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REVIEW

A Review on Anthropogenic Biomass Burning: Emission of Aerosol Pollutants, Impact on Climate Change, Human Health and its Mitigation Strategies

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Biomass burning is a complex process, encircling chemical and physical responses covering, transmission of mass and warmth. A large number of investigations were accumulated on the significant emissions from various kinds of anthropogenic biomass burning in the recent decade. In India, an increasing trend of biomass burning is an important cause to release a large volume of reactive gases with other impurities and intensify the level of invisible particles into the troposphere, which affects humans health and leads to the probable alteration of the weather and global climate. The present review looks at the interpretations for a diverse investigation of distinct body and monitoring interventions, pertinent to our country, relating to the significance of particulate matter emissions, sources of aerosols and their health implications. This study also discusses numerous persuaded investigations, conducted on the impact of aerosol, attributed to climate change and also points out precise matters such as spatio-temporal variability of fire occurrences detected in India. Furthermore, the present study reveals that substantial quantities of data, along with a variety of enhanced simulation models and investigational validations, are essential for the development of efficient mitigation strategies with the objective of protecting the environment of the Indian Peninsula.

Keywords: Biomass burning, Aerosol effects, Climate change, Black carbon, Particulate matter.

INTRODUCTION

Atmospheric pollution is a significant environmental subject of recent decades with its effects on health, biological environment, well-being of humans, economy and nutrition safety. It accounts for 5th risk factor for massive demises [1]. In view of World Health Organization Air quality guidelines, it has been estimated that 9 out of 10 individuals are exposed to air contaminants worldwide [2]. In India, air contaminants that knockout new records with acceptable particulate matter concentrations ($PM_{2.5}$) that crossed 1,000 μg m^{-3} in Delhi were reported [3]. Current information stated that $PM_{2.5}$ concentrations for an annual exceed 5 to 9-folds, compared to WHO annual ambient standards for Southeast Asian countries [4]. IQ Air (2020) [5] reported that among detected 50 utmost polluted cities, 49 were located in countries such as India, Pakistan, Bangladesh and China.

Endless use or exploitation of country resources over times, that leads to environment dilapidation, is a resultant of anthropogenic pressures such as tree cutting, contamination of air, uncleanliness of water, unusual foraging and soil destruction [6]. Several studies have highlighted the strong connection

between anthropogenic activities, greenhouse gas emissions, aerosol production, climate change and health hazards [7].

In recent times, biomass burning is of great scientific interest, owing to the inferences for climatic change that resultant an alteration in landscape, piling of aerosols that hint gases in the troposphere. Among Asian continents, the chief contributor to the biomass burning is detected as China, tracked by India, Indonesia and Myanmar with burning activity about 25%, 18%, 13% and 8% respectively [8].

Experiencing ambient particulate matter (PM) is a hazard to the environment and consequently to human health care. However, Indian ruling classes instigated numerous actions to decrease discharges from the electricity, industries and conveyance segments in recent decades, such approaches found inadequate in curtailing the ambient $PM_{2.5}$, lower than the Indian National Standard of 40 $\mu g/m^3$, diagonally throughout the nation. Enormous investigations are focusing entire aspects of biomass burning, covering its varieties, on the measurements of emissions and on evaluating their different effects. A number of reviews appeared in the literature, illustrating *vis-à-vis*, assessments in outdoor, in door investigations and the impacts of biomass burning, targeting definite environments on the limit and exchange of aerosol absorption between them, pertinent to India and other continents [9].

Among them, few reports alarmed that in urban India, emissions from agricultural burning are mixed with other anthropogenic activities and dust, which raises $PM_{2.5}$ concentrations to the unsafe limit [10]. Contact to exceed the limit of $PM_{2.5}$, shown to be connected with a number of antagonistic health illnesses, like bronchitis, serious asthma, unbalanced heartbeat, other cardiological impairment and respiratory dysfunction and lead to demise [11]. Ambient standard particles are also related to the abundant ecological effects, such as falling perceptibility and altering steadiness of globe radiation [12,13].

Another important dominant focal point in literature is emission of atmospheric aerosols, which represent the minute particles in dense or fluid stages, placed in the air, covering inorganic dirt, sulphate, nitrate, residue, grime and burned coal. They emerge from both natural and anthropogenic activities like farming, engineering, coal burning, *etc*. [14-17]. Aerosols are diverse in nature, driven by troposphere rollers, whereas, eliminated either by dry deposition through clouds and precipitation progressions [18-20].

Aerosol chemical composition involves a life-threatening role in regulating, magnitude of the aerosol while dwelling in the air. There are numerous studies designate, Asian countries emit a considerable quantity of black carbon and organic carbon, the key elements, from biomass burning, involved in forming aerosols and estimated as ~ 0.45 Tg yr^{-1} and ~3.3 Tg yr^{-1}, respectively [8]. Such fractions are the decisive limit of biomass burning emission in the World [9]. Lately, few authors outlined that South and East Asia contribute nearly ~83% of the carbon-containing aerosol from open fires [21,22].

Numerous reviews deliberated on the up-to-date tendencies associated with the aerosol discipline for valid developments in the troposphere. Few emphasis on particular aging effects of atmospheric aerosols from biomass emissions [23]. Moreover, Miinalainen [24] used a simulated climate model, based on global scale, for detecting, concurrently both urban limit air quality and provincial and international scale on the value of driven factors for human made aerosols.

Therefore, in this review, we focused few selected demonstrated studies related to the biomass burning emission of aerosol pollutants and particulate matter, due to human activities, pertinent to India and also reports their associated effects on climate change with human health care.

Significance of anthropogenic biomass burning: Biomass burning is an intricate course, involving numerous physical and chemical responses and transference of mass and heat. In earlier decades, biomass burning is believed to be a tropical event, relatively it ensues around the world [25]. In literature, a number of convincing studies on anthropogenic biomass burning appeared and disclosed three general focuses, such as (i) quantification of emission of particulate matter and its emission factors, according to the different types of burning sources such as agriculture residues, forest fires, stubble burning and so on, due to the human implications; (ii) assessment of air quality, due to the greenhouse gases production from biomass burning to the atmospheric aerosol pollutants; and (iii) occurrence and effects of biomass burning, specifically, regional wise studies, using satellite fire data sets and also on the health issues.

In the majority of studies, it has been mainly emphasized on the effects of biomass burning aerosols pollutants deliberated with two wide-ranging objectives, such as (i) direct effects on humans well-being as a consequent of inhaling, which is close to the earth, and (ii) their physical properties and chemical composition, subsequently, probable impacts on regional as well as worldwide climate.

Initially, a study must be conducted to collect a vast amount of physical data related to environmental requirements in the atmosphere. Other words, data sets pertinent to the size, conformation and concentration of aerosols with their functional role of place and period are crucial. Time-sequence information offers most valuable evidence about the seasonal disparity and numerical inconsistency of data sets as a function of regional climatology. Many investigations have also been conducted on the chronological time-series information and limitation of appropriate practices to the definite objectives. Real-time techniques produced information is valuable on the occurrence of aerosol pollutants associated to the destiny and transport within quick timescales, although time-averaged information is suitable for various sets of evidence to the different objectives. It has been signified that coupled with facts of pollution sources, features and climatology in a given area, it is possible to detect the virtual input of different identified sources in a specific area. While these data series are statistically impregnable, it can be employed to express or alter civic policy and regulation.

Few investigations focus in wide-range, on the behavioural pattern of aerosols detected in one segment of the world and compared with various portions of the world. There are specific aerosol behavioural patterns analyzed, which were useful to understand the local aerosol pollutants. These sets of data deliver valid perception into the processes, which distressing local and regional pollutant behaviour. Assessing aerosols released

from biomass burning in the environment can serve multiple reasons related to selecting, implementing, and analyzing the data collected. The following section illustrates significant data obtained during various regulatory authority agencies. However, key curiosity in the majority of assessment studies is to display suspended matter mass concentrations in ambient air. It has been observed as a serious threat to human health.

Driven factors for atmospheric pollutants: Particles represent a combination of hard particles and fluid condensations in the air along fluctuating physico-chemical characteristics [26]. Particulate matter (PM) is a leading supplier to air contamination. Large body of analysis outlined suitable indicators for measuring air pollutants, that include inhalable constituents with a size of less than 10 μm, that signified PM_{10}, inhalable size denoted as 'fine particles' measured size known to be less than 2.5 μm, that symbolized $PM_{2.5,}$ lastly 'coarse PM' has been distinct as variation amongst PM_{10} & $PM_{2.5}$ [26]. Moreover, PM_1 is denoted as 'ultrafine particles', when particulate constituents are found to be less than 0.1 μm, known as 'nanosized particles'. Besides, while in the combustion process, emission constituents are shown to be slighter than 1 μm. In numerous analytical investigations, such nanoparticles served as key factor, predominantly for health implication, due to large surface area to the volume ratio and enlarged motion in the human body [27,28].

Particulate matter is placed as an important contaminant and receives more attention and research interests. The concentration of mass, number, size and distribution of particles are unique features of particulate matter. Although, they depend on source, life time and their physico-chemical characteristics of particles [29]. The $PM_{2.5}$ contaminants are connected with lots of untimely mortality worldwide [29,30]. As outlined by WHO, the $PM_{2.5}$ values obtained are knowingly exceeded, when compared to the mean value of 25 $\mu g/m^3$ safer limit.

In actual fact, few studies affirm that sources of biomass burning discharged largely carbon based elements to the troposphere [31-33]. Another investigation conducted by Hammer *et al*. [34] elucidated the $PM_{2.5}$ comprehensive trends have been detected with little elevation in the recent past.

According to Chan & Yao [35], the majority of particulate matter (PM) released into the troposphere consists of carbon-containing components, which can be either organic or elemental in nature. Such carbon based types affect universal energy equilibrium. When, black carbon fascinates inward solar radiation and is causative to increase atmospheric temperatures, whereas, organic carbon chills the atmosphere, by sprinkling the sun radioactivity [36].

Emission of biomass burning pollutants and emission factors: There are an immense number of investigations that look at various kinds of claims on the emission factors which are quantified based on the biomass sources. Such appreciated information would help to make clear thoughts on the biomass emission factors. It is well known that biomass burning includes the burning of lifeless and living beings, consisting of vegetation, crop residues and forest-consequent resources [37,38]. The gaseous contaminants from biomass burning, that hold abnormal amounts of ambient particulate matter. They exhibit significant levels of noxious gases and particle phase, such as SO_2, nitrogen oxides (NO_x), CO, CO_2 and PAHs. Various kinds of pollutants discharged from burning cause climatic alteration in several countries. Among them, the prime and most risk factors that are produced from biomass burning is $PM_{2.5}$.

Nowadays, in various developed countries, including the USA, emission factors are mostly reliant on fossil fuels [39]. Because, in recent times, renewable energy is considered as a substitute for fossil usage [40-42]. Anenberg *et al.* [43] reported that more than 3 billion people habitually use dense coals as the chief source of energy at their residences. Saud *et al.* [44] acknowledged in a study, biomass fuel usage, dominantly employed in many growing countries, including India. While burning, particulate matter emissions were subjugated by the range of sub micrometer sized particles [45] that resulted in severe health effects such as lung cancer and chronic lung and heart diseases [38,40].

To improve our consideration, the role played while emission, specific information on kinds of biomass burnt is necessary. Such data helps for analyzing various kinds of biomass that discharge excess impurities, while burning. Additionally, these specifics are useful for developing mitigation strategies. Few investigations reported the emissions of constituents from burning of biomass employed as coal [37,46-49]. However, such investigations have addressed sources of emission, which cross the threshold into the air and sampling from an open and in a closed environment is applicable.

Several studies [50-60] emphasized that releases from biomass burning deliver a key cause of main contaminants or otherwise pioneer aerosol impurities into the air. Discharge covers dominant carbon contain aerosols like black carbon and organic components [52-54,61,62], mineral components together with K, Cl, SO_4 and supplementary inert salts and trace inorganic deposits and inorganic as well as organic plumes [51,52,56,60]. Particulate matter has significant implications for climate change, fluctuation in quality of air [63-67] and human health [68,69]. It has also been reported and highlighted the need for devious discharge concentrations and quantities. Authors specified that effects of emissions to the physiological condition to the man and environment can be resolved through certain particulate indicators. Scaling includes particle size, shape and their external features [37,47]. Usually, features of the elemental emission are associated with varied physico-chemical nature that includes mass, diameter and size distribution, in number.

Emission factor (EF) is a demonstrative rate that relies on the amount of a contaminant discharged to the troposphere during anthropogenic motion. Emission factors, generally stated as the mass of contaminant divided by unit mass, dimensions, distance or period of the activity when discharging contaminants. This factor enumerates the extent of emissions [58]. The emission factor, commonly helpful for various investigations to measure aerosol pollutants [70-74]. For illustration, it can be measured as kilograms of constituents released, per megagram of firewood scorched. Such influences aid for detecting approximate emissions from different sources of atmospheric pollution. Emissions factors used as essential in many developing

countries including India, regional and local emissions, records that are helpful for air quality management decisions and their mitigating practices [75].

Types of biomass burning: An increasing number of reviews pointed out elaborately, various types of biomass burning, in specific, garden, forests and farming wastes burning in natural pertinent to India. Though, among them, 16% of investigations alone are known to have biomass burning in the compressed system. Such compacted biomass inclines to emanate varied planes of contaminants, associated with biomass burning pollutants [76-79]. According to Ghafghazi *et al.* [79], biomass pellets appear to be high quality fuel and suggested that pellets produce less particulate matter emissions, when compared to wooden fuels. Shen *et al.* [70] reported that the plant based capsules can be used as sparkling supernumerary for biomass. Such facts validate succeeding investigations on the releases from crushed plant form incineration.

The potential usage of briquettes made from discarded plant based firewood ash, a typical fuel utilized by inhabitants has also been examined. The prime goal of the investigation was to quantify the merits of briquette to decrease emission of greenhouse gases. Njenga *et al.* [76] reported that briquettes made from burnt firewood dust had a promising ability to reduce greenhouse gasses and produced the least emissions.

One interesting study was performed by Wei *et al.* [80], involving grass sticks from different types of yields to examine the effects of stove age and types of released pollutants. The results showed that carbon based discharges appeared in the 15-years aged stove exhibited 2.5 folds larger to its counterpart. Therefor, it was also inferred that the age of the stove is also a determined indicator for reducing carbonaceous releases.

Bray *et al*. [14] conducted a study focusing on the emission of paddy scum and wheat burning pollutants in India during the midst of 2016-2017. Discharges of reactive nitrogen species were estimated separately by employing MODIS sensors. The results exhibited that daily mean value of $PM_{2.5}$ observed in Delhi was found to be mid limit of 22.43 μg m^{-3} to 718.94 μg m^{-3} (daily ambient average value of $PM_{2.5}$ concentration was found to be 127.15 μg m^{-3} ± 95.23 μg m^{-3}), which showed larger than ambient air quality national standard of 60 μg m^{-3}. $PM_{2.5}$ and occurred during October–November months, that matches with the habitual residue burning recorded in the Indo-Gangetic plain.

Particulate matters in Indian metro cities: In few reports, commonly ambient particulate matters and ultrafine occurrence information in different places pertinent to Delhi was extensively studied. Certain studies of them, resulted in the specific associations between vehicular traffic discharge and patterns and compared with ambient concentrations ultrafine particles. In another interesting study, estimation of ambient concentration in Chennai city was also recorded as 7 tonnes/day of particulate matter [81]. Commonly, there was a link in standard assessment at a specific places prone to traffic flow or drift, conformation and intensity indicators [82-88]. Measured exposed concentrations of mean values derived from 60 data sets were found to be particulate and black carbon as 190 μg/m^3 and 42 μg/m^3, respectively, with 280 × 10^3 particles/cm^3, respectively [89]. Discharge of in-vehicle concentrations were a suggestively larger quantity than the ambient measured concentration indices. Release of average RSPM levels were restrained as 370-2860 μg/m^3 [90]. Such data is valuable for developing fortification strategies for two-wheelers and also other vehicular discharges of black carbon.

Cheng *et al*. [91] conducted a mega studies regarding the presence of ambient $PM_{2.5}$ in different big cities around the world. Unfortunately, Delhi has been listed as severe contaminated city in the world with top mean value exhibited as 143.0 ± 17.8 μg/m^3. The top level of PM_{10} was observed as 426.77 μg/m^3 whereas $PM_{2.5}$ was recorded as 301.91 μg/m^3 when 2019 January, covering traffic flow areas [92].

Major anthropogenic biomass burning activity include vehicular abundant, industrial incineration and other cremation activities were enlisted as the principal causes for worsening ecological setting across India and Pakistan. TERI [93] has assessed that in India, particulate discharges, specifically, $PM_{2.5}$, would rise suggestively by year 2030, due to brick manufacturing, biomass burning and vehicular emission. It has been reported that among other impurities exist in the megacities, release of biomass burning is recognized to produce a huge quantities of impurities into the troposphere and resulted deprived atmospheric condition, both in resident and provincial sectors [94-96].

Singh & Kaskaoutis [97] demonstrated that in India, the residue of paddy is scorched in October-November, whereas the wheat burns during April and May in a year 2017. In earlier study, Gupta *et al.* [98] stated that burning agricultural waste emits several gases into the atmosphere, including methane, carbon monoxide, ammonia, nitrous oxide, nitrous oxides, sulfur dioxide and hydrocarbon derivatives.

Aerosol effects on climate change: Growing number of research are conducted on the effects of aerosol in India [99, 100]. Such studies pointed out the radiative forcing effect and climate alteration in the specific region. Moreover, numerous investigations appeared in literature, targeting characterization of aerosols in intermittent style in various places of different states of India. However, few reports described the techniques and progressions involved in establishing aerosols that are not considered covering air quality in the Indian subcontinent.

Aerosol effects on radiative forcing: Many investigations, in general, focused on the radiation budget taking place from earth and climate change, which are deliberately inclined by normal and human made sprays. However, inconsistency in data sets of misters, in atmosphere and short period resident in the cloud, stand as a challenging task to measure their impacts on the microenvironments of clouds, rainfall and water cycle. Black carbon aerosol displays, apart from negative effects on human health, hold light absorbing potential to offer in radiative characteristics and strong affinities with clouds, resulting in the climate change.

There have been limited research focusing on analyzing aerosol properties using different devices to measure aerosol concentration intensity, which is influenced by the type of species present in the aerosol, like black carbon. In a study conducted in Central India, considering a main focal point on seasonal

variability in aerosol loading, specifically in Nagpur, using multiple assessment tools in 2008-2014 [101]. They used varied restraints such optical depth, liquid vapour, black carbon and others.

Few investigations emphasized that an increasing number of occurrences in fog development, was recorded specifically in Northern India, that tends to make unadorned trouble of practicable movement, steam of traffic and in few cases, highway transport [102]. Another investigation elucidated that $PM_{2.5}$ and PM_{10} distract meteorological conditions and diminish perceptibility [15]. A report stated that atmospheric spray can amends the earth's radiation budget that leads to change in the weather system. Besides, it also reveals that black carbon, discharged due to incomplete burning, yields remarkable inputs to universal heating. Such elemental constituents are able to fascinate cosmological light significantly [103]. Talukdar *et al.* [104] described that abundant black carbon displays a positive correlation with the ecological warmth.

It is well-known that atmospheric aerosol is a vital feature, involving in the alteration in climate and health care and also to the regional and global air quality concern. The chief focus appeared in many studies is the occurrence of aerosols, specifically, effects of black carbon on fallout driving or changes in quantity of radioactivity obtained in specific places on the surface of the earth. However, the chemical reactions among aerosol particles and with radiation is still uncertain. A wide range of independent and combined studies have observed at aerosols, commonly, targeting on explicit ingredients in the atmosphere [105-113].

Thus, certain collaborative package research involved in quantifying the impacts of radioactivity driving power by air sprays [114,115]. Limited attention from regional scholars is devoted to exploring the fluctuations in weather patterns, particularly the seasonality that is prevalent in India, due to its critical nature. Research on changes in local weather patterns, linked to significant variations in pollutant emissions, led to investigations into contamination sources, actions by regulatory agencies, and administrative procedures [116].

Purohit *et al*. [117] conducted a brief study on the atmospheric aerosols in West Bengal state and identified a regional outflow of contaminant elements from biomass burning aerosol impurities into the atmosphere, specifically in India. The results showed that in 2015, just 59% of the yearly $PM_{2.5}$ emissions in the state of West Bengal were detected. Of these, 17% come from neighboring states, 7% from beyond India (Bangladesh and beyond), another 7% from outside India (western Gangetic states) and 2% from other sources (soil and maritime sprays). Moreover, they also claimed that the source for aerosols, such as secondary aerosols (52%) and household emissions (31%) have been formed due to the gaseous precursors *via* atmospheric processes and also triggered that emissions from households are a solitary largest source of ambient $PM_{2.5}$ in year 2015 on a regional scale.

Aerosol trace gases: In past 10 years, there has been a lack of research that effectively assesses aerosol trace gases from different biomass burning methods. Andreae & Metlet [94] described a set of various kinds of gases released from biomass fires. Such data were not reported earlier. In their study, authors have anticipated estimates of a variety of important emitted species from different biomass burning by employing suitable extrapolation methods. They also compared the findings with outcomes of inverse modelling analysis. Such information can be useful as benchmark data on the carbon based gaseous contaminants from biomass burning.

A study conducted by Kumar *et al.* [118] examined data on black carbon release and shed light on the impact of site specific climatological variables such as airstream, heat, drizzle and atmospheric boundary layer on black carbon build height. The results showed that there is a negative relationship between rain, relative wetness, airstream hurriedness, warmth and height. A wide variety of pollutant pathways, including domestic anthropogenic movements, are responsible for the dramatic shifts in black carbon mass concentration. These studies are helpful to understand the changes in the black carbon mass concentration and behaviour of black carbon with its effects on the local anthropogenic activity and long range transport of aerosol in India at different regions. Another study has been conducted associated with aerosol emission and air-quality assessment to examine and expand our thoughts on the spatio-temporal analysis to find aerosol impacts, pertinent to Asian countries east end [119].

Occurrences of fire counts in Indian states: Large scale forest fires and plant scum scorching are well-known usual and human intervention actions that lead long standing effects on ecological milieu, specifically, on land protection, land practices, harbours of biological entity and macroclimate alteration. An accumulated research looks at the consequence of fire on surface black carbon and atmospheric nitrous oxide, pertinent to the north eastern region of India. In a study, it was performed over a prolonged period 15 years, using recent techniques, such as MODIS, MERRA-2 and OM I data. Findings indicated that the beginning of four months each year was significantly associated with dominant fire occurrences. Nearly 65,000 fire occurrences have been chronicled in March and April, for the span of 15 years [120].

Certain reports look at the focal point also on the spatial temporal distribution of fire occurrences. In Chhattisgarh state, India, a collective information on active forest fires over a 17 years period using intermediate resolution image spectroradiometer indicated that occurrence of fire has been amplified for a long duration and observed as 1487 and 3074 number of fires occurred in forests during 2005 and 2021, respectively. Among them, during 2009 and 2017 the highest number of fires occurred. There is a consistent seasonal pattern to the fire events that occur in deciduous and savanna forests. The hotspot of the fire prone area was detected in the southwest region. These findings are helpful to formulate efficient fire management approaches in fire risk segments [121,122].

Health effects on humans: While exposure to particulate matter or aerosols, to humans, leads to ailment from mild to severe health effects, were extensively studied. They may cause breathing illnesses to reach severe chronic effects, such as respiratory dysfunction. Numerous epidemiological studies were conducted on the effects attributed to aerosols, they were

determined on the data from insignificant groups of patients or clinical data of patients with signs reflecting work-related data sets.

Contini & Costabile [123] outlined the antagonistic properties of atmospheric particulates rest on, its extent and physical nature and chemistry of impurities, that powerfully connected to their emission sources. Exact aerosol components, like organics, metals and black carbon, are supposed to contain pertinent toxic effects. Exposure and respiration rates, as well as the spatial and temporal distributions of these factors, have a significant impact on the health of people [124]. Moreover, evolving an effective regulator to curtail environmental health risks factors linked with aerosols is a challenging task in the environmental research.

Benedusi *et al.* [125] look at the circadian misalignment, activated by industrial development and habits of modern lifestyles. These are connected to various pathological appearances, with probable loss of the quality of life quality. Study demonstrated contaminant-induced tissue damage linked to circadian rhythmicity. In a study, bioaerosol samples collected from neighbourhood wastewater treatment plants showed a higher level of living entities in the troposphere, such as endotoxins and microorganisms. Professionals of the treatment plant demonstrated signs of breathing failure, stomach dysfunction, as well as annoyance. Such symptoms are due to the responses of the biological endotoxins. A report also claimed that health effects of indoor contaminants released in demolition of buildings located in New Delhi, India [126].

Some studies, commonly focused on the discharged particulate matter arised from biomass burning affect severe human health care, covering cardiovascular illness, respiratory dysfunction signs and adult death occurred, among high-risk individuals [127-130]. Since tiny sized units emitted from the biomass burning, can easily invade into the lungs-largely in the alveolar segments [131]. Toxic chemical particle matter, such as tumor-inducing hydrocarbons, consistently directly harm human well-being [132-134].

Mitigation strategies: Exposure to ambient particulate matter has been identified as a risk factor for both humans and the natural environment in India. Despite authorities executing the numerous mitigation strategies to decrease releases from the electrical energy, engineering and transport segments in recent decades, such approaches seem to be inadequate to a lesser value of 40 $\mu g/m^3$. To notify the action on considerable limits in India, Purohit *et al.* [117] appraised experimentation to ambient particulate level, based on simulations techniques. Many Indian states release the reasons obtained from the neighbouring jurisdictions (Table-1). The study also concluded that sophisticated technology strategies or approaches may deliver quality air to 60% of the population.

Xua & Ramanathan [135] demonstrated a three lever systems of approaches to reduce global warming to below the unsafe

TABLE-1
ESTIMATED FIRE OCCURRENCE OBSERVED FOR THE DIFFERENT STATES OF INDIA FOR THE SPAN OF 2003-2018, USING MODI SENSOR (*Adapted from* [Ref. 123])

Name of the state	Check value	Observed mean value of fire count	Tendency (%)	Statistical outcome
Punjab	14655	16715	1.05	Significant
Madhya Pradesh	1348	5350	13.39	Significant
Mizoram	5056	4909	-5.32	Moderate
Maharashtra	3366	4134	3.41	Significant
Assam	2858	3912	1.57	Insignificant
Odisha	3076	3790	6.29	Significant
Uttar Pradesh	2304	3640	5.5	Insignificant
Manipur	3104	3257	-2.38	Significant
Chhattisgarh	2282	3244	9.51	Significant
Haryana	2159	3102	3.71	Moderate
Nagaland	2271	2359	-2.13	Insignificant
Meghalaya	1869	2336	-0.2	Insignificant
Andhra Pradesh	1336	2306	5.68	Moderate
Karnataka	1073	2071	4.91	Moderate
Arunachal Pradesh	1592	1843	-1.85	Insignificant
Telangana	999	1796	11.25	Highly significant
Jharkhand	683	1686	13.39	Moderate
Uttarakhand	1461	1559	-0.61	Insignificant
Tripura	1562	1299	-5.23	Significant
Gujarat	700	1206	2.65	Insignificant
Tamil Nadu	628	825	0.90	Insignificant
Bihar	386	791	13.15	Highly significant
Rajasthan	250	678	25.53	Highly significant
Jammu Kashmir	291	571	5.81	Insignificant
Himachal Pradesh	435	430	1.05	Insignificant
West Bengal	208	428	14.95	Significant
Kerala	172	316	3.2	Insignificant
Goa	23	25	1.57	Insignificant
Sikkim	6	16	16.67	Moderate

level. firstly, the carbon neutral (CN) lever system can be used to attain the complete discharge of CO_2, secondly, super pollutant lever strategy for diminishing short-lived weather contaminants, and lastly, carbon extraction and sequestration lever system has been suggested to remedy the atmospheric CO_2 extensiveness.

Shrestha *et al.* [136] outlined a successful strategy of biomass burning pollutants reduction in Surat city, located in the Western India. They targeted this issue by attempting a waste management approach to check open burning. Later this inventiveness, more attention is given on the construction sector. Advent of zigzag technology employed in the brick industry for falling emissions is under practice. Development of greener construction codes, added support for removing the aerosol impurities. Increased trend of advocating electricity mode transports, it is a positive trend toward green mobility in urban cities of India. They need significant maintenance from governments in the region to implement. Furthermore, Bhutan and Nepal have adopted a hydropower surplus that provides the scope for the adoption of induction based clean cooking to mitigate the emissions.

Conclusion

There is a growing number of investigations involved in the biomass burning aerosols, however it seems to be an infrequent way at varied places of the country. When compared to developed countries, such as the US and China, the quantity of environmental data relating to the biomass burning discharge and aerosols in India is limited. Accurate data on the effects of Indian aerosols at higher spatial and temporal resolution is an immediate necessity. Similarly, particulate pollutant transference models are well recognized and validated all over the world, local microenvironments, (busy traffic location) and occupational sites, where in pollutant transport evaluation would offer the best revelation and risk. Despite, the general principles of atmospheric aerosol are well documented in earlier studies and accessible elsewhere in much literature, the presented intensive investigations will support in validating those principles in site specific areas and will be helpful in detecting emerging biomass burning problems, pertinent to India.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this article.

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