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Original Article

Distribution, Water Soluble ions, Monitoring of Indoor Particulate Matter PM_{10}, $PM_{10-2.5}$, CO and CO_2 during Burning of Dhoop Samples

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Abstract - *Incenses, mosquitoes, dhoop, and other indoor combustion sources are frequently employed for aesthetic and religious purposes in a variety of indoor and outdoor contexts. Due to particulate matter exposure from inhaling the smoke produced by the combustion, there is a risk to one's health (PM). Monitoring of PM (PM_{10}, $PM_{2.5}$, and PM_1) levels during the preparation, lighting, and extinguishing of incense (agarbatti and dhoop) and the use of a mosquito coil in an enclosed space. The amount of carbon dioxide and carbon monoxide in the exhaust and how indoor pollution affects their health.*

Keywords - *Droop, PM_{10}, Inorganic ions, Source apportionment.*

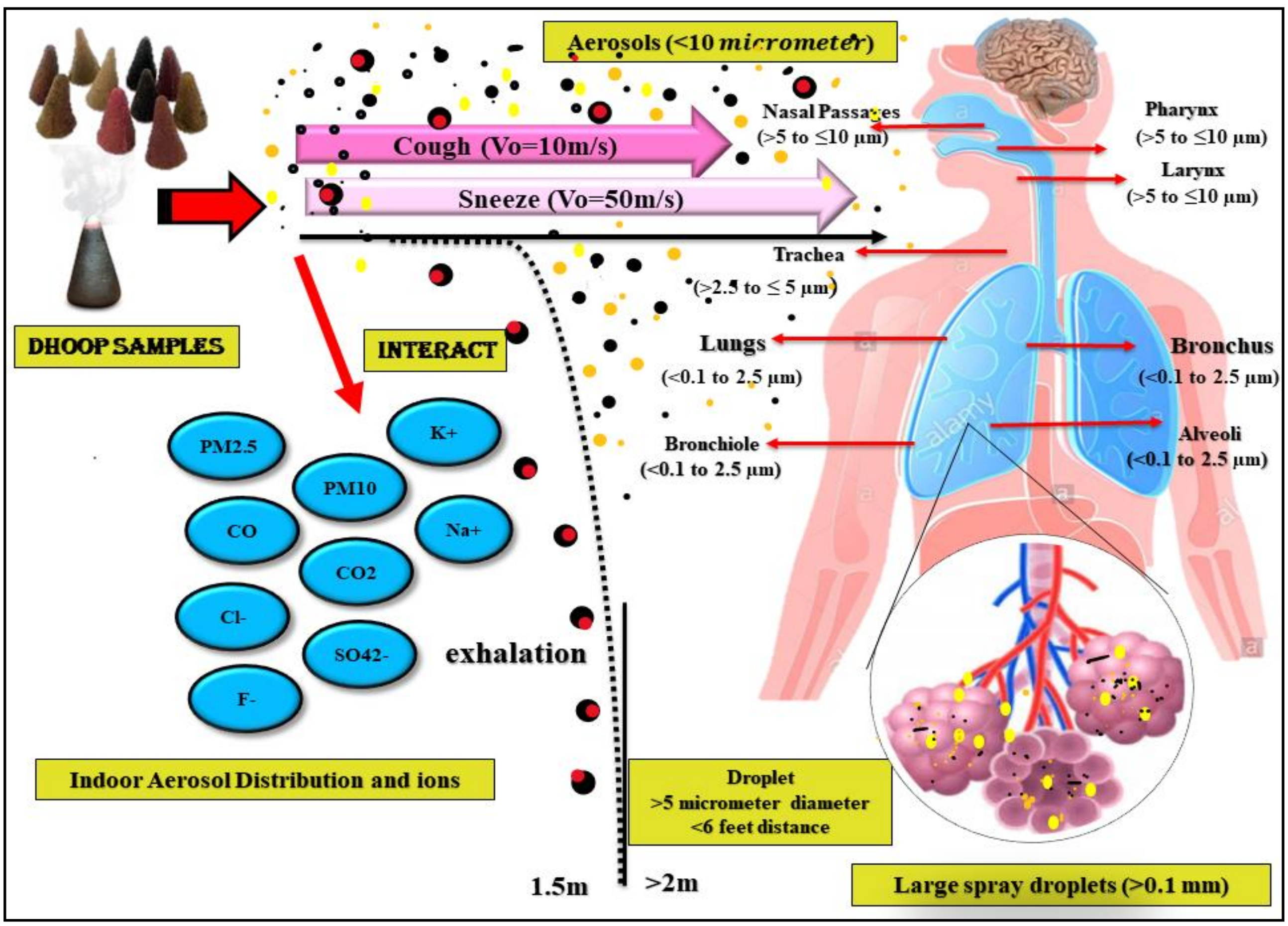

Fig. 1 Graphical Abstract

1. Introduction

Common indoor air pollutants may be categorized in several different ways. In a 1987 state-of-the-art article, Samet et al.' divided the major pollutants by origin [1-2].

This review will center on indoor air pollution that emanates from combustion sources. Tobacco smoke is an aerosol containing several thousand substances distributed as gases, vapors, or particulates [3]. Environmental tobacco smoke will be discussed in detail elsewhere in this supplement. It is important to note, however, that tobacco smoke is a significant source of indoor nitrogen dioxide (NO,) and carbon monoxide (CO). This is a much larger problem in lesser developed nations [4]. For several reasons (e.g., economic and aesthetic), there has been a resurgence in the use of wood as a fuel in the home in the United States. Wood burning, in addition to producing polycyclic aromatic hydrocarbons and increased respirable particles, is a significant source of indoor CO [5-8]. The other nitrogen oxides, as well as NO, are the third category of important indoor air pollutants of this class that come from combustion sources, and CO is a fourth [9]. Depending on the fuel and combustion conditions, many different chemicals may be produced by combustion. Although they might have a similar impact on the interior environment, these compounds are not included in this paper [26]. The comparable molecule described in this study, carbon dioxide (CO), differs in that it serves more as a sign of poor air quality than a particular indoor air pollutant [11–15]. Incenses are a common indoor combustion source used for aesthetic and religious purposes in a variety of indoor and outdoor contexts [16]. The combustion leads to the production of a large amount of smoke, which can pose a health risk due to inhalation exposure of particulate matter (PM).[17]

For aesthetic and religious purposes, indoor combustion sources like incense or dhoop are frequently utilised. Sticks, joss sticks, cones, coils, powders, rope, rocky charcoal, and smudge bundles are just a few types of incense or dhoop available [18–20]. Particulate particles (PM), gas byproducts, and several chemical compounds are all present in incense smoke (fumes) [21]. Incense burning typically creates particles larger than 45 mg/g burned compared to cigarettes' 10 mg/g burned. CO, CO_2, NO_2, SO_2, and other gases are produced when burning incense [22]. Burning incense also releases polycyclic aromatic hydrocarbons, aldehydes, and volatile organic chemicals like benzene, toluene, and xylenes (PAHs). [23] Dhoops are burned in households as well as in public spaces like shops, malls, and houses of worship in developing nations. [24-26]. The importance of Respirable Suspended Particulate Matter (RSPM) cannot be overstated because it has the potential to have a substantial impact on human health. [27] The Environmental Protection Agency (2006) regulates particulate matter (PM) as PM_{10}, $PM_{2.5}$ and $PM_{1.0}$ [25] PM_{10}, particle <10 µm, can penetrate the defense mechanisms of the upper and middle regions of the respiratory tract, while $PM_{2.5}$ particles <2.5 µm, is transported into the lower pulmonary system. According to World Health Organization (WHO) recommendations for air quality, the 24-hour mean PM level is 25 g/m^3 for $PM_{2.5}$ and 50 g/m^3 for PM_{10} (particles 10 m) [25]. However, there isn't a set reference value for PM2.5 concentrations in interior air pollution. There are few data on indoor PM_{10}, $PM_{2.5}$, and $PM_{1.0}$ levels related to the burning of mosquito coils, incense sticks, and dhoop, according to a thorough assessment of the literature [25]. Large communities in underdeveloped nations continue to utilise mosquito coil smoke and incense burning in daily life despite evidence of potential harmful health effects [15].

1.1. Human Health Effects from Burning of Droop it May Lead to Respiratory Infection

A recent study suggests that dhoop sticks pose a health risk. The findings demonstrated that burning dhoop indoors produces air pollutants, specifically carbon monoxide. The smoke contributes to indoor air pollution, which may result in lung cell inflammation and raise the risk of respiratory problems as well as other issues. Due to hypersensitivity brought on by excessive smoke inhalation, most persons develop coughing and sneezing [20–25]. The bronchial passages that carry air to the lungs get inflamed due to the toxins generated by burning dhoop. When inhaled frequently, these sticks' sulphur dioxide, carbon monoxide, nitrogen oxides, and formaldehyde (both in gas and particle form) can trigger inflammatory reactions like the common cold and asthma. The bronchial passages that carry air to the lungs get inflamed as a result of the toxins generated by burning dhoop. When inhaled frequently, these sticks' sulphur dioxide, carbon monoxide, nitrogen oxides, and formaldehyde (both in gas and particle form) can trigger inflammatory reactions like the common cold and asthma. The amount of smoke the lungs inhale is equivalent to what happens when someone smokes a cigarette [26]. Prolonged exposure to dhoop smoke irritates the eyes, particularly in children and the elderly. The elbow region, the base of the nose, and other areas with thin skin are particularly prone to allergies [24]. The dhoop smoke contains particles that can irritate the skin and trigger allergies. Increased headaches, attention deficit disorder, and amnesia were discovered to be common neurological symptoms related to daily exposure to dhoop sticks [22].

Dhoop stick burning contributes to indoor air pollution, which raises blood levels of nitrogen oxide (NOx) and carbon monoxide (CO) as a result. By affecting brain cells, high concentrations of these gases create neurological issues. Another direct contributor to female impotence According to a study published in the Journal of the American Cancer Society, regular use of incense sticks (dhoop) increases your risk of developing upper respiratory tract cancer [22]. Your daily use of dhoop may be detrimental to your heart's health.

Table 1. Collection of the dhoop samples

S. No	Sampling Date	Name of Dhoop Saples	Wt of dhoop (g)	No. of dhoop
1	31/01/2020	Daze Pooja Paath dhoop D1	19.895	8
2	01/02/2020	Devdarshan 4 in one dhoop D2	49.077	16
3	05/02/2020	Deluxe 4 in 1 dhoop D3	46.343	16
4	05/02/2020	Dhuna Kali Pooja dhoop D4	53.704	20
5	06/02/2020	Vinayaka's Lavender D5	23.453	12
6	10/02/2020	Patanjali Aastha Rose dhoop D5	40.999	10
7	10/02/2020	Patanjali Aastha Cone Dhoop (sandal) D6	22.942	13
8	10/02/2020	Zed Black Perfum Black D7	23.678	12
9	11/02/2020	Vinayaka's Mogra D8	19.910	12
10	11/02/2020	Hari Darshan Hari Sai Gugal dhoop D9	74.129	10
11	12/02/2020	Spark Deluxe Supreme Premium D10	47.422	10
12	13/02/2020	Zed Black Panch Deep Gulab D11	47.213	20
13	13/02/2020	Prabhu Ki Astha Loban Premium D12	38.296	10
14	14/02/2020	Zed Black Vedi Premium dhoop D13	62.703	10
15	18/02/2020	PAW Pareen Sangam dhoop D14	24.114	10
16	19/02/2020	Moksh Agarbatti Swarna Gulab D15	20.638	10
17	19/02/2020	Krishnam Gulab Premium dhoop D16	40.207	10
18	20/02/2020	Vidhan Peace dhoop D17	19.988	10
19	20/02/2020	Krishnakala Dhuna Chandan dhoop D18	34.176	10
20	25/02/2020	PAW Pareen Poojan's Gugal D19	24.601	10

According to the study, long-term incense usage elevated the risk of coronary heart disease by 10% and cardiovascular mortality by 12%. It is mostly brought on by increased exposure to agarbatti smoke (containing volatile organic compounds and particulate matter). Additionally, it worsens blood vessel inflammation and impairs blood flow, contributing to cardiac problems. The blood vessels are swelling [25].

2. Materials and Methods

Twenty materials from different companies were collected from the market of Raipur, Chhattisgarh area, during the month of January 2020. The details of the samples are described in Table 1.

3. Methodology

3.1. Collection of PM_{10} and $PM_{10-2.5}$

The collection of particulate matter (PM) was done using quartz fibre filters in moulded filter cassettes and an APM 250 combination PM_{10} and $PM_{10-2.5}$ air sampler (Lata Envirotech, New Delhi). The same place also yielded a sample blank that was collected. The sampler was set up in the living space. To reduce the background levels of contaminants in the filters before sampling, they were heated to 600° C and put in clean polyethylene dishes. Filters were weighed and placed in the sampler, which ran nonstop for three hours. The loaded filters were removed from their mountings, covered in aluminium foil, put in a polyethylene dish, and transported to the lab. After being placed in desiccators, the filters were weighed to determine the total particulate.

3.2. Sample Preparation

Filters were heated to 600° C before sampling to lower their background levels of pollutants and placed in a cleaned polyethylene dish. The aerosol collected samples were transferred into the desiccators and weighed to record the total particulate matter (PM) content against the blank. The loaded and blank filters were dried in the oven for 6 hr at 50°C and weighed out their masses before sampling. The weight of the filter paper before and after sampling was calculated by using the following equation:

$$W = X-Y$$

Where scripts W, X and Y denote the weight of aerosols filter + aerosol and blank filter paper, respectively, See Figure. 1

Fig. 2 Collection of PM_{10} and PM $_{10\text{-}2.5}$ in Droop samples

Table 2. Distribution of $PM_{10\text{-}2.5}$ in dhoop samples, µg m^{-3}

S. No.	Date	Dhoop Sample	Smoking Time, min	Flow rate (1m^3/h)	Volume (m^3)	Distribution (µg m^{-3})
1	31/01/2020	D1	74	16.7	0.571	77058
2	01/02/2020	D2	38	16.7	0.342	67251
3	05/02/2020	D3	113	16.7	0.825	103030
4	05/02/2020	D4	32	16.7	0.322	21739
5	06/02/2020	D5	65	16.7	0.601	13311
6	10/02/2020	D6	127	16.7	1.127	40816
7	10/02/2020	D7	100	16.7	0.596	31879
8	10/02/2020	D8	50	16.7	0.449	13363
9	11/02/2020	D9	76	16.7	0.753	15936
10	11/02/2020	D10	137	16.7	1.417	67749
11	12/02/2020	D11	117	16.7	1.102	68058
12	13/02/2020	D12	153	16.7	1.317	74412
13	13/02/2020	D13	103	16.7	1.117	71620
14	14/02/2020	D14	144	16.7	1.474	113976
15	18/02/2020	D15	60	16.7	0.652	7669
16	19/02/2020	D16	212	16.7	2.231	29135
17	19/02/2020	D17	127	16.7	1.335	71161
18	20/02/2020	D18	59	16.7	0.658	4559
19	20/02/2020	D19	95	16.7	1.092	29304
20	25/02/2020	D20	142	16.7	1.529	20275

3.3. Chemical Characteristics of Droop Ash

The conventional method of analysis was used to examine the chemical parameters. With the aid of an ion-selective electrode and a 1:1 total ion strength adjustment buffer, the fluoride ion concentration was measured (TISAB). The buffer preparation consisted of 58 g of NaCl, 5 g of CDTA (trans-1, 2, NNNN, cyclodiamine tetraacetic acid), 57 ml of glacial acetic acid, and 5 mol of NaOH to bring the pH close to neutral. The ion selective electrode method with 1:1 buffer KNO_3 and NaCl was used to test the concentration of NH_4^+, and Ion selective electrode method with 1:1 total ion strength adjustment buffer was used to measure the concentration of ammonium ions (TISAB). 10g of NaOH was added to the buffer preparation before being combined with distilled water and regular NH_4Cl. N^+ and K^- ions

Table 3. Distribution of PM_{10} in dhoop samples, μg m^{-3}

S. No.	Date	Dhoop Sample	Smoking Time, min	Flow rate 1m^3/h	Volume m^3	Distribution μg m^{-3}
1	31/01/2020	D1	74	16.7	0.52	80769
2	01/02/2020	D2	38	16.7	0.309	126214
3	05/02/2020	D3	113	16.7	0.91	94505
4	05/02/2020	D4	32	16.7	0.29	37931
5	06/02/2020	D5	65	16.7	0.534	14981
6	10/02/2020	D6	127	16.7	0.885	66667
7	10/02/2020	D7	100	16.7	0.526	70342
8	10/02/2020	D8	46	16.7	0.399	22556
9	11/02/2020	D9	76	16.7	0.664	43675
10	11/02/2020	D10	137	16.7	1.054	116698
11	12/02/2020	D11	117	16.7	1.013	67127
12	13/02/2020	D12	153	16.7	1.144	53322
13	13/02/2020	D13	103	16.7	1.074	73557
14	14/02/2020	D14	144	16.7	1.424	114466
15	18/02/2020	D15	60	16.7	0.618	16181
16	19/02/2020	D16	212	16.7	2.19	23288
17	19/02/2020	D17	127	16.7	1.265	77470
18	20/02/2020	D18	59	16.7	0.624	6410
19	20/02/2020	D19	95	16.7	1.092	32967
20	25/02/2020	D20	142	16.7	1.455	8935

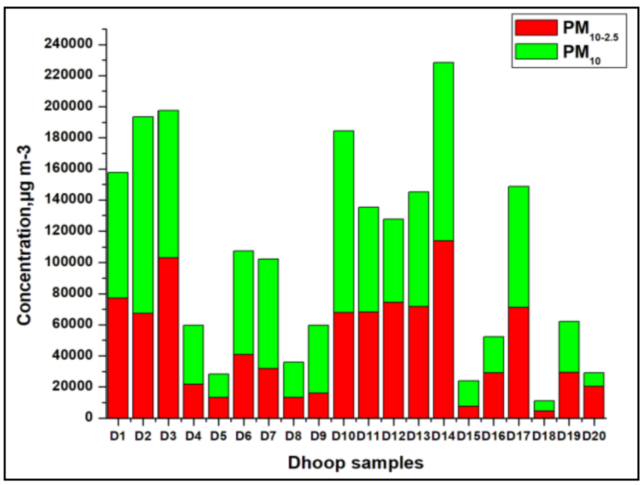

Fig. 3 Distribution of various dhoop samples in PM_{10} in indoor pollution

4. Result and Discussion

4.1. Distribution of PM $_{10\text{-}2.5}$ in Droop Samples of Indoor Air

The concentration of $PM_{10\text{-}2.5}$ in the indoor air is presented in Table 2. The minimum and maximum values of $PM_{10\text{-}2.5}$ in dhoop samples ranged from 4559-113976 μg m$^{-3,}$ with the mean value with confidence limit ranging from 47115±14425 μg m^{-3} m^{-3}. The highest concentration was observed in Dhoop Sample 14, with a concentration of 113976 μg m^{-3}.

4.2. Distribution of PM_{10} in the indoor air

The concentration of PM_{10} in the indoor air is presented in Table 3. The range of PM_{10} readings in dhoop samples is 6410–126214 g m^{-3}, with a mean value and 95% confidence interval of 57403–16351.6 g m^{-3}. The moist dhoop and its low-burning dhoop, which made up Droop Sample 2, had the highest concentration. In all of the dhoop samples, $PM_{10\text{-}2.5}$ has a greater aerosol concentration than PM_{10} because it enters the respiratory system and causes various health problems in humans (see Fig. 3).

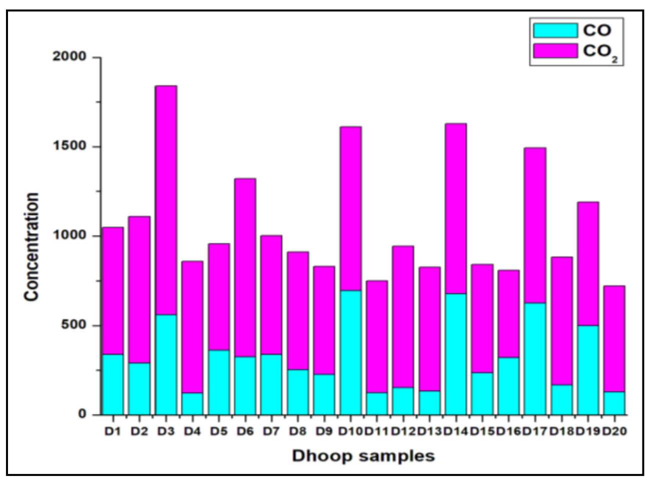

Fig. 4 Concentration of CO emission and comparison of CO and CO_2 in dhoop samples

4.2.1. The concentration of Carbon monoxide CO and Carbon dioxide CO_2 Emissions in Dhoop Samples

CO is a colorless, odorless gas that may result from the incomplete combustion of any carbonaceous material.

Table 4. Concentration of CO and CO_2 in dhoop samples

S. No.	Date	Dhoop samples	CO (ppm)	CO_2 (ppm)		Mean T °C	Humidity %
				Min	Max		
1	31/01/2020	D1	337	653	711	24	48.80
2	01/02/2020	D2	290	810	818	26.4	41.20
3	05/02/2020	D3	560	703	738	19.6	81.90
4	05/02/2020	D4	121	1258	1280	20.7	83.80
5	06/02/2020	D5	361	560	594	18.3	83.90
6	10/02/2020	D6	324	821	978	21.2	48
7	10/02/2020	D7	338	651	653	19	69.30
8	10/02/2020	D8	252	642	661	21.3	61.60
9	11/02/2020	D9	227	587	605	18.7	69.80
10	11/02/2020	D10	696	680	714	20.2	66.80
11	12/02/2020	D11	123	557	628	22.5	56.10
12	13/02/2020	D12	153	717	790	23.2	56.70
13	13/02/2020	D13	132	672	694	24.2	44.90
14	14/02/2020	D14	679	803	849	25.5	56.40
15	18/02/2020	D15	235	576	608	25.5	46.40
16	19/02/2020	D16	320	459	490	23.1	58.50
17	19/02/2020	D17	627	757	766	25.5	49.20
18	20/02/2020	D18	167	656	716	25.4	53.20
19	20/02/2020	D19	500	680	716	28.1	41.40
20	25/02/2020	D20	129	588	593	24.6	73.80

Baseline CO levels in the blood are determined by the endogenous production of the gas by the catabolism of hemoglobin and other heme-containing compounds, in addition to the intake of low ambient CO levels. Automobiles are the most prolific sources of CO. The minimum and maximum values ranged from 121-696 ppm, and the mean value was 329±83 ppm. The highest concentration is found in the D10 sample. The concentration of Carbon dioxide in the Droop samples ranged from 490-1280 ppm, and the mean value ranged from 750±80 ppm in indoor pollution. (Table 4) Figure. 4 As the concentration of CO is found higher in all the dhoop samples above the permissible limit, i.e. 50 ppm.

5. Physico-Chemical Properties of Dhoop Ash Samples

5.1. Physical Characteristics of the Dhoop Ash

The maximum and minimum concentrations of pH, EC, and TDS ranged from 8.6-12.41, 2.27-18.93 µs/cm and 1.56-12.79 mg/L, and the mean value of the dhoop ash samples are as follows 11.196±0.472, 11±2.169 µs/cm and 7.27±1.447 mg/L respectively. (Table 5) The highest pH concentration is found in sample no D15, the highest concentration of EC is found in sample no D13, and the highest concentration of TDS is found in sample no D13. The Chemical Characteristics of the dhoop samples and the Minimum and maximum range was carried out with the range of 70-2986, 98-568, 556-10500, 876-6540, 998-2125,1110-4975 mg/kg in respect of the total concentration of the F^-, Cl^-, SO_4^{2-}, NH_4^+, Na^+ and K^+ are 14619, 4578, 78498, 43471, 27388, 72266, 43471, 27388, and 72266 mg/kg respectively, and the mean concentration value of the F^-, Cl^-, SO_4^{2-}, NH_4^+, $Na^{+,}$ and K^+ dhoop ash samples vary from 731±446.7., 229±65.75, 3925±1600, 2174±512.6, 1369±148.4 and 3613±546 mg/kg. A higher concentration is being found in all the samples. Figure. 5

5.2. Statistical Parameters of the Dhoop Ash Samples

The statistical parameters are being detected by various physico-chemical characteristics with the mean value, Minimum, Maximum, Standard deviation, Confidence limit , and mean concentration of various dhoop samples. (Table 6) The EC had a good correlation with TDS. Similarly, F^- also shows a good correlation with Cl^- and Na^+ Similarly, K^+ and SO_4^{2-} also show a good correlation with each other see Table 7.

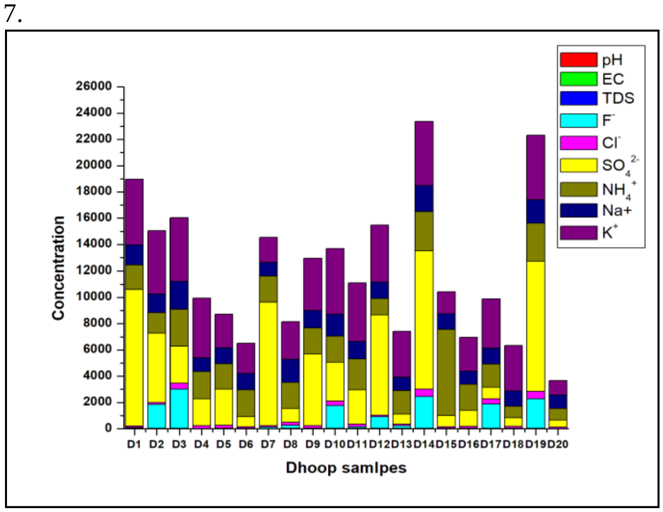

Fig. 5 Concentration of various parameters in Droop ash samples

Table 5. Physico-chemical characteristics of Dhoop Ash samples., mg/kg

S.No	Sample	pH	EC µs/cm	TDS mg/L	F^-	Cl^-	SO_4^{2-}	NH_4^+	Na^+	K^+
1	D1	11.79	11.29	7.72	70	108	10375	1845	1550	4975
2	D2	9.87	14.89	9.98	1825	133	5275	1563	1425	4800
3	D3	11.81	14.53	9.9	2986	438	2825	2805	2125	4825
4	D4	8.6	4.99	3.35	0	205	2050	2083	1050	4525
5	D5	12.31	8.83	5.91	0	238	2750	1915	1225	2575
6	D6	11.49	10.65	7.14	0	125	750	2050	1250	2300
7	D7	10.37	2.86	1.91	104	120	9400	1968	1025	1900
8	D8	12.13	5.34	3.58	236	225	1050	1980	1775	2850
9	D9	12.19	6.3	4.27	0	203	5450	1995	1325	3950
10	D10	11.55	11.61	6.68	1735	338	2950	1988	1675	4975
11	D11	11.92	12.37	8.31	112	190	2634	2345	1345	4440
12	D12	11.07	18.45	12.37	860	113	7654	1235	1267	4300
13	D13	9.73	18.93	12.79	178	135	765	1786	1009	3490
14	D14	10.37	15.45	10.4	2413	554	10500	2987	1980	4890
15	D15	12.41	13.32	7.73	0	109	865	6540	1189	1670
16	D16	11.76	14.79	9.99	0	127	1245	1965	1008	2568
17	D17	9.71	15.76	10.25	1840	405	876	1765	1200	3769
18	D18	12.35	10.41	7.01	0	146	654	876	1178	3457
19	D19	11.05	6.88	4.6	2260	568	9874	2900	1789	4897
20	D20	11.43	2.27	1.56	0	98	556	880	998	1110

Table 6. Statistical Parameters of the Dhoop Ash Samples

S.No	Parameters	F^-	Cl^-	SO_4^{2-}	NH_4^+	Na^+	K^+	pH	EC	TDS
1	Mean	731	229	3925	2174	1369	3613	11.196	11	7.273
2	Minimum	0	98	556	876	998	1110	8.6	2.27	1.56
3	Maximum	2986	568	10500	6540	2125	4975	12.41	18.9	12.79
4	Std	1019	150	3651	1170	339	1246	1.076	4.95	3.301
5	Conf Limit	446.7	65.751	1600	512.665	148.402	546	0.472	2.16	1.447
6	Mean conc	731±446.7	229± 65.75	3925± 1600	2174± 512.6	1369± 148.4	3613±546	11.196±0.472	11± 2.16	7.27± 1.447

Table 7. Correlation matrix of various parameters

	pH	EC	TDS	F^-	Cl^-	SO_4^{2-}	NH_4^+	Na^+	K^+
pH	1								
EC	-0.121	1							
TDS	-0.140	0.994	1						
F^-	-0.246	0.363	0.357	1					
Cl^-	-0.150	0.095	0.092	0.816	1				
SO_4^{2-}	-0.139	-0.037	-0.011	0.340	0.325	1			
NH_4^+	0.196	0.133	0.066	0.104	0.181	0.010	1		
Na^+	0.193	0.132	0.134	0.750	0.726	0.398	0.203	1	
K^+	-0.271	0.375	0.391	0.614	0.526	0.461	-0.117	0.606	1

6. Conclusion

According to the study, smoking dhoop, incense, and mosquito coils indoors release noticeably more respirable particulates (PM), which may accumulate over time. Better ventilation in homes is required to prevent PM buildup. Living in such a higher particle concentration could therefore have detrimental effects on respiratory health.

A quick analysis focused on three of the main indoor air contaminants. These are all combustion products (CO, PM, and CO2 from human metabolism). Clinically serious side effects are probably infrequent at indoor levels. However, it's critical to maintain awareness of the possible issue to prevent situations when routine indoor concentrations might exceed harmful levels. Burning dhoop is harmful to human health.

Authors' Contribution

Both authors discussed and planned the reviews, interpretations, and conclusions. The first author (Dr. Shobhana Ramteke) wrote the first draft of the manuscript and critically reviewed the whole manuscript for further valuable intellectual content. The second author (Dr. Bharat Lal Sahu) collected all the information and wrote and edited the entire manuscript. Meanwhile, both authors read and agreed to the published version of the manuscript.

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