but only in other parts of the country. Further, the pan India ban on the sale of firecrackers through e-commerce websites was imposed.

In 2019, the Supreme Court laid emphasis on the regulation of crackers and suggested exploration of alternatives to deal with pollution such as community bursting of crackers etc.

Delhi Government Initiatives

On 13th September 2019, the Chief Minister, Arvind Kejriwal, announced a seven-point 'Parali Pradushan' Action Plan. The plan involved the following steps:

1.Odd Even
2. Pollution Masks
3. Community Diwali Laser Show
4. Environment Marshals
5. Hotspot Control
6. Dust Control
7. Tree Challenge

Estimation

We estimate the effect of the Supreme Court orders of 2017 and 2018 and the measures taken by the Delhi government in 2019 on Diwali air pollution in Delhi.

We have collected average PM 2.5 particulate concentration levels at 8 p.m. from four regions in Delhi for 13 days, including Diwali (6 days before and after Diwali) for the years 2017,2018 and 2019, studying the impact of orders and measures.

Daily mean is the mean of the average PM 2.5 particulate concentration levels across the four regions in Delhi on a particular day out of the 13 days taken in a year. Yearly mean is the mean of the daily means of all the 13 days taken in a particular year. So we calculated the daily mean of PM 2.5 levels across the four regions in Delhi for all three years. Then we used paired two-tailed t-test on our data to compare the means of the years, taking two years at a time. The **paired two-tailed t-test** was conducted to detect whether a significant difference existed between the means of 2017, 2018 and 2019. The level of significance for the t-test is taken as 0.05. We have used a comparison between the two-tailed p-value and level of significance to check whether our yearly means for the 13 days have a significant difference or not. The standard relation used is that if the p-value is less than the significance level, we reject the null hypothesis, or else we accept it. The t-test was performed in MS Excel.

DATA

PM 2.5 levels at 8 p.m. across 4 regions in Delhi for 13 days' duration, including Diwali

"-- "represents data unavailability

Dates	NSIT, Dwarka	Dilshad Garden	DTU	ITO	Mean(2017)
13th October,2017	291	219	286	222	254.5
14th October,2017	277	233	270	236	254
15th October,2017	309	278	-	295	294
16th October,2017	328	287	341	303	314.75
17th October,2017	306	258	319	347	307.5
18th October,2017	327	266	349	288	307.5
19th October,2017(Diwali)	320	267	360	320	316.75
20th October,2017	376	310	429	392	376.75
21st October,2017	376	305	423	419	380.75
22th October,2017	294	248	330	357	307.25
23rd October,2017	378	225	350	342	323.75
24th October,2017	353	248	387	345	333.25
25th October,2017	322	268	402	369	340.25
				Mean=	316.230769

	NSIT, Dwarka	Dilshad Garden	DTU	ITO	Mean(2018)
1st November,2018	311	357	412	361	360.25
2nd November,2018	250	322	387	377	334
3rd November,2018	257	272	340	336	301.25
4th November,2018	198	110	168	166	160.5
5th November,2018	368	398	449	450	416.25
6th November,2018	277	273	307	296	288.25
7th November,2018(Diwali)	248	267	292	303	277.5
8th November,2018	404	424	425	432	421.25
9th November,2018	379	370	404	421	393.5
10th November,2018	353	374	428	403	389.5
11th November,2018	339	355	385	405	371
12th November,2018	364	357	416	--	379
13th November,2018	349	378	423	412	390.5
				Mean=	344.826923
	NSIT, Dwarka	Dilshad Garden	DTU	ITO	Mean(2019)
21st October,2019	275	236	277	242	257.5
22nd October,2019	226	166	249	--	213.666667
23rd October,2019	252	224	304	--	260
24th October,2019	333	282	339	327	320.25
25th October,2019	265	238	302	292	274.25
26th October,2019	271	229	324	292	279
27th October,2019(Diwali)	322	314	340	316	323
28th October,2019	377	375	394	407	388.25
29th October,2019	368	409	425	414	404
30th October,2019	355	404	437	413	402.25
31st October,2019	368	410	441	420	409.75
1st November,2019	442	457	482	479	465
2nd November,2019	360	414	425	450	412.25
				Mean=	339.166667

RESULTS

The mean for the years 2017, 2018 and 2019 is calculated by taking the mean of the daily means.

The yearly means mentioned at the end of each year reveal that the mean of the three years are as follows

2017: 316.2308

2018: 344.8269

2019: 339.1667

Hence the pollution levels, as indicated by PM 2.5 levels, have been the lowest in 2017 compared to 2018 and 2019 since the complete ban on the sale of crackers was imposed before Diwali in 2017. The reason for a higher mean in 2018 than in 2019 is the fact that the Supreme Court's 2018 orders were not properly implemented. Also, the Delhi government introduced several measures like carpooling and community Diwali celebration in 2019, which proved beneficial in reducing pollution levels.

Level of Significance = 0.05 for all the t-tests

t-Test: Paired Two Sample for Means		
	Mean(2017)	*Mean(2018)*
Mean	316.23077	344.8269231
Variance	1430.1298	5267.472756
Observations	13	13
Pearson Correlation	0.3047873	
Hypothesized Mean Difference	0	
df	12	
t Stat	-1.4545603	
P(T<=t) one-tail	0.0857221	
t Critical one-tail	1.7822875	
P(T<=t) two-tail	**0.1714441**	
t Critical two-tail	2.1788128	

Fig. 1

The t-test in Fig.1 compares the yearly means of 2017 and 2018 in order to find out whether the difference between the yearly means is statistically significant or not.

Null hypothesis: $\mu 1 \neq \mu 2$

Alternative hypothesis: $\mu 1 = \mu 2$

Where μ1 and μ2 are the yearly means of 2017 and 2018, respectively.
Since the two-tailed p-value = 0.1714441 is greater than the significance level, i.e., 0.05, our null hypothesis is accepted, i.e., there is a significant difference between the two means.

t-Test: Paired Two Sample for Means			
	Mean(2018)	*Mean(2019)*	
Mean	344.82692	339.1666667	
Variance	5267.4728	6157.475694	
Observations	13	13	
Pearson Correlation	0.3819379		
Hypothesized Mean Difference	0		
df	12		
t Stat	0.2426371		
P(T<=t) one-tail	0.406192		
t Critical one-tail	1.7822875		
P(T<=t) two-tail	**0.8123841**		
t Critical two-tail	2.1788128		

Fig. 2

The t-test in Fig. 2 compares the yearly means of 2018 and 2019 in order to find out whether the difference between the yearly means is statistically significant or not.
Null hypothesis: μ2 ≠μ3
Alternative hypothesis: μ2 = μ3
Where μ2 and μ3 are the yearly means of 2018 and 2019, respectively.
Since the two-tailed p-value = 0.8123841 is greater than the significance level, i.e., 0.05, our null hypothesis is accepted, i.e., there is a significant difference between the two means.

t-Test: Paired Two Sample for Means

	Mean(2017)	*Mean(2019)*
Mean	316.23077	339.1666667
Variance	1430.1298	6157.475694
Observations	13	13
Pearson Correlation	0.7508482	
Hypothesized Mean Difference	0	
df	12	
t Stat	-1.477823	
P(T<=t) one-tail	0.0826077	
t Critical one-tail	1.7822875	
P(T<=t) two-tail	**0.1652155**	
t Critical two-tail	2.1788128	

Fig. 3

The t-test in Fig. 3 compares the yearly means of 2017 and 2019 in order to find out whether the difference between the yearly means is statistically significant or not.
The null hypothesis is: $\mu 1 \neq \mu 3$
Alternative hypothesis: $\mu 1 = \mu 3$
Where $\mu 1$ and $\mu 3$ are the yearly means of 2017 and 2019, respectively.
Since the p-value = 0.1652155 is greater than the significance level, i.e., 0.05, our null hypothesis is accepted, i.e., there is a significant difference between the two means.

Hence with the help of the data and the paired two-tailed t-test, we conclude:
1) There is a statistically significant difference between the yearly means of the three years
2) The yearly mean of 2017 is the least due to the imposition of a complete ban on the sale of firecrackers prior to Diwali in this year.
3) The yearly mean of 2019 is lower than 2018 due to the government measures introduced in 2019 and better implementation of the Supreme Court orders of 2018 in 2019.

CONCLUSION

The statistical analysis of PM 2.5 observations indicates that a complete ban and restraining the use of firecrackers in Diwali are plausible and constructive strategies for regulating and monitoring air pollution in Delhi. The data can also be studied to infer that a planned course of action by the government of impeding the use of crackers by strict punishments for violating the issued guidelines by the Supreme Court along with the implementation of innovative policies and measures also ascertain reduction in air pollution level. The results thus obtained also validates our supposition that post- Diwali air pollution can be classified as a tragedy of the commons.

Therefore, it is important to acknowledge the reckless bursting of firecrackers will eventually lead the residents of Delhi to the tragedy of the shared common resource- air until we take cognisance of the precarious situation and work to maintain sustainable air quality levels.

Recommended measures

From the above results, we can conclude that regulating the sale of firecrackers is an effective way to reduce air pollution in Delhi post-Diwali. Therefore, this scenario classifies as a tragedy of the commons. To avert this tragedy of the commons, apart from the court's order, we need other competent policies and measures to discourage and deter people from burning crackers in Diwali and celebrate it in an ecologically sound manner. Besides these measures, we need alternative sources of amusement and spreading awareness so that each of us become socially conscious for a sustainable livelihood for all. Some of these measures can be categorised as:

Alternative Sources of Recreation:

Although firecrackers originated in China, they have been a regular part of almost all Indian festivals and celebrations, especially Diwali, the festival of lights. But undeniably, they are the most unusual source of short term anthropogenic pollution, which causes serious health hazards. Hence there is a serious need for alternative sources of entertainment and recreation to ensure an ecofriendly celebration of all such festivals. Some of these sources are:

- **Green crackers**

The Council of Scientific and Industrial Research (CSIR) developed eco-friendly crackers after Supreme Court imposed a ban on conventional crackers in 2017. These crackers are believed to be 'less hazardous' as it promises to reduce the particulate emissions by 30% and are available at the same cost as conventional crackers. CSIR primarily focused on reducing Barium Nitrate emissions – one of the key ingredients of conventional firecrackers. These crackers have been labelled 'Safe Water Releaser' (SWAS), 'Safe Minimal Aluminium' (SAFAL) and 'Safe Thermite Cracker' (STAR). However, according to the reports, only a few players were provided with the license to manufacture green crackers. Hence the market saw a low supply and lacked in varieties. This is a major problem that needs to be addressed for the customers to shift to eco-friendly alternatives. The government and the society as a whole, therefore, need to take measures to create a market for green crackers that could work efficiently. An efficient market with strategised promotions of eco-friendly crackers by the government could be a key to switch from conventional crackers to eco-friendly crackers.

- **Laser light shows**

The Delhi government came up with a refreshing idea of laser light shows during Diwali in 2019. It was hosted at Central Park, Connaught Place, one of the busiest and happening places in Delhi. The show allowed free entry, and the park also hosted food, beverages and handicraft kiosks. It was one of the major attractions for the Delhi residents and proved to be a fascinating source of entertainment, also ensuring an inclusive celebration due to free entries.

Hence such alternatives can be organised at a large scale level by the governments as The Delhi government came up with a refreshing idea of laser light shows during Diwali in 2019. It was hosted at Central Park, Connaught Place, one of the busiest and happening places in Delhi. The show allowed free entry, and the park also hosted food, beverages and handicraft kiosks. It was one of the major attractions for the Delhi residents and proved to be a fascinating source of entertainment, also ensuring an inclusive celebration due to free entries. Hence such alternatives can be organised at a large scale level by the governments as it ensures a safe and eco-friendly way to celebrate the festival as a community. It does not involve burning crackers, but the illusion of fireworks through projection mapping is a smart and innovative way to celebrate. 3-D projections can also be used to appeal the people. Such measures should be encouraged by the government and each and every responsible citizen.

- **Collectively responsible local celebrations:**

Our country has a tradition of celebrating all festivals as a community. Thus these celebrations organised at local levels should offer other sources of entertainment such as plays, dance and singing performances, diya-lighting competitions, food and other creative ways to celebrate Diwali safely with the collective responsibility of the society as a whole to discourage and prevent the bursting of crackers.

Punitive measures and Disincentives

Regulations and restrictions are necessary to keep the commons from being overexploited. Likewise, punitive measures and disincentives further deter the individuals from misusing the shared resource. In order to minimise the consumption of firecrackers, the following measures can be put to use during Diwali:

- **Regularisation of firecracker production**

Prior to Diwali, the government should prohibit the production of crackers without a license. The procedure of obtaining a license may be based on parameters like quality checks and standardised production. Having a cumbersome procedure on its own acts as a disincentive. This can further be paired with strict legal actions for unauthorised producers in the form of hefty fines or detention.

- **Market-based instruments**

Conventional crackers can be highly taxed. On the other hand, green crackers should be subsidised. Both these measures should be done in a way such that conventional crackers become relatively expensive for the consumers and the producers find a better profit margin in producing green crackers. This will increase the demand and supply of green crackers.

- **Time slot violation penalty**

In the past few years, The Supreme Court has been allotting time slots to each state for bursting crackers. A helpline number can be circulated before Diwali for reports of violation with video evidence of time and the person's identity. This will increase the risk of facing a penalty for violation and will act as a deterrent.

Awareness Measures and Incentives

Coercion alone is not enough to bring about a change in human behavior. Humans tend to put an act of defiance when they're not convinced with the purpose of coercion. One effective way of dealing with the inertia of changing is to justify and explain the need for that change. This calls for raising awareness regarding the pressing issues. Some effective ways of spreading awareness are mentioned below:

- **Economic incentives and promotion of innovation**

Giving awards, recognition and incentives for industrial set-ups at green sites and others who take initiatives or innovate new ideas for environment protection. Innovation must be promoted through financing sustainable agricultural activities, and eco-friendly cookstoves, supporting NGO led voluntary initiatives etc.

- **Spreading awareness and public participation**

Using media communication platforms for educating and involving the masses in protecting air quality, especially during Diwali when pollution levels are at their peak, is very necessary. Involving influential leaders and personalities in this task can make it more effective. If people are made aware of the hazardous consequences of poor air quality by mere burning of crackers, it will indeed profit the entire country. China introduced different activities and campaigns to enhance public participation in environmental protection for specific target groups. For teenagers, a series of environmental protection events were carried out, such as the 'I Love Mother Earth' Primary and Secondary School Students Speech Competition, Beijing Children's Environmental Protection Art Festival, and so on, which has immensely contributed to protecting air quality. In India, initiatives like the Save your lungs Dilli campaign, four-day laser show organised by the Delhi government to encourage avoidance of cracker bursting, societies celebrating a cracker free Diwali etc. have yielded immense positive results

- **Spreading awareness in the uneducated masses**

Convincing the farmers to refrain from stubble burning is a big need of the hour since it contributes immensely to polluting Delhi and nearby areas. It can be done by giving them incentives and buying it off from them, then using this paddy straw to produce high-value products for the energy industry. Imbibing and instilling a realistic concern in all children by briefing them with consequences of polluted air is urgently needed since they are the country's future citizens, and they majorly indulge in bursting crackers.

Technological Measures

Faced with similar crises, cities worldwide have adopted clean-tech solutions as an integral part of their plans to combat air pollution, and Delhi should follow suit.

- **Cloud seeding**

It is the process of artificially harnessing the clouds and making rain by seeding clouds with silver iodide or dry ice. This artificially induced rain could be used to wash away the toxic pollutants that plague Delhi each year after Diwali.

- **Smog eating infrastructure**

Photo-catalytic treatments remove pollutants from the air in the presence of sunlight. These treatments can be applied to a range of surfaces, for example, roofing tiles, even the surface of roads. A hospital building in Mexico City has a facade made up of titanium oxide coated tiles that break down smog into safer chemicals. Similarly, Netherlands has a smog-eating pavement. India should also introduce photo-catalytic materials in its future constructions.

- **Smart Trees**

These have the environmental benefits of a small forest. These vertical units have their surfaces covered with moss and lichen with a large surface area to absorb nitrogen oxides and particulate matter. Asia's first smart tree has been installed in Hong Kong.

- **Smog free towers**

Developed by a Dutch design company, these air-purifying towers suck in pollution and expel clean air, and the extracted pollution is converted into gems. The first tower has been installed in Rotterdam, and they are planning to roll them out across global cities.

Finally, considering all these measures to avert the ill-effects of firecrackers on air quality, we also need to emphasise the need for collaborative efforts of both the government and every citizen. A joint action as a community is the need of the hour so that we restore the natural equilibrium of the ecosystem. Otherwise, our callousness would imperil our lives as well as successive generations.

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