

# The ambient air and noise quality in India during diwali festival: A Review

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## Abstract

This study deals with the effects of fireworks on the air quality over the major cities of India during the festival of light known as "Diwali". The effects of firecrackers during the festival was assessed from the ambient concentrations of various air pollutants such as sulphur dioxide (SO<sub>2</sub>), nitrogen dioxide (NO<sub>2</sub>) and particulate matter (PM) with diameter less than 10 µm. The concentrations of gaseous pollutants such as SO<sub>2</sub> and NO<sub>2</sub> as well as particulate pollutants such as PM<sub>10</sub> and PM<sub>2.5</sub> was found about 2-6 times higher during the day of festival because of the use of huge quantity of firecrackers that emits a large amount of pollutants into the atmosphere. Previous studies indicated that the concentrations of above air pollutants during Diwali festival was found several folds higher as compared to the 24-h standard of National Ambient Air Quality Standards of India (NAAQS) given by the Central Pollution Control Board (CPCB), India. Concentrations of metallic elements analysed in fireworks aerosol samples in previous studies in India reported its higher contribution during Diwali festival as compared to the limit value of NAAQS of India. The noise levels in the Indian cities during the night of Diwali festival were also found to be higher. The deterioration of ambient air quality due to the anthropogenic activity such as the use of firecrackers in the megacities of India has significant impacts on human health on a regional scale. This review suggested the development of serious strategies to control the use of firecrackers during the festival of light in the major cities of India to protect human health.

**Keywords:** Fireworks; RSPM; Air pollution; Noise pollution; Health effects

## INTRODUCTION

Diwali is a festival of light that is celebrated with great enthusiasm all over India during the month of October or November. Burning of firecrackers and illumination is a symbol of joy and prosperity. Firecrackers are associated with worldwide festivities such as New Year's Eve celebrations, the Las Fallas in Spain, the Lantern Festival in China, Bonfire Night in UK, Tihar in Nepal, Day of Ashura in Morocco, Skyfest in Ireland, Bastille day in France and Diwali in India, and also with many other communities of the world.

Fireworks contain chemical species such as sodium oxalate, aluminium, arsenic, sulphur, manganese, iron dust powder, potassium perchlorate, strontium nitrate and barium nitrate etc. [1]. The burning of firecrackers also produces gaseous pollutants such as SO<sub>2</sub> and NO<sub>2</sub>, and produce huge amount of ambient particulates into the atmosphere that generates dense clouds of smoke [2-3].

Studies have been made in several parts of the world to determine the effects of firework activities on the ambient air quality. A study [4] revealed that highly toxic pollutants like polychlorinated dioxins and furans are produced during the display of fireworks like "blue lighting rockets" and "Fountains". Bach et al. 1975 [5] found that firework activities on New Year's Eve on Oahu were responsible

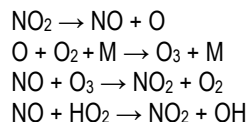
for an increase in Total suspended particulate matter (TSPM) by an average of three times higher at fourteen locations and about seven times higher at one location. Fireworks display during Lantern Festival in Beijing reported to be 57%, 25% and 123% increase in SO<sub>2</sub>, NO<sub>2</sub> and PM<sub>10</sub> levels, respectively over previous day. A detailed study revealed that over 90% of the total mineral aerosol and 98% of lead (Pb), 43% of total carbon (TC), 28% of zinc (Zn), 8% of nitrate ion (NO<sub>3</sub><sup>-</sup>) and 3% of sulphate ion (SO<sub>4</sub><sup>2-</sup>) in PM<sub>2.5</sub> aerosols were from the fireworks activity on the Lantern Day. Liu et al. 1997 [3] and Drewnick et al. 2006 [6] showed the effect of firework activities on aerosol concentrations in the air during the celebration of New Year's Eve 2005 in Germany. Fireworks during the FIFA World Cup 2006 celebration increased the concentration of metals like Sr, Mg, Ba, K and Cu by 120, 22, 12 and 6 times, respectively in the ambient air of Italy [7]. Bates et al. 1996 [8] suggested that an increase in dioxin and furan concentration by a factor of four occurred during the period of Bonfire night over Oxford in England.

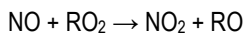
Attri and co-workers [9] reported that display of fireworks could produce Ozone (O<sub>3</sub>), a strong and harmful oxidising agent at the ground level without the formation of NO<sub>x</sub>. Victoria advocate reported that firework display during the New Year's eve in Mexico city increased the level of ozone to 190 on a scale with a normal cut off level of 100 [10]. Nishant et al. 2010 [11] suggested a different scheme of formation of O<sub>3</sub> during night time on the basis of emission spectra derived from UV visible spectrophotometer.

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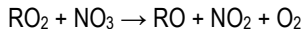
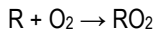
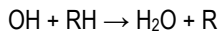
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Alkanes are formed in the gaseous phase during the burning of firecrackers which may react with the OH radical in the presence of O<sub>2</sub> to form alkyloxy (RO<sub>2</sub>) radicals. This RO<sub>2</sub> reacts with NO<sub>3</sub> radicals to form NO<sub>2</sub>, and NO<sub>2</sub> is further photolysed in the presence of fireworks to generate O<sub>3</sub>.



Source :[11-12]

Along with the air quality, noise quality is also affected by the fireworks activity during Diwali festival. Noise is an unwanted and unpleasant sound, which acts as environmental pollutant in the atmosphere which creates interference in communication and created health problems [13-15].

### Health Effects

Health effects of PM and their components are well documented. Hirai et al. 2000 [16] found that inhalation of smoke from fireworks causes cough, fever and dyspnoea, and leads to acute eosinophilic pneumonia (AEP). Previous studies indicated that fine particles such as PM<sub>2.5</sub> or PM<sub>1</sub> can penetrate deep into the respiratory system [17, 18]. Recent studies have shown that PM<sub>2.5</sub> and PM<sub>1</sub> aerosols can penetrate into the alveolar region of the lungs [19, 20]. Measurement of PM<sub>10</sub> is necessary because it contributes to health effects such as exacerbation of asthma attacks [21, 22]. Fleischer and co-workers reported the concentrations of organic toxic species, including octachlorinated dioxins, furans, and hexachlorobenzene, in the remains of fireworks [4]. Ambient PM may be carriers of toxic species like heavy metals, acids and carcinogenic compounds which have adverse effects on environment as well as human health. At higher concentrations, all metals are harmful to living beings including humans [23]. Apart from higher concentration of PM, studies have shown that there is a strong relation between the concentration of SO<sub>2</sub> and NO<sub>2</sub> that has severe health impacts [24], cardiovascular diseases, respiratory health effects such as asthma and bronchitis [25], reproductive and developmental effects such as increased risk of pre-term birth [26]. Allergic bronchitis, acute exacerbation of bronchial asthma, chronic bronchitis, emphysema, chronic obstructive pulmonary diseases (COPD), allergic, rhinitis, laryngitis, sinusitis, pneumonia and common cold increase with the concentration of gaseous pollutants [27, 28]. In India, 30% to 40% increased cases of wheezing, respiratory diseases, exacerbation of the bronchial asthma and bronchitis patients have been reported during the Diwali festival [29, 30]. Short term but high emission of trace elements such as As, Cd, Co, Cr, Ni, Pb and Se, which are animal or human carcinogens even in trace amounts have severe health impacts [6]. Pb can cause neurological and haematological impacts on the exposed population; Cd and Ni can cause carcinogenic effects in humans through inhalation, occupational level of Cd exposure is a risk factor for chronic lung diseases ([31], [32]). Cr (VI) has carcinogenic effect on the bronchial tree, increased Mn leads to neurotoxic impairments, increased level of Cu leads to respiratory irritancies ([32], [33],[34]).

Noise pollution due to fireworks not only distracts our attention but also causes psychological stress. The most dangerous effect of

noise from firecrackers is loss of hearing ability, which may be temporary or permanent depending on time of exposure ([35], [36], [37]). Excessive noise may cause severe sleep disturbance, fatigue and irritation due to community noise [38]. Continuous noise levels increases the cholesterol level, which increases the possibility of heart attacks [39].

Firecrackers during Diwali emit large amount of PM and poisonous gases in the air. They deteriorate the air quality as well as they cause noise pollution in the society leading to serious health hazards and disturbance in the ecosystem. The aim of this study is to review the concentrations of PM, poisonous gases, heavy metals and noise level during Diwali festival found in various cities of India by previous studies as well as the information available from the various State Pollution Control Boards.

### Ambient Air Quality Measurements

The national ambient air quality standards of some air pollutants are listed in Table 1.

Table 1. National ambient air quality standards of air pollutants prescribe by Central Pollution Control Board (CPCB), India

S. no.	Pollutants	Time weighted average	Concentration in ambient air ( $\mu\text{g}/\text{m}^3$ )
1	SO <sub>2</sub>	Annual	50
		24-h	80
2	NO <sub>2</sub>	Annual	40
		24-h	80
3	PM <sub>10</sub>	Annual	60
		24-h	100
4	PM <sub>2.5</sub>	Annual	40
		24-h	60
5	Ozone	8-h	100
		1-h	180
6	Lead	Annual	0.5
		24-h	1
7	CO	8-h	02
		24 hours	04
8	NH <sub>3</sub>	Annual	100
		24-h	400

Source: <http://cpcb.nic.in>

It has been found in many studies that the ambient air quality decreases during the Diwali festival. The more alarming situation is that in many cities this degradation of air quality is increasing every year during the Diwali festival, exposing the human lives to a greater risk.

### Respiratory Suspended Particulate Matter (RSPM)

Determination of RSPM ( $D_a \leq 10 \mu\text{m}$ ) in the ambient air is necessary because they carry a complex mixture of toxic pollutants from fireworks which enter deep into the respiratory system causing paediatric respiratory diseases. The results from previous studies during Diwali are shown in Table 2.

The concentration of PM<sub>10</sub> was very high during Diwali as compared to the normal days and the day before Diwali. The post Diwali concentrations are high because the fireworks activity continues 2 to 3 days after Diwali celebration. The concentration of PM<sub>10</sub> is high due to the fact that the aerosol released in the ambient air remains suspended in the air. An important study ([1], [41]) reported that the PM<sub>10</sub> concentration remained high in the ambient air for even about one month after the Diwali festival. The higher value of PM<sub>10</sub> as compared to the NAAQS is a serious indication of

air pollution which affects the health of people. The results of Rajim sampling site, a rural area, which is 45 kms away from Raipur, shows that even a rural and religious area, which is supposed to be environmentally clean, is seriously affected by fireworks during Diwali. The high concentrations of water-soluble ionic species were

mainly due to the abundant use of salts in manufacture of fireworks. Higher concentrations of  $Mg^{2+}$ ,  $K^+$ ,  $NH_4^+$ ,  $SO_4^{2-}$  and  $NO_3^-$  is mainly due to their use in making of sparklers and crackers which mainly contain potassium nitrate, ammonium nitrate, charcoal and sulphur [40].

Table 2. Comparison of  $PM_{10}$  and water-soluble ionic concentrations ( $\mu g/m^3$ ) in the ambient air observed during Diwali fireworks across India

	$PM_{10}$	$Na^+$	$Mg^{2+}$	$K^+$	$Ca^{2+}$	$NH_4^+$	Cl <sup>-</sup>	$NO_3^-$	$SO_4^{2-}$
Nagpur (a) [40]									
Pre Diwali	250	5	7	5.5	4.8	6	4	5	8
Diwali	930	13	29.6	26	12	16.8	12.5	16	19.9
Post Diwali	590	9	13	17	7	9	7	8	11
Lucknow (b) [32]									
Pre Diwali	300	NA	NA	NA	2.85	NA	NA	NA	NA
Diwali	753.3	NA	NA	NA	3.17	NA	NA	NA	NA
Post Diwali	NA	NA	NA	NA	NA	NA	NA	NA	NA
Rajnandgaon (a) [28]									
Pre Diwali	110.23	5	6	8	5	7	3	4	6
Diwali	431.43	13	13.75	13.75	13	14	11	10	15
Post Diwali	321.65	11	10	12	12	11	8	8.5	12
Hyderabad (c) [41]									
Pre Diwali	NA	0.17	1	1	NA	NA	NA	NA	NA
Diwali	NA	0.4	4	58	0.25	NA	NA	NA	NA
Post Diwali	NA	0.8	1	1	NA	NA	NA	NA	NA
Kolkata [30]									
Pre Diwali	125	NA	1.5	8.5	4	NA	6	17.5	30
Diwali	711	NA	2.5	51.5	7.5	NA	22.5	23.5	95
Post Diwali	507	NA	1	26.5	6	NA	19	15	46.5
Hissar [1]									
Pre Diwali	150	NA	NA	NA	NA	NA	NA	NA	NA
Diwali	210	NA	NA	NA	NA	NA	NA	NA	NA
Post Diwali	195	NA	NA	NA	NA	NA	NA	NA	NA
Delhi (e) [42]									
Pre Diwali	342.7	6.36	7.65	17.97	9.9	NA	NA	NA	NA
Diwali	507.2	13.5	21.3	46.8	16.5	NA	NA	NA	NA
Post Diwali	339.8	6.25	8.51	19.09	10.44	NA	NA	NA	NA
Rajim [43]									
Pre Diwali	212.8	NA	NA	NA	NA	NA	NA	NA	NA
Diwali	555.5	NA	NA	NA	NA	NA	NA	NA	NA
Post Diwali	284.4	NA	NA	NA	NA	NA	NA	NA	NA

NA: Not available

a: 24 hrs sampling

b: Values reported are mean of four sites

c: Values are approximate

d: Values reported are average of day and night

e: Values are average of three sampling sites.

Higher concentration of metals was also observed during Diwali which is shown in Table 3.

Table 3. Comparison of concentrations ( $\mu g/m^3$ ) of heavy metals in the ambient air during Diwali festival across India

	Fe	Zn	Pb	Mn	Cu	Cd	Cr	Ba	Ni
Rajnandgaon (a) [28]									
Pre Diwali	0.2	0.24	0.1	0.5	0.5	0.05	NA	NA	NA
Diwali	0.9	0.875	0.5	0.1	0.5	0.05	NA	NA	NA
Post Diwali	0.6	0.62	0.38	0.1	0.5	0.05	NA	NA	NA
Hyderabad (a) [41]									
Pre Diwali	0.8	NA	NA	0.05	0.18	NA	NA	2	NA

Diwali	1.2	NA	NA	0.1	0.4	NA	NA	13	NA
Post Diwali	1.3	NA	NA	0.05	0.1	NA	NA	2	NA
Lucknow (b) [32]									
Pre Diwali	0.95	0.41	0.29	0.75	0.24	0.24	0.3	NA	0.16
Diwali	0.75	0.54	0.3	0.84	0.45	0.34	0.42	NA	0.41
Post Diwali	NA	NA	NA	NA	NA	NA	NA	NA	NA
Delhi (c) [42]									
Pre Diwali	6.78	2.05	0.266	0.266	0.533	NA	0.47	1.66	0.12
Diwali	6.3	0.82	0.36	0.93	0.55	NA	0.28	16.8	0.07
Post Diwali	5.17	0.96	0.21	0.41	0.5	NA	0.4	5.24	0.11

NA: Not available

a: Values are approximate

b: Values are average of four sampling sites

c: Values are average of three sampling sites

Higher values of Fe, Ba and Cu are reported because these are used to give red, green and blue fireworks [41]. Zn is used to create smoke effects. Calcium Chlorides and sulphates give rise to orange flames [42]. The high

concentration of metals during Diwali is a result of fireworks activity as a part of celebration. The concentration ( $\mu\text{g}/\text{m}^3$ ) of RSPM on the Diwali Day in major cities is depicted in Fig. 1.

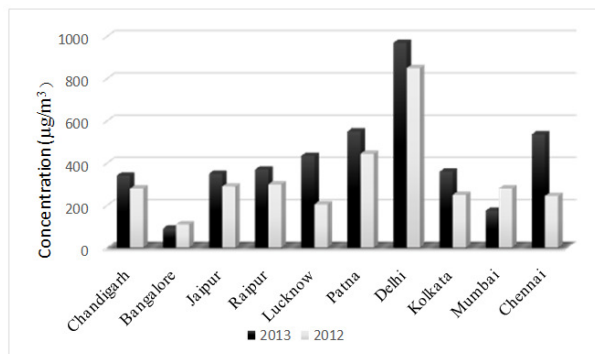


Fig 1. Comparison of RSPM concentrations on the Diwali day

The high values of  $\text{PM}_{10}$  in the ambient air as compared to NAASQ may be attributed to the increasing vehicles on the road and setting up of industries in the nearby area whereas the high  $\text{PM}_{10}$  concentration particularly on the day of Diwali, as compared to normal days, is caused by the fireworks. Delhi reported extremely high concentration of  $\text{PM}_{10}$  aerosols, which may be due to low night temperature, low mixing height and low wind speed. Mumbai being a densely populated city showed fair results on the Diwali Day. Bangalore is the only city in which  $\text{PM}_{10}$  concentration was below the permissible limit of  $\text{PM}_{10}$  of NAASQ ( $100 \mu\text{g}/\text{m}^3$ ). In almost all the cities, the concentration of  $\text{PM}_{10}$  on the day of Diwali is increasing every year which is a challenging issue for the government.

**Sulphur Dioxide ( $\text{SO}_2$ ) and Nitrogen Dioxide ( $\text{NO}_2$ )**

Generally firecrackers contain 75% potassium nitrate, 15% carbon (C) and 10% sulphur (S). Potassium nitrate is a strong oxidising agent, when burnt with C and S, it releases gases such as  $\text{CO}_2$  and  $\text{NO}_2$  [1].  $\text{SO}_2$  are more toxic because they slowly get absorb in the fine particles and are transported deep into the lung [28].  $\text{SO}_2$  damage the tracheal nasal system [44].  $\text{NO}_2$  destroys the linings of the respiratory surface and thus reduce the intake of oxygen for the body [28]. It has been found that  $\text{NO}_2$  is a deep lung irritant, which generates biochemical alterations and histological demonstrable lung damage in laboratory animals as a result of both acute and chronic exposure [45]. The concentrations of  $\text{SO}_2$  and  $\text{NO}_2$  during Diwali in previous studies are given in Table 4.

Table 4. Comparison of concentrations ( $\mu\text{g}/\text{m}^3$ ) of  $\text{NO}_2$  and  $\text{SO}_2$  in the ambient air during Diwali festival across India

	$\text{SO}_2$	$\text{NO}_2$
Rajnandgaon (a) [28]		
Pre Diwali	8	90
Diwali	12	110
Post Diwali	10	90
Nagpur (a) [40]		
Pre Diwali	10	50

Diwali	30	100
Post Diwali	20	60
Lucknow (b) [32]		
Pre Diwali	75	55
Diwali	140	110
Post Diwali	NA	NA
Kolkata (c) [30]		
Pre Diwali	8	NA
Diwali	50	NA
Post Diwali	65	NA
Hissar (b) [1]		
Pre Diwali	11.62	18.9
Diwali	23.52	24.35
Post Diwali	9.35	37.3

The concentrations of SO<sub>2</sub> and NO<sub>2</sub> in the recent Diwali festival can be seen in Fig. 2.

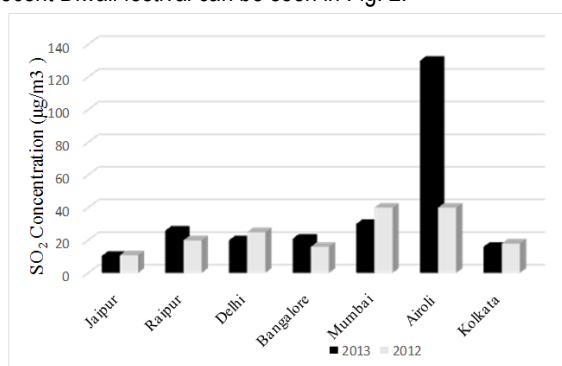


Fig 2. Comparison of SO<sub>2</sub> concentration on the Diwali day

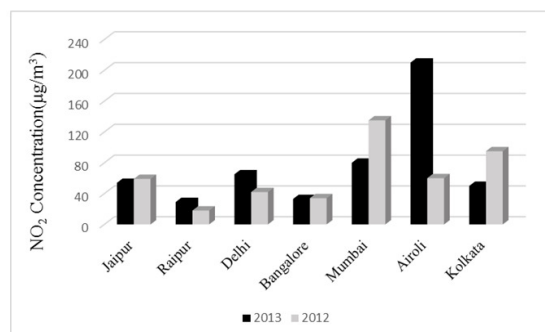


Fig 3. Comparison of NO<sub>2</sub> concentration on the Diwali day

In most cities, 24-h concentrations of SO<sub>2</sub> and NO<sub>2</sub> on the day of Diwali were found within their permissible limit as per NAASQ. Their concentrations on the day of Diwali were much higher as compared to the normal days. In cities like Kolkata, Patna and Lucknow, the night concentrations of SO<sub>2</sub> and NO<sub>2</sub> on the day of Diwali (2012 and 2013) were found above the permissible limit, indicating immense firework activity on the Diwali night. The high concentrations in Airoli, a

residential area near Navi Mumbai, on the Diwali night are a serious issue for the health of people. A positive result is that the SO<sub>2</sub> and NO<sub>2</sub> concentrations on the Diwali day have decreased in many cities in 2013 as compared to 2012.

### Noise Quality

Table 5. Ambient air quality standard of noise levels

Category of Zone/Area	Day time dB (A) Leq	Night time dB (A) Leq
Industrial Zone	75	70
Residential Zone	55	45
Commercial Zone	65	55
Silence Zone	50	40

Day time means 6 am to 10 pm and Night time means 10 pm to 6 am. dB (A) Leq means time weighted mean average of the noise level in dB on a scale A, which is associated to the human earshot. The

noise levels in different cities of India on the Diwali Day can be observed in the figure below.

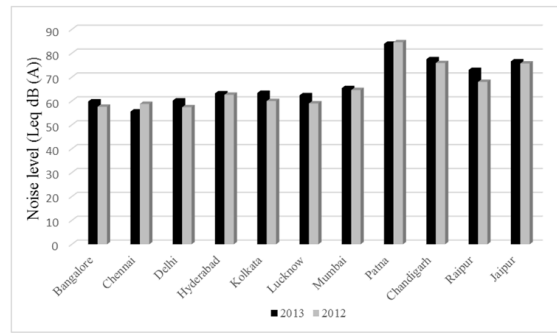


Fig 4. Comparison of noise level in Leq dB (A) on the day of Diwali

The noise level on the day of Diwali was found to be high in residential, commercial and industrial areas particularly during the night time. The fireworks activity are particularly carried during the night time and the maximum noise level reported in cities during night time were, Patna - 111 dB , Chandigarh - 77.5 dB, Raipur - 97 dB, Chennai - 121 dB and Mumbai - 103 dB. The high noise levels particularly during the night violate the permissible limit issued by CPCB. Noisy crackers have

always been a threat to children and pregnant women. Also there is possibility of loss of hearing due to noisy crackers.

**Discussion**

The effects of various components and by products of fireworks are given in Table 6.

Table 6. The effects of various components and by products of fireworks

Toxic Element	Fireworks Usage	Toxic Effect of Fallout Dust and Fumes
Aluminum	Brilliant whites	Contact dermatitis, bioaccumulation
Antimony sulfide	Glitter effects	Toxic smoke, possible carcinogen
Arsenic compounds	Used as colorants. Sadly still out there	Toxic ash can cause lung cancer, skin irritation and wart formation.
Barium Nitrate	Glittering greens	Poisonous. Fumes can irritate respiratory tract. Possible radioactive fallout
Copper compounds	Blues	Polychlorinated dioxins and dibenzofurans Can bio accumulate. Cancer risk.
Hexachlorobenzene (HCB)	Use was supposed to be banned globally	Persistent environmental toxin. Is a carcinogen, mutagen and a reproductive hazard?
Lead Dioxide/Nitrate/ Chloride	Oxidizer	Bioaccumulation, developmental danger for kids and unborn babies, may remain airborne for days, poisonous to plants and animals
Lithium compounds	Blazing reds	Toxic and irritating fumes when burned
Mercury (Mercurous chloride)	Chlorine donor	Toxic heavy metal. Can bio accumulate?
Nitric oxide	Fireworks by product	Toxic by inhalation. Is a free radical
Nitrogen dioxide	Fireworks by product	Highly toxic by inhalation. SIDS risk
Ozone	Fireworks by product	Greenhouse gas that attacks and irritates lungs
Perchlorate - Ammonium and Potassium	Propellant/oxidizer	Can contaminate ground and surface waters, can cause thyroid problems in humans and animals
Potassium Nitrate	Black powder	Toxic dusts, carcinogenic sulfur-coal compounds
Strontium compounds	Blazing reds	Can replace calcium in body. Strontium chloride is slightly toxic.
Sulphur Dioxide	Gaseous by product of sulphur combustion	Acid rain from sulphuric acid affects water sources, vegetation & causes property damage. SIDS risk

Diwali is the major festival of India, which is celebrated since ancient times. Earlier earthen lamps were used and the celebration was eco-friendly, whereas with the growing civilisation and introduction of new fireworks in the market, the mode of celebration is harming the environment that too on the auspicious occasion of a festive day. For many people burning of fireworks has become the central attraction of this festival. Brighter sparkles and loud noise firecrackers have become very popular among the people. Generally Diwali is celebrated during the months of October or November. During these winter months, the air circulation is less

and the gaseous pollutants from fireworks remain in the atmosphere for about 15-20 days. Moreover, the solid waste from the burned crackers pollutes the roads and is required to be safely disposed off.

We have discussed the concentrations of RSPM, water-soluble ions, heavy metals as well as SO<sub>2</sub> and NO<sub>2</sub> concentrations on the day of Diwali across major cities of India. The values are higher than the NAASQ in most of the Indian cities particularly the concentration of PM<sub>10</sub> is increasing every year. The noise levels were found to be very high and dangerous for human health.

Bangalore showed 32% reduction in pollution in the year 2013 as compared to 2012 as reported by Karnataka Pollution Control Board. The awareness programmes about ill effects of burning crackers to the people as well as school children have paid off in Bangalore. Strict laws by the government are the need of the hour to put brakes on the increasing pollution. Some measures are suggested below:

1. Noise levels of crackers must be checked before they are sold.
2. A team should be formed for inspecting the firecrackers sold in the market, supervising the time limit of burning firecrackers on night and penalising the law breakers.

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