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Study on the Indoor Air Pollution

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=Abstract=

실내공기오염에 관한 연구

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우리 일상생활 가운데 80% 이상은 실내에서 보내기 때문에 실내공기는 우리 인체에 대단히 중요하다. 실내공기를 오염시키는 오염원들은 담배연기, 연탄 및 석유난로 음식요리과정, 실내 건축 자재 등이라고 추정할 수 있다.

저자등은 겨울철에 석유나 연탄으로 난방을 하는 사무실, 시장, 식당, 연구실 등의 실내를 대상으로 흡입성 분진량과 연량을 측정하여 실내공기 오염도를 조사한 결과 흡입성 분진량은 0.03mg/m³–16.14mg/m³이였으며 연의량은 0.250–3.975ug/m³로 나타났다.

Introduction

Over 80% of our lifetime is spent in the indoor environments so that indoor air pollution is a very important phenomenon in our office and home live[1]. The most significant sources of indoor air pollution are cigarette smoking, stove and oven operation, cooking, and emanations from certain types of particleboard cement, and other building materials.

The impact of energy conservation on the indoor environments in winter season may be substantial, and tight buildings are constructed to minimize the infiltration of outdoor air, with respect to decrease in ventilation rates[2-3]. There is a need for proper building design, construction, and ventilation guidelines to avoid the exposure of inhabitants to unhealthy environments.

The life style in Korea is different from that of the western in winter heating system. Usually, we use three kinds of heating system in winter season; coal briquette stove, petroleum stove, and central steam or hot air facillities to keep energy in the indoor spaces from late autumn through early spring. As a result, sulfur dioxide, nitrogen oxides, carbon monoxide, respirable dust, metals could be deposited in the office and home indoor spaces where large amounts of the above pollutants could be inhaled and accumulated into the lungs causing a great human health. They are so small to be eluded from the body's defense system that, eventually, being deeply breathe into the lower lung, where they may remain for a long period of time before completely cleared[4]. Raspirable particulates reach in very large numbers to polluted air; they can represent as much as 90 to 99 percent of the number of airborne partciles in urban areas[5]. Respirable particulates are complex mixtures that contain harmful substances associated with various human diseass, including respiratory illness, cardiovascular disease, neurological damage, and cancer. These include polynuclear aromatic hydrocarbons and metals, such as arsenic, beryllium, nickel, lead and chromium[6]. All are occupationally associated with the increased risks of cancer. In addition, vapors, such as nitrosamines, may be carried into the lungs by respirable particles[7].

The authors tried to measure the respirable dust in the indoor environments by using the gravimetric dust sampling kits on membrane filter holder and analyzed lead contents.

Experiment

Sampling. The sampler was Gravimetric Dust Sampling Kit (MSA, U.A.S.) consists of three components: a battery-powered, diaphragm-type pump with calibrated flow rate (2.0l/m); a dual-rase battery charger; and a cyclone assembly which removes the nonrespirable fraction of the dust, with filter holder for collecting dust sample. Flow is controlled by a critical orifice which is checked before and after each sampling. Filters are weighed at the electrical balance (Mettler H18, 0.1mg) and kept them always in dessicator to eliminate moisture. The concentration of respirable dust is calculated from the mass collected and the volume of air sampled calculated from flow measurements. The filter for the detection of respirable dust was glass fiber filter (gelman, AE 0.3u) and for metal analysis membrane filter (Millipore, AA 0.8u) was used.

Digestion. The filter is transfered to a clean 100ml beaker and treat the sample with 2-3ml of concentrated nitric acid to destroy the ortanic filter matrix. Covered each beaker with a watch glass and heat on a hot plate (140°C) in a fume hood until most of the acid has evaporated. Repeated this process twice and after cooling transfered the clear solutiont to 5ml mess tube and rinsed each beaker at least 3 times with 0.5ml portions of distilled water and quantitatively made 5ml sample solution.

Pb Detection

Instrument: Furnace Atomizer(Instrumentation Laboratory Co., Model 655). Conditions

Lamp: Pb Hollow Cathode Lamp
Lamp Current: 5mA
Wavelength: 283.3nm
Analysis Mode: DB A-Bkg
Integration Time: 12 sec
Readout Mode: P/H
Purge Gas: Nitrogen (30ml/min)
Temperature Program:
dry at 400°C for 25 sec
ash at 650°C for 25 sec
atomize at 1900°C for 10 sec

Co Detection

Carbon monoxide monitor(Ecolyzer, U.S.A.) 200 series which could detect up to 1000ppm

SO_2 Detection

p-Rosaniline method is used after collecting samples in impinger.

Results and Discussion

Respirable Dust

By using MSA respirable dust sampler, the authors operated this instrument for eight hours in selected offices, restaurants, coffee shops, markets, and billiard rooms. As mentioned before, we have three main heating system; central heating system by steam or hot air, radiation heating systems by petroleum and briquette stove. The authors chose the sampling locations where petroleum and briquette stove were used, specially the indoor air quality was supposed to be the worst.

Among 8 sampling sites, there were two nonsmkoing areas and the other space where mixed air pollutants of cigarette smoke and combustion gases were accumulated. The respirable dust concentrations were as follows: 0.52–9.13mg/m^3 in school office, 0.12–8.32mg/m^3 in billiard room, 0.86–13.52mg/m^3 in coffee shop, and 0.11–13.41mg/m^3 in snack corner, respectively, where petrolleum stove were used. In briquette stove indoor areas, the respirable dust concentrations were as follows: 0.74–16.14 mg/m^3 in building guard room, 0.35–11.62mg/m^3 in restaurant, 0.03–1.04mg/m^3 in market area, and 0.15–2.02mg/m^3 in copy room.

Sulfur dioxide and carbon monoxide were main air pollutants in burning petroleum and briquettes. The highest SO_2 concentration was 1.88ppm in market area where briquette stove without chimney are used. Carbon monoxide contents were ranged from 1ppm to 59ppm, and the highest concentration was slso found in the maket areas having concentrations of 5 to 59 ppm. There were no distinctive differences between petroleum and briquette stove heating systems about SO_2, CO, and respirable particle emissions. All the above sampling areas are the traditional indoor envirnments using local heating sysystem without mechanical ventilation facilities.

The total range of respirable dust concentration was 0.03–16.14mg/m^3, the highest value was in building guard room where SO_2 and CO concentrations were 0.06–1.10ppm and 3–26ppm. respectively, whose values were exceeded the standards for SO_2 and CO. In market area using the ventilation by natural air movements owing to large spaces, the respirable dust concentration was 0.03–1.04mg/m^3 whose value was the lowest among 8 sampling areas.

The total average values for respirable dust were 0.36–9.43mg/m^3, SO_2 were 0.16–0.83ppm, and CO were 4.88–24.5ppm. In sampling sites, room spaces were different from one another, such as ranging from 54 to 4800m^3. There were no relationships between the space and respirable dust concentrations, because of the ventilation status and heating capacities. Even a small space room as in the building guard room, the room volume was 64m^3, but the respirable dust concentration was 0.74–16.14mg/m^3, higher SO_2 value was 1.10ppm, and higher CO value was 26ppm. But even more samller space such as in a copying room, the space volume was 36m^3, the respirable dust concentration was 0.15–2.02 mg/mg^3, higher SO_2 value was 0.47ppm, and CO value was 7ppm. The copy room mas heated with one small briquette stove, but in the building guard room, there were two large briquette stoves and cigarette smoke was filled in there.

Fine particulates are generally defined as particles smaller than 1 to 2 micrometers in diameter, or roughly one-fiftieth the width of a human hair. Because of their small size, fine particulates pose a serious threat to human health. They are small enough to elude the body's defense system and to be breathed deep into the lower lung, where they can remain for long periods before being cleared[8]. Unlike larger particles, fine particulates easily reach the lower lung. Studies have indicated that all but a small fraction of particles larger than 10 micrometers in areodynamic diameter are trapped in the nasal passages and prevented from entering the lungs[9~11]. Particles greater than 10 micrometers are almost all deposited in the nasopharyngeal system with only a small fraction will be retained in the pulmonary region. Of inhaled particles between 2 to 5 micrometers, less than 10 percent is deposited in the tracheobronchial compartment and about 20 to 30 percent in the pulmonary region. By contrast, the model predicts a maximum efficiency of deposi-

Table I. Respirable Dust, SO_2, and CO Concentrations in Various Indoor Environments

Sites	Respirable Dust (mg/m^3)	Space Volume (m^3)	SO_2(ppm)	CO(ppm)	Fuel
School office	0.52～ 9.13	54	0.017～0.21	1～ 5	Petroleum
Billiard Room	0.12～ 8.32	202	0.43 ～0.61	7～36	Petroleum
Coffee Shop	0.86～13.52	270	0.03 ～0.47	3～19	Petroleum
Snack Corner	0.11～13.41	120	0.08 ～1.15	8～35	Petroleum
Building Guard Room	0.74～16.14	64	0.06 ～1.10	3～26	Briquette
Restaurant	0.35～11.82	46	0.26 ～0.77	11～36	Briquette
Market	0.03～ 1.04	4800	0.24 ～1.88	5～32	Briquette
Copy Room	0.15～ 2.02	36	0.14 ～0.47	1～ 7	Briquette
Mean Value	0.36～ 9.43		0.16 ～0.83	4.88～24.5	

tion in the alveoli or pulmonary region for particles smaller than 2 micrometers[12)].

The amount of deposition of particulates in the alveoli appears to vary with the degree of activity and pattern of breathing of the individual. For example, individuals who are exercising strenously and mouth-breathers are subject to deposition of significantly greater amounts of coarse particles than the general person. For mouth-breathers, an estimated 10 to 30 percent of paricles of 5 to 7 micrometers may be deposited in the lower lung[13)]. Liu, et al.[14)] pointed out that in the normal individual, the largest size of particles that can be inhaled into the lungs through the nose is 10μm. However, when mouth breathing is considered, particles as large as 15μm can be inhaled. There is also considereable variation among individuals, particularly between smokers and nonsmokers.

Lead Concentration

In analyzing micro amounts of Pb in respirable dust, the standard addition method for furnace atomizer atomic absortption spectroscopy was applied. The digested sample solution of 20μl was placed on graphite micro boat which was dried on a hot plate at 90°C and dried. On the 3 same micro boats containing sampe solution 1ppm Pb standard solution of 5μl, 10μl, and 15μl were addea and dried again, and then put into the furnace atomizer. The results are shown on the Table II.

The lead concentrations were as follows: 1.125～3.975μg/m^3 in school office, 0.175～2.650μg/m^3 in laboratory, and 0.250～2.675μg/m^3 in office(A) respectively, where fuel was petroleum. In briquette stove area, the Pb concentrations were 0.250～1.5μg/m^3、 in guard

Table II. Lead Concentration in Indoor Air(μg/m^3)

Sampling Sites	Sample Size	Pb Concentration	Fuel	Mean Value	Section Mean
School Office	4	1.125～3.975	Petroleum	3.225	
Laboratory	22	0.175～2.650	〃	1.325	1.975
Office(A)	17	0.250～2.675	〃	1.350	
Building Guard R	5	0.250～1.500	Briquette	0.900	
Home Kitchen	5	0.700～1.300	〃	0.950	0.775
Office(B)	6	0.250～1.400	〃	0 500	

Table III. Calculation Method of Pb Concentration in Respirable Dust

Sampling Sites	Sampling Time (min)	Pb Contents in 20μl Among 5ml(ng)	Pb Concentration ($\mu g/m^3$)
Office (A)	480	7	1.83
Office (B)	700	6	1.08
Home Kitchen	720	5	0.88

Flow Rate: 2L/min

$$Pb(\mu g/m^3) = \frac{\text{Pb Contents in Filter}}{\text{Samping Time(min)} \times \text{Flow Rate}(m^3/min)}$$

Table VI. Precision of Pb by Standard Addition Method

Sample	Sampling Time (min)	Dust (mg/m^3)	Pb Contents in 20ug Among 5ml(ng)	Pb($\mu g/m^3$)	Mean±SD
A	480	0.208	7	1.83	
B	480	0.213	6	1.58	1.57±0.27
C	480	0.198	5	1.30	

room, 0.7~1.3$\mu g/m^3$ in home kitchen, and 0.25~1.4$\mu g/m^3$ in office(B), respectively.

The Pb mean value of petroleum using indoor environments was 1.975$\mu g/m^3$ and briquette using indoor was 0.775$\mu g/m^3$, which neans the petroleum stove heating system emit more than twice amounts of lead than briquette stoves. The highest Pb mean concentration was 3.225 $\mu g/m^3$ in school office and the lowest value was 0.5$\mu g/m^3$ in office(B).

To represent calculation method of Pb concentration, Table III summarized the necessary items.

To see the precision of the standard addition methods the following Table IV and Figure 1 were arranged by operating 3 respirable dust sample simultaneously in a office room.

According to Salmon, et al.[15], the concentration of lead in urban air range in general from 0.5 to 5$\mu g/m^3$. The annual avarages over a five year period, 1972~77, at four large urban centers in Belgium ranged from 0.6 to 1.2$\mu g/m^3$. The authors analyzed Pb concentration in respirable dust on the roadsides and found 0.26~0.78$\mu g/m^3$ in Seoul area[17].

Chamberlain et al.[18], found high absorption of retained amounts following inhalation of motor èxhaust by man but determined that 50% of the lead is taken up from plasma to red cells and retained in blood and the remainder is transfered to extracellular fluids and other sites in the body. Pb containing particles in ambient air of aerodynamic diameter 0.1 to 1.0μm have a predicted retention in the pulmonary region of lungs of about 35%[19]. Actual measurements of retention in human volunteers range from 10 to 60%[20]. Absorption to blood depends on the physicochemical form of the lead. A portion of the deposited amount is cleared by mucociliary action to the gastro-intestinal tract. Marrow, et al.[21], utilizing lead aerosols of hydroxide and chloride forms in human experiments, determined that there is nearly complete absorption of the lead retained in the lungs.

The lead concentration in outdoor ambient air comes from tetraethyllead which is used as antiknocking agent in automobile engines. Through this experiment, the highest concentration was 3.975$\mu g/m^3$, whose value was five times higher than the outdoor ambient air in Seoul. The indoor lead comes mainly from combustion of petroleum and briquette. Sometimes, outdoor lead could combine the indoor concentration, but its amount would be neglegible to compare with emission from heating appliances.

Between the two types of fuel stoves, the petroleum stove emitted much more lead than briquette stove. The authors didn't analyze directly the lead contents in both fuels, but the fuel consumptions would have relations with emission of metals. For example petroleum consumptions for 8 hour would be 16kg and 3.6kg for briquette. Also the factor of high lead concentration in the indoor air is related with leakage from stove's structural connecting area. There were some leaking areas around stove surfaces and the combustion gases usually escape from there even though electrical ventillating equipment is attatched. The fuel consumption rate could also affect lead concentration; in cold weather, fuel would be supplied much more than in warm climate to keep heat in the indoor environment.

Conclusion

In the indoor environments where petroleum and briquette stoves are used in winter season, respirable dusts were collected by using MSA respirable dust sampler. The highest concentration was 16.14mg/m^3 in a building guard room and the lowest value was 0.03mg/m^3 in a market area. Respirable dust concentration dose not seem to have relation with the indoor spaces because of matural ventillation.

Lead concentration in indoor environment was analyzed by digesting dust collected on filter with acid and using furnace atomizer. Pb concentration range was 0.250~3.975μg/m^3, whose value is higher than the outdoor by 5 times, and 1.975(mean value) μg/m^3 was in the petroleum stove environment and 0.775(mean value) μg/m^3 was in the briquette stove area.

Sulfur dioxide concentration range was 0.017~1.88ppm and carbon monoxide was in the range of 1~36ppm.

The authors suggest that the best way to eliminate indoors air pollutants, such as, respirable dust, Pb, SO_2, CO, etc, is prevention of combustion gas emission from heating appliances, and stoves should have vent systems.

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