ENVIRONMENTAL TOBACCO SMOKE IN DUTCH HOMES

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This paper presents an overview of recent studies in The Netherlands on ETS in homes. Exposure to ETS in the home environment is expressed as the percentage of homes with one or more smokers, and as the amount of tobacco consumed inside homes. RSP levels (weekly average & repeated weekly average in living rooms, and instantaneuos levels in kitchen, living room & bedroom) in relation to smoking habits are presented, and the contribution of indoor smoking to VOC levels is discussed.

INTRODUCTION

Probably the first person to study ETS in the Netherlands was Fokker, who, in 1884, exposed rabbits to ETS in public gathering places and subsequently determined the CO-level in the blood of the animals (1). In the Sixties, Biersteker and co-workers measured 'Standard Smoke' (in combination with SO_2 indoors and outdoors at 65 homes in Rotterdam (2). They reported that, on average, the 'Standard Smoke' levels indoors were about 80 % of the outdoor levels. Indoor concentration was positively associated with tobacco consumption. In a study on lead exposure, long-term average concentrations of RSP measured in 84 homes near a secondary lead smelter. In 26 of the homes additional information on indoor smoking was gathered by Brunekreef and Boleij (3).They reported monthly average RSP levels from 20 to 570 $\mu g/m^3$, with a geometric mean of 120 $\mu g/m^3$. Levels in the first and second measurement period correlated highly: r=0.79 (n=76). A clear relation was observed between indoor RSP levels and the number of smoking occupants. In the last decade, several studies in the Netherlands have particularly addressed the problem of exposure to environmental tobacco smoke (ETS) in Dutch homes. This paper presents a summary of this work. The first study was aimed at the characterization of the typical indoor pollutant levels in Dutch homes, in relation to properties of the home and its occupants. Also, exposure indicators were developed for use in future studies. The study involved three measurement programmes: real-time monitoring of CO and NO_2; week-long measurements (during the heating season) of CO, NO_2, RSP and VOC levels in pre and post-war homes in respectively Rotterdam and Ede; and repeated measurements of NO_2, RSP and VOC in different seasons. In the week-long measurement programme, additional information on home characteristics was gathered by inspection, questionnaires and diaries which were filled in during the measurement week (4). After the characterization of indoor pollutant levels, the second study in North-East Brabant was aimed at assessing the impact of indoor exposure to NO_2 and ETS on pulmonary function and respiratory symptoms. In this study, exposure to tobacco smoke in the homes of over 800 children (aged 6 to 10) was assessed

by questionnaire information (5). Parallel to these studies, the mutagenic activity of indoor aerosols was determined in the Ames-test (6).

EXPOSURE TO TOBACCO SMOKE IN DUTCH HOMES

Exposure to ETS can be expressed in terms of number of affected homes, amount of tobacco consumed indoors, or in terms of the concentration of one

Table 1 Percentage of homes with one or more smokers

Town/Region	% with smokers	Reference
Ede (n=174)		
post-war homes	60	4
Rotterdam (n=102)		
inner-city pre-war homes	66	
Ede (n=103)		
homes build after 1976	61	
IJmond (n=559)		
homes with primary-school children	65	7
North-east Brabant (n=779)		
homes with primary-school children	69	5
- with smoking mother	46	
- with smoking father	52	
- with one smoker	39	
- with two smokers	30	

or more constituents of ETS. The percentage of homes with one or more smokers is over 60 % (cf. Table 1). This percentage is fairly consistent over different regions in independent studies (4, 5, 7). According to the diary-information, the geometric mean tobacco consumption was 4 cigarettes per day (range 0-75) respectively 6 cigarettes per day (range 0-51) in Ede and Rotterdam. The indoor tobacco consumption broken down by the number of smoking occupants is presented in Table 2. The table shows that in non-smoker's homes, on average, one or two cigarettes per day were smoked

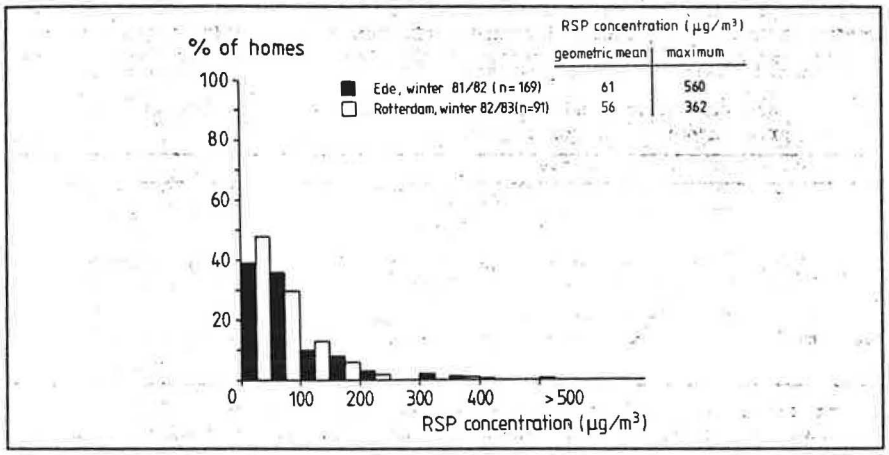
Table 2 Geometric mean and range (in parenthesis) of daily tobacco consumption in Ede and Rotterdam, according to diaries-information, broken down by the number of smoking occupants (4)

number of smoking occupants	daily tobacco consumption in cigarettes/day	
	Ede post-war homes	Rotterdam pre-war homes
0	1 (0-10) n=48	2 (0-12) n=30
1	7 (0-32) n=53	11 (0-33) n=35
2	21 (4-44) n=23	25 (10-44) n=15
3	19 (15-25) n=3	29 n=1
4	66 n=1	7 n=1
all homes	5 (0-66) n=128	7 (0-44) n=82

during the measurement period, presumably by guests. The number of smokers in the home explained 60%, respectively 54% of the variance in the logarithm of the tobacco consumption during the measurement period in Ede and Rotterdam. A large overlap in tobacco consumption in successive groups of the number of smoking occupants was observed (cf. Table 2). In the homes of Ede and Rotterdam weekly average RSP levels were determined in the living room. The distribution of RSP levels is presented in Figure 1. Outdoor levels were averaging approximately 45 $\mu g/m^3$. On average, indoor RSP levels were about 55-60 $\mu g/m^3$, but a wide range was observed. In non-smoker's homes levels were about 30 $\mu g/m^3$.

To explain the variance in the observed indoor RSP levels, multiple regression analysis was carried out with the logarithm of the RSP level as the dependent variable and with three sets of independent variables. In the first set, tobacco consumption was represented by the number of smoking occupants; other independent variables in this set were: family size, frequency of vacuum cleaning, volume of the living room, type of space heating, and location (Ede, Rotterdam). Only the number of smoking occupants had a significant association with the log(RSP), with a R^2 of

Figure 1 Frequency distribution, geometric mean and maximum of weekly average RSP levels ($\mu g/m^3$) in living rooms of homes in Ede and Rotterdam (4)



0.40 (n=254). In the second set, indoor tobacco consumption was represented by questionnaire information about the average daily consumption of cigarettes, cigars and pipes; the other independent variables were as in set one. Here, 49 % of the variance in the log(RSP) was explained by cigarette consumption, cigar consumption and family size. In the third set, diary information about the situation during the measurement week was used as independent variables: 'person-hours', the daily number of people in the home times the hours spent indoors by these persons, represented indoor activity. Information about the percentage of time that ventilation provisions were used in the living room 'use of ventilation provisions' (use ventil. provis.), and about number of cigarettes (# cigarettes), cigars and pipes that were smoked indoors was also obtained from the diaries. The regression equation for the second and third set of variables were:

Set two:

log(RSP)=1.4+0.37*log(# cigarettes)+0.53*log(# cigars)+0.03*log(family size)

R^2 = 0.49; d.f.= 3, 250; F-model=83.70 $p < 0.001$

Set three:

log(RSP)=1.3+0.24*log(# cigarettes)+0.19*log(# cigars)+0.002*log(pers.-hrs)+0.05*log(use ventil.provis.)

R^2 = 0.49; d.f.= 4,179; F-model=43.20 $p < 0.001$

The variables 'frequency of vacuum cleaning', 'volume of the living room', 'type of space heating' or 'location' were not selected in either of the three sets of regression analyses. The difference in the regression coefficients for set two and three were mostly due to differences in range of the independent variables. The standardized regression coefficients for cigarette consumption were 0.65 and 0.64 for set two and three respectively; for cigar consumption this was 0.23 and 0.16. The average contribution of indoor tobacco consumption to weekly average RSP levels, as calculated from these regression equations was 2-5 $\mu g/m^3$ per cigarette smoked per day, and about 10 $\mu g/m^3$ per cigar per day.

In addition to the measurements of weekly average RSP levels, instantaneous RSP measurements were carried out with a TSI Piezobalance in the kitchen, living room and one bedroom on the day that the sample equipment was installed in the homes. The results of these measurements are given in Table 3.
Table 4 presents the effect of prior smoking on the instantaneous RSP levels in the living room. The information on prior smoking explained 53 % of the variance of the logarithm of the instantaneous RSP level in the living room. To establish the relation between simultaneous RSP levels in different locations of the home, pearson correlation coefficients were calculated between the log(RSP) level in kitchen, living room and bedroom. During, or within half an hour after smoking, the correlation between RSP level in the living room with that in the kitchen and the bedroom was 0.44 and 0.40 respectively (n=75, $p < 0.001$). For all homes regardless of prior smoking, these correlations were 0.57 and 0.64 (n=187, $p < 0.001$).

Table 3 Geometric mean (and range) of instantaneous RSP levels ($\mu g/m^3$) in three indoor locations in two towns (4)

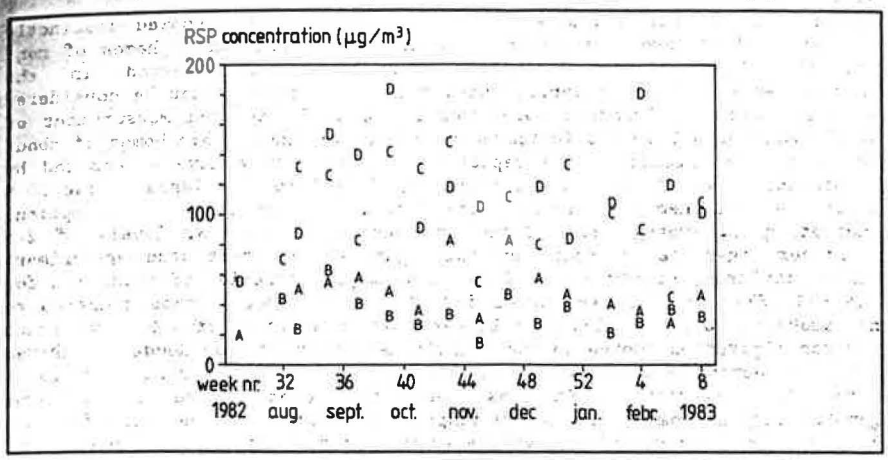
	Ede	Rotterdam
kitchen	61 (10-769) n=112	78 (10-780) n=95
living room	68 (10-681) n=121	80 (10-1000) n=92
bedroom	47 (10-255) n=105	54 (10-1000) n=94

Table 4 Geometric mean of instantaneous RSP levels ($\mu g/m^3$) in living rooms, broken down by prior smoking (4)

Time since smoking		Geom. mean RSP level
no smoking	n=98	41
more than one hour ago	n=18	52
between half and one hour ago	n=7	76
less than half an hour ago	n=27	141
during the measurements	n=54	191

Repeated indoor measurements of RSP in the living room were obtained from four homes during 16 weeks between July and March (cf. Figure 2). Smoker's

Figure 2 Weekly average RSP levels ($\mu g/m^3$) in four homes (A, B non-smoker's homes; C, D smoker's homes) versus time (4)



homes had consistently higher levels than non-smoker's homes. During the two weeks that home A had higher than usual RSP levels, a smoking guest visited the house. Using analysis of variance, reliability coefficients were calculated for these repeated measurements. The reliability coefficient of a single week-long RSP measurement was 0.69, indicating that about 30 % of the total observed variance could be considered error variance or 'noise', and 70 % as the true variance between homes.

Indoor tobacco consumption also appeared to have an effect on the levels of VOC measured in the study (4, 8, 9). Although the measured VOC cannot be

Table 5 Geometric mean of straight-chain and aromatic hydrocarbon levels ($\mu g/m^3$), broken down by presence of smokers in the home and solvent use during the measurement week

Compounds	presence of smokers	solvent use	
		no	yes
straight-chain hydrocarbons	no smokers	39 (n=110)	66 (n=17)
	smokers	54 (n=168)	185 (n=23)
aromatic hydrocarbons	no smokers	67 (n=110)	104 (n=17)
	smokers	87 (n=168)	226 (n=23)

considered dominant constituents, nor typical indicators of tobacco smoke, many VOC have been identified in ETS. The concentrations of n-hexane, benzene, toluene, xylenes, ethylbenzene, i-propylbenzene, 1-methylnaphtalene, and 1,2,3-trichlorobenzene had a significant correlation coefficient in both Pearson (with and without logarithmic transformation) and Spearman correlation analysis with the indoor RSP level, as well as with the number of cigarettes smoked indoors (according to diary-information). The impact of indoor tobacco consumption on the VOC levels in

homes was also visible after taken the indoor use of solvents into account (cf. Table 5).

DISCUSSION

Measurements of RSP and other air pollutants like VOC showed distinctly elevated indoor levels in homes of smokers in comparison to homes of non-smokers. Considerable within-home variation was observed in the instantaneous RSP measurements, showing that the home cannot be considered a single micro-environment for exposure to ETS. Repeated measurement of weekly average RSP levels indicated an error variance within homes of about 30 %, a good agreement with repeated monthly average levels reported by Brunekreef & Boleij (3). Of the remaining 70 % 'true' variance, about 50 % could be explained by questionnaire information on tobacco consumption, indicating an average contribution to weekly average RSP levels of 2-5 $\mu g/m^3$ per cigarette. Houthuis and colleagues (5) in their study on primary school children, observed a decline of pulmonary function of about 1 % for the FVC, FEV_1 and PEF, and about 3 % MMEF for smoker's homes compared to non-smoker's homes. An increase in respiratory symptoms of 4-9 % was found per ten cigarettes smoked in the child's neighborhood. van Houdt (6) showed that in Dutch homes indoor particulate matter may contain mutagenic compounds; cigarette smoke was the predominant source of airborne genotoxicity in homes. ETS is a widespread problem in the Netherlands; with 62 % smoker's homes and an average occupancy rate of 1.6 for non-smokers (assuming that only one occupant smokes) there are $5.5*10^6$ non-smokers (out of a population of approx. $15*10^6$) exposed in the home environment in the Netherlands. In the year 2010 this is expected to be $2.9*10^6$, with an estimated 36 % smoker's homes and an occupancy rate for non-smokers of 1.2 (10). This forecast is based on a yearly 2 % cumulative reduction in percentage of smokers.

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