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Study on Indoor Air Pollutants: Toxicity Screening of Suspended Particulate Matter

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Biomass fuel such as wood which is the intrinsic source of sulphur and other trace metals, still remains a major source of domestic energy for the urban poor and rural populations in the developing countries. (Dary et al.1981, Hex 1986, Aggarwal et al. 1982). It is one of the major sources of indoor air pollutants (Behera, 1995), the others being building material, the ground under the building and the biological agents. It is also reported that half of the world's households cook their food on the unprocessed solid fuels that release at least 50 liters or more air pollutants than the cooking gas (Cooke et al 1982) when they are used in chulas (native stoves) for cooking because the fuels are incompletely burned. Due to this incomplete combustion of biomass, carbon monoxide, hydrocarbons, suspended particulate matter (SPM) etc. are produced. When this polluted air is inhaled, there is obviously an impact on the health, causing respiratory morbidity like cough, expectoration, dyspnoea, abnormal lung function, etc. Thus it serves as one of the potential health risk factor, especially among housewives and growing children (Smith 1987). To minimise such exposure risk as well as to have better energy efficiency, improved 'chulhas' were introduced. This study was aimed at to assess the impact of improved chulhas on indoor air quality in comparison to traditional chulhas. While SO_2, NOx and HCHO were measured chemically, toxicity of SPM was determined in bacterial tests systems (Ghosh et al. 1997) using three microbial test systems namely Microtox™ (Bulich and Isenberg, 1980), the Motility test (Dutka, 1980) and the Growth zone inhibition test (Liu et al. 1989).

MATERIALS AND METHODS

The indoor air pollutants were the by-products of burning of fuel woods like neem, babul and mango in modified stoves. The resultant pollutants were collected in air samples using high volume samplers and analysed for SO_2, NO_x, and HCHO using the standard recommended methods.

The resultant particulate matters were collected in the filter mat using high volume samplers. The residue alongwith the filter was extracted with 5 ml dichloromethane (DCM). DCM was subsequently evaporated to dryness in a vaccum evaporator and the residue was redissolved in 5 ml dimethyl sulphoxide

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(DMSO). This residue dissolved in 80% DMSO was tested in bacterial screening system. Control samples comprised of only filter mat were processed in the same way.

The experiment was carried out with a Microtox™ Model 2055 Toxicity Analyzer System (Beckman Inc. Carlsbad, USA). This system is based on monitoring changes in natural light emission of the luminescent bacteria, *Photobacterium phosphoreum* when challenged to a toxic compound. The toxicity end point is determined as the effective concentration of a test sample that causes 50% decrease in light output (EC_{20}).

Details of the test system are described elsewhere (Bulich and Isenberg 1980, Ghosh and Doctor 1982). Results were expressed in terms of gamma Υ i.e. the ratio of light lost during the test time (t) to the light remaining at the time (t).

In the motility test system, toxicity is determined in terms of minimum effective concentration that causes a loss of 90% motility (MEC_{90}) of *Spirillum volutans* during the test period. A strain of *S.volutans* (ATCC 19554) obtained from Dr. B.J. Dutka, Canada Centre for Inland Waters, Canada was used for all bioassays. The standard method test as described by Dutka (1980) was followed. Slides were prepared at 0, 5, 15, 30, 60, 90 and 120 min intervals and were observed under the dark field microscope (125X) to assess the motility of the organism.

In this method, the growth of the test organism, *Bacillus cereus* is monitored after exposure to a toxicant (Liu et al 1989). A locally isolated strain of *B.cereus* was used in this investigation. Three subcultures in modified nutrient broth at 20°C were done before performing the toxicity screening. Plates were seeded with the organism and both the experimental and control (dissolved in glycerol and DMSO (20:80) were spotted onto the seeded agar (10 µl/spot). After 18 hr of incubation at 37°C, the zone of inhibition was measured. The minimum concentration that inhibited growth was regarded as toxic.

RESULTS AND DISCUSSION

Table 1 shows the ambient air quality levels (AQL) of SO_2, NO_x and HCHO as reported by Central Pollution Control Board. Concentrations of indoor air pollutants such as SO_2, NO_x and HCHO as observed during combustion of biomass are given in Table-2.The variables were subjected to log transformations and ANOVA (Tukey) were used to compare the improved chulas with traditional chulas. In case of improved chulas, the concentrations of SO_2 were significantly less compared to the traditional chulas. Similarly, HCHO concentrations also showed the same trend – significantly less in the improved chulas compared to traditional chulas. However, NOx concentration although was less compared to the traditional chulas, but the values were not significantly less except in one case (Improved chula type A) where it was significantly less ($P<0.05$).

Table 1 Ambient air quality levels of SO_2, NO_x, HCHO and SPM

Pollutants	Concentration ($\mu g/m^3$)
SO_2	80
NO_x	100
HCHO	100
SPM	200

Table 2 Indoor air pollutants generated during combustion of fuel wood in traditional and improved chulas (Mean ± S.D.)

Type of chulas	Indoor air pollutants ($\mu g/m^3$)		
	SO_2	NO_x	HCHO
Traditional	457.60 ± 1.43	118.40 ± 1.42	448.90 ± 2.28
Improved A	56.80 ± 3.13**	72.40 ± 1.86**	71.60 ± 1.22*
B	79.70 ± 2.33**	80.90 ± 2.35	122.20 ± 1.75*
C	86.20 ± 1.85**	78.20 ± 1.68	61.70 ± 1.87**
D	89.60 ±1.92**	81.90 ± 1.32	96.60 ± 1.95**

- $P < 0.05$
- ** $P < 0.001$

The results of toxicity screening using bacterial test systems against the extracts of collected particulates matters are described in Table 3. Table 3 shows the concentration required to produce clear zone on seeded agar with *B. cereus*. This table also shows the concentration required to produce halo. The diamter of halo

Table 3 Toxicity screening of indoor air pollutants (SPM) generated during combustion of fuel wood in traditional and improved chulas using growth zone inhibition test ($T_{28°C}$ t_{18h})

Type of chulas	Mean concentration required to produce clear zone ($\mu g/g$)	Mean diameter of clear zone (mm)	Final concentration (mg/L)
Control (filter mat)	Nil	Nil	Nil
Traditional	5	10	45.00
Improved A	10	6.4	100.00
B	25	5.8	50.00
C	20	10.5	100.00
D	50	10.2	50.00

(in mm) was found to be variable with concentration of the pollutants applied in each spot (5,10,20, 25 and 50 µg/spot). Final concentration (mg/L) to produce growth zone inhibition was found to be 100 (type A and C) and 50 (Type B and D) and 45 in the case of traditional chulas. In Table-4 results of toxicity screening of three test system are given. The EC_{50} values of the SPM extracts as determined by Microtox™ using *P.phosphoreum was less* (43.5 mg/L) compared to the other two test systems. Toxicity end point of the motility system employing *Spirillum volutans* as the test organism (i.e. MEC_{90}) was 67.0 mg/L whereas 75.0 mg/L was required to produce halo in growth zone inhibition test.

Table 4 Toxicity screening of indoor air pollutants (SPM) generated during combustion of fuel wood in traditional and improved chulas using three microbial systems.

System	Sensor organism	Optimum conditions	Toxicity endpoint	Concentration	
				Traditional Chula	Improved Chula
Microtox ™	*Photobacterium Phosphoreum*	$T_{15°C}$ t_{15min}	EC_{50}	29.50	43.50
Motility test	*Spirillum volutans*	$T_{28°C}$ t_{60} min	MEC_{90}	40.50	67.00
Growth zone Inhibition test (Agar plate method)	*Bacillus cerreus*	$T_{28°C}$ t_{18h}	Halo	45.00	75.00

The emisssion of air pollutants (SO_2, HCHO and NOx) was significantly reduced in improved chulas in comparison to traditional chulas. On an average there was 70% reduction in SO_2, 85% in HCHO and 15% in NOx except in one (Type-A) where 30% No_x reduction was recorded. It is reported that the total organic emissions are temperature dependent (Corke et al 1982). The emission seems to reach the highest peak at about 600°C and decrease above 900°C and below 300°C. This indicates that at temperature between 300°C and 900°C THC (total hydrocabon) emission could be of high magnitude. On the contracy, PAH (polycyclic aromatic hydrocarbon) emission seems to be low at this range of temperature. When the temperature is high the emission factor is low. This is applicable to all pollutants emitted due to biomass combustion except NOx. As the temperature reach 16500°C NOx emission can rise significantly. But such high temperatures are seldon reached in hand fire units.

Toxicity screening carried out in bacterial test system reveals that the SPM collected on the filter mat was less toxic in case of improved chulas compared to the traditional chulas. This might be due to accumulation of more AH in case of traditional chulas.

All the tests employed in this investigation fulfilled their required criteria of rapid toxicity screening. They are not only simple, but also reproducible and inexpensive. Microtox™ appeared as the most sensitive test in compared to other two tests. Although growth zone inhibition test is simple, but it is less sensitive than the Microtox™. It is generally, believed that the determination of the toxic response to a sample by any single organism can not completely predict the response of the other organism to the same sample as observed in the present investigation. Therefore, a battery of short-term tests should be employed for a more comprehensive and meaningful toxicity assessment. Hence in the present study three such test system have been employed.

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