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Addition of Olfs from Different Pollution Sources, determined by a Trained Panel

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Abstract

The purpose of this study was to predict how indoor air is perceived when polluted by different materials simultaneously. A panel of five trained judges was exposed to air polluted by each of 11 different single pollution sources. The panel was also exposed to 13 pair combinations of these single pollution sources and to one combination of five sources. The pollution sources comprised typical indoor building materials, materials from ventilation systems and other frequently occurring indoor pollution sources. The results indicate that the total sensory pollution load in a space may, as a first approximation, be predicted by simple addition of the olf values of the single sources.

KEY WORDS:
Indoor air quality, Olf, Trained panel, Addition, Pollution, Materials.

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Introduction

The main task of ventilation in nonindustrial buildings is to provide air acceptable to human beings. Although the ventilation rate follows existing ventilation standards, people do not always find the air acceptable. Chemical and physical measurements have frequently been unable to identify reasons for complaints of poor indoor air quality. The human nose is at present the only instrument available for judging perceived air quality.

The perceived air quality, expressed in decipol, is the combined response of two senses: the olfactory sense, sensitive to odours, and the common chemical sense, sensitive to irritants. One decipol is defined as the perceived air quality in a space with a pollution source strength of one olf, ventilated with 10 l/s of unpolluted air. One olf is defined as the pollution from a standard person (Fanger, 1988). Any other pollution source may be quantified by the number of olfs (standard persons) required to make the air just as annoying as the actual pollution source.

Existing ventilation standards (ASHRAE, 1989; DIN, 1983) are mostly based on the number of occupants. However, previous studies have identified that materials in buildings and ventilation systems can be important pollution sources (Fanger et al., 1988).

The required ventilation rate in a space depends on all pollution sources present, and not only the occupants. Recently Fanger introduced a comfort equation for indoor air quality (Fanger, 1989). The model predicts the ventilation required to obtain a desired perceived air quality (in decipol) in a space. The model acknowledges all pollution sources, i.e. both the occupants and the many materials present in the space.

The perceived air quality is a combination of the perceived air qualities caused by all the different individual sources. The question is whether this combination can be predicted by simple addition of the olf values of each source in that space.

Berglund et al. (1976) did not study emissions from materials directly, but investigated mixtures of two to five individual gases in the laboratory. They established a vector model predicting the odour intensity to be equal or less than the simple addition of the odour intensities of the individual gases.

In real buildings, conditions are more complex. Typically, thousands of gases are emitted from numerous sources. Lauridsen et al. (1988) investigated five materials, human bioeffluents and tobacco smoke individually or mixed in eight combinations. A panel of 88 untrained judges evaluated whether the air quality was acceptable or not. The data showed no evidence that the simple model of adding olf values from single pollution sources should provide either an over- or an underestimation of the perceived air pollution caused by the mixture.

The purpose of this paper is to study the addition of a wide range of pollution sources by using a panel of judges trained to assess the air quality directly in decipol (Bluyssen, 1990).

Large panels of untrained subjects were used to evaluate the air quality in office buildings (Fanger et al., 1988). An alternative is to use a smaller panel of trained subjects.

The definitions of the olf and the decipol are based on the dissatisfaction caused by human bioeffluents from a standard person (Fanger, 1988). In practice it is hard to produce such a reference since human bioeffluents comprise a large number of chemical compounds and vary considerably from person to person. To be able to train a panel to evaluate perceived air quality directly in decipol instead of using an acceptability scale, a reference gas (2-propanone) was identified and the relation to the perceived air quality in decipol was determined in earlier studies by 265 untrained subjects (Figure 1) (Bluyssen et al., 1989). A method to train a panel to evaluate perceived air quality directly in decipol using this reference gas has been developed as well (Bluyssen, 1990). A short de-

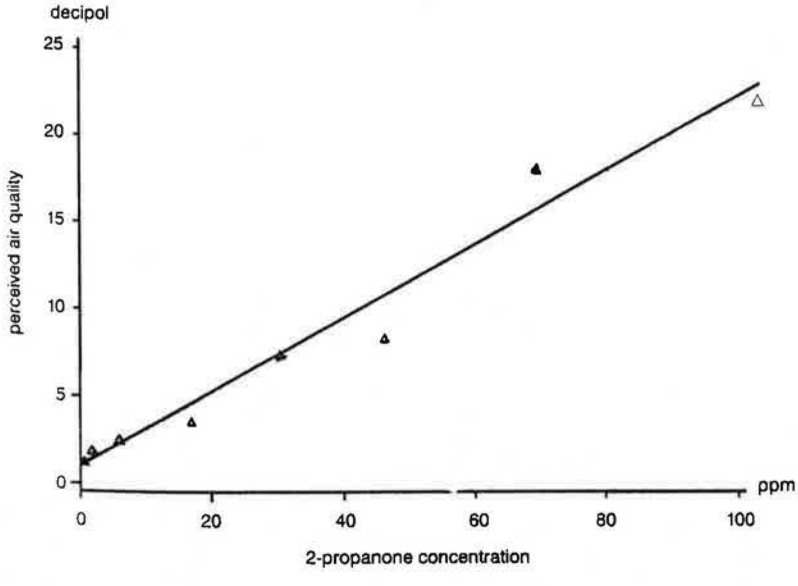

Fig. 1 The relation between perceived air quality in decipol and 2-propanone concentration (ppm). Each point is based on votes of 265 untrained subjects (decipol = 0.84 + 0.22 × ppm; R^2 = 0.97).

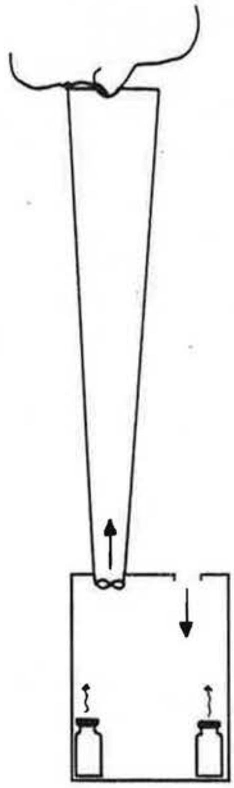

Fig. 2 Instrument to expose a human subject to a certain 2-propanone concentration (decipolmeter). By varying the number of bottles with 2-propanone and the diameter of the hole in the cap of these bottles, different concentrations can be established.

scription of this training method will be given in this paper.

Method

Training

The first step is to select suitable persons to be trained. In previous studies (Bluyssen, 1990) it has been found that a selection of persons for a panel to be trained to evaluate air quality in decipol can be based on an entrance test determining the ability to evaluate 2-propanone (the reference gas).

During the selection and the training the relation between the decipol and the 2-propanone concentration, obtained from previous experiments with the 265 untrained subjects, served as the reference curve (Figure 1). Four different 2-propanone concentrations (decipol levels) generated by four decipolmeters (Figure 2) were prepared. The production of 2-propanone in air was based on passive evaporation of pure liquid 2-propanone from 30-ml bottles placed in a 3-litre glass jar. Air is sucked through the jar by an axial fan and the polluted air leaves the jar through a diffuser. An airflow of 0.86 l/s is sufficient to ensure that all air inhaled by a subject at the top of the diffuser has passed the jar (no "false" air).

During the training, four perceived air qualities (2, 5, 10 and 20 decipol) served as references ("milestones") for the panel members. Several unknown air qualities were evaluated using the four milestones as a reference. The procedure of judging was as follows (Figure 3): a panel member was exposed to an unknown 2-propanone concentration and then asked to compare it with the milestones and to determine the perceived air quality (in decipol). The panel member was allowed to go back and forth between the unknown 2-propanone and the milestones as frequently as he or she required. However, one sniff of any 2-propanone level should be followed by at least two inhalations of room air before another sniff was taken. This procedure prevented the panel member from adapting. After the judgement the correct answer was given to the panel member, who

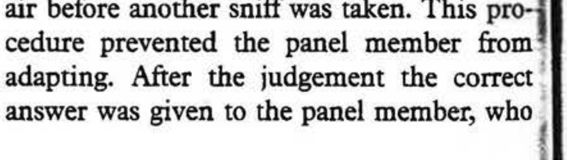

Fig. 3 The four "milestones" (2, 5, 10 and 20 decipol) and a decipolmeter with an unknown decipol level.

Table 1 The selected pollution sources

Building materials	
	carpet (pile fibre: polyamide; backing polypropylene and synthetic latex)
	rubber doormat
	sealant (silicon caulking)
	painted metal plate (acrylic-based)
	linoleum
Ventilation system materials	
	panel filter (glass fibres)
	rotating heat exchanger (silica-based material)
	humidifier paper
	galvanised steel
Other sources	
	newspapers
	cigarette butts

was asked to percieve the "unknown" level again to compare the correct answer with his/her own judgement.

During the training the panel members were also exposed to other pollution sources than 2-propanone, including several common materials from buildings and ventilation systems.

The training of a selected panel of untrained subjects required at least 30 minutes per day during three days. The panel members were trained in groups of four persons and each panel member evaluated seven unknown 2-propanone levels per day and several other pollution sources.

Subjects

Five panel members were selected among a group of 20 trained judges. They were all students between 18 and 30 years of age who were trained to evaluate perceived air quality in decipol. The selected panel members were re-trained for one hour. Nine unknown levels were evaluated.

Pollution Sources

Eleven pollution sources commonly present in many nonindustrial buildings were selected for the study. These 11 pollution sources represented three groups of sources: materials frequently used for construction and furniture in buildings, materials often used in ventilation systems, and sources related to occupant activities. Data for the selected sources are given in Table 1. All sources except the newspapers and the cigarette butts had been stored in closed jars for approximately one year.

Fig. 4 A trained panel member evaluating a pollution source at the bottom of the jar.

Procedure

Ventilated jars (decipolmeters) were used to expose the subjects to air polluted by different sources (Figure 4).

The source was placed at the bottom of the jar. Each subject placed his/her nose at the top of the diffuser to perceive the outcoming air.

The 11 single sources, 13 pair combinations of these sources and one combination of five single sources, were placed in ventilated jars, located in a well ventilated room with a constant temperature of 22 °C. It is rather well established that the strength of a pollution source is proportional to the amount of that source present in a space. To make the com-

Table 2 Source strength of each individual material

	Perceived air quality[a] (decipol)			Source strength[b] (olf)	Reproducibility[c] (%)
	1st	2nd	mean		
Carpet	10.2	10.7	10.5	0.90	2
Rubber doormat	15.4	14.4	14.9	1.28	3
Sealant	14.2	6.0	10.1	0.87	41
Paint	2.2	3.4	2.8	0.24	21
Linoleum	4.6	3.2	3.9	0.34	18
Filter	2.5	5.4	4.0	0.34	36
Heat exchanger material	11.1	10.1	10.6	0.91	5
Humidifier paper	6.6	7.2	6.9	0.59	4
Galvanised steel	1.4	1.7	1.6	0.14	9
Newspapers	6.4	6.6	6.5	0.56	2
Cigarette butts	17.0	17.0	17.0	1.46	0

[a] The perceived air quality caused by each source was evaluated twice (1st and 2nd evaluation). The mean is the average of these two evaluations.

[b] The source strength for each source was determined from the mean perceived air quality.

[c] The reproducibility is defined as the standard deviation of the perceived air quality divided by the mean value.

Table 3 Measured and predicted source strength of mixtures of materials

	Perceived air quality[a] (decipol)			Source strength[b] (olf)		Reproducibility[c] (%)
	1st	2nd	mean	measured	predicted	
Carpet and linoleum	8.2	8.6	8.4	0.72	0.62	2
Rubber doormat and sealant	11.6	8.9	10.3	0.89	1.08	13
Rubber doormat and paint	9.8	7.4	8.6	0.74	0.77	14
Rubber doormat and linoleum	9.5	11.8	10.7	0.92	0.81	11
Sealant and paint	4.9	4.2	4.6	0.40	0.56	8
Paint and linoleum	4.2	2.0	3.1	0.27	0.29	35
Filter and heat exchanger material	9.8	7.5	8.7	0.75	0.64	13
Filter and humidifier paper	8.3	6.8	7.6	0.65	0.47	10
Filter and galvanised steel	3.1	2.0	2.6	0.22	0.24	21
Heat exch. mat. and hum. paper	6.2	8.2	7.2	0.62	0.76	14
Heat exch. mat. and galv. steel	9.2	8.1	8.7	0.75	0.52	6
Hum. paper and galv. steel	3.5	3.9	3.7	0.32	0.37	5
Newspapers and cigarette butts	13.0	10.2	11.6	1.00	1.01	12
Carpet, paint, filter, galv. steel and newspaper	4.8	5.3	5.1	0.44	0.44	5

[a] The perceived air quality of each source was evaluated twice (1st and 2nd evaluation). The mean is the average of these two evaluations.

[b] The measured source strength was determined from the mean perceived air quality; the predicted source strength for a pair combination was determined by adding half of the olf values of the single sources determined in Table 2. For the combination of five, one fifth of the olf values of the single sources was added.

[c] The reproducibility is defined as the standard deviation of the perceived air quality divided by the mean value.

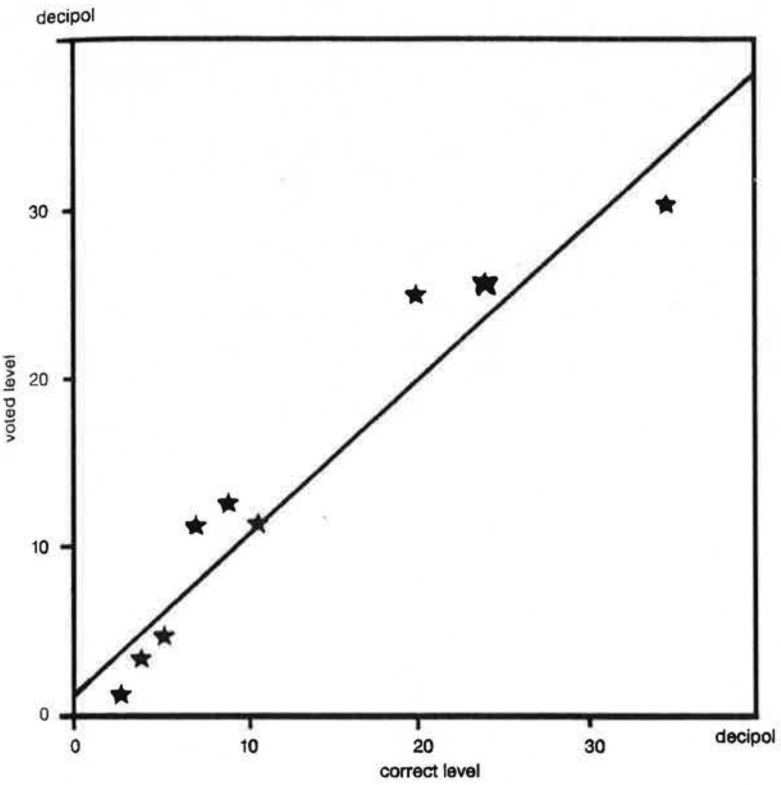

Fig. 5 Performance of the trained panel during the re-training period. The relation between voted and correct decipol levels when the panel was asked to judge air polluted by nine different concentrations of 2-propanone (voted = 1.4 + 0.92 × correct; R^2 = 0.97).

binations of materials provide a perceived air quality of a similar order of magnitude as the single source, it was decided to make pair combinations comprising half the amount of the single sources. Similarly, the combination of five sources was established by using one fifth of each single source.

Tables 2 and 3 show the exposures, including the single materials and the combinations. After re-training, the panel evaluated all single sources and source combinations twice on the same day in random order. To make certain that the condition of the sources was the same, each jar was on average ventilated 10 minutes before the evaluation. The perceived air quality was evaluated in decipol by comparison with the "milestones".

Results

The performance of a panel or panel member can be assessed by comparing the given decipol votes to the correct decipol values for the unknown 2-propanone levels. The reproducibility when exposed several times to other pollution sources is another measure of the performance.

The linear regression of all given votes versus the correct values indicates the performance. The ideal relation occurs when the vote is identical to the correct value. Figure 5 shows the relation between the given votes and the correct levels during the re-training of the panel of five persons.

The mean difference between the correct decipol value and the voted decipol value divided by the correct decipol value for all evaluated levels per day, the so-called performance index, together with the standard deviation, describes the performance of the training level of a panel or panel member. The present panel had a mean performance index of 17% with a standard deviation of 15%.

Several evaluations of the same pollution source provide information on the reproducibility of a panel or panel member. The standard deviation around the mean for two or more repeated evaluations of a source, divided by the mean of that source, determines the reproducibility of a panel member or of the whole panel for that source. A standard deviation of zero is ideal. After the re-training the trained panel evaluated single sources and combinations of sources, each two times. For each of the 11 single pollution sources and the 14 different combinations, the mean voted decipol values of the panel and the corresponding source strength in olfs are given in Tables 2 and 3. The reproducibility, defined as the standard deviation divided by the mean vote, was on average 12%.

The predicted source strength of a pair combination was calculated by simple addition of half the source strength of the single sources. For the combination of five, one fifth of the source strength of the single sources was added. Figure 6 presents the relation between the predicted source strength and the measured source strength for the 14 combinations.

Discussion

The selected panel of five trained panel members in this study had a mean performance index of 17% with a standard deviation of 15% and a mean reproducibility of 12%. A regression line of voted and correct values with an intercept of 1.4 and a slope of 0.92 was established (Figure 5). In earlier studies (Bluyssen, 1990) the mean performance index of trained panels was below 20% with a standard deviation below 40% and the mean reproducibility for other pollution sources than 2-propanone was around 8%. The previous trained panels established a regression line of voted and correct decipol values with an intercept of 1.3 and a slope of 0.81.

Considering the retraining results and the reproducibility of the panel in this study, it can be concluded that the panel was well trained.

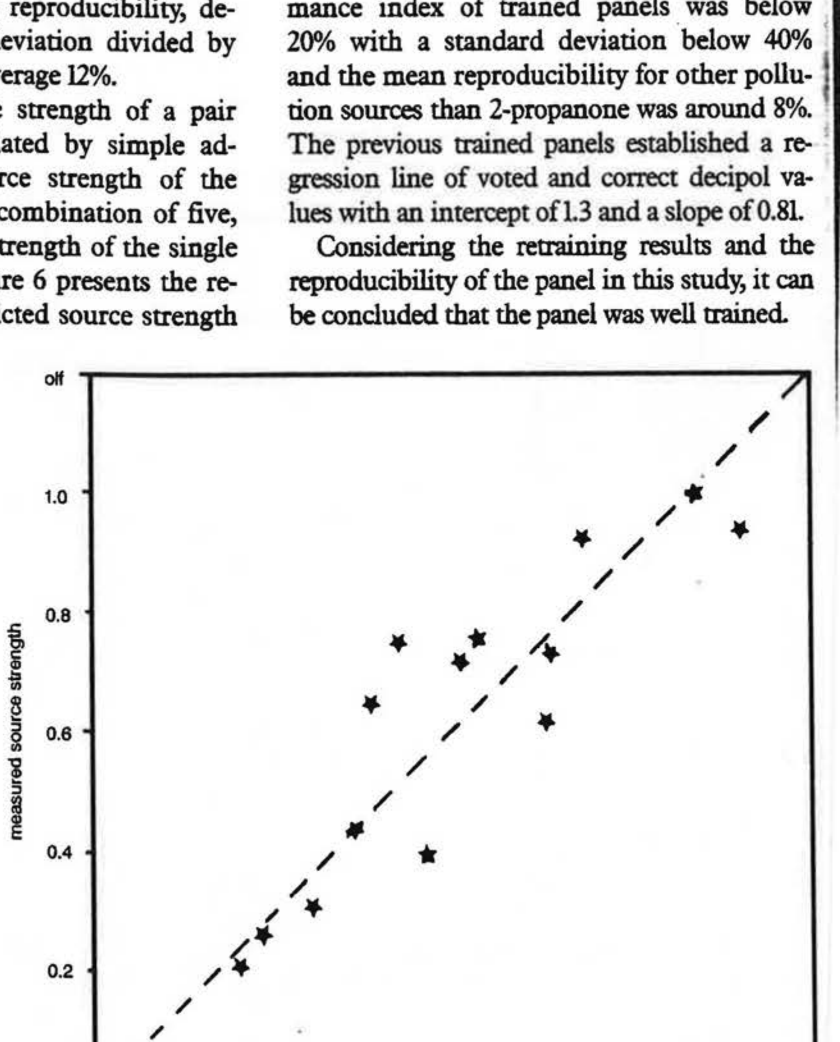

Fig. 6 Relation between measured and predicted olf values for mixtures of sources.

The results presented in Figure 6 indicate that the sensory pollution load (the source strength) in a space may be found by simple addition of the load (the strength) of the single sources. This confirms the findings of Lauridsen et al. (1988) for other sources. Still there is a need for further studies of a wider range of materials and mixtures.

It should be emphasized that when predicting perceived air quality based on the olf and the decipol units, simple addition of different pollution sources does not necessarily apply. Further research may show that air qualities caused by mixtures of some materials may be perceived stronger or weaker than simple addition predicts. But it may be noted that simple addition of sources also applies to perceived light and noise. The illumination in a space can be predicted by adding the strength of widely different light sources (in lumen). Noise can be predicted by adding the strength of widely different noise sources (in watt). The addition of sources also applies to the thermal environment. The temperature of a space may be predicted by adding widely different heat sources in the space (in watt).

The present data indicates that it is a fair approximation to add pollution sources expressed in olfs. But it should be noted that the strength of a pollution source may not be constant. It may be influenced by the pollution level in the space, the air temperature, the relative humidity, the air velocity around the source and the age of the source and its emitted pollutants. Each source may be differently related to these parameters of the space.

The perceived air quality (in decipol) in a space with different sources may also be found by adding perceived air qualities caused by each single source. But although 1 decipol + 1 decipol = 2 decipol, it does not follow that 2 decipol is perceived twice as strong as 1 decipol. On the contrary, it is well known that the perceived intensity of air pollution similar to the perceived intensity of sound and light, is related to the logarithm of the physical exposure. But the decipol scale does not express intensity of odour or irritation. It is an expression of the degree of nuisance or the percentage of persons predicted to be dissatisfied. There is therefore no contradiction to the finding of Berglund et al. (1976) that the odour intensity of two gases is less than or equal to that obtained by simple addition of the intensities of each individual gas.

Conclusions

- A trained panel was used to determine the source strengths of different pollution sources and combinations of those pollution sources.

- In spaces with different pollution sources the total source strength may, as a first approximation, be predicted by simple addition of the olf values of the single sources.

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