

A Study on Indoor Air Pollution due to Tobacco Smoke: Measuring the Dust Concentration (Report I)

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INTRODUCTION

An injurious influence of tobacco smoke on smokers' health has already been pointed out a number of studies¹⁾⁻³⁾. Recently it has been made clear⁴⁾⁵⁾ that tobacco smoke is one of the main pollutants and is 'conducive' to indoor air pollution.

Dust concentration is one of the indices which shows the degree of indoor air pollution Kimura⁶⁾ reports that the dust concentration due to tobacco smoke is higher than that due to other pollutants though it differs according to smoking conditions. Muramatsu⁷⁾ reports that tobacco smoke accounts for a large part of floating dust, especially in office rooms, and the meaning of tobacco smoke among indoor air pollution is regarded as becoming more important in the future.

Air-conditioners are equipped in modern buildings to reduce indoor air pollution, but the problem⁴⁾⁷⁾ of dust pollution due to tobacco smoke still remains unsolved.

Tobacco smoke is a mixture of various uncondensed gases, vapour and liquid corpuscles and so far it has been clarified that there are about 2000⁸⁾ kinds of compounds in tobacco smoke. Tobacco smoke has been separated into gas and particulated phases.

It is difficult to measure exactly how much of indoor air pollution is due to tobacco smoke because the degree of indoor air pollution by tobacco smoke

is greatly influenced by the number of smokers, the number of cigarettes that have been smoked or are being smoked, the period of smoking, and the capacity of rooms.

The purpose of this study is to clarify how badly the air in the closed room, especially in an unventilated one, is polluted by tobacco smoke.

Therefore we attempted to measure the dust concentration by tobacco smoke in a vinyl chamber where supposed to be on other pollutants (capacity : $1.8 \times 1.8 \times 2.4$ meters).

METHODS

We measured how the dust concentration in a vinyl chamber using a Digital Dust Indicator (P-3 type made by Shibata Kagaku Kikai Co.) from

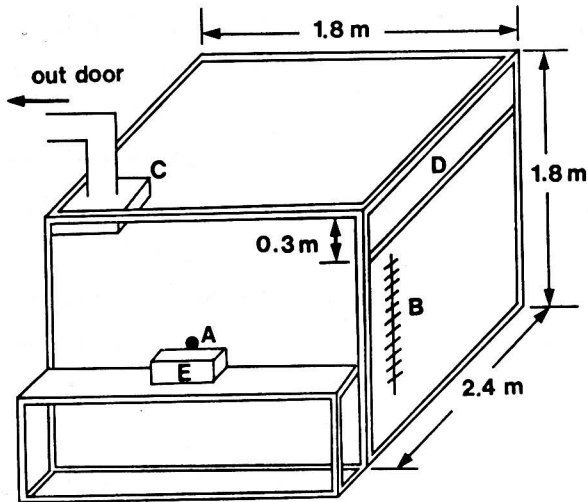


Figure 1. The Sketch of the Vinyl Chamber.

- A : Entrance of Inhalation
- B : Entrance
- C : Ventilation
- D : Open Space
- E : Dust Meter

July to November, 1978. We used an electric fan (the velocity of current was about 2 m/sec) to make the concentration even in the chamber.

Figure 1 shows a sketch of the vinyl chamber, the capacity of which is about 7 m³. A 95 centimeter long zipper is equipped on one side of the chamber. When the zipper is closed, the chamber is cut off from the flow of the outside air. We got into and out of the chamber by this zipper.

The dust concentration was measured at position A in Figure 1, which is about one meter above the floor. It is about as high as an adult's face is when he sits on a chair. Before each experiment we ventilated and adjusted the dust concentration in the chamber at about 10 CPM⁹⁾ (background level).

Each experiment took 40 minutes, and we measured the dust concentration

Table 1. The Conditions of the Experiments

No. of Experiment	Door Closed or Open	Smouldering or Smoked	No. of Cigarettes Burned Simultaneously	Time of Burning	Total No. of Cigarettes Burned
1	Closed	Smouldering	1	10(min.)	1
2	Closed	Smouldering	2	10	2
3	Closed	Smouldering	3	10	3
4	Closed	Smouldering	1	20	2
5	Closed	Smouldering	2	40	8
6	Closed	Smoked	1	5	1
7	Closed	Smoked	2	5	2
8	Closed	Smoked	3	5	3
9	Closed	Smoked	1	10	2
10	Closed	Smoked	1	40	8
11	Open	Smouldering	1	10	1
12	Open	Smouldering	2	10	2
13	Open	Smouldering	3	10	3
14	Open	Smouldering	2	40	16
15	Open	Smoked	2	5	2
16	Open	Smoked	3	5	3
17	Open	Smoked	2	40	16

in the chamber every two minutes. As each measurement takes one minutes we made a total of 20 evaluations.

We measured the dust concentration of indoor air due to smoked cigarettes and smouldering cigarettes respectively in two conditions, that is, 1) when the chamber is closed and, 2) when the upper part of the one side of the one side of the chamber is taken off, so the air runs freely into and out of the chamber.

Table 1 shows the conditions of the experiments. We repeated each experiment ten times. We calculated the average after subtracting the value of the room prior to experiments from the experimental values we got. The brand of cigarettes we used in the experiments was 'Cherry' of Japan Monopoly Corporation.

In preliminary experiments we learnt that it takes smouldering cigarettes 8 to 12 minutes to burn 5 centimeters from their tip, while it takes 4 to 6 minutes for smoked cigarettes. The word 'burn' here means that the cigarettes are in the state of kindling not extinct, whether it is being smoked or smouldering. Allowances should be made for the slight infiltration of the air when the experimenters get into and out of the chamber to kindle or extinguish cigarettes.

RESULTS

(1) When the chamber is closed.

a) Smouldering cigarettes

As is shown in Figure 2, the dust concentration rises rapidly to a peak and stays nearly as high as even after the cigarettes are extinguished. When one cigarette is smouldering, the maximum value is 64.4 CPM. When two cigarettes are smouldering, it is 153.5 CPM. When three cigarettes are smouldering, it rises as high as 355.9 CPM.

Figure 3 shows that, when one cigarette after another is kept smouldering for 20 minutes, the value rises still higher, reaches a maximum, 134.3 CPM, 22 minutes after the first cigarette is kindled and remains as high as later.

Figure 4 shows that, when two cigarettes are kept smouldering consecu-

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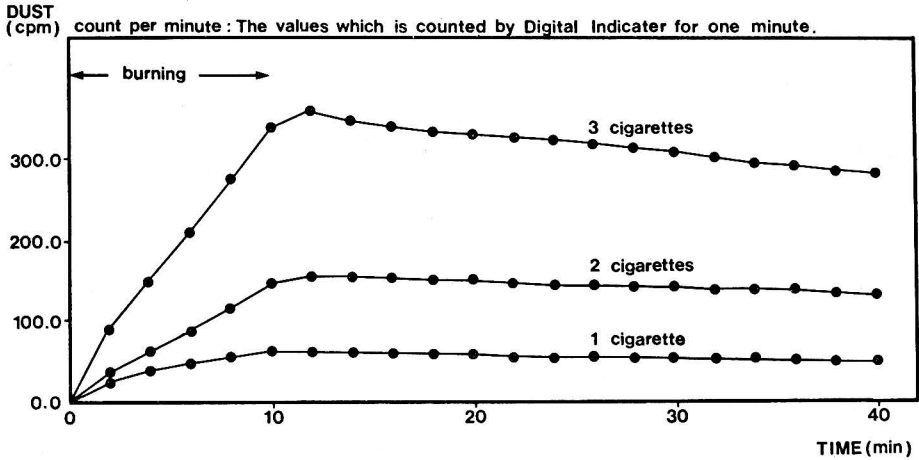


Figure 2. Dust Concentration by Smouldering Cigarettes in the Closed Chamber.

During the burning		After extinguished	
1 cigarette	$Y = 5.050 X + 10.857, r = 0.959$		$Y = -0.383 X + 68.024, r = 0.992$
2 cigarettes	$Y = 13.016 X + 7.217, r = 0.993$		$Y = -0.621 X + 162.873, r = 0.994$
3 cigarettes	$Y = 30.152 X + 21.975, r = 0.991$		$Y = -2.466 X + 383.037, r = 0.999$

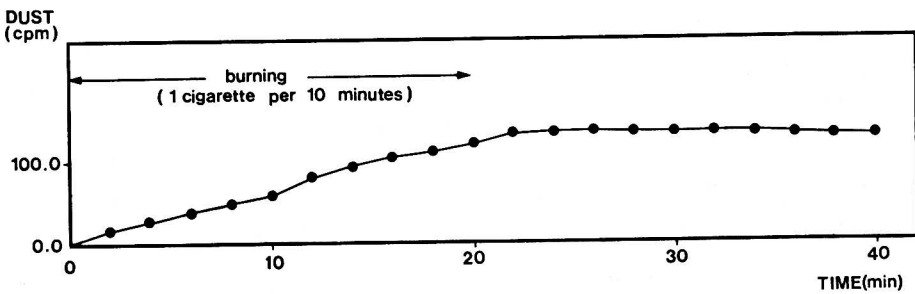


Figure 3. Dust Concentration by Smouldering Cigarettes in the Closed Chamber.

During the burning	After extinguished
$Y = 6.689 X - 0.283, r = 0.995$	$Y = -0.358 X + 149.351, r = 0.963$

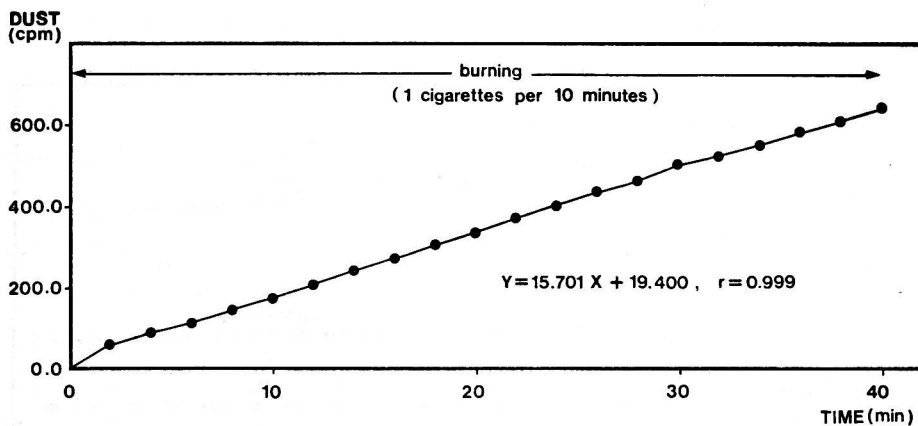


Figure 4. Dust Concentration by Smouldering Cigarettes in the Closed Chamber.

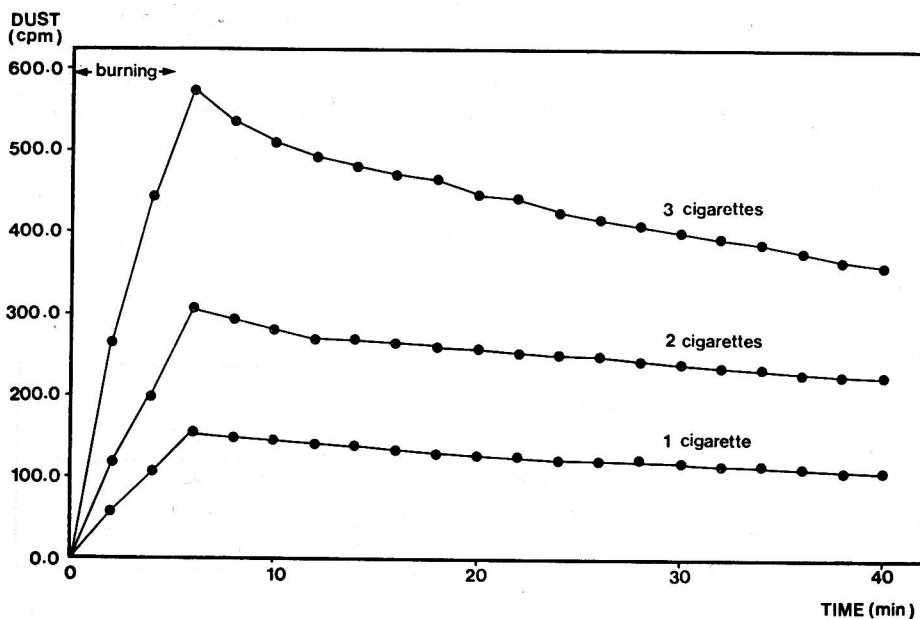


Figure 5. Dust Concentration by Smoked Cigarettes in the Closed Chamber.

During the burning

1 cigarette $Y=25.245 X + 2,390$, $r=0.999$

2 cigarettes $Y=50.180 X + 1,510$, $r=0.999$

3 cigarettes $Y=94.840 X + 36.780$, $r=0.987$

After extinguished

$Y=-1.260 X + 153.206$, $r=0.994$

$Y=-1.883 X + 296.200$, $r=0.993$

$Y=-0.520 X + 556.656$, $r=0.993$

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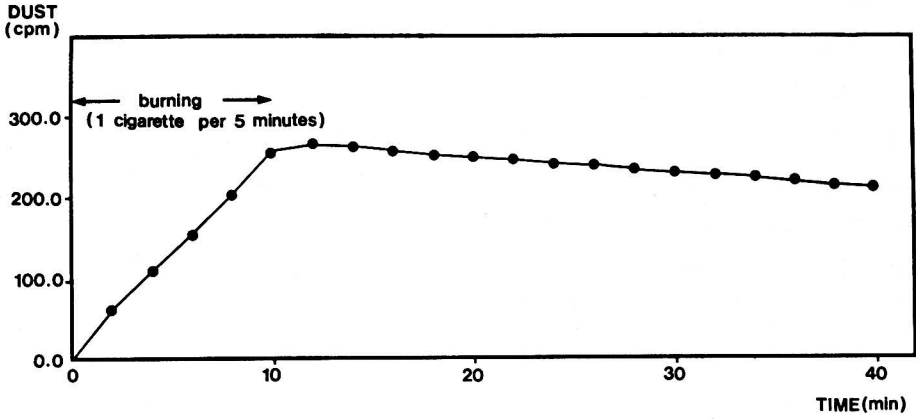


Figure 6. Dust Concentration by Smoked Cigarettes in the Closed Chamber.

During the burning
 $Y = 22.882 X + 12.893, r = 0.992$

After extinguished
 $Y = -1.818 X + 286.535, r = 0.998$

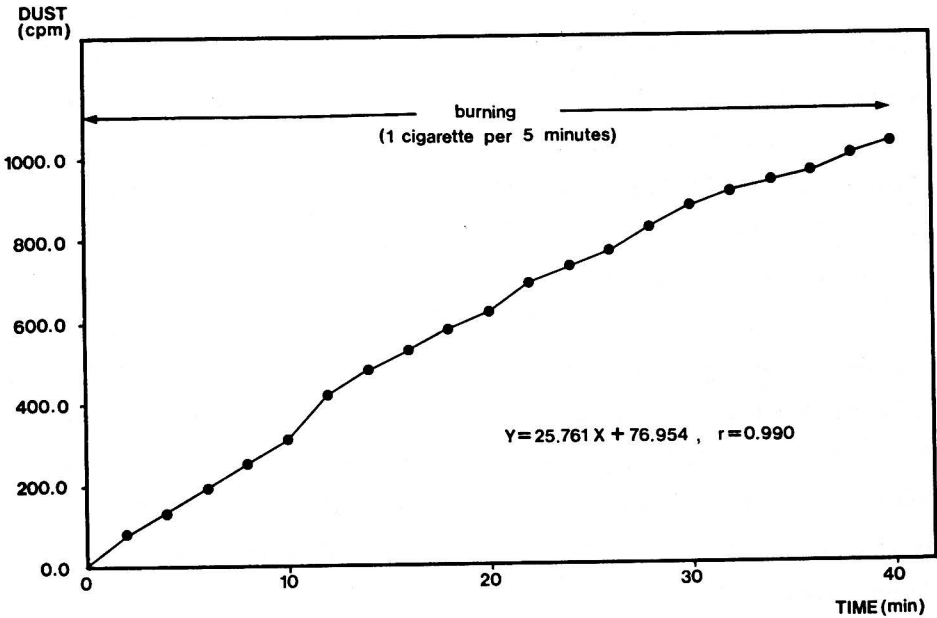


Figure 7. Dust Concentration by Smoked Cigarettes in the Closed Chamber.

tively 40 minutes, the value rises in a straight line and reaches as 639.8 CPM at the end of the experiment.

b) Smoked cigarettes

The dust concentration due to smoked cigarettes is Figure 5. When one cigarette is smoked, the value reaches the maximum 151.9 CPM 6 minutes after kindling. When two cigarettes are smoked simultaneously, the maximum is 304.1 CPM. When three cigarettes are smoked simultaneously, the maximum is 574.3 CPM. The dust concentration decreases gradually after the cigarettes are extinguished.

As is shown in Figure 6, when the volunteer chain smokes two cigarettes for 10 minutes, the value reaches 265.5 CPM 12 minutes after he began smoking. Figure 7 shows that, when the volunteers keep smoking two cigarettes simultaneously and consecutively for 40 minutes, the value reaches a maximum of 1025.0 CPM at the end of the experiment.

c) Comparison between the dust concentration by smouldering cigarettes and that by smoked cigarettes

As is shown in Figure and 5, when the same number of cigarettes are burning the dust concentration due to smoked cigarettes is higher than that due to smouldering cigarettes. The maximum value when three cigarettes are smoked, 574.3 CPM is much higher than the maximum value when as many cigarettes are smouldering, 355.9 CPM. The maximum value when one cigarette is smoked is about two and a half times as high as the maximum value when one cigarette is smouldering.

As is shown in Figure 4 and 7, at the end of the experiment in which one cigarette is smoked consecutively for 40 minutes (8 cigarettes in all), the value reaches 1025.0 CPM. On the other hand, at the end of the experiment in which two cigarettes at a time are consecutively kept smouldering for 40 minutes (8 cigarettes in all), the reaches 639.8 CPM. When the same number of cigarettes are smoked or smouldering, the smoked cigarettes have more polluting effect.

(2) When the chamber is open.

The electric fan is not used when the chamber is open, while in the closed

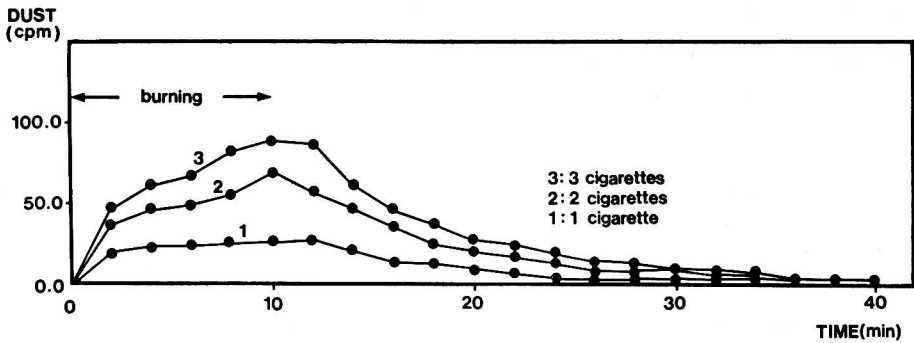


Figure 8. Dust Concentration by Smouldering Cigarettes in the Open Chamber.

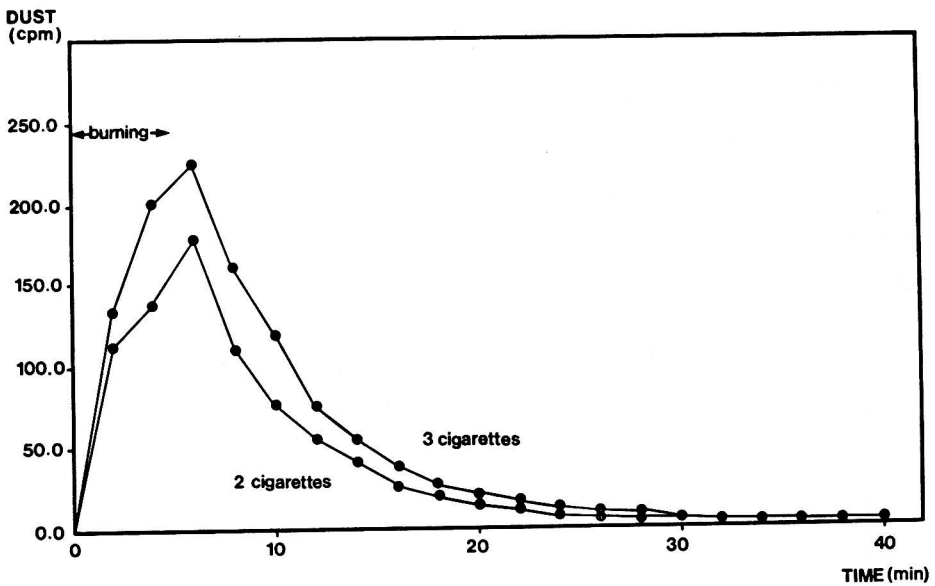


Figure 9. Dust Concentration by Smoked Cigarettes in the Open Chamber.

chamber it is kept working to make dust concentration even. When the chamber is open, the velocity of air current in the center of the chamber is 0.08 to 0.40 m/sec, and the velocity at the opening is 0.07 to 0.90 m/sec.

a) Smouldering cigarettes

Figure 8 shows that, when cigarettes are kept smouldering in the open chamber, the amount of dust rises as follows; one smouldering cigarette raises the amount to the maximum 28.5 CPM 12 minutes after the kindling; two

smouldering cigarettes raise it the maximum 69.9 CPM 12 minutes after the kindling ; three smouldering cigarettes raise it to 88.9 CPM in as many minutes. The degree gradually falls after the cigarettes are extinguished.

b) Smoked cigarettes

When cigarettes are smoked in the open chamber, the amount of dust rises steeply, as is shown in Figure 9. When two cigarettes are smoked, the amount reaches a maximum 180.4 CPM in 6 minutes, and when three cigarettes are smoked, it reaches a maximum 226.6 CPM in as many minutes. However, in both cases the degree falls soon after the cigarettes are extinguished.

c) Comparison between the dust concentration by smouldering cigarettes and that by smoked cigarettes

When the same number of cigarettes are burned, smoked cigarettes have more polluting effect than smouldering ones, as is shown in Figure 8 and 9. In both cases where two cigarettes are burned and three cigarettes are burned, the maximum values by smoked cigarettes are about two and a half times as high as those by smouldering cigarettes.

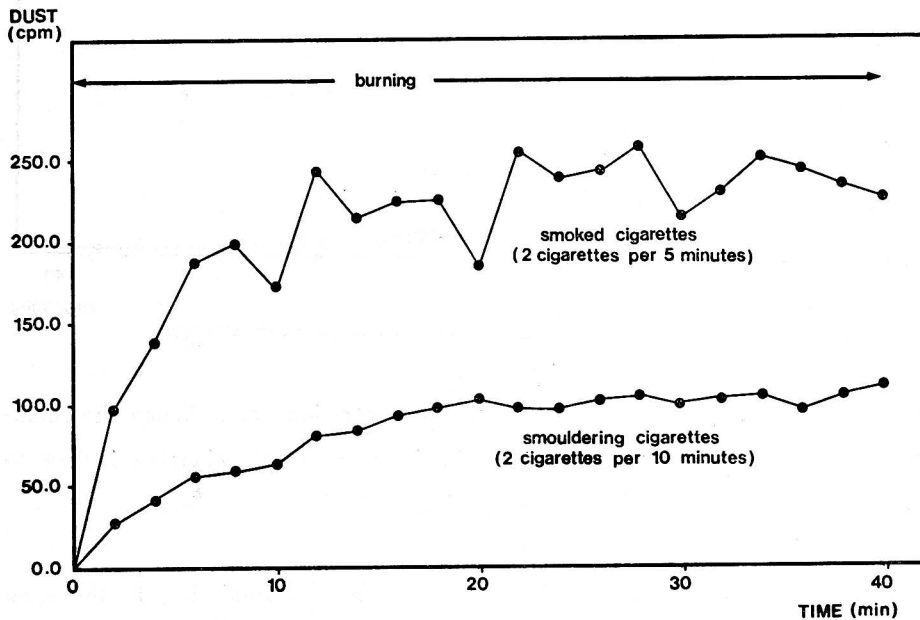


Figure 10. Comparison between Dust Concentration by Smouldering Cigarettes and that by Smoked Cigarettes in the Open Chamber.

- (3) Comparison between the dust concentration in the open chamber and that in the closed chamber.

As is shown in Figure 2, 5, 8 and 9, in the closed chamber the amount rapidly rises and falls only slightly after the cigarettes are extinguished. On the other hand, in the open chamber the values are lower and the degree decreases soon after it has reached the maximum.

Figure 10 shows that, when cigarettes are kept burning consecutively, the amount does not fall even in the open chamber.

DISCUSSION

From our experiments it is made clear that when cigarettes are burned in an unventilated chamber, the dust concentration rapidly rises and dust keeps floating for a long time even after the cigarettes are extinguished.

Ro, et al¹⁰⁾, have also reported that the air in an unventilated laboratory is rapidly polluted by smoking. Kimura⁴⁾ reports that, if we observe experiments of smoking in much the same conditions, the amount often widely varies, and with that of smoking in our daily lives it will vary more widely according to inhaling speed, the amount of exhaled smoke, the interval of exhaling, and so on.

We repeated the experiment 10 times in each case and although there were slight differences in the values of each experiment, we observed that the amount due to smoked cigarettes is higher than that due to smouldering cigarettes.

Muramatsu¹¹⁾, et al. have presented a report to same effect. But there are some differences among the quality between the smoke due to smouldering and smoked, that is, the former is composed of only sidestream smoke and the latter is composed of both sidestream and the smoke exhaled by the smokers. The moisture from the interior of the body condensed¹²⁾ the particles of the smoke exhaled by the smokers, and also there is a problem as to how the values registered by the Digital Dust Indicator are influenced by this moisture. Therefore to what extent the amount depends on so greatly upon the conditions of experiments are yet to be examined.

The results of experiments performed in the open chamber shows that the

amount of dust rises, though to a lesser degree than in the closed condition, and decreases soon after the cigarettes are extinguished. But, when cigarettes are kept burning consecutively, the amount does not fall even in the open chamber.

Konishi¹³⁾ reports that the air in rooms, if ventilated, becomes polluted a good deal by tobacco smoke and dust and carbon monoxide are consecutively high. Kimura⁷⁾ reports that the amount of dust in the air in rooms, if ventilated, where are a number of smokers is 4 to 5 times as high as the outdoor air, and tobacco smoke accounts for a great part of the dust. He reports that air-conditioners do not suffice to purify the indoor air, and moreover the polluted air once absorbed into air-conditioners circulates and even pollutes the air in rooms which are not supposed to be polluted by tobacco smoke. Therefore, in air-conditioned rooms the problem of pollution by tobacco smoke remains unsolved.

The influence of smoking on nonsmokers, especially on children, is by no means negligible. According to Colley's survey¹⁴⁾, the incidence of pneumonia and bronchitis among first-year babies whose parent has smoking habit is higher than among babies whose parents don't smoke and the incidence is highest among babies whose parents both habitually smoke. Cameron¹⁵⁾ also reports that smokers' children more often suffer from respiratory illness than the nonsmokers' children.

Muramatsu¹⁶⁾, et al. have shown that about 80% of elementary school children, about 70% of junior high school students and about 60% of senior high school students complain at least of one symptom or more by Second-Hand Tobacco Smoke, and the commonest symptoms are coughing and nose irritation. Cameron¹⁷⁾ have noticed that Second-Hand Tobacco Smoke is clearly an annoyance to most children and the most common are eye irritation and coughing. Second-Hand Tobacco Smoking here is synonymous with 'Passive Smoking'. Weber¹⁸⁾, et al. have reported that the irritating effects were recorded by questionnaire and related to concentration of pollutants due to tobacco smoke and that the eyes are most sensitive to these irritants, followed by the nose.

Recently low tar and low nicotine cigarettes have become popular probably

because they are supposed to be less injurious to their health. But, whatever is claimed about their development, the occurrence of various combustibles, including dust and carbon monoxide is unavoidable when they are burned. The problem of pollution of indoor air by these combustibles are yet to be solved, and so far as dust is concerned, it is difficult to maintain¹⁹⁾ the amount below the environmental standard, 0.15 mg/m^3 , even in air-conditioned rooms. Although inhaling of indoor air polluted by tobacco smoke does not immediately injure our health, careful attention should be paid to the extent to which the indoor air is polluted.

When we consider countermeasures against the pollution of indoor air due to tobacco smoke, it is necessary not only to reform radically methods of air conditioning and ventilation, but more importantly to amend the smokers way of thinking to smoking itself. That is to say by education of the dangers and this hopefully reduce the number of smokers and cigarettes smoked to as few as possible.

SUMMARY

It has recently been pointed that tobacco smoke is one of the main pollutants of indoor air, and that nonsmokers' health also is influenced by the indoor air pollution due to tobacco smoke.

The purpose of this study is to clarify the indoor air pollution due to tobacco smoke by measuring the dust concentration in a chamber.

The results obtained from the experiments are as follows ;

- 1) When cigarettes are burned in a closed, unventilated room, the amount of dust rapidly increases and dust keeps floating for a long time even after the extinction of the cigarettes.
- 2) When cigarettes are burned in an open room, the amount of dust increases, but it decreases soon after the extinction of the cigarettes. However the amount does not decrease when the burning of cigarettes continues.
- 3) When the same number of cigarettes are burned, the amount of dust due to smoked cigarettes is higher than that due to smouldering cigarettes.

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