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H-3 AN INVESTIGATION INTO CIGARETTE SMOKE IN DIFFERENT TYPE OF ROOM

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1. INTRODUCTION

The degree of indoor pollution depends, together with other factors, on the amount of tobacco smoked and upon the ventilation rate supplied. We therefore need to quantify the pollution generated by cigarette smoking so that it can be diluted to an acceptable level. The quantity of cigarettes smoked will depend upon the use of the room. We therefore need to identify the smoking habits of the occupants of different type of room.

This paper describes the investigation by Osaka University to quantify the proportion of occupants who smoke, the quantity of cigarettes smoked, the time taken to smoke a cigarette and the interval between cigarettes smoked. The spaces studied were an office, a conference room, a cafe and the waiting room in a bank.

2. INVESTIGATION METHOD

The proportion of adult occupants actually smoking is defined as β % which is different from α % the proportion of habitual smokers in the adult. In this report β_M is the fraction of males, β_F is that for females and β_S the proportion of habitual smokers who are smoking. The average value of β was obtained by counting the number and sex of the smokers and of the total occupants of the room every ten minutes. This determined the average number of smokers. All the cigarette butts thrown away during the investigation were collected and counted. The butt length was then measured so that the burning

length of each cigarette could be calculated. This enabled the average burning length of the cigarettes to be estimated. Calculations were then made on the following basis:

$$\begin{aligned} & \left(\begin{array}{l} \text{Average smoking time} \\ \text{per cigarette} \end{array} \right) T_s \text{ (min/cig.)} \\ &= \frac{\text{Total smoking time (min)}}{\text{Total number of cigarette butts (cig.)}} \\ &= \frac{\left(\begin{array}{l} \text{Duration of} \\ \text{investigation} \end{array} \right) \times \left(\begin{array}{l} \text{Average number} \\ \text{of smokers} \end{array} \right)}{\text{Total number of cigarette butts}} \quad (1) \end{aligned}$$

$$\begin{aligned} & \left(\begin{array}{l} \text{Average burning} \\ \text{rate of cigarette} \end{array} \right) V_s \text{ (mm/min)} \\ &= \frac{\left(\begin{array}{l} \text{Average butt length} \\ \text{per cigarette} \end{array} \right) \text{ (mm/cig.)}}{\left(\begin{array}{l} \text{Average smoking time} \\ \text{per cigarette} \end{array} \right) \text{ (min/cig.)}} \quad (2) \end{aligned}$$

Average smoking interval; S.I. (min)

$$= \frac{\left(\begin{array}{l} \text{Period of} \\ \text{investigation} \end{array} \right) \times \left(\begin{array}{l} \text{Number of habitual} \\ \text{smokers in room} \end{array} \right)}{\text{Total number of cigarette butts}} \quad (3)$$

3. RESULTS OF DISCUSSION

1) α %. The Monopoly Corporation's report shows the trend in time in the proportion of people who habitually smoke (Table 1). Japanese men have the highest proportion of habitual smokers in the world. However, there are clear sexual differences in α %. The cigarette smoke condition in a room

Table 1 Proportion of habitual smokers in the adult population: α (%) (from the Monopoly Corporation's reports)

Year	Male	Female	Total
'66	83.7	18.4	—
74	78.3	15.1	—
75	76.2	15.1	44.5
77	75.1	15.1	44.0
78	74.7	16.2	—
79	73.0	15.0	—
80	70.2	14.4	—

would therefore be strongly influenced by the proportion of each sex present.

2) $\beta\%$. The number of smokers present in a room can be estimated from knowledge of the occupancy ratio and β the proportion of smokers.

i) A LABORATORY CONFERENCE ROOM

The occupants and smokers were few in number. Comprehensive details of the cigarettes smoked are given in Fig. 1. The average number of smokers was recorded at 1½, 5 and 10 minute intervals (Table 2). The dispersion of those values decreases as the time interval is reduced and as the number of smokers and occupants increased. For other investigations numbers of smokers and occupants were recorded at 10 minute intervals. Three investigations are summarised in Table 3, and show average values for β , β_M and β_S . The female was a non-smoker. These values are not typical, except for β_S , because the sample size was so small. The average number of smokers in a conference room can generally be estimated by taking 28% of the habitual smokers β_S .

ii) AN OFFICE The smoking habits, identified by questionnaire, are given in Table 4. The value for α is smaller than the national figure. The change in the proportion of people smoking β throughout the day suggests that smokers are more likely to smoke immediately when they enter the office just before or after lunch time and around 3 p.m. The average values of β are given in Table 5. Slightly higher values of β would be expected based on the national value for habitual smokers α . People smoking at any one time can be estimated as 15% of the number of habitual smokers.

iii) A BANK WAITING ROOM Visitors comprised 53% male and 47% female. Average values for the smokers β , β_M and β_F are listed in Table 6. Accepting the national average of habitual smokers α , typical values would be 13% of the males and 15% of the females would be smoking at any one time.

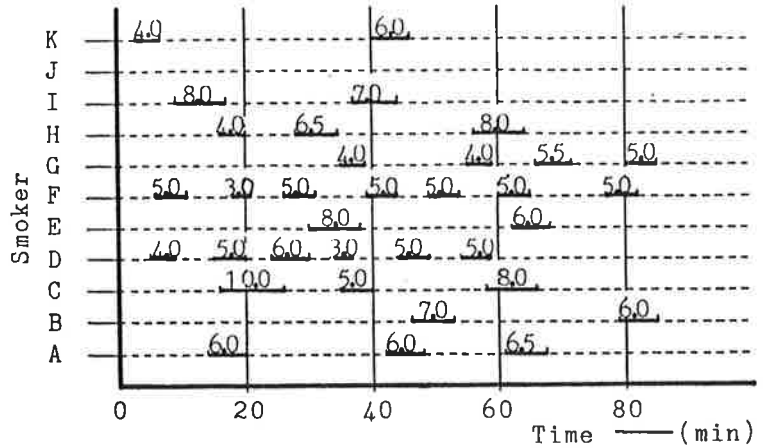


Fig. 1 Smoking condition in a conference room. The numerals on the figure are smoking times (min).

Table 2 The average number of smokers in a conference room

Survey intervals (min)	Survey number	Investigation		
		I	II	III
1.25	No.1	2.8	1.8	2.3
5.0	No.1	2.8	1.5	2.5
	2	2.8	2.1	2.2
	3	3.0	1.8	2.3
	4	2.7	1.8	2.1
10.0	No.1	2.4	1.3	2.6
	2	2.6	2.0	3.0
	3	3.0	1.4	3.1
	4	3.0	1.6	2.6

Table 3 Ratio of smokers to occupants in a conference room

Investigation	I	II	III
Duration (min)	85	88	75
Number of occupants (persons)	21	18	21
Number of habitual smokers (persons)	10	6	9
Average number of people smoking (persons)	2.8	1.8	2.3
Proportion of people smoking	13.3	10.0	11.0
Proportion of males smoking	14.0	10.6	11.5
Proportion of habitual smokers	28.0	30.0	25.6

Table 4 The proportion of habitual smokers in an office room

	Male	Female	Total
Number of questionnaire (persons)	69	20	89
Number of no answer (persons)	7	8	15
Ratio of sexual composition (%)	84	16	100
Number of habitual smokers (persons)	38	1	39
α_s (%)	61.3	8.3	52.7

Table 5 The proportion of people actually smoking in an office

Date	Time	β (β_M)		
		9 ~ 12	13 ~ 16	12 ~ 13
Sep. '74	10th	8.2	7.5	8.4
	11	9.1	7.6	5.7
	12	8.5	7.6	8.1
	Ave.	8.6	7.6	7.4
Feb. '75	17th	6.9 (9.3)	6.0 (7.6)	—
	18	4.1 (9.8)	5.7 (6.5)	—
	19	7.5 (9.8)	4.9 (6.5)	—
	20	7.3 (9.8)	5.5 (7.2)	—
	21	8.5(11.4)	7.1 (9.6)	—
	Ave.	6.9(10.0)	5.8 (7.4)	—

iv) A CAFE The proportion of people smoking was recorded during the peak periods of noon to 2 p.m. and 5 to 7 p.m. Average values are given in Table 6. The proportion of people smoking β is much higher than in the previous rooms. The proportion of women smoking is particularly high. Accepting the national values for habitual smokers results in 33% of habitual male smokers and 33% of the habitual female smokers actually smoking at any one time. The distinction between sexes has disappeared here.

4. SMOKING DURATION PER CIGARETTE: T_s , AVERAGE BURNING RATE: V (mm/min), AND SMOKING INTERVAL: S.I. (minutes)

i) AN OFFICE Values for the smoking time, cigarette length and smoking interval are presented in Table 7. The length of cigarette burned is slightly greater in the morning than in the afternoon, but is greatest at lunch time. The time taken in smoking the cigarette is longer during lunch time than during work. The burning rate is correspondingly lower during lunch time. The time interval between starting one cigarette and starting the next is significantly shorter in the morning than the afternoon.

ii) A BANK WAITING ROOM AND A CAFE

The analysis is presented in Table 8. This suggests that smokers are more likely to smoke in a cafe than elsewhere.

iii) A LABORATORY CONFERENCE ROOM.

The smoking behaviour of each smoker in a conference room is presented in Table 9, together with the ones obtained by the same method in an office. There is good agreement. S.I. can be calculated from the knowledge of daily cigarette consumption and the 16 hours awake. Table 9 shows the comparison between the measured value and the estimated value of this elapsed time. The values are quite different. There is also a difference between conference room and office. This suggests that the rate of smoking cigarettes rises during a conference.

Table 6 Proportion of people smoking in a bank waiting room and a cafe

Type of room	Date	Actually smoking	Males actually smoking	Females actually smoking
Bank waiting room	'75 April 1st	5.7	9.9	0.5
	" " 2nd	5.3	9.6	1.2
	Average	5.5	9.7	0.8
a cafe	'75 March 26th	15.9	24.6	4.9
	" " 28th	17.1	26.3	4.9
	Average	16.5	25.4	4.9

5. CONCLUSION

There is a large difference in the proportion α of habitual smokers in men and women. If the number of occupants and the proportion of each sex are known, then the number of people smoking at one time could be estimated roughly from these values of β_M and β_F found in these surveys. If, in addition, the number of habitual smokers in a space is known, then the number smoking at any one time can be estimated with even more accuracy, using this data for β_S , the proportion of smokers smoking. In general, the proportion of people smoking rises in relaxing circumstances such in a cafe, and also in a conference meeting, in comparison with ordinary office work. The particulate matter generated continuously by smoking cigarettes one by one for an hour (mg/hour) is nearly proportional to the rate of burning the cigarette V_s (mm/min). This burning rate is a function of the room use. Values of V_s for a relaxing cafe atmosphere and also for a conference room may be smaller than that for an office. The particulate matter generated will therefore be a function of the product of burning rate V_s and percentage of habitual smoker who are likely to be smoking at any one time. Values of this product, an index of pollution, are given by:

Type of room	β_s^{*1}	V_s^{*2} (mm/min)	$(\beta_s \times V_s)^{*3}$
An office	0.15	9.0	1.4
A conference room	0.28	7.0	2.0
A cafe	0.34	6.8	2.3

*1) Fraction of habitual smokers who will on average be smoking

*2) Burning rate of cigarette

*3) Index of pollution

Table 7 Cigarette smoking in an office

Date	Time (hour)	N ^{*1} (cig.)	n _s ^{*2} (person)	T _s (min/cig.)	L _s ^{*3} (mm/cig.)	V _s (mm/min)	S.I. (min)
10th	9 ~ 12	269	4.6	3.1	37.4	12.1	26
	12 ~ 13	31	2.7	5.2	38.5	7.4	—
	13 ~ 16	236	5.5	4.2	36.1	8.6	30
Sept. '74	11 9 ~ 12	255	6.3	4.4	35.6	8.1	28
	12 ~ 13	28	1.8	3.7	35.6	9.6	—
	13 ~ 16	211	5.1	4.4	33.8	7.7	33
12	9 ~ 12	267	6.4	4.3	35.5	8.3	26
	12 ~ 13	27	2.7	6.0	35.8	6.0	—
	13 ~ 16	203	5.0	4.4	34.0	7.7	35
17th	9 ~ 12	230	6.1	4.8	36.4	7.6	31
	13 ~ 16	180	4.6	4.6	36.7	8.0	39
18	9 ~ 12	224	3.3	2.7	37.3	14.1	31
	13 ~ 16	204	4.4	3.9	37.2	9.6	34
Feb. '75	19 9 ~ 12	301	6.5	3.9	38.6	9.9	23
	13 ~ 16	231	4.2	3.3	35.4	10.8	30
20	9 ~ 12	264	5.9	4.0	36.0	9.0	27
	13 ~ 16	237	4.5	3.4	35.0	10.2	30
21	9 ~ 12	257	7.1	5.0	36.3	7.3	27
	13 ~ 16	229	5.2	4.1	34.9	8.5	31
Average	—	—	—	4.2	36.0	9.0	30

*1) N : Total number of cigarette butts

*2) n_s: Average number of smokers*3) L_s: Average burning cigarette length by smoking

Table 8 Cigarette smoking in a bank waiting room and in a cafe

Type of room	Date	Time (hour)	N (cig.)	n _s (person)	T _s (min/cig.)	L _s (mm/cig.)	V _s (mm/min)
Waiting room	April 1st	11 ~ 15	106	1.8	4.1	37.2	9.1
	" 2nd	11 ~ 15	75	1.4	4.5	40.5	9.0
A cafe	March 26th	12 ~ 14	93	4.2	5.4	37.6	6.9
		17 ~ 19	176	7.2	4.9	37.2	7.6
	" 28th	12 ~ 14	76	3.2	5.1	36.1	7.2
		17 ~ 19	188	10.5	6.7	37.0	5.5

Table 9 Cigarette smoking in a conference room

Smoker	S.C.* (cig/day)	T _s (min/cig)	S.I. (measured) (min)	S.I. (estimated) (min)
A	15	5.0	18.8	64
B	12	5.4	27.8	80
C	25	8.0	17.7	38
D	50 - 60	4.6	8.9	16 - 19
E	20	6.1	26.6	48
F	50 - 60	3.7	11.1	16 - 19
G	30	5.1	17.3	32
H	25	5.5	21.8	38
I	25	7.3	35.3	38
Average	29	5.6	20.6	33
Average (estimated)	—	5.2	21.0	—

* S.C. : Smoking rate of cigarette per day