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Assessment of the Effect of Diwali Festival on Ambient Air Quality in Delhi

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ABSTRACT
Fireworks displayed during festival celebrations can cause acute short-term air pollution. Fireworks cause the release of harmful gases in the atmosphere which in turn irritates the eyes and other diseases like asthma. Due to the increased use of fireworks in Diwali in past years, the problem has taken a big form after the recent development of smog clouds surrounding the city suffocating its residents and causing watery eyes, etc. which has motivated our study. Previous studies indicated that the concentrations of above air pollutants during the Diwali festival were several folds higher as compared to the 24-h standards of National Ambient Air Quality Standards of India (NAAQS) given by the Central Pollution Control Board (CPCB), India. Concentrations of metallic elements analyzed in fireworks aerosol samples in previous studies in India reported its higher contribution during the Diwali festival as compared to the limit value of NAAQS of India. This study investigates the effects of fireworks on the air quality over the Indian capital city of Delhi during the festival of light known as "Diwali". The effects of firecrackers during the festival were assessed using the data of the Central Pollution Control Board for ambient concentrations of various air pollutants, such as Sulphur dioxide, nitrogen dioxide, and particulate matter with a diameter less than 2.5 and 10 µm. The concentration of air pollutants, such as suspended particulate matter, PM10, PM2.5, SO2, and NO2 were monitored for five consecutive days during Deepawali in Delhi. The concentrations of gaseous pollutants, such as SO2 and NO2, well as particulate pollutants, such as PM10 and PM2.5 was found about 2-7 times higher during the day of the festival because of the use of the huge quantity of firecrackers that emits a large number of pollutants into the atmosphere. This review and analysis of data suggested the need of developing appropriate strategies to control the use of firecrackers during the festival of light especially in the major cities of India to protect human health.

I. CHAPTER – 1 INTRODUCTON

Air is an envelope of gases surrounding the earth's surface. Clean air in its pure form is composed of around 78% Nitrogen, 21% Oxygen, and 1% of Argon, Carbon Dioxide, Water Vapor, and some other Gases. It is one of the most vital forms of matter, which is required for the sustenance of life on earth. Living organisms breathe in this air to carry on their life functions. For example, Plants prepare their food through photosynthesis[20].

The process of change in natural characteristics of air either being a change in percentage composition of air or from its contamination through foreign substances such as harmful gases like Sulfur Dioxide, Nitrogen Dioxide, Carbon Dioxide, Methane, etc. which results in its deterioration is called as Air Pollution. This contamination of the air is mainly due to the burning of fossil fuels in automobiles, thermal power plants, volcanic eruptions, forest fires, smoke from factories, etc.

Diwali: The festival of light is one of the major Hindu festivals celebrated in India during the month of October-November every year. It is celebrated by lighting diyas,candles, and firecrackers across the whole country. The burning of firecrackers at this scale causes a lot of atmospheric and noise pollution. Harmful gases emitted from firecrackers remain at ground levels of the atmosphere, making the air unhealthy for breathing for quite a long time. It causes discomfort in patients with breathing-related problems such as asthma and chronic bronchitis. It may lead to toxic smog-causing watery eyes and severe breathing problems such as seen in Delhi after Diwali 2016.

Delhi is the second most polluted city in the world according to[2]. Vehicular pollution contributes to a significant 72% of sources of pollution in Delhi.

Domestic pollution, road dust, industrial emission, and garbage burning leads to a further increase in the air pollution problem in Delhi. This deteriorating condition is further worsened by the bursting of firecrackers in Delhi which leads to the sudden release of harmful gases into the atmosphere in a very short duration of time. Environmental factors such as relative humidity, temperature, wind speed & wind direction have failed to counter this sudden outburst of harmful gases in Diwali. Its result can be observed in form of toxic smog which caused watery eyes and severe breathing problems in people in November 2016 after Diwali.

The toxic smog cloud in Delhi caused a panic-like situation among people and the Indian Government forced them to take steps to tackle the problem. Schools colleges, all the construction work, movement of heavy vehicles were suspended to counter this problem and control the level of pollution in Delhi. Such a situation draw the attention of various researchers, who witnessed the situation themselves, to study and observe the phenomenon and effect that Diwali had on the people of Delhi. Some of the objectives of conducting this research are

1) Studying extend of the effect of Diwali on people of Delhi when compared with normal days to Diwali days.
2) Variation in concentration of parameters such as SO2, NO2, O3, andparticulate matter during normal days and Diwali days.
3) Relating annual data and Diwali days data with seasonal data to study its effect concerning seasons.

1.1 Categories of Pollutants

The burning of fossil fuels for the generation of energy and transportation purpose is one of the prime causes of air pollution.[1] Air Pollutants are classified into four major categories concerning their differing in their chemical composition, reaction properties, emission and persistence in the environment, ability to be transported in long or short distances, and their eventual impactson human and animal health, and few similarities.

They are as follows:

1) Gaseous Pollutants such as SO2, NOx, CO, Ozone, and Volatile Organic Compounds.
2) Persistent Organic Pollutants such as Dioxins.
3) Heavy metals such as Lead Mercury.
4) Particulate Matter

Gaseous Pollutants derived from the burning of fossil fuels contribute to air pollution to a great extent. Oxides of Nitrogen which are emitted as NO react quickly with atmospheric Ozone or Radicals thereby forming NO2[1] Ozone is formed by a series of reactions involving NO2 and a few other volatile organic compounds in presence of sunlight in the lower atmospheric layers. CO is formed when a substance containing carbon is burned in a limited supply of oxygen. SO2 is released when fossil fuels containing Sulphur are burned such as Coal and heavy oils and the smelting of carbon-containing ores such as volcanoes and oceans. Volatile Organic Compounds (VOCs) include compounds of organic nature like benzene and are produced from the burning of fossil fuels for energy and road transportation.

Persistent organic pollutants are nothing but a toxic group of chemicals such as dioxins furans and PCBs which sustain them in the environment for long periods and are magnified as they move up the food chain. Dioxins are formed during incomplete combustion and when materials containing chlorine (e.g. plastics) are burned which when emitted in the atmosphere tend to deposit on soil and water but, being water-insoluble, they do not contaminate groundwater sources. They enter plants from dust and pesticides and make their way through the food chain by bio-accumulating due to their ability to be stably bound to lipids [1].

Heavy Metals such as mercury, lead, silver nickel, cadmium, vanadium, chromium, and manganese are naturally occurring metals on earth's crust that cannot be degraded or destroyed and can be transported by air, and enter the water and human food supply. They come in contact with the environment from combustion, wastewater discharge from factories, etc. They enter the human body as trace elements in very low quantities as they are required for maintaining normal metabolic reactions. At higher concentrations, they can become toxic as they tend to bio-accumulate over time in living organisms.

Particulate matter is a term coined for general types of air pollutants such as complex and varying mixtures of particles suspended in the breathing air, which vary in size and composition. Major sources of particulate pollution are factories, power plants, refuse incinerators, motor vehicles, construction activity, fires, and natural windblown dust. They have been classified under various classes based on their sizes such as Ultrafine particles smaller than 0.1 µm in aerodynamic diameter, Fine particles, smaller than 1 µm, and coarse particles, larger than 1 µm. The size of the particle helps tell the site at which they will deposit in the respiratory tract. PM10 particles deposit mainly in the upper respiratory tract while fine and ultra-fine particles can reach lung alveoli. The size and surface of particles are the most important parameters that play an important role in extracting health effects. The composition of PM varies, as they can absorb and transfer a multitude of pollutants. There is strong evidence to support that ultra-fine and fine particles are more hazardous than larger ones (coarse particles), in terms of mortality and cardiovascular and respiratory effects.

Air Quality

The state of the air around us is defined as "Air Quality". If the air around us is clean, clear, unpolluted, and suitable for breathing, such air quality is called "Good". When the pollutants in the air reach certain high levels such that air is no longer suitable for breathing for humans and animals, the air is quality is said to be "Poor". The quality of air environment surrounding us measured at the ground level given no source of pollution is nearby is termed as "Ambient Air Quality". Air quality when measured in enclosed spaces such as home, office, school, etc. is termed as "Indoor Air Quality" [4].

Diwali

Diwali also known as Deepawali is one of the biggest festivals of India. It is one of the two major festivals of the Hindu Religion. This "Festival of Lights" (deep
= light and avail = a row i.e., a row of lights) is marked by four to five days ofcelebration separated by a different tradition.

Diwali commemorates the return of Lord Rama along with Sita and Lakshmana from his fourteen-year-long exile and vanquishing the demon- king Ravana. In joyous celebration of the return of their king, the people of Ayodhya, the Capital of Rama, illuminated the kingdom with earthen diyas (oil lamps) and burst

crackers. Each day of Diwali has its tale, legend, and myth to tell. In Sikhism, it marks the day that Guru Hargobind Ji, the Sixth Sikh Guru was freed from imprisonment. Jainism marks the nirvana or spiritual awakening of Lord Mahavira on October 15, 527 B.C [6].

Concerning religion, the first day of the festival Naraka Chaturdasi marks the vanquishing of the demon Naraka by Lord Krishna and his wife Satyabhama. Amavasya, the second day of Deepawali, marks the worship of Lakshmi, the goddess of wealth in her most benevolent mood, fulfilling the wishes of her devotees. Amavasya also tells the story of Lord Vishnu, who in his dwarf incarnation, vanquished the tyrant Bali, and banished him to hell. Bali was allowed to return to earth once a year, to light millions of lamps to dispel the darkness and ignorance, and spread the radiance of love and wisdom. It is on the third day of Deepawali — Kartika ShuddaPadyami that Bali steps out of hell and rules the earth according to the boon given by Lord Vishnu. The fourth day is referred to as Yama Dwitiya (also called Bhai Dooj) and on this day sisters invite their brothers to their homes.

Whereas in modern times on the first day of Diwali, people consider it auspicious to spring clean the home and shop for gold or kitchen utensils. On the second day, people decorate their homes with clay lamps and create design patterns called rangoli on the floor using colored powders or sand. The third day is the main day of the festival when families gather together for Lakshmi puja, a prayer to Goddess Lakshmi followed by mouth- watering feasts and firework festivities. The fourth day is the first day of the New Year when friends and relatives visit with gifts and best wishes for the season. On the last day of Diwali, brothers visit their married sisters who welcome them with love and a lavish meal.

The Significance of Lights and Firecrackers

All the simple rituals of Diwali have significance and a story to tell. The illumination of homes with lights and the skies with firecrackers is an expression of obeisance to the heavens for the attainment of health, wealth, knowledge, peace, and prosperity. According to one belief, the sound of firecrackers is an indication of the joy of the people living on earth, making the gods aware of their plentiful state. Still another possible reason has a more scientific basis: the fumes produced by the crackers kill a lot of insects and mosquitoes, found in plenty after the rains [6].

Adverse Effects of Bursting Crackers on Health

Apart from the mild burns and accidents the children also breathe the toxic airand suffer from nasal irritation and throat congestion.

The smoke also irritates the eyes causing tears and redness. Sometimes, the sound makes the ears go dumb and causes deafness.

Bursting crackers may increase blood pressure and aggravate heart disease. Nausea, Headache, and giddiness are common effects of bursting crackers. Lung infections such as coughing, sneezing. Respiratory disorders like asthma, wheezing often get severe during the Deepawali festival. The pollution hazards such as toxic smoke cause a lot of discomfort in breathing.

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The poisonous gas can also affect pregnant women adversely. It may also affect mentally ill patients leading to depression, fear, and stress [7].

Objective of the study

- Studying the effect of Diwali on people of Delhi when compared with normal days to Diwali days.
- Variation in concentration of parameters such as SO2, NO2, O3and particulatematter during normal days and Diwali days.
- Relating annual data and Diwali days data with seasonal data to study its effectconcerning seasons.

II. CHAPTER – 2 REVIEW OF LITERATURE

North zone: North zone of India comprises Jammu & Kashmir, Punjab, Haryana, Chandigarh, Himachal Pradesh, Delhi, Uttarakhand, Uttar Pradesh, and Rajasthan.

S. C. Barman et al.,2007[8] studied the effect of fireworks on ambient air quality of Lucknow city. Trace metals associated with PM10 such as PM10, Sulphur Dioxide, Oxides of Nitrogen, and 10 others were estimated at four representative locations, during day and night times for Pre-Diwali and Diwali day. The average concentration of PM10, Sulphur Dioxide, and Oxides of Nitrogen was found to be 753.3, 139.1, and 107.3 µg m-3, respectively taking 24hrs period on Diwali day. The concentration was found to be higher at 2.49 and 5.67 times for PM10, 1.95 and 6.59 times for Sulphur Dioxide, and 1.79 and 2.69 for NOx, when compared with the concentration of Pre-Diwali and normal day, respectively. 24hours'concentration were taken for PM10, Sulphur Dioxide, and NOx were taken for Diwali day and were found to be higher than the prescribed limit of NAAQS, and had exceptionally high concentration (7.53 times) for PM10. On the night of Diwali (12 h), the mean level of PM10, Sulphur Dioxide and NOx was 1,206.2, 205.4, and 149.0 µg m-3 respectively, which was 4.02, 2.82, and 2.27 times higher than their respective daytime concentration showing strong correlations ($p<0.01$) with each other.

West zone: The West Zone of India comprises Gujrat, Maharashtra, and Rajasthan.

Dhananjayan et al., 2015[11] conducted to understand the impact of crackers and related fireworks usage during the Diwali festival (Festival of lights) in the ambient air quality status of Bhuj city during October 2014. This was assessed by evaluating the air quality status by measuring the concentration of various air pollutants such as Sulphur Dioxide, Nitrogen Dioxide, Suspended Particulate Matter (SPM) and Respirable Suspended Particulate matter (RSPM). Since the usage of crackers is found to be the major activity during this particular festival and such firework-related activity releases various gaseous and particulate air pollutants and toxic metals to a greater extent. Hence, in the present study, SO2, NO2, SPM, and RSPM were estimated at selected residential sites during the day and night on Diwali, Pre- Diwali, and Post Diwali period. As a whole, it is understood that though the concentration of SO2, NO2, SPM, and RSPM was found to be at a higher rate at the pre-and post-Diwali period, these specified parameters had recorded significantly higher levels of this concentration on the day of Diwali. On the day of Diwali, the levels of NO2, SO2, SPM, and RSPM concentration in a residential area have been recorded as 65.86, 21.06, 311.8, 235 µg/m3 respectively and the concentration has also recorded a higher range when compared with National Ambient Air Quality Standards (NAAQS). The present study elucidated that the usage of fireworks and bursting crackers were found to be the major factors for such elevated levels of pollutants in the atmosphere during the Diwali festival.

East zone: East zone of India comprises Bihar, Jharkhand, Orrisa, West Bengal, Sikkim, Meghalaya, Assam, Arunachal Pradesh, Nagaland, Manipur, and Tripura.

A. Chatterjee et al., 2013[16] studies effects of fireworks on air quality was assessed from the ambient concentration of PM10, water-soluble ionic species, metals, and SO2 over Kolkata metropolis, India during the Diwali festival in November 2010. PM10concentration on Diwali night was found to be ~5 times higher than the normal day night-time average. The increase in night- time concentration of the metals on Diwali night spanned over a wide range (Al,Zn, Pb, and Cd showed 5–12 times increases, Cu, Fe, and Mn showed 25–40 times and Co and V showed 70–80 times) compared to normal night-time concentration. The water-soluble ionic species showed 1.5–6 times higher concentrations on Diwali night than on normal days. The most significant increases were found for K+, Ca2+, Mg2+. The diurnal variations in PM10 and SO2 were also studied at one of the sites, and the results showed that their maximum concentration was on Diwali night between 8 P.M.–3 A.M., indicating maximum firework activities during this period. PM10 and SO2concentration increased by ~5 times

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compared to those on normal days during this period at this site. The extensive use of firecrackers during the Diwali festival thus leads to significant increases in these air pollutants, and since they are associated with serious, adverse health impacts, the use of fireworks during this kind of festival in a highly-populated city, like Kolkata, India, needs to be controlled.

South zone: South Zone of India comprises Maharashtra, Goa, Karnataka, Kerala, Tamil Nadu, Andhra Pradesh, Telangana, Orrisa, and Chhattisgarh. Anu Rani Sharma et al., 2013[18] Diwali is one of the largest festivals for the Hindu religion which falls in the period October–November every year. During the festival days, extensive burning of firecrackers takes place, especially in the evening hours, constituting a significant source of aerosols, black carbon (BC), organics, and trace gases. The widespread use of sparklers was found to be associated with short-term air quality degradation events. The present study focuses on the influence of Diwali fireworks emissions on surface ozone (O3), nitrogen oxides (NOx), and BC aerosol concentration over the tropical urban region of Hyderabad, India during three consecutive years (2009–2011). The trace gases are analyzed for pre-Diwali, Diwali, and post-Diwali days to reveal the festivity's contribution to the ambient air quality over the city. A twofold to threefold increase is observed in O3, NOx, and BC concentration during the festival period compared to control days for 2009–2011, which is mainly attributed to firecrackers burning. The high correlation coefficient (~0.74) between NOx and SO2concentration and higher SO2/NOx (S/N) index suggested air quality degradation due to firecrackers burning. Furthermore, the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation-derived aerosol subtyping map also confirmed the presence of smoke aerosols emitted from firecrackers burning over the region. Nevertheless, the concentration level of pollutants exhibited a substantial decline over the region during the years 2010 and 2011 compared to 2009 ascribed to various awareness campaigns and increased cost of firecrackers.

III. CHAPTER – 3

STUDY AREA AND METHODS

General Description of the Study Area

Delhi Is the capital of India, located in North India within the latitude 28°24'17" and 28°53'00"N, and longitude 77°45'30" and 77°21'30"E.

Delhi is the fifth most populous city in the world and the largest city in India area-wise having an area of 1483 km2. Delhi has an estimated 2016 population of 18.6 million. The NCT and its urban area are granted the special status of National Capital Region, and this NCR includes neighboring cities of Baghpat, Alwar, Sonepat, Gurgaon, Ghaziabad, Faridabad, Greater Noida, Noida, and nearby towns. The NCR has an estimated population of 24 million, exceeding the Delhi population of 17.8 million in 2014. Delhi has a rapidly growing population, which was just 16.7 million in 2011. The city has a population density of 29,259.12 people per square mile, which is one of the highest in the world [19].

Data Collection

Data is collected from CPCB's online database for the period of the year 2012- 16 in January- February 2017. The data provided by CPCB is on an average interval of 24 hours. There is no regular consistency maintained by CPCB while collecting data from the atmosphere i.e. CPCB does not provide data of each and every date, data is not made available for all of the dates. Data for all of the pollutants monitored under our study is not available in all the sites selected for the study. Details about data are provided in the data tables under the Appendices section.

Observations

The details about data collection are provided below according to the site selected.

Anand Vihar

No data was available for the years 2014-15.
No data was available for parameter CO for the years monitored understudy
No data was available for parameters PM2.5 and PM10 for the year 2012-15.

Dwarka

No data was available for parameter O3 for the year 2012-16 No data was available for parameter PM2.5 for the
year 2012-15
No data was available for parameter PM10 for the year 2016-17

IGI

- No data was available for the year 2016-17.
- No data was available for the parameter NO2 for the year 2014-15

ITO

- No data was available for parameters PM2.5 and PM10 for the year 2012-16.

Mandir Marg

- No data was available for the year 2014-15.
- No data was available for parameters PM2.5 and PM10 for the year 2012-14.

Data Analysis

The raw data on a 24-hour duration format is then processed and analyzed in Microsoft Excel spreadsheets such as those attached in the Appendices section. Data is grouped and analyzed according to:Years:

- 2012-13
- 2013-14
- 2014-15
- 2015-16
- 2016-17

Diwali dates (5days)

- 11 November 2012 to 15 November 2012
- 01 November 2013 to 05 November 2013
- 21 October 2014 to 25 October 2014
- 09 November 2015 to 13 November 2015
- 28 October 2016 to 01 November 2016

IV. CHAPTER – 4 RESULTS AND DISCUSSIONS

Following are the observations made in the data obtained from CPCB for the place Anand Vihar, Dwarka, ITO, Indira Gandhi international Airport (IGI)& Mandir Marg.

With Respect to Parameter
Ozone

Table 4.1 Annual average diurnal variation of Ozone concentration

Year	**Annual concentration**
2012	64
2013	51
2014	69
2015	48
2016	28
Ozone average concentration	51

Table 4.2 Annual average diurnal variation of Ozone concentration during Diwali

Year	**Concentration during Diwali (5 days)**
2012	59
2013	59
2014	94
2015	31
2016	53
Ozone average concentration	59

From Fig. 4.1, it is observed that the concentration of Ozone has shown an increase during years 2012-2015. However, the year 2014 shows highest ozone concentration (69 µg/m^3). After the year 2015 concentration of ozone has shown a constant decline. Same trend is observed during Diwali festival i.e. concentration of ozone has shown an increase in years 2012-15 having highest ozone concentration (94 µg/m^3) in the year 2014 and a decline afterwards from the year 2015-16. It also observed that the air in Diwali festival is more polluted (except year 2015) than normal days this may be due to pollution caused by fireworks. On comparing both the lines it is evident that the peak concentration are achieved during Diwali as compared to normal days.

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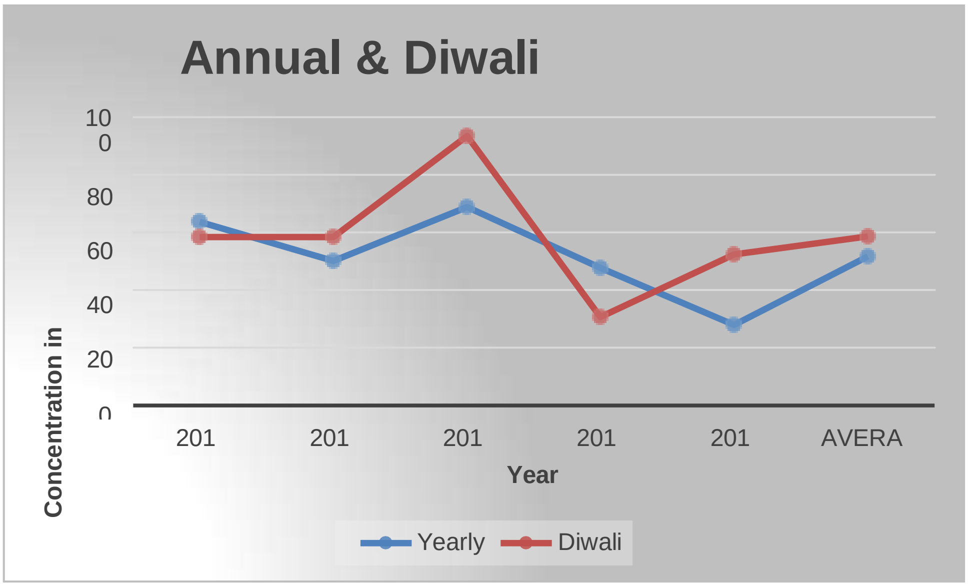

Fig. 4.1 Comparison between annual and Diwali concentration for O3

Sulphur Dioxide

Table 4.3 Annual average diurnal variation of Sulphur Dioxide

Year	**Annual concentration**
2012	18
2013	19
2014	11
2015	16
2016	17
Sulphur Dioxide average concentration	16

Table 4.4 Annual average diurnal variation of Sulphur Dioxide during Diwali

Year	**Concentration during Diwali(5 days)**
2012	31
2013	17
2014	21
2015	29
2016	30
Sulphur Dioxide average concentration	25

From Fig. 4.2, it is observed that the concentration of Sulphur Dioxide has shown nominal increase and decrease of 1-2 during period 2012-14 and 2015-17. The only exception being year 2014-15 when concentration of Sulphur dioxide has shown a decline from 19 µg/m3 to 11 µg/m3. During Diwali days concentration of Sulphur has shown increase during years 2013-2016 from 17 µg/m3 to 30 µg/m3 in 2016-17. It has shown a decline during year 2012-14.

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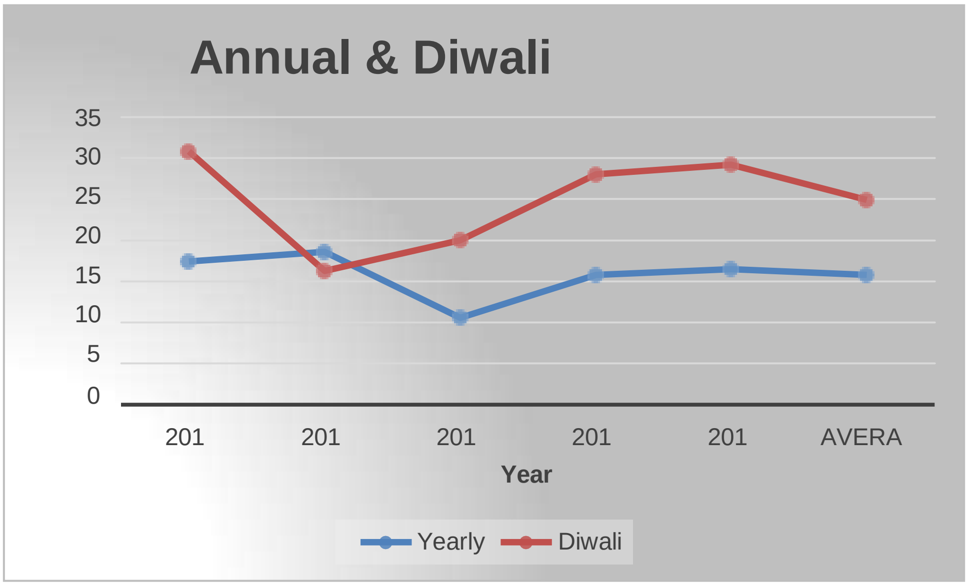

Fig. 4.2 Comparison between annual and Diwali concentration for SO_2

Nitrogen Dioxide

Table 4.5 Annual average diurnal variation of Nitrogen Dioxide

Year	**Annual concentration**
2012	88
2013	76
2014	101
2015	66
2016	61
Nitrogen Dioxide average concentration	78

Table 4.6 Annual average diurnal variation of Nitrogen Dioxide during Diwali

Year	**ConcentrationDuring Diwali(5 days)**
2012	156
2013	61
2014	117
2015	65
2016	83
Nitrogen Dioxide average concentration	96

From Fig. 4.3, it is observed that the concentration of nitrogen dioxide has shown constant decrease during year 2012-14 and 2015-17. The concentration of nitrogen dioxide has shown huge increase during year 2014-15 corresponding to 101 µg/m^3. During Diwali days concentration of nitrogen dioxide is observed very high during years 2012-13 and year 2014-15 corresponding to 156 µg/m^3 and 117 µg/m^3 respectively. The concentration has shown increase during years 2015-2016.

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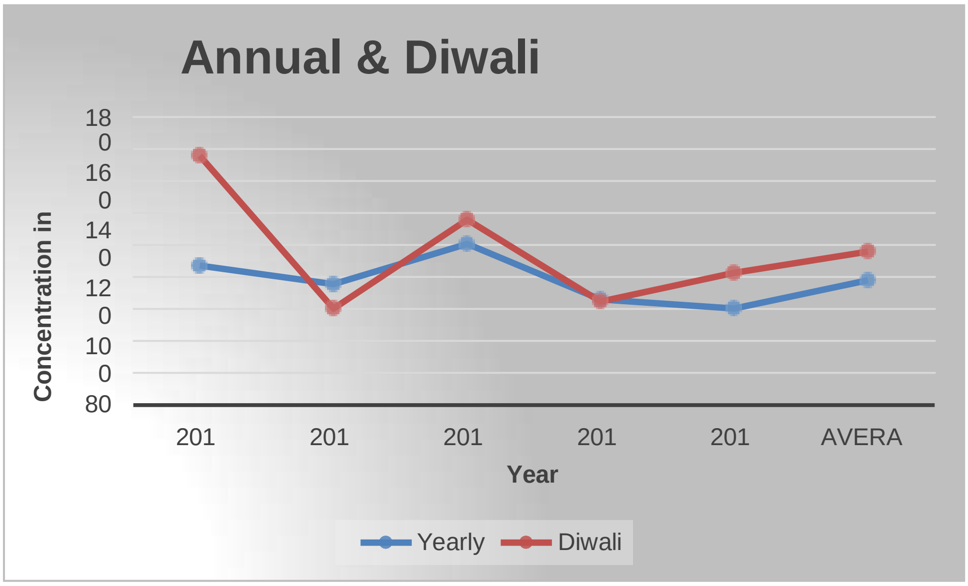

Fig. 4.3 Comparison between annual and Diwali concentration for NO_2

Particulate Matter 2.5 ($PM_{2.5}$)

Table 4.7 Annual average diurnal variation of Particulate Matter 2.5

Year	Annual concentration
2012	248
2013	201
2014	198
2015	130
2016	167
PM2.5 average concentration	189

Table 4.8 Annual average diurnal variation of Particulate Matter 2.5 during Diwali

Year	Concentration during Diwali (5 days)
2012	339
2013	277
2014	111
2015	252
2016	318
PM2.5 average concentration	259

From Fig. 4.4 it is observed that the concentration of PM2.5 has shown constant decrease during years 2012-2016 from 248 µg/m^3 to 130 µg/m^3. Concentration has shown an increase in year 2016-17 from 130 µg/m^3 to 167 µg/m^3. During Diwali days concentration of PM2.5 has shown a decrease during years 2012-15 from 339 µg/m^3 to 111 µg/m^3. The concentration increased during years 2014-17 from 111 µg/m^3 to 252 µg/m^3

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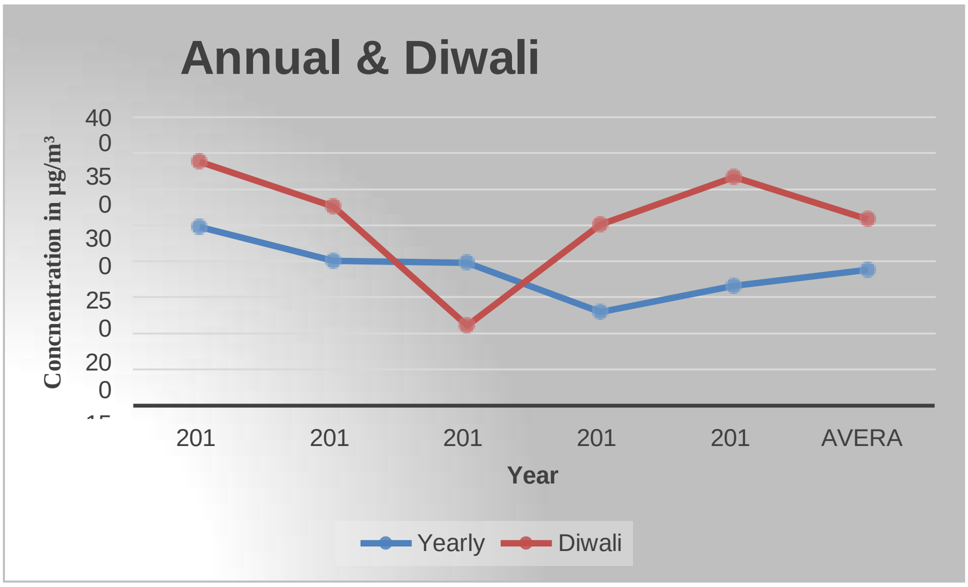

Fig. 4.4 Comparison between annual and Diwali concentration for PM2.5

Particulate Matter 10 (PM10)

Table 4.9 Annual average diurnal variation of Particulate Matter 10

Year	**Annual concentration**
2012	272
2013	270
2014	428
2015	350
2016	250
PM10 average concentration	314

Table 4.10 Annual average diurnal variation of Particulate Matter 10 during Diwali

Year	**Concentration during Diwali (5days)**
2012	410
2013	-
2014	287
2015	563
2016	736
PM10 average concentration	499

From Fig. 4.5 it is observed that the concentration of PM10 has shown an increase during 2012-15 from 272 µg/m^3 to 428 µg/m^3. Concentration has shown a decrease from 2014-17 from 428 µg/m^3 to 250 µg/m^3. During Diwali days concentration of PM10 has shown a decrease during year 2012-2015 from 410 µg/m^3 to 287 µg/m^3. Concentration has shown huge increase during 2014-16 from 287 µg/m^3 to 736 µg/m^3.

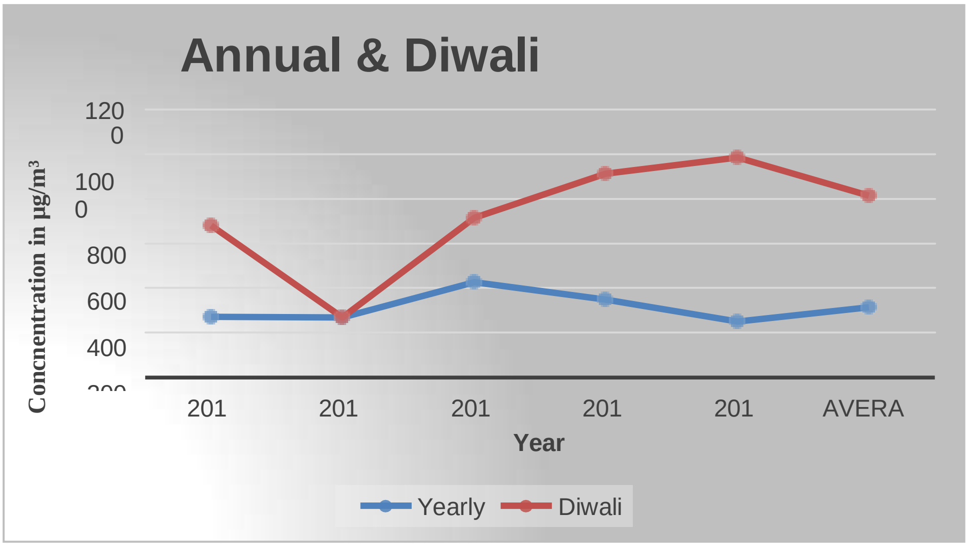

Fig. 4.5 Comparison between annual and Diwali concentration for PM10

With Respect to Years
Year 2012

Table 4.15 Average annual concentration during year 2012

Place/Parameter	Ozone	Sulphur Dioxide	Nitrogen Dioxide	PM2.5	PM10
Anand Vihar	82	31	140	-	-
Dwarka	-	11	49	-	201
ITO	45	14	109	-	-
IGI	86	16	66	248	344
Mandir Marg	44	17	74	-	-
Yearly Average	64	18	88	248	272

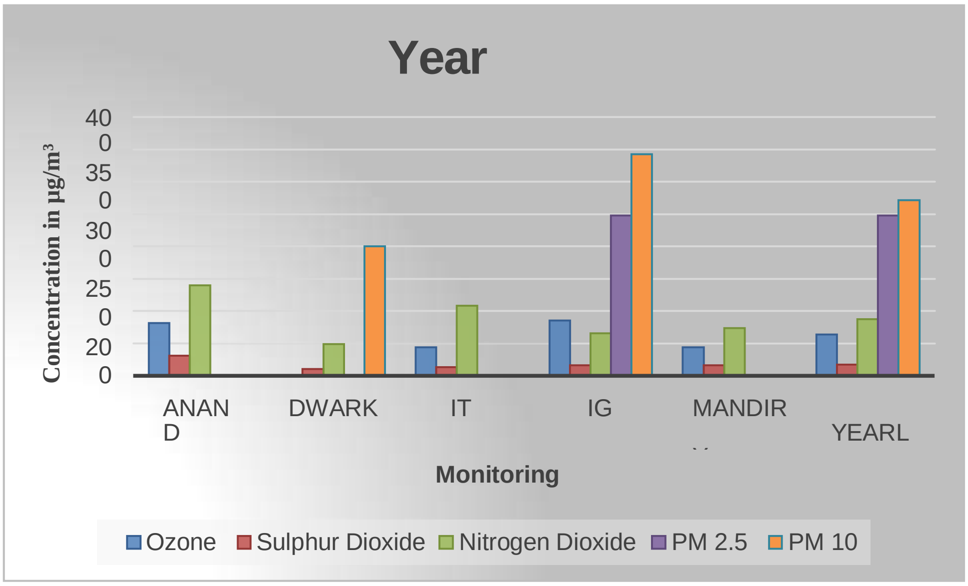

Fig. 4.10 Average annual concentration during year 2012

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Table 4.16 Average concentration during Diwali year 2012

Place/Parameter	Ozone	Sulphur Dioxide	Nitrogen Dioxide	PM2.5	PM10
Nov 11, 2012	64	29	168	209	280
Nov 12, 2012	45	34	143	304	360
Nov 13, 2012*	62	39	142	369	481
Nov 14, 2012	63	29	137	431	479
Nov 15, 2012	61	25	191	384	451
Festival Average	59	31	156	339	410

Ozone Concentration has shown a nominal decrease in concentration from the year average concentration of 64 µg/m^3 to Diwali average concentration of 59 µg/m^3.

Whereas concentration of Sulphur dioxide, nitrogen dioxide, PM2.5 and PM10 has shown tremendous increase in concentration from 18 µg/m^3 to 31 µg/m^3, 88 µg/m^3 to 156 µg/m^3, 248 µg/m^3 to 339 µg/m^3 and 272 µg/m^3 to 410 µg/m^3 respectively.

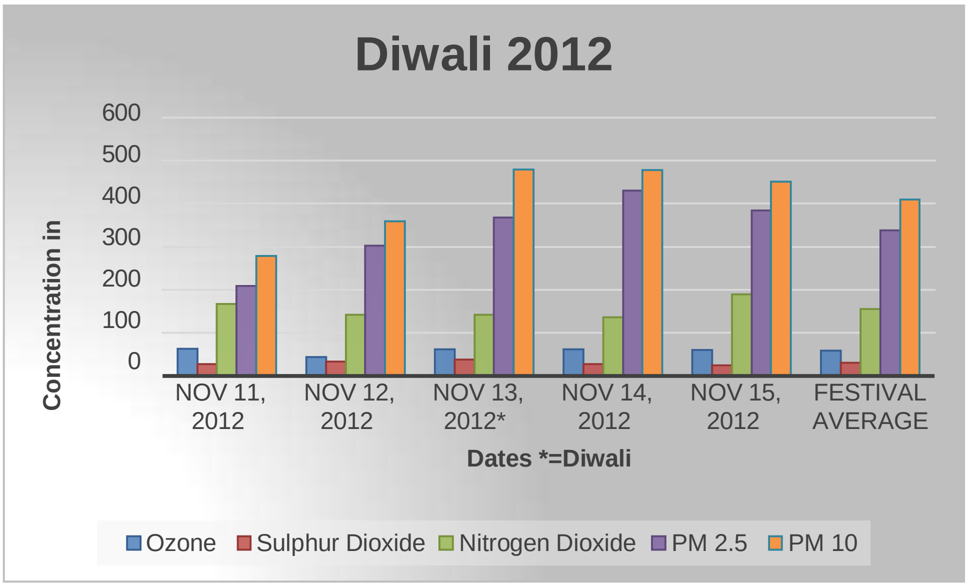

Fig. 4.11 Average concentration during Diwali year 2012

Year 2013

Table 4.17 Average annual concentration during year 2013

Place/Parameter	Ozone	Sulphur Dioxide	Nitrogen Dioxide	PM2.5	PM10
Anand Vihar	30	24	145	-	-
Dwarka	-	16	39	-	175
ITO	36	7	45	-	-
IGI	93	18	60	201	365
Mandir Marg	44	31	90	-	-
Yearly Average	51	19	76	201	270

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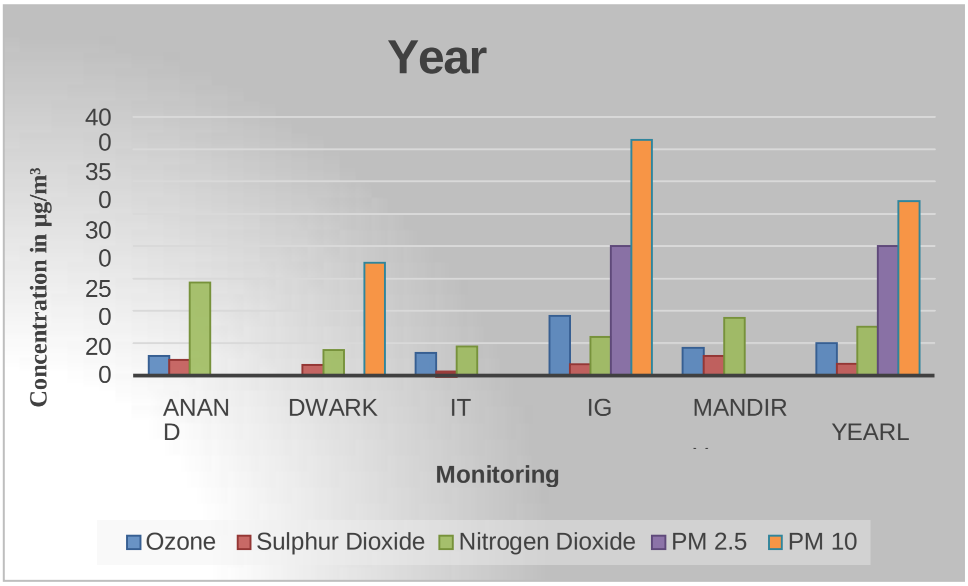

Fig. 4.12 Average annual concentration during year 2013

Table 4.18 Average concentration during Diwali year 2013

Place/Parameter	**Ozone**	**Sulphur Dioxide**	**Nitrogen Dioxide**	**PM2.5**	**PM10**
Nov 01, 2013	52	14	66	-	273
Nov 02, 2013	62	11	55	-	339
Nov 03, 2013*	70	14	44	-	592
Nov 04, 2013	68	34	55	-	129
Nov 05, 2013	43	12	84	-	51
Festival Average	59	17	61	-	277

Concentration of ozone and PM10 has shown a nominal increase from yearly average concentration 51 µg/m^3 to Diwali average concentration 59 µg/m^3 and 270 µg/m3 to 277 µg/m^3 respectively. Whereas concentration of Sulphur dioxide and nitrogen dioxide has shown a nominal decrease from 19 µg/m^3 to 17 µg/m^3 and 76 µg/m^3 to 61 µg/m^3 respectively.

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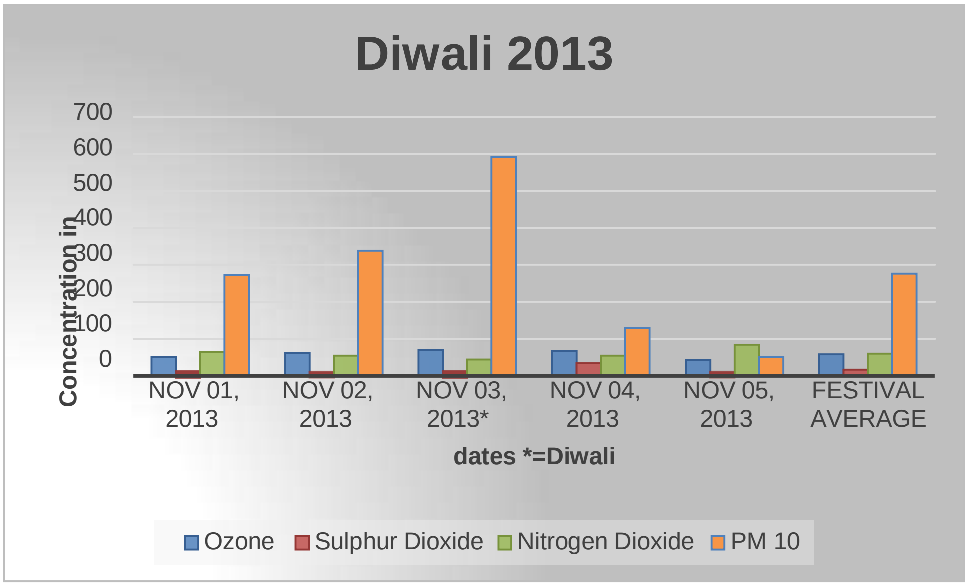

Fig. 4.13 Average concentration during Diwali year 2013

Year 2014
Table 4.19 Average annual concentration during year 2014

Place/Parameter	Ozone	Sulphur Dioxide	Nitrogen Dioxide	$PM_{2.5}$	PM_{10}
Dwarka	-	12	105	-	247
ITO	53	5	97	-	-
IGI	86	16	-	198	609
Yearly Average	69	11	101	198	428

*Anand Vihar and Mandir Marg are excluded from table 4.19 because of lack of data.

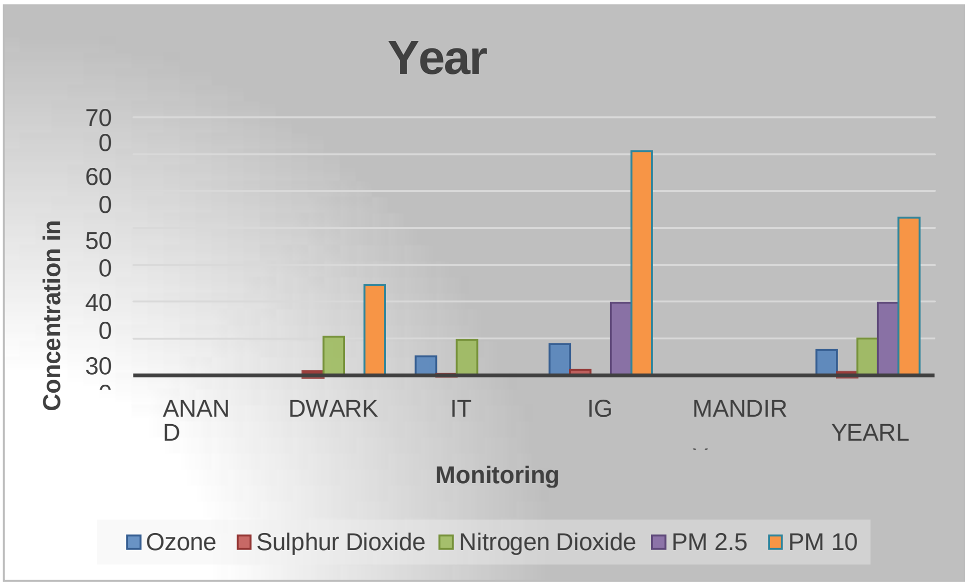

Fig. 4.14 Average annual concentration during year 2014

Table 4.20 Average concentration during Diwali year 2014

Place/Parameter	Ozone	Sulphur Dioxide	Nitrogen Dioxide	PM2.5	PM10
Oct 21, 2014	77	16	126	86	241
Oct 22, 2014	82	27	146	91	308
Oct 23, 2014*	112	28	116	128	350
Oct 24, 2014	111	17	88	127	260
Oct 25, 2014	89	13	106	123	277
Festival Average	94	21	117	111	287

Concentration of PM2.5 and PM10 has shown a decrease from 198 µg/m^3 to 111 µg/m^3 and 428µg/m^3 to 287µg/m^3 respectively when compared from yearly average concentration with Diwali average concentration. Concentration of ozone, Sulphur dioxide and nitrogen dioxide has shown an increase from 69 µg/m^3 to 94 µg/m^3, 11 µg/m^3 to 21 µg/m^3 and 101 µg/m^3 to 117 µg/m^3 respectively.

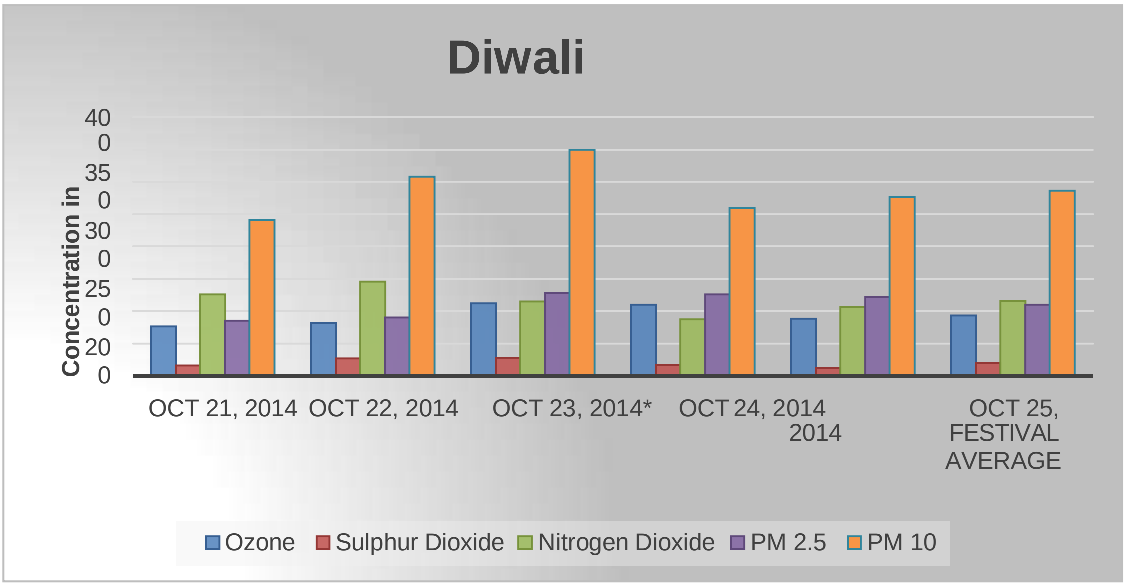

Fig. 4. Average concentration during Diwali year 2014

Year 2015

Table 4.21 Average annual concentration during year 2015

Place/Parameter	Ozone	Sulphur Dioxide	Nitrogen Dioxide	PM2.5	PM10
Anand Vihar	27	22	88	193	551
Dwarka	-	10	41	102	229
ITO	37	10	80	-	-
IGI	80	12	57	84	398
Mandir Marg	49	25	66	140	223

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Yearly Average	48	16	66	130	350

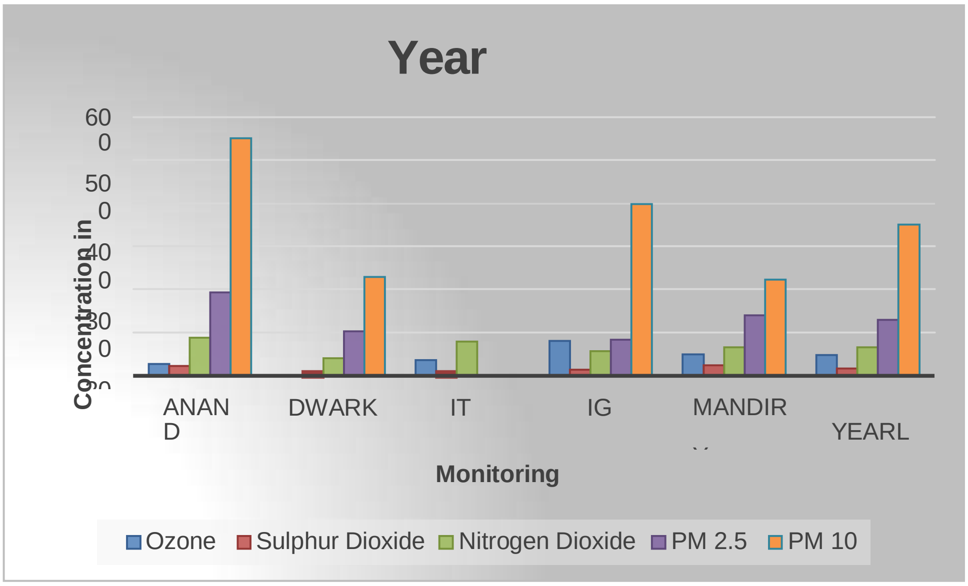

Fig. 4.16 Average annual concentration during year 2015

Table 4.22 Average concentration during Diwali year 2015

Place/Parameter	Ozone	Sulphur Dioxide	Nitrogen Dioxide	PM2.5	PM10
Nov 09, 2015	49	34	84	262	472
Nov 10, 2015	29	29	87	243	626
Nov 11, 2015*	27	35	51	194	512
Nov 12, 2015	27	27	52	257	513
Nov 13, 2015	23	18	52	302	689
Festival Average	31	29	65	252	563

Concentration of ozone and nitrogen dioxide has shown nominal decrease from 48 µg/m^3 to 31 µg/m^3 and 66 µg/m^3 to 65 µg/m^3 from compared from yearly average concentration to Diwali average concentration. Concentration of Sulphur dioxide, PM2.5 and PM10 has shown increase from 16 µg/m^3 to 29 µg/m^3, 130 µg/m^3 to 252 µg/m^3 and 350 µg/m^3 to 563 µg/m^3 respectively when compared from yearly average concentration to Diwali average concentration.

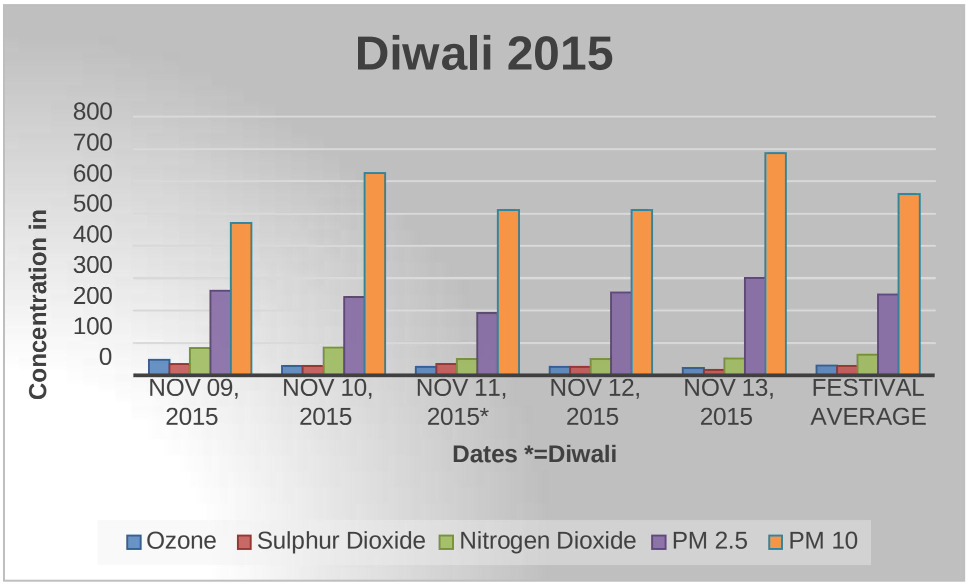

Fig. 4.17 Average concentration during Diwali year 2015

Year 2016

Table 4.23 Average annual concentration during year 2016

Place/Parameter	Ozone	Sulphur Dioxide	Nitrogen Dioxide	PM2.5	PM10
Anand Vihar	26	24	87	185	471
Dwarka	27	10	26	147	-
ITO	27	19	72	214	291
Mandir Marg	34	16	57	119	240
Yearly Average	28	17	61	167	334

*IGI is excluded from Table 4.23 because of lack of data.

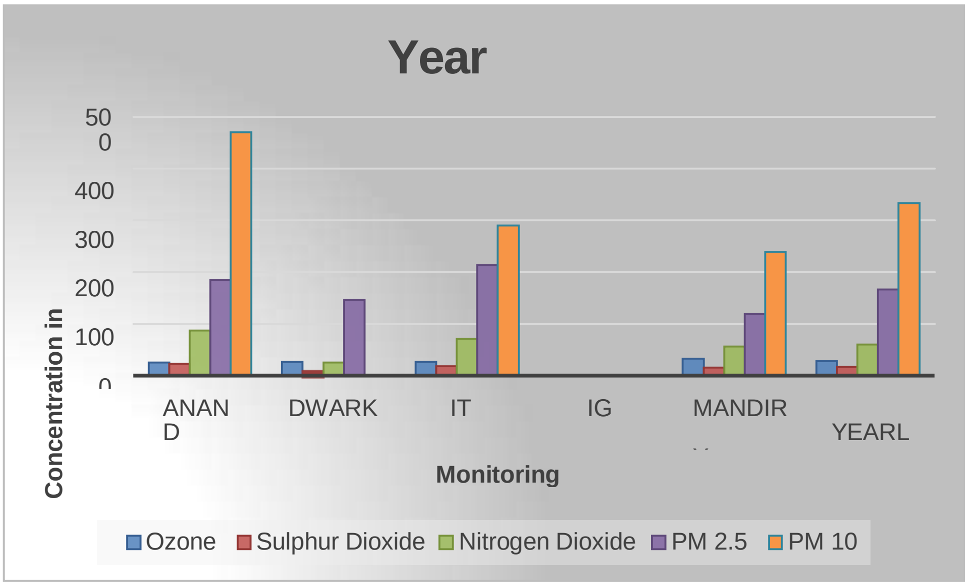

Fig. 4.18 Average annual concentration during year 2016

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Table 4.24 Average concentration during Diwali year 2016

Place/Parameter	Ozone	Sulphur Dioxide	Nitrogen Dioxide	PM2.5	PM10
Oct 28, 2016	44	20	86	257	509
Oct 29, 2016	63	41	107	281	596
Oct 30, 2016*	67	25	73	297	1127
Oct 31, 2016	62	44	70	426	660
Nov 01, 2016	30	19	79	328	787
Festival Average	53	30	83	318	736

Concentration of ozone, Sulphur dioxide, nitrogen dioxide, PM2.5 and PM10 have shown huge increase from 28 µg/m^3 to 53 µg/m^3, 17 µg/m^3 to 30 µg/m^3, 61 µg/m^3 to 83 µg/m^3, 167 µg/m^3 to 318 µg/m^3 and 334 µg/m^3 to 736 µg/m^3 respectively when compared from yearly average concentration to Diwali average concentration.

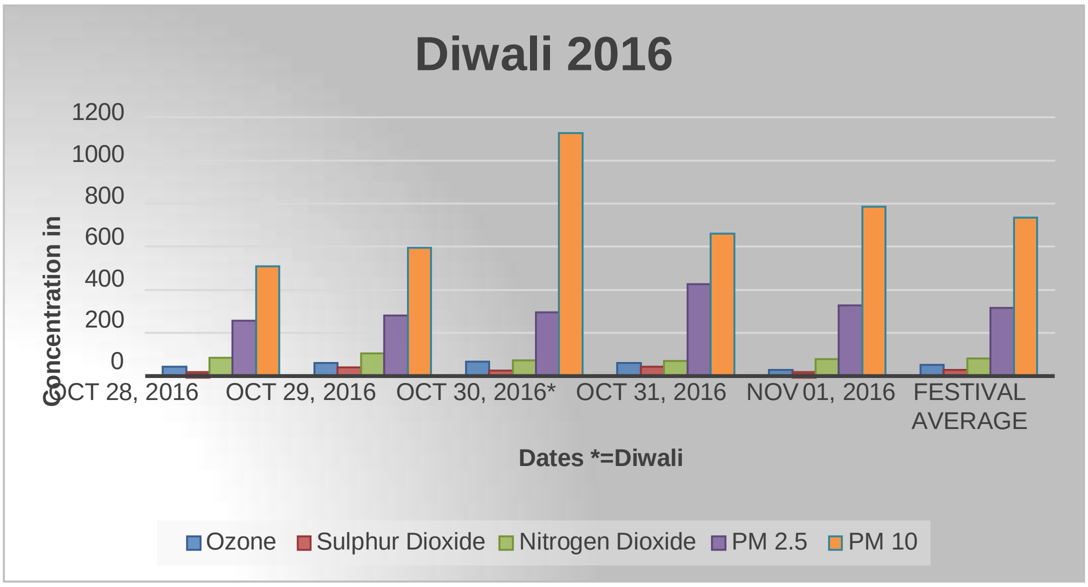

Fig. 4.19 Average concentration during Diwali year 2016

V. CHAPTER – 5 CONCLUSION

Concentration of SO_2 is found well within the range prescribed by NAAQS irrespective of whether we consider Diwali days or yearly average. No measure is needed to control SO_2 concentration in environment.

Average Concentration of NO_2 is found higher than NAAQS continuously in all the years included in study. Levels of NO_2 are found 2 times, 2.5 times and 1.5 times higher than the prescribed NAAQS in the years 2012-14, 2014-15 and 2015-16 respectively. On Diwali days, the concentration of NO_2 is found high when compared to NAAQS in years 2012, 2014 and 2016. However, Concentration of NO_2 is observed well within range in year 2013 and 2015 during Diwali days.

Concentration of PM2.5 has observed a constant increase of 3-6 times when compared to NAAQS which is extremely harmful for health. During Diwali days concentration of PM2.5 has shown no significant increase or decrease when compared to yearly concentration. However, during Diwali days concentration of pollutants was still 3-5 times higher than NAAQS as well as annual average concentration.

Average concentration of PM10 is observed to be 4-7 times higher than prescribed NAAQS. Concentration of PM10 has shown a decrease in year 2013-14 when compared to average annual concentration but is still found 2.5 times higher but is well within permissible limits.

The latest concentration from year 2016 has shown that Diwali had a strong impact on PM10 increasing its concentration to 7.5 times higher during Diwali days from that an average of 5 times higher during normal days.

Recommended Action

Extreme concentration of PM2.5, PM10 and NO_2 during Diwali days has shown its impact on our environment. Pollutants from firecrackers in Diwali makes air extremely poisonous for breathing, causing a lot of health-related problems in both men and women of any age. Therefore, it is recommended to ban use of fireworks during Diwali to avoid air pollution due to firecrackers.

What needs to be recommended

Diwali festival is attached with Hindu religion, a religion practiced by majority of population in India. Therefore, for the sake of religious sentiments and significance attached with the festival recommended action to ban festival cannot be implemented. Therefore, an arrangement must be reached between religion and environment so that both aspects are fulfilled. Some of the steps which can be taken are

- Checking and conducting study on types of firecrackers and banning those which are found to cause extreme pollution having huge impact on environment.
- Limiting use of firecrackers by government to a specific day and time limit allowing it to be used only on specific time period on festival day. If the law is not followed penalty should be imposed.
- Limiting purchase of firecracker by an individual/family by government to check minimal use of firecrackers by people for the sake of festival spirit.
- Educating people about harmful effects of pollutants on our body and diseases associated with them, requesting them not to use firecrackers in big amount in Diwali.
- Encouraging people to celebrate eco-friendly Diwali with use of scented diyas and candles.

BIBLIOGRAPHY

[1]. MarilenaKampa& Elias Castanas, "Human Health Effects of Air Pollution", Elsevier, June 2007.
[2]. "National Air Quality Index", PR Division on behalf of Dr. A. B. Akolkar, Secretary CBCB,
[3]. "Air Quality Guidelines: 2nd Edition", WHO Regional Office for Europe Copenhagen, Denmark, 2000
[4]. CPCB (2003) "Guidelines for Ambient Air Quality Monitoring", National Ambient Air Quality Monitoring Series: NAAQMS/2003-04
[5]. "Air Quality of Delhi", www.cpcbenvis.nic.in/envis -newsletter.
[6]. "Diwali-Festival of Lights", www.articlebiz.com.
[7]. "Ambient Air Quality and noise level during Diwali 2013", Central Pollution Control Board.
[8]. S. C. Barman, Ramesh Singh, M. P. S. Negi & S. K. Bhargav, "Ambi(R.K.Srivastava, february 2015)ent Air Quality of Lucknow City (India) during using of fireworks on Diwali festival" Springer, June 2007
[9]. M. Gupta, A. Sharma, N. Bajaj and A. Mandal, "Study of Temporal Variation in Ambient Air Quality during Diwali festival in Delhi – A Case Study", International Journal of Advance Research and Innovation, Volume 4, Issue 4 (2016).
[10]. Papiya Mandal, Mamta Prakash and J. K. Bhasin, "Impact of Diwali celebrations on urban air and noise quality in Delhi City, India" Springer Science + Business Media, B. V. 2011
[11]. Dhananjayan T., Nithul Lal, K.P. and Karhtikeyan K.,"A STUDY ON AIR QUALTIY STATUS DURING DIWALI FESTIVAL AT BHUJ CITY, KACHCHH DISTRICT GUJRAT, WESTERN INDIA**",** Asian Journal OF Science and Technology, Vol. 6 Issue 6, June 2015.
[12]. U. P. Nasir, D, Brahmaiah, "Impact of fireworks on ambient air quality: a case study", International Journal of Environmental Science Technology, 2015.
[13]. Shamsh Pervez, Rajan K. Chakrabarty, ShippiDewanagan, John G. Watson, Judith C. Chow and Jeewan Lal Matawle, "Chemical speciation of aerosol and air quality degradation during the festival of lights (Diwali)", Elsevier October 2015.
[14]. R. K. Srivastava, Kalpana Sagar and GufranBeig, "Comparative Study of Air Quality Jabalpur during Diwali Festival", International Journal of Advancements in Research and Technology, Volume 4 Issue 2, February 2015.
[15]. Shivangi Nigam, Navneet Kumar, N. K. Mandal, B. Padma and S. Rao, "Real Time Ambient Air Quality Status during Diwali Festival in Central, India", Journal of Geoscience and Environment Protection,

2016 Volume 4.

[16]. A. Chatterjee, C. Sarkar, A. Adak, U. Mukherjee, S.K. Ghosh and S. Raha, “Ambient Air Quality during Diwali Festival over Kolkata- a megacity in India”, Aerosol and Air Quality Research, 2013

[17]. Sapan Bhatnagar and Shubham Dadhich, “Assessment of Impact of Fireworks on Ambient Air Quality”, International Journal for Research in Applied Science and Engineering Technology (IJRASET), Volume 3 Issue 4, April 2015

[18]. Venkata Swamy Yerramsetti, Anu Rani Sharma, Nikhil GauravarapuNavlur, VenkannaRapolu, N. S.

[19]. K. Chitanya Dhulipala and P. R. Sinha. “The Impact Assessment of Diwali fireworks emission on the air quality of tropical urban-site Hyderabad, India during three consecutive years” Springer Science + Business Media,Dordecht 2013.

[20]. “Delhi population (2016, Dec 16) www.worldpopulationreview.com.