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Heavy metal content of airborne particles in indoor air: Combustion of biomass in rural sites

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ABSTRACT

Monitoring and chemical analysis of airborne particles in the smoke of dried cow dung (biomass) is very important for the health of human. The cow dung biomass is used as energy source in several rural areas of Turkey and other countries in world. In this regards, this study is focused on the quantitative and qualitative chemical analysis of indoor airborne particles distributed by combustion of this biomass were made. Mass concentration and heavy metal content of airborne particles in filter samples were determined by using Scanning Electron Microscope and Atomic Absorption Spectrometer analysis methods. The mean concentrations of Pb, Cu, Mn, Sn, Zn, Al, Bi, Ni, Cd, Hg, Fe, Cr, Co, Ag, As are ranged from 0.95±0.25 to 1.85±0.66, from 1.44±0.39 to 3.04±0.54, from 0.32±0.005 to 0.85±0.006, from 0.03±0.002 to 0.28±0.006, from 23.25±7.54 to 44.06±9.12, from 11.20±2.22 to 20.04±2.05, from 0.05±0.001 to 0.18±0.02, from 2.69±0.86 to 6.44±2.99, from 0.03±0.002 to 0.06±0.009, from 19.16±2.86 to 56.26±14.36, from 0.06±0.004 to 0.15±0.02, from 0.11±0.03 to 1.17±0.05, from 0.10±0.05 to 0.27±0.07, from 0.80±0.06 to 3.58±0.60, and from 1,48±0.093 to 5.23±0.91 μg/m^3 respectively. These results showed that the heavy metal concentrations of the indoor airborne particles were higher than the limited values guidelines by World Health Organization.

KEYWORDS

Biomass;
Indoor air;
Heavy metals;
Indoor PM mass;
Air pollution.

INTRODUCTION

Approximately half of the world use biomass (dried cow dung) fuels for cooking and heating at home. Biomass fuels refer to burned plant or animal material; wood, charcoal, dung and crop residues. These sources account for more than half of the domestic energy in most developing countries and can account for as much as 95% in lower income countries[19]. Around 2.4 billion people rely on biomass fuels as their main source of domestic energy for cooking, heating and lighting[2,19] and a further 0.6 billion people use coal. Dried animal dung is cheap but an inefficient material that greatly pollutes the environment[8]. The adverse health effects of indoor air particulates are often exacerbated by lack of ventilation in homes using biomass fuels and by the poorly-designed stoves in these living areas. The combustion efficiency of biomass fuels is also very low, thus it yields relatively high levels of incomplete combustion products, which are more harmful to human health. In-

door air pollution is critical also because people are always in close proximity to the sources and people spend a great fraction of their time indoor. Furthermore, suspended particles in particular have received much interest due to epidemiological and experimental evidence displaying a negative health impact. Both mass and concentration of particulate matter (PM) have shown a correlation between acute health effects and measurable functional changes in the cardiovascular and respiratory system[4]. According to another study performed in Turkey, Gani and collaborate investigated to effect on lipid peroxidation and antioxidant activity of exposed to biomass. They observed to increase of lipid peroxidation and decrease of antioxidant activity as a result of exposed to biomass[14].

Indoor air pollution concentrations depend on a large number of factors such as indoor sources and the emission rates, the penetration of outdoor pollutants into the indoor environment, and the pollutant sink or removal rate on indoor surfaces.

Studies indicate that there are more than 30 cancerous materials in the polluted indoor air[1,3,5,21,27]. Most these are heavy metals (Pb, Cu, Mn, Sn, Zn, Al, Bi, Ni, Cd, Hg, Fe, Cr, Co, Ag, As etc.), carbon monoxide, asbestos, polycyclic aromatic hydrocarbons and their derivatives, oxygenated organics, free radicals and radioactive materials (such as Rn e.t.c),, which adhere to the indoor airborne particles[16,27]. Therefore, it is very important to identify the sources of indoor airborne particles.

Given that so many households cook indoors with biomass fuels under open combustion conditions and that such combustion leads to relatively large air emissions, it would seem possible that the resulting indoor concentrations would be significant. Indeed, simple equilibrium calculations using assumptions about the room (volume and ventilation) and fuel (burning rate and emission factor) indicate that potential indoor concentrations of particulates could be several tens of milligrams per cubic meter (mg/m^3) during the cooking time[20]. This is two orders of magnitude greater than the limit the World Health Organization recommends for 24 hour public exposures (0.10 – 0.15 mg/m^3). Further, the Japanese 1 h standard of 0.20 mg/m^3, and new Indian annual standard of 0.20 mg/m^3 for residential areas are also violated[28]. It is noted that if these calculations are accurate, a village woman cooking for 3 h per day would inhale the equivalent of what she would receive by smoking ten or more packs of cigarettes per day[18].

The biomass combustion at a small scale can be emitted to near environment the particulates with heavy metal content at significant concentration due to the lack of ventilation and poorly designed stoves in living areas. For this aim, the objectives of the present study are to measure mass and number concentrations of indoor particles in different households in rural areas, and determine their heavy metal concentration by using Atomic Absorption Spectrometer analysis technique.

EXPERIMENTALS

Sampling sites

To investigate the indoor air quality in several rural areas of Turkey, sampling was carried out during biomass burning from November 2007 until February 2008. Sites were selected depending on the household and fuel used. Air samples were collected from twenty two rural site households. The type of biomass used in these areas varies due to different agricultural patterns. For example, inhabitants that utilize cattle tend to use dried animal excrement as a fuel. The majority of houses in rural village areas are made of mud, stone and brick. The ventilation of these houses is through windows or doors and a detailed description of the houses is shown in TABLE 1.

Sampling procedures

The particle samples were collected filtering approximately 5.00 cubic meters of air onto 47 mm diameter and 0.45 μm pore size: Millipore SA 67120 Molshem, France, mixed cellulose acetate and nitrate filters using a high volume Air Sampler was developed and used previously in laboratory[26]. Sampling system shown in Figure 1 is equipped with a plastic stamp to avoid metal contamination, and have a flow rate of 12 liter per minute.

Sample preparation

The samples for the analysis of heavy metals were extracted into acid solutions using a hot plate in the following sequence. Filter samples were placed in a Teflon container and treated initially by concentrated acid solutions (3 mL HNO_3, 1 mL H_2SO_4, 1 mL H_2O_2)

(suprapur, Merck), evaporated to dryness, heated again at 60 °C, treated with 1 mL concentrated H_2SO_4 (suprapur, Merck), 1 mL HNO_3 and 1 ml H_2O_2 (suprapur, Merck), and then diluted with double deionized water (Milli-Q Millipore 18.2 MΩ cm^{-1} resistivity) up to a volume of 10 ml. Blank filters were also treated in the same manner with sample filters to check the heavy metal impurities[13].

TABLE 1 : General description of sampling sites.

Site	Area	Sampling space	Height (Meter)	Room Area(m^2)	Ventilation, condition	Fuel used/activity
1	Rural, residential, lost of greenery, low traffic, large number of livestock in most houses	Living room	3	12	Window opening (one), close	Dung/normal household activites, smoking.
2	Rural, residential, mud building, low traffic,	Hall living room	2.5	20	Window opening (close) and door (close)	Dung and crop residues
3	Urban, no greenery, low traffic.	Living room	2.8	15	Door (open)	Dung and crop residues./ coocing.
4	Urban, near road, midle traffic	Grocery	3.5	30	Door (open)	crop residues
5	Rural, residential, mud building,	kitchen	2.5	9	Window opening (close) and door (open)	Dung and crop residues / coocing
6	Rural, residential,	Coffee house	3	48	Window opening (two) (open) and door (open)	Dung/ smoking.
7	Rural, residential, mud building,	Living room	2.8	13	Window opening (close) and door (close)	Dung/normal household activites,
8	Rural, residential, mud building, large number of livestock in most houses	Hall living room	2.5	15	Door (three) (close)	Dung/normal household activites,
9	Urban, residential, close to road,	Grocery	3	25	Door (open)	Dung and crop residues
10	Rural, residential, mud building,	Willage mosque	11	220	Window opening(four) (close) and door (two) (open)	Dung and crop residues
11	Rural, residential, mud building, large number of livestock in most houses	coffee house	4	35	Door (open)	Dung/ smoking.
12	Rural, residential, mud building,	kitchen	2.8	14	Door (open)	Dung
13	Rural, residential, lots of greenery	Willage mosque	7	180	Window opening (close) (two) and door (open)	Dung and crop residues
14	Rural, residential,	Living room	2.5	20	Window opening (close)	Dung / coocing
15	Rural, residential, mud building,	kitchen	2.5	14	Door (close)	Dung / coocing
16	Rural, residential,	coffee house	3	40	Window opening (close) and door (open)	Dung/ smoking.
17	Rural, residential,	Living room	2.8	22	Window opening (open) and door (open)	Dung/ smoking.
18	Rural, residential, mud building,	Willage mosque	6.5	140	Window opening (close)(two) and door (open)	crop residues
19	Rural, residential, mud building,	coffee house	3	40	Door (open)	Dung/ smoking.
20	Rural, residential,	Hall living room	3	20	Door (three) (close)	Dung / coocing
21	Rural, residential, close to road, large number of livestock in most houses	kitchen	2.8	20	Door (close)	Dung / coocing
22	Rural, residential, mud building,	coffee house	3	50	Window opening (open) and door (open)	Dung/ smoking.

Instrumentation

Sampling operations were conducted in each month of the biomass burning period (3 times total). During the remaining biomass burning period, sampling operation was performed twice. The sampling operation was performed in day time and lasted for about 7 hours each time. The indoor medium temperature during sampling was between 18-21°C.

Health risk values of particle sizes have been defined by the International Standards Organization (ISO), in ISO 7708 (ISO, 1995). Particle sizes are based on the behavior of particles in the human respiratory tract, and are derived from the depth of entrance into it. Human health-related sizes according to these conventions are classified as: inhalable (particles which can be inhaled through the nose and mouth), thoracic (particles inhaled which can penetrate into the larynx), and respirable (particles which can go beyond the larynx and penetrate into the unciliated respiratory system) (EN, 1993).

Solair 1001+ model airborne particle counter was used to measure the particle number concentration. The Solair 1001+ airborne particle counter offers a sensitivity of 0.1 micron with a flow rate of 0.01 CFM (0.283

LPM) and a wide range of up to 20.0 microns.

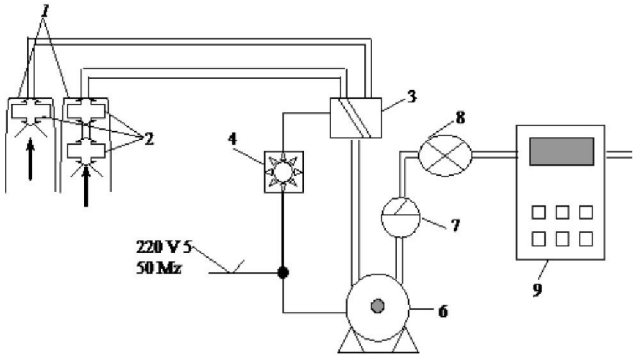

Figure 1 : Sampling system 1)Funnel, 2)Filter place, 3)Conversion valve, 4)Timer, 5)Power Switch, 6)Pump, 7)Pressure measure, 8)Air flow control valve, 9)Air volume measure.

Weighing was carried out with an electronic microbalance with 0.0001 mg resolution. For the heavy metals analyses, a Perkin–Elmer Analyst 700 Atomic Absorption Spectrometer (AAS) was used. Pb and Cd levels in the filter samples were determined by a HGA graphite furnace, using argon as an inert gas. The mass concentrations of Hg, As and Ag in the samples were analyzed using the Perkin–Elmer Optima 2100 DV model ICP (Inductive Coupled Plasma) and hydride system. Determinations of other heavy metal contents were carried out in an air/acetylene flame. Treatment response was assessed according to World Health Organization criteria[29]. Experimental data is given as mean values of at least three measurements of each sample collected.

Particulate matter is not a single pollutant, but a mixture of many types of pollutants. The term PM can be defined as a complex mixture of suspended particles with different physical, chemical and biological characteristics, which determine both its behavior, as well as its environmental and health effects. The heterogeneous characteristic of PM includes particles of different nature, shape, size, density and chemical composition. The microstructure of the samples and the PM mass concentrations was detected using a Scanning Electron Microscope (SEM a Philips 30XL SFEG, Netherland).

RESULTS AND DISCUSSION

Mass concentration

The mass variations of particulates calculated are shown in the Figure 2. PM total mass concentration values ranged between 255.0 ± 23.43 μg/m^3 and 316.7 ± 14.47 μg/m^3 inside the house where biomass was used as an energy source (Figure 2). At sampling sites, there was variation in the mass of PM. This change in variation was principally governed by the activities of inhabitants along with factors such as biomass combustion. For all sampling sites, when biomass combustion was in progress, the mass concentration rose sharply and peak concentrations of 2220 - 3870 μg/m^3 were observed (Figure 2(a,b,c,d)). A study conducted in rural Lahore, Pakistan by Colbeck et al.[16] on exposure from cooking with solid biomass revealed that PM_{10} ranged from 500 – 18,900 μg/m^3 during a cooking period. This variation was primarily due to the contribution from biomass smoke indoors. These findings are in agreement with Park and Lee[12], who reported the particle exposure and size distribution from wood burning stoves in Costa Rica. They pointed out that particulate levels increased rapidly during cooking and decreased quickly after cooking. Concentrations of PM in air particulate samples of the study area were found higher than that of the WHO[30] standards. PM concentrations were also found variable across the different sampling areas.

The largest PM concentrations were observed at site 19, site 16, site 11 and site 6, where biomass burning was used heavily and people smoked and no ventilation was in action. The lowest PM concentrations were noticed in site 10, site 17, site 5 and site 22 of which ventilation was sufficiently provided through windows and doors.

It is known that indoor PM levels are influenced by indoor particle generation and by infiltration of outdoor air. Particle generation indoors can be caused by specific sources by human activities such as biomass combustion and environmental tobacco smoke[9]. It has been shown that in indoor micro-environments where there is no specific indoor source of pollution (e.g. smoking or combustion processes), people's activities may represent an important source of suspended particles[23,25]. Even the very presence of people in an indoor microenvironment may cause elevated PM concentration levels. Thus, the high indoor PM concentrations presented in the present work may be attributed to the suspension and generation of particles by the combustion of biomass inside the houses.

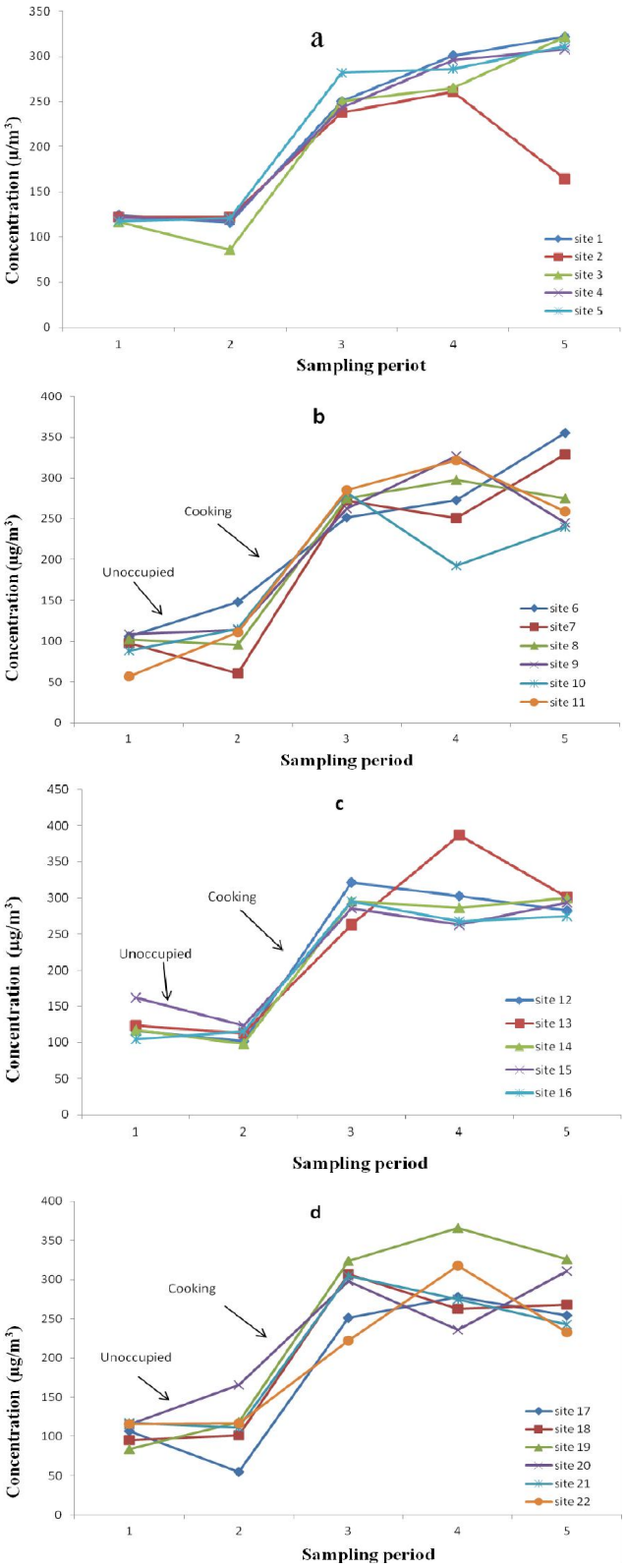

Figure 2 (a,b,c,d) : Mass concentration variations of PM from sampling sites (µg/m³).

Number concentration

The exchange of number concentrations for filter samples is shown in Figure 3. Indoor number concentrations in sampling sites were greater than those observed in literature[5]. The particle size of the pollutant was variable and thus the concentration values showed total dust. The number concentration values ranged between 22, 862 ± 944 of particles per cubic centimeter and 84,720 ± 868 of particles per cubic centimeter. The highest indoor particle concentrations was observed at site 9 (59,615 ± 2017 of particles per cubic centimeter) and the minimum indoor particle concentration was measured at site 7 (23,705 ± 2271 of particles per cubic centimeter). The concentrations of microscopic particles were significant, especially when compared to results found in other international studies. Ian and colleagues (2008) measured indoor air quality at rural and urban sites in Pakistan. The $PM_{2.5}$ and PM_{10} maximum and minimum concentrations were found to be between 310 and 8,170 µg/m³, and between 500 and 18,900 µg/m³, respectively. They also measured the indoor number concentration values between 6,624 and 53,053 of particles per cubic centimeter.

Chemical analysis

The heavy metal concentrations in the obtained filters are evaluated and the results from the chemical analysis of half of the filters collected at the twenty-two sites are presented in TABLE 2. Indoors, heavy metal concentrations which were obtained in emitted particulates from combustion of biomass were generally higher than the WHO standards[30]. The levels of Pb in the filter samples ranged from 0.95 ± 0.25 to 1.85 ± 0.66 µg/m³, and the highest Pb levels were obtained for site 2 and site 15 (TABLE 2). As annual average Pb limit concentrations in PM was suggested as 0.2 – 0.5 µg/m³ by WHO. High lead concentrations in PM in every sampling site may be significant for human health as lead particles are known to be highly toxic[29].

The proposed values for Pb are based on the concentration of Pb in the blood. The upper critical value of Pb is 54.00 µg/L in the blood. A Low value of Pb in the blood is also dangerous. WHO was suggested a 0.50 µg/m³ limit value for Pb in air. Department of Environment and Conservation suggest 0.05 µg/m³ per day as an annual average and 2.00 µg/m³ as a daily average in the air. In this study, Pb concentration in biomass combustion smoke was found higher than these suggested values.

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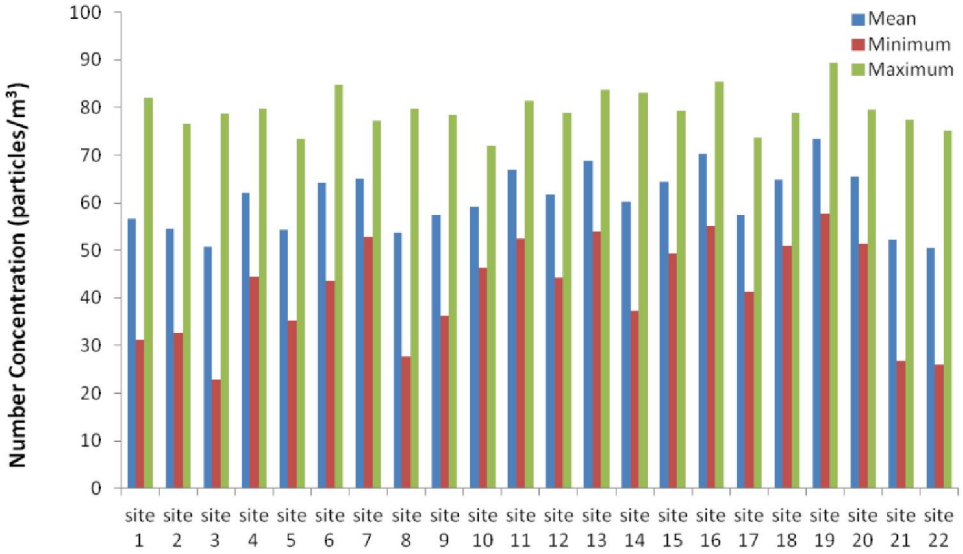

Figure 3 : Number concentrations of particles.

TABLE 2 : Heavy metal concentrations in filter samples analyzed.

Site	Pb	Cu	Mn	Sn	Zn	Al	Bi	Ni	Cd	Fe	Cr	Co	Ag	Hg(x10^{-3})	As(x10^{-2})
1	1.39±0.22	2.57±0.92	0.59±0.005	0.03±0.002	36.64±10.06	14.24±7.77	0.07±0.001	2.74±1.08	-	29.98±11.14	0.08±0.004	0.27±0.04	0.19±0.04	1.48±0.95	2.90±3.00
2	1.85±0.66	1.95±0.59	0.36±0.004	0.03±0.002	36.31±3.83	13.12±2.89	0.05±0.002	6.44±2.99	-	28.74±12.75	0.14±0.08	0.43±0.06	0.13±0.05	2.37±0.45	2.89±1.21
3	1.42±0.24	2.33±1.31	0.41±0.007	-	38.60±2.98	11.13±5.88	0.05±0.001	4.25±1.83	-	34.40±14.60	0.11±0.009	0.29±0.04	0.15±0.07	2.43±1.48	2.02±0.52
4	1.27±0.22	3.04±0.54	-	-	34.89±15.70	12.17±4.00	0.06±0.002	3.85±0.81	0.06±0.009	21.70±10.03	0.15±0.02	-	0.27±0.07	2.18±0.89	3.79±2.21
5	0.96±0.41	1.56±0.38	-	-	32.34±4.40	15.81±8.59	-	3.97±1.98	-	26.63±15.97	0.11±0.02	0.43±0.01	0.21±0.004	3.55±3.09	1.62±2.25
6	1.48±0.35	2.67±0.16	0.32±0.005	0.06±0.001	40.93±6.72	13.95±4.58	0.08±0.006	4.65±1.89	-	31.24±3.79	-	0.44±0.04	-	1.37±0.73	3.07±3.38
7	1.65±0.23	2.60±1.00	0.39±0.009	0.08±0.001	35.94±5.44	13.54±4.43	0.18±0.02	2.77±0.95	0.05±0.005	28.12±5.43	-	0.48±0.06	-	3.12±0.23	1.73±1.62
8	-	2.49±0.58	0.45±0.007	0.04±0.002	29.13±13.69	16.86±7.95	0.09±0.005	2.91±0.47	-	22.43±0.06	-	-	0.21±0.02	2.75±0.54	5.23±0.91
9	1.51±0.50	1.76±0.23	-	-	32.48±8.29	15.43±1.97	0.08±0.001	5.69±1.02	0.04±0.007	34.91±15.85	-	0.51±0.17	-	2.36±1.71	2.26±0.36
10	1.65±0.84	1.95±0.31	-	0.06±0.002	30.98±12.86	16.28±4.82	0.08±0.001	4.92±1.25	0.05±0.004	22.39±5.69	0.12±0.03	0.74±0.33	0.17±0.06	2.15±1.36	2.98±0.78
11	1.49±0.21	1.63±0.22	0.42±0.005	0.06±0.003	44.06±9.12	17.30±6.67	-	4.13±1.92	0.05±0.003	28.65±22.21	0.12±0.06	-	-	1.77±1.16	3.46±1.04
12	1.50±0.25	2.51±0.09	0.62±0.007	0.05±0.002	31.44±5.69	16.69±11.84	-	5.28±2.92	0.05±0.008	30.29±19.54	0.12±0.05	1.17±0.05	0.20±0.02	2.48±0.86	4.63±1.84
13	1.66±0.28	2.71±0.39	0.42±0.006	0.07±0.003	28.46±11.69	13.81±5.45	0.08±0.004	4.50±1.99	0.05±0.004	19.16±2.86	0.14±0.04	0.69±0.30	0.14±0.06	3.58±0.60	4.20±0.12
14	-	2.14±0.64	0.63±0.004	-	43.31±2.56	11.20±2.22	0.10±0.009	4.56±0.75	-	24.48±4.38	0.12±0.02	0.11±0.03	0.21±0.02	1.55±1.22	2.50±0.85
15	1.76±0.54	1.91±0.53	0.71±0.007	-	42.22±3.40	13.94±6.31	0.07±0.003	3.75±1.10	-	27.73±7.69	-	0.86±0.50	0.14±0.08	1.78±1.11	1.48±0.93
16	0.95±0.25	2.17±0.73	0.46±0.006	-	36.07±11.45	14.07±2.79	-	4.12±2.79	-	56.26±14.36	0.07±0.003	0.38±0.08	-	0.80±0.06	3.15±2.01
17	1.43±0.79	2.40±0.93	-	-	35.06±6.61	17.98±8.43	-	4.07±2.10	-	40.76±11.84	0.08±0.007	0.33±0.22	0.17±0.04	2.06±0.61	2.63±0.12
18	-	2.29±0.23	-	0.09±0.001	33.16±4.21	20.04±2.05	0.12±0.008	2.69±0.86	-	27.50±3.03	-	-	0.16±0.06	0.89±0.72	3.96±1.37
19	1.49±0.49	1.99±0.73	0.60±0.005	0.06±0.004	33.61±7.04	14.52±7.15	0.13±0.009	3.31±1.13	0.03±0.002	29.90±2.94	-	-	0.10±0.05	1.37±1.20	3.92±1.43
20	1.47±0.23	1.44±0.39	0.85±0.006	0.06±0.001	36.71±8.23	8.42±1.97	0.09±0.004	5.23±2.38	0.05±0.006	38.03±12.23	0.06±0.004	0.36±0.16	0.15±0.04	2.68±0.88	2.95±1.31
21	1.03±0.49	1.98±0.54	0.62±0.005	0.28±0.006	34.98±6.75	11.36±5.18	0.05±0.001	3.21±1.06	-	29.21±10.29	-	0.56±0.22	0.20±0.03	2.17±1.68	3.42±1.42
22	1.31±0.21	1.69±0.77	-	0.04±0.001	23.25±7.54	12.46±2.19	-	3.36±1.15	-	21.18±2.96	-	0.14±0.06	0.13±0.04	1.56±0.01	3.81±0.56
Limit value	0.2-0.5[a]	0.1[b]	0.15[b]	-	-	5.0[b]	-	1.0[a]	0.005[b]	-	0.11[a]	0.1[b]	-	0.13[b]	0.0055[b]

[a]WHO, 2000; [b]DEC, 2006

WHO recommended 0.0011 µg/m^3 as a limit value for chromium VI and 0.11 µg/m^3 for chromium III in PM. In this study, minimum and maximum values of Cr (III) were obtained for site 20 (0.06±0 µg/m^3) and site 4 (0.15±0.05 µg/m^3) (TABLE 2). Cr (III) results correspond with WHO standards.

The highest Al concentration was found in site 18 as 20.04±0.05 μg/m^3 while the lowest Al concentration was obtained in site 20 (8.42±1.97 μg/m^3). Aluminum content in filter samples of the present study was also high when compared to the Al limit value (annual: 5 μg/m^3) suggested by Department of Environment and Conservation (DEC) (DEC 2006).

DEC suggested the values of 0.33 μg/m^3 and 0.13 μg/m^3 for inorganic and organic mercury, respectively; and 0.0055 μg/m^3 and 0.055 μg/m^3 for arsenic and arsine, respectively. DEC suggested 1.0 μg/m^3 Hg per day as an annual average and 2.0 μg/m^3 Hg as a daily average in breathed air. The levels of inorganic Hg in the filter samples ranged from 0.80 ± 0.06 ng/m^3 to 3.58 ± 0,60 ng/m^3 and the highest Hg levels were obtained in site 13 and site 5 (TABLE 2).

Hg and As values were measured at ppb levels in the present study, both of these elements are strictly dangerous for human health and should be monitored. The fatal risk values for Hg and As are approximately 66.00 ng/m^3 (1:10 000) in the air.

The limit values for Mn in air as recommended by DEC are 0.15 μg/m^3 per day as an annual average and 2.50 μg/m^3 as a daily average. Considering the neurotoxin effects of Mn, WHO was suggested a 0.15 μg/m^3 limit value. In this study, the lowest Mn levels obtained were in site 6 (0.32 ± 0.10 μg/m^3) and site 2 (0.36 ± 0.02 μg/m^3). The highest Mn concentration was obtained in site 20 (0.85 ± 0.88 μg/m^3) (TABLE 2). Mn content was not determined in some sampling sites.

Nickel causes dermatological effects in humans, if swallowed; it may lead to cancerogenic effect. DEC suggested 0.015 μg/m^3 per day as an annual average and 2.00 μg/m^3 as a daily average in the air. Alternatively, WHO gives 1 μg/m^3 as a daily average for Ni in air. 250 ng/m^3 (1:10 000) is determined as fatal. Ni concentrations are also found to be considerably high in biomass combustion smoke. The highest concentration of Ni was found in site 2 (6.44 ± 2.99 μg/m^3) (TABLE 2).

One of the other health treating elements is Cd for which 0.005 μg/m^3 per day as an annual average and 2.00 μg/m^3 daily averages were given by DEC. In the filter samples, Cd concentrations varied between 0.03 ± 0.01 μg/m^3 – 0.06 ± 0.01μg/m^3 and Cd content was not determined in some sampling sites.

DEC advice a limit value of 0.02 μg/m^3 of Co per day as an annual average and 0.10 μg/m^3 as daily average, but our measurements are slightly higher than these suggested values. The highest Co concentration was determined as 1.17 ± 0.05 μg/m^3 in site 12. However, the Co content was not determined in site 4, site 8, site 11, site 18 and site 19 (TABLE 2).

The results of our measurements for Cu are lower than the recommended limit values provided by DEC (0.10 μg/m^3 per day as the annual average and 5.00 μg/m^3 as the daily average). In the filter samples, the highest Fe content was 56.26 ± 20.36 μg/m^3 in site 16 and 40.76 ± 11.84 μg/m^3 in site 17 (TABLE 2). The lowest Fe content was found to be 19.16 ± 2.86 μg/m^3 at site 13.

Sn is a very important element which is highly dangerous. The values for Sn are between 0.03μg/m^3 and 0.28 μg/m^3 according to our measurements.

CONCLUSIONS

In this study, the chemical analyses of indoor airborne particles distributed by combustion of the cow dung biomass used as energy source in houses of some rural regions of Turkey were made quantitatively and qualitatively. Mass concentration and heavy metal content of airborne particles were determined by using SEM and AAS analysis methods. The measurement results indicated that the mass of particulate matters were found to be higher than the standards values. Moreover, the AAS results showed that the heavy metal concentrations in different particulate matters emitted inside as a result of biomass burning were detected to be higher than the limit values suggested by WHO. These results associated with indoor air particulates in some rural houses are due to the lack of ventilation in living areas using biomass fuels and poorly-designed stoves and thus low combustion efficiency of the biomass. In this regard, it is also concluded that the investigated living-environments is so critical for especially children and women should be a first priority of the public health authorities in terms of design and implementation of intervention actions.

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