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Characterization of Indoor Particulate by Burning of Incense and Mosquito Coil

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***Abstract*: India is a religious country and almost people use incense for worshipping the God. The study area has a high temperature that is suitable for mosquito breeding; therefore, they use mosquito coil frequently in indoors to repel the mosquitoes. The incense and mosquito coil emission are known to be an important factor contributing to the indoor particulate (PM) like cooking activities. Thus, the PM and associated eight ionic species i.e. Cl^-, NO_3^-, SO_4^{2-}, NH_4^+, Na^+, K^+, Mg^{2+} and Ca^{2+} emitted during burning of incense (i.e. incense sticks, dhoop, lobhan powder and camphor) and mosquito coil in indoor environments in central India, Raipur, Chhattisgarh is investigated. A Partisol Model 2300 sequential speciation air sampler (Thermo Fisher Scientific, USA, 10 L min-1) was used for collection of PM_{10} and the ion chromatograph (DX120, Dionex, USA) was used for analysis of the ions. The higher PM_{10} concentration was found with stick incense whereas, the mosquito coil was observed to be acidic in nature due to emission of high concentration of ions, indicate need of solution to reduce health risks from the harmful emitted particulate in indoors**

***Keywords:* Indoor air, particulate, ions, incense, mosquito coil**

I. Introduction

The incense materials are used for worship as well as to fragrance the environments in the Asia for centuries [1]. The incense sticks are made by the blending of woods, resins, fragrant gums, herbs and spices into a paste and then, rolled the paste onto a bamboo stick. The stick incense is a most popular in India. Other incenses (i.e. Dhoop, Kapoor, Lobhan, etc.) have very concentrated scents and contain a high percentage of Sandal wood. Kapoor is also known as camphor**,** a waxy, white or transparent solid with a strong, aromatic odor give a lot of smoke when burnt [2]. When incense is burnt, it emits smoke containing particulate (PM), PAHs, carbon monoxide, isoprene etc. Incense smoke particulate was found to be mutagens in the Ames Salmonella test [3].

The mosquito coils are fumed to repel mosquito in Asia and to limited extent in other parts of the world, including the United States. The mosquito coils are made by biomass base materials containing some insecticides most likely pyrethrins; d-allethrin, accounting for 0.3 – 0.4% of coil mass [4]. The incense and mosquito coil smoke exposure results many health problems i.e. genetic toxicity, lung cancer, respiratory dysfunction or asthma, coughing, headache, dizziness, nausea and allergic to the skin and eyes, etc. [5,6]. The increased levels of PM generated during burning of incense and mosquito coils in the indoor environments was investigated by different authors [7-11].

Chhattisgarh is a state of central India. It is the 16th most-populated state of the India. Due to tropical climate, almost similar type of indoor environments is allocated all over the India. Therefore, Raipur city, Chhattisgarh, India is selected for the present work. In best of my knowledge, the indoor PM during burning of incense (i.e. incense sticks, dhoop, lobhan powder and camphor) and mosquito coil materials in central India, Raipur, Chhattisgarh is reporting first time. This study may be useful to evaluate future harmful impact from burning of these materials and also to find out solution against to use this.

II. Experimental

MATERIALS

India is a religious country and they use different types of incense i.e. incense stick, dhoop (log), camphor, lobhan powder to worship the God as well as to fragrance the indoor environments. Incense paste is rolled around a bamboo stick, is one of the main forms of incense in India. Mosquito coil is widely used in India because they have mosquito problem due to high temperature increasing the breeding of mosquitoes. Biomass is a base material of these two products i.e. incense and mosquito coil and rest part of material is an organic and inorganic ingredients.

COLLECTION OF PM

The indoor environments (a standard room (3x2x3 m^3) equipped with one door and one window (1x1 m^2)) i.e. bedroom for incense and mosquito coil burning was selected for collection of particulate PM_{10}. A Partisol Model 2300 sequential speciation air sampler (Thermo Fisher Scientific, USA, 10 L min-1) was used for collection of PM_{10} on 47-mm quartz fiber filters (Whatmann, QMA) housed in molded filter cassettes, in the indoor environments for the duration of 1 hrs. The air sampler was installed at the ground level and operated at flow rates of 10 l min^{-1}. Always at least one blank filter was used to correct for the background values. The filters were heated to 600˚C for 6 hrs prior to exposure for reducing the carbon blank values. The filters were weighted by using the Mettler Toledo balance type - AG245 and placed in the sampler and run for the duration of the burning process. The loaded filters were heated up to 50˚C for 6 hrs to remove the moisture contents. The filters were transferred into the desiccators, and finally weighted to measure the particulate mass load. The mass distribution of the particulate in the air was calculated by dividing the aerosol mass with volume of the air passed.

ANALYSIS OF IONS

The PM content was extracted with 15 ml of de-ionized water (0.054 µS cm^{-1}) with sonication for 15 min and heated at 60ºC for approximately ≈ 24 hrs. The extracts were filtered through 0.45 µm tracer filters and its 200 µl aliquot was injected. The ion chromatograph (DX120, Dionex, USA) equipped with anion separation column (AS9-HC, 250x4 mm), cation separation column (CS12A, 250x4 mm) and conductivity detector was used for analysis of the ions. The eluents, 9 mM Na_2CO_3 (1.4 ml min^{-1}) and 20 mM methane sulfonic (0.8 ml min^{-1}) wereused for leaching of the anion and cation, respectively. Standards (AR, E. Merck) were used for preparation of the calibration curves to evaluate the soluble ion content in the samples. The laboratory blank was used to assess possible contaminations.

EMISSION FLUX MEASUREMENT

The emission flux was measured for four types of stick incense and mosquito coil. The flux of PM_{10} were determined by burning the materials in a closed chamber (0.5x0.5x0.5 m^3) made up of wood equipped with the exhaust fan and UC Davis (USA) portable air sampler (Fig. 1). The sampler was mounted in the chamber. Two gram of each material was taken for the burning. The burning was carried out till the complete burning of the materials with simultaneous collection of the PM_{10} over the quartz filter paper (47 mm). Similarly, the sample blank (i.e. without collected on filter) was carried out for the correction. The PM_{10} mass was weighted out, and the flux was evaluated by dividing the PM_{10} mass with amount of the material burnt. The flux for the PM_{10} was calculated by using the following equation (1):

$$PM_{flux} = PM_m/W \quad (1)$$

Where, PM_m and W denote the mass of PM_{10} in the filter and amount of the materials for burning. The flux for the ions associated to the PM_{10} was calculated by using the following equation (2):

$$A_{flux} = PM_{flux} \times F \quad (2)$$

Where, A_{flux}= Fluxes of ion in the PM_{10}, F = Ionic fraction in the PM_{10}.

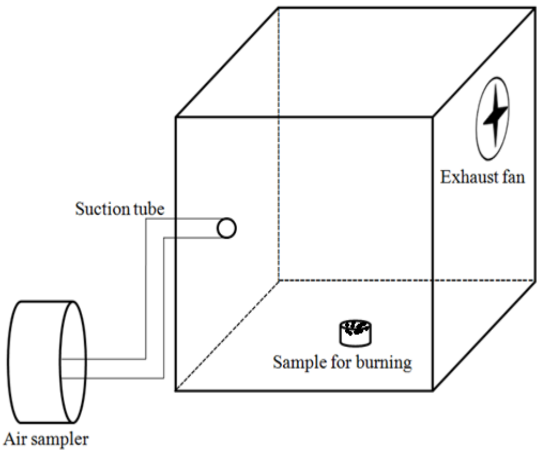

Fig. 1 A closed chamber (0.5x0.5x0.5 m^3) equipped with the exhaust fan and UC Davis (USA) portable air sampler.

III. RESULTS AND DISCUSSION

CONCENTRATION OF PM

The four different types of incense (sticks (n = 4), dhoop (n = 1), lobhan powder (n = 1) and camphor (n = 1)) and four mosquito coil (n = 4) are used for measuring PM concentration in indoor air is presented in Fig. 2. The PM_{10} concentration for stick incense (n = 7) was ranged from 3310 – 15939 µg m^{-3} with mean value of 10273±5106 µg m^{-3}. The concentration trend of PM for different four type of incense was i.e. dhoop (15767 µg m^{-3}) > stick incense (10273 µg m^{-3}) lobhan powder (3915 µg m^{-3}) > camphor (3207 µg m^{-3}). The highest PM concentration for dhoop was observed than the other incense materials. Jetter *et al.* [12] has investigated PM concentration for different incense (n = 23) in which the concentration trend for the same incense as this study, was found to be like dhoop > stick incense > powder and shows that the highest PM concentration with dhoop incense. The different study has measured the high PM concentration of incense materials and found the variations due to using different methods for burning, PM collection and also different ingredients used for making incense [1,13,14]. However, the concentration of PM_{10} for mosquito coil (n = 4) smoke was ranged from 988 – 1458 µg m^{-3} with mean value of 1144±209 µg m^{-3}. The highest PM concentration was found with the incense smoke than the mosquito coil. In particular, such emissions are observed to be important contributor similar to cooking activities which are claimed as the main indoor particle source [15,16]. The mean indoor PM_{10} concentration during burning in this study was also observed to be higher than the mean outdoor concentration of PM_{10} (270.5 µg m^{-3}) of the selected study area Raipur city, Chhattisgarh, India, shows indoor PM is most dangerous than the outdoor PM [17].

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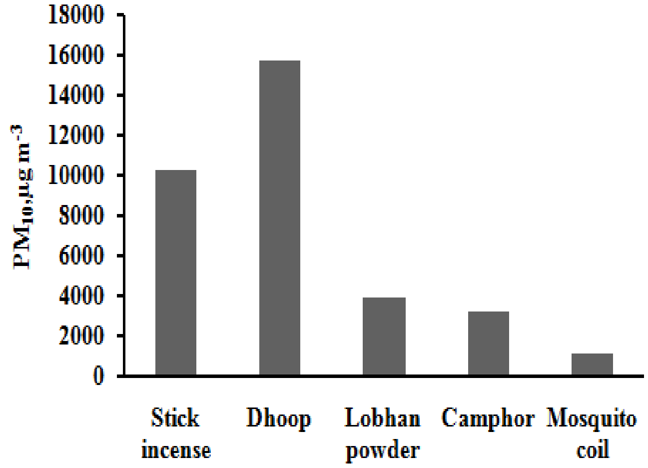

Fig. 2 Mean PM concentration in indoor air during burning of different incense materials.

CONCENTRATION OF IONS

The stick incense is more popular than the other incense in these study area and it burns daily for worshipping the Gods. Therefore, the PM_{10} samples of stick incense (n = 4) and mosquito coil (n = 4) were analyzed for the determination of eight ions i.e. Cl^-, NO_3^-, SO_4^{2-}, NH_4^+, Na^+, K^+, Mg^{2+} and Ca^{2+}, Table 1. The concentration of sum of eight ions, $\sum ion_8$ for the incense (n = 4) and mosquito coil (n = 4) was 127±66 and 263±94 µg m^{-3}, contributing 1.2% and 24.2% to the PM_{10}, respectively. In $\sum ion_8$, the highest anionic contribution was marked i.e. 16.0% and 24.0% for incense and mosquito coil, respectively. The cations were found to be 10.4% and 5.6% for incense and mosquito coil, respectively. The highest anionic and cationic contribution was observed with mosquito coil and incense, respectively. The different concentration trend of each ion for fuming materials observed was: $K^+ > Cl^- > Ca^{2+} > NO_3^- > SO_4^{2-} > Mg^{2+} > Na^+ > NH_4^+$ for incense; $SO_4^{2-} > Cl^- > K^+ > NO_3^- > Ca^{2+} > Na^+ > Mg^{2+} > NH_4^+$ for mosquito coil. Remarkably higher concentration of Cl^- and SO_4^{2-} with mosquito coil smoke was observed to be 69 µg m^{-3} and 87 µg m^{-3}, contributing 24.1% and 37.5% to the $\sum ion_8$, respectively. The mosquito coil was found to be 2-folds higher to the $\sum ion_8$ than the incense, may be due to addition of ingredients like sodium benzoate, potassium nitrate, etc. during making coils. Similarly, due to high concentration of anions Cl^- and SO_4^{2-}, mosquito coil smoke was observed to be acidic nature and indicating more harmful than the incense.

The Ion equilibrium calculations were measured to observe the acid-base equilibrium of ions particulate in the burning emissions [18]. Estimation of charge equilibrium between anions and cations was measured by converting the concentrations into ion microequivalents as following equation (3):

TABLE 1. Concentration of ions in PM_{10}in indoor air, µg m^{-3}

Sample type	Materials	Cl^-	NO_3^-	SO_4^{2-}	NH_4^+	Na^+	K^+	Mg^{2+}	Ca^{2+}
Incense (n = 4)	Mumtaj	26.6	7.9	25.0	0.3	4.4	52.4	18.2	69.7
	Krishna	44.5	23.9	8.7	0.7	5.7	40.1	1.0	7.2
	Lubhan	32.7	29.4	15.3	1.1	7.6	32.7	1.1	10.9
	Parivar 100	9.0	5.3	4.2	0.2	1.5	10.9	1.8	7.6
Mosquito coil (n = 4)	Hit	94	20	21	1	8	88	1	7
	Jet	33	29	175	2	22	15	2	24
	Mortein	13	13	96	2	6	4.5	1	6
	Tartoise	136	51	57	1	18	54	5	45

TABLE 2. Particulate equivalent concentrations of ions, µEq

Sample type	Cl^-	NO_3^-	SO_4^{2-}	NH_4^+	Na^+	K^+	Mg^{2+}	Ca^{2+}	∑anion	∑cation	∑anion/ ∑cation
Incense (n = 4)	0.75	0.13	0.52	0.02	0.19	2.28	1.52	3.49	1.40	7.50	0.19
	1.25	0.39	0.18	0.04	0.25	1.74	0.08	0.36	1.82	2.47	0.74
	0.92	0.47	0.32	0.06	0.33	1.42	0.09	0.55	1.71	2.45	0.70
	0.25	0.09	0.09	0.01	0.07	0.47	0.15	0.38	0.43	1.08	0.40
Mosquito coil (n = 4)	2.64	0.33	0.44	0.08	0.33	2.26	0.07	0.33	3.40	3.05	1.12
	0.93	0.47	3.65	0.08	0.96	0.38	0.19	1.20	5.05	2.81	1.80
	0.37	0.21	2.00	0.13	0.25	0.12	0.04	0.29	2.58	0.83	3.11
	3.83	0.83	1.19	0.05	0.76	1.37	0.42	2.25	5.85	4.84	1.21

$$\text{Anion micro equivalents} = Cl^-/35.5 + NO_3^-/62 + SO_4^{2-}/48$$

$$\text{Cation micro equivalents} = NH_4^+/18 + Na^+/23 + K^+/39 + Mg^{2+}/12 + Ca^{2+}/20 \qquad (3)$$

The particulate equivalent concentration ratio of the ∑anion to ∑cation in the incense and mosquito coil emissions was observed to be 0.51±0.25 and 1.81±0.90, respectively, Table 2. It means that an acidic particulate environment with the mosquito coil emission was observed, may be due to presence of Cl^- and SO_4^{2-} at the elevated levels. Generally, the houses of poor classes have no ventilation or sufficient exhaust systems and therefore, exposed with higher concentration of particulate. Our result suggests that reduce health risks from emitted particulate in indoor air have the potential to improve indoor air quality and health, and also need of solution against to use this.

EMISSION FLUX OF PM AND IONS

The PM_{10} emission fluxes for the stick incense and mosquito coil materials during the combustion were ranged from 2.42 – 10.77 and 31.87 – 36.93 mg g^{-1} with mean value of 6.94±3.25 and 5.61± 0.38 mg g^{-1}, respectively. The higher emission fluxes were observed with the MC burning may be due to burning in smoldering fire and presence of different ingredients [5]. However, the emission flux of $\sum ion_8$ for the incense and mosquito coil (n = 4) is presented in Fig. 3. The $\sum ion_8$ emission flux for incense and mosquito coil materials was ranged from 0.30 – 1.39 and 7.26 – 21.46 mg g^{-1} with mean value of 0.86±0.48 and 13.18±5.89 mg g^{-1}, respectively. The several folds higher flux of ions was observed with the mosquito coil than the incense, may be due to addition of the ingredients i.e. starch, oils, sodium benzoate, potassium nitrate, etc. during making the coil.

IV. CONCLUSION

The concentration of PM for incense was found to be greater than the mosquito coil. The incense and factor contributing to the indoor PM like cooking activities. The mosquito coil emission was observed to be more acidic and harmful than the incense burning, may be due to presence of Cl^- and SO_4^{2-} at the elevated levels. Generally, the houses of poor classes have no ventilation or sufficient exhaust systems and therefore, exposed with higher concentration of particulate. Our result suggests that reduce health risks from emitted particulate in indoor air have the potential to improve both indoor air quality and health, and shows need of solution against to use this.

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