Formaldehyde in the indoor environment - health implications and the setting of standards

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Abstract: Exposure to formaldehyde vapour causes irritation especially of the eyes and upper airways; skin irritation may occur. The background conc. in outdoor air is ab. o.o5 mg/m^3. Indoor conc. up to 1-2 mg/m^3 have been found in rooms with emanations from construction materials made of resins. The literature on the biological effects of formaldehyde is reviewed, and the results of an exposure of 16 young healthy subjects to o.3, o.5, 1.o or 2.o mg formaldehyde/m^3 air during 5 hours are described. There was no change in airway resistance. The odour threshold (ethyl valeriate) was increased at 2.o mg/m^3. A small decrease in nasal mucus flow was found in the first part of the nose at all concentrations except 1.o mg/m^3. Eye irritation and dryness in the nose and throat was experienced by 3 subjects at o.3 and by 15 at 1.o mg/m^3. There was no change in performance.

A standard for continuous exposure protecting all but subjects sensitized to formaldehyde against any adverse health effect and the majority of the subjects against discomfort is suggested at or lower than o.15 mg formaldehyde/m^3 air.

Formaldehyde is a gas, which is toxic to most forms of life due to its ability to coagulate proteins.

Formaldehyde is an important, very cheap, high volume chemical, which is used in a wide variety of products - mainly phenolic, urea, melamine and acetal resins. These resins are used in great quantities in the building industry for the production of chipboard, plyboard, insulation materials, adhesives, textiles, papercoatings etc.

Formaldehyde in the indoor environment.
Formaldehyde in the indoor non-industrial environment derives mainly from two sources - infiltration of outdoor air and background emission from construction materials, fixtures, textiles etc.

In Los Angeles the average outdoor background conc. is appr. o.o5 mg/m^3. Auto exhaust add to this concentration; further hydrocarbons in the exhaust are photochemically converted to formaldehyde. The maximum concentrations measured are ab. o.18 mg/m^3 (1). In Denmark at our laboratory, which is situated in an area without trafic, the average ambient concentration is o.o4 mg/m^3.

The first comprehensive study of formaldehyde in the indoor environment was made in Denmark. After a series of complaints about eye and upper airway irritation in new homes we made a survey of 25 homes less than five years old and found an average formaldehyde conc. of o.62 mg/m^3 (SD = o.2o). The highest value was 2.24 mg/m^3, which is above the Danish TLV (threshold limit value) for workrooms (1.2 mg /m^3). The main source of formaldehyde was chipboard, which in Northern Europe is used as a construction material for walls, floors and ceilings and for fixtures and furniture. Combining the results of the study in the homes with a climate chamber study of the formaldehyde emission from chipboard, a mathematical model for the room air concentration of formaldehyde was developed, which may be used for prediction purposes. Also a preliminary standard for continuous exposure to formaldehyde was proposed at o.4o mg/m^3 (2).

The Danish chipboard producers after this changed the production methods to make boards with a lower formaldehyde emission. In 1976 we made a new investigation of homes, where the new type of chipboard was used. The formalde-

hyde concentration in the air was then ab. o.3o mg/m^3, which is ab. 5o% of the 1973 value.

In Sweden, Norway, Germany, the Netherlands and US complaints due to formaldehyde conc. in indoor air from o.5 to 3 mg/m^3 also have been reported recently.

Biological effects of formaldehyde vapours. Formaldehyde is very soluble in water (98o l per l water at 2o°C and 76o mmHg) for which reason its main effects on human subjects in non-lethal doses are irritation of the mucous membranes of the eyes, nose and upper respiratory tract. Skin irritation may be observed in sensitive subjects.

Most subjects can tolerate but are discomfortable due to irritation of mucous membranes at 2-4 mg formaldehyde/m^3; the individual variability is great. Above this level coughing, sneezing, lacrimation, dyspnoe, feeling of suffocation etc. occur immediately. During short term exposures of 5 minutes duration eye irritation has been reported at o.ol mg/m^3. This is hardly probable as this concentration is lower than the background conc. in outdoor air, and as in the same study the irritation was found to be equivalent at o.o7 and o.7o mg/m^3 (3). In the rat o.6 mg formaldehyde/m^3 air depresses the response of the trigeminus nerve to amyl alcohol. The decrease is related by a power function to stimulus conc. (4).

In experiments with guinea pigs exposed during 1 hour periods to various conc. of formaldehyde airway resistance was increased at o.4 mg/m^3. The resistance was found to increase in accord with the conc. of formaldehyde. Aerosolized NaCl, which was inert by itself, increased the effectiveness of formaldehyde in heightening resistance (addition effect) (5). No studies of the effect of for-

maldehyde in combination with dust e.g. house dust have been made.

The odour threshold values for formaldehyde reported in the literature varies widely. The highest threshold reported is 1.2 mg/m^3 and the lowest is o.o3 mg/m^3 (6). In a recent, well designed acute exposure experiment comprising 64 subjects (17-63 years) the odour threshold was o.o5 mg/m^3; half of the subjects had 6 correct hits in 6 trials at o.17 mg/m^3 (7). The ability to perceive the odour of formaldehyde is blunted within 1-2 hours of exposure but this ability returns when the exposure is interrupted by lunch or upon returning the following day (8).

In the airways low levels of formaldehyde stop the mucociliary flow. Exposure to o.6 mg/m^3 for 15o seconds causes cessation of the ciliary movement and mucous transport in the respiratory tract in anestetized tracheotomized rats (9), this mucostatic effect of formaldehyde has been confirmed in other animal experiments (1o). During nasal breathing the retention of formaldehyde from the nose to the tracheal bifurcation in the dog exceeds 95% at a conc. of 35o mg/m^3 (11). This indicates, that at lower conc. and during normal nasal respiration only very small amounts will reach the lower airways and the lungs.

Several Russian investigators (e.g. 12) have shown that inhalation of low conc. of formaldehyde will affect the central nervous system, but the practical consequence of these investigations is difficult to estimate.

After absorption the body efficiently detoxifies small quantities of formaldehyde. The liver and the erythrocytes have enzymes for oxidation of formaldehyde to formic acid. There is no evidence of significant cumulative effects, and studies to date have failed to indicate any gross teratogenic or mutage-

nic response to formaldehyde. It is unlikely that it is a strong carcinogen in mammals (1o).

Hypersensitivity to formaldehyde in the form of contact dermatitis is well recognized and occupational formaldehyde astma has also been reported. No case of astma or dermatitis developed due to exposure to the low conc. (<2 mg/m^3) met in the home or in the non-industrial environment has been described.

A five hour exposure study.

In order to obtain a better background for the setting of a standard for indoor air in homes we have recently studied the effects of five hour exposures to o.3, o.5, 1.o and 2.o mg formaldehyde/m^3. The study took place under controlled conditions in an exposure chamber supplied with fresh, particle free air at 23°C and 5o% RH. The subjects were 16 healthy young subjects studied in groups of four in the chamber seven to eight hours a day during four consecutive days. The order of exposure to the four different formaldehyde concentrations was assigned at random. Each day after a control period of two hours duration in clean air formaldehyde was added to the air. After about 1 hour a steady state conc. was reached, and this was maintained during the rest of the day. Formaldehyde was generated by heating paraformaldehyde. The weight loss was measured continuously and further the formaldehyde conc. in the chamber was measured by the cromotropic acid method.

We measured physiological parameters (nasal resistance, tracheo-bronchial resistance with the single breath test, the odour threshold for ethylvaleriat and nasal mucociliary flow), subjective discomfort (with a voting apparatus) and performance (speed of accuracy of

multiplication, of addition and of card punching). The procedures have been described in details in other publications (13, 14). Each measurement was performed three times each day - once in the control period in clean air, and twice during the exposure period - after 1 to 3 hours exposure and again after 3 to 5 hours exposure.

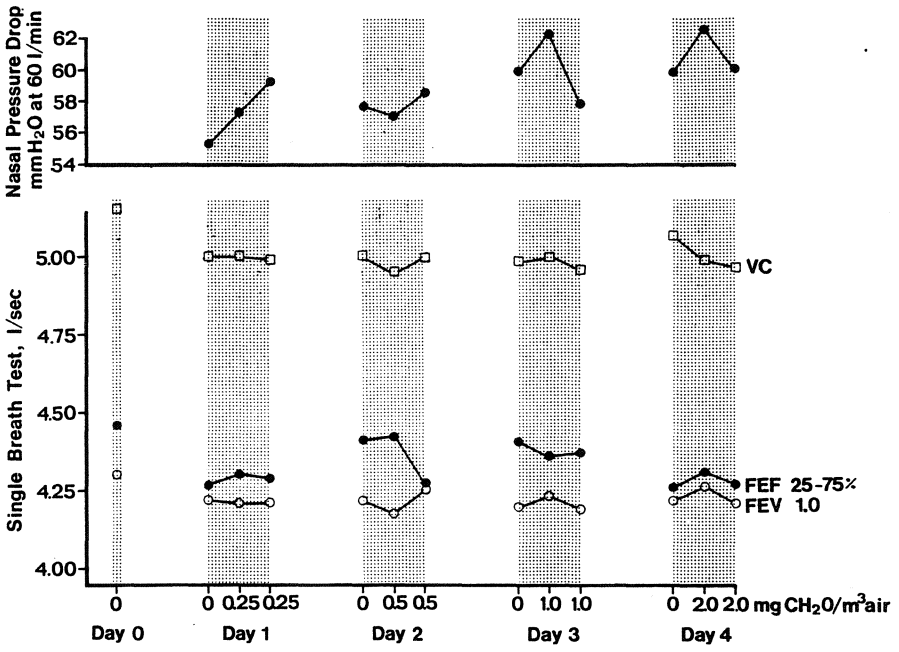

Figure 1. The variation with time of the averages of nasal pressure drop (upper part), of vital capacity (VC), forced expiratory flow ($FEF_{25-75\%}$) and forced expiratory volume during the first second of the expiration ($FEV_{1.0}$) (lower part). The interval between the measurements each day is appr. 2 hours.

The result of the measurements of flow resistance in the airways is shown in fig. 1. The standard deviations for the nasal pressure drop, VC, $FEF_{25-75\%}$ and $FEV_{1.0}$ are about 15, 1, 1.1 and 0.9 respectively. There was a tendency to increase in nasal pressure drop at higher concentrations, but there was no statistically significant changes in any of the airway resistance parameters not even at 2.0 mg/m^3 during

5 hours. At this concentration there was a significant increase in the odour threshold for ethylvaleriate after 2 and after 4 hours exposure; at the lower concentrations the odour threshold was unchanged. The nasal mucus flow rate was reduced in the first third of the nose at all conc. except at 1.o mg/m^3. The reduction was greater after 4 than after 2 hours exposure. The greatest reduction in nasal mucus flow was from o.5 to o.24 cm/min. Mucostasis was never found, and no changes occurred in the mucus flow rates in the posterior two thirds of the nose.

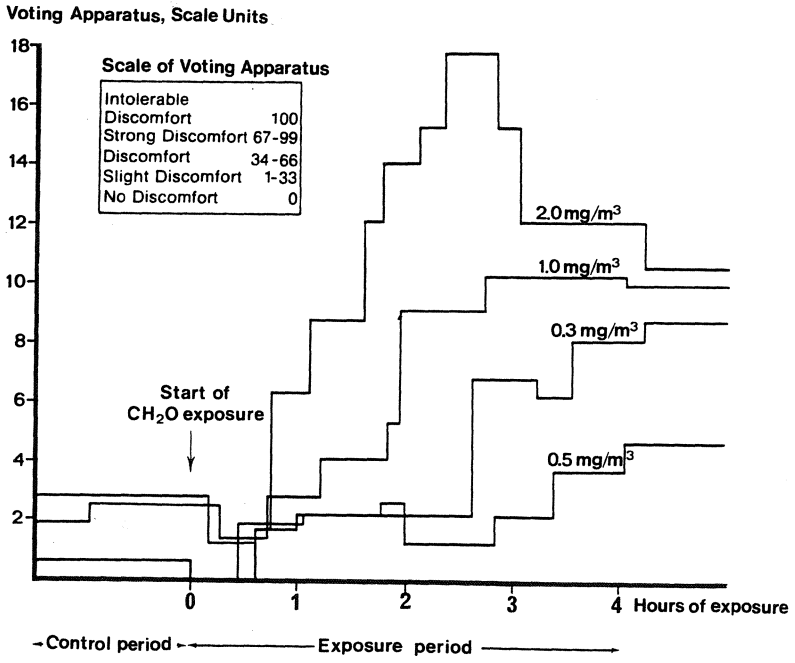

Figure 2. Variation with time of the mean discomfort vote in scale units at the four different conc. of formaldehyde. In the control period clean air without formaldehyde was supplied to the subjects.

The subjective discomfort votings are shown in fig. 2. It appears, that a direct relationship between conc. and response only exists above 1.o mg/m^3, and that the discom-

fort at 2.o mg/m^3 is lower in the last part of the exposure period than in the first part indicating that acclimatization occurs. Even at the highest conc. the discomfort was low, it never exceeded 18 scale units, which was in the middle of the "slight discomfort" range. After the exposure the subjects were asked about the character of their symptoms. The complaints were mainly conjunctival irritation and dryness in the nose and throat. After the exposures to o.3, o.5, 1.o and 2.o mg/m^3 3, 5, 15 and 15 subjects respectively had these complaints. There was no carry-over symptoms, the following morning all subjects were without complaints. Symptoms from the lower airways were never experienced.

The performance of the subjects measured by the speed and accuracy in addition and multiplication tests and of card punching was the same at all conditions.

Setting of a standard for continuous exposure to formaldehyde in the indoor non-industrial environment.

So far standards for continuous exposure mainly have been set for pollutants in outdoor air. In USSR this standard for formaldehyde is o.o35 mg/m^3 (12). In Europe or USA no official standards for formaldehyde in outdoor air exist, but o.12 mg/m^3 has been suggested (15). The American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) in its ventilation standards 62-73 and 9o-75 specifies, that air used for ventilation purposes in the indoor environment must not contain contaminants at concentrations greater than 1/1o af the TLV. With the present US TLV (1977) for workrooms at 3 mg/m^3 the standard for indoor would be o.3 mg/m^3 and with the proposed TLV standard at 1.2 mg/m^3 (8) o.12 mg/m^3. For spacecrafts it has

been suggested, that o.12 mg/m^3 would allow an adequate margin of safety for either 9o or looo day missions (16).

The basis for the setting of any standard for continuous exposure should be that all but the sensitized subject are protected against adverse health effects. Further the majority of the subjects should not experience discomfort or decrease of performance.

From our exposure study at controlled conditions it appears, that even at o.3 mg/m^3 3 of 16 subjects had eye and airway irritation, there was no changes in airway resistance but a significant, although small decrease in nasal mucociliary flow. With an odour threshold of o.o5 mg/m^3 in acute exposures and 6 correct hits in 6 trials of half of the subjects at o.17 mg/m^3 (7) a standard of continuous exposure at or lower than o.15 mg/m^3 would comply with the suggested basis for standard setting. This is 3 to 4 times higher than the background concentration in outdoor air and ab. 5o% of the threshold for objective biologic response, which in animals is ab. o.4 mg/m^3 (5), and in the present study on human subjects lower than o.3 mg/m^3.

The proposed value at o.15 mg/m^3 is 1/8 of the present Danish and German TLV-value for workrooms. The Russian PDK-value for workrooms is o.5 mg/m^3. Converting the TLV-value for intermittant exposure to a value for continuous exposure (even if TLV's are not intended for that use, as they are not uniformly generated) the TLV has to be multiplied by 4o/168, the fraction of time one is exposed to a working place environment. The higher susceptibility of young children due to their higher respiratory frequency (about twice that of adults) is taken into account by multiplying with o.5. From the Danish and German TLV-value we then get:

Continuous Exposure Value (CEV) =

$$1.2 \cdot \frac{40}{168} \cdot \frac{1}{2} = 0.14 \text{ mg/m}^3$$

which is very near the proposed standard.

To obtain greater certainty in the setting of standards for continuous exposure, studies especially designed for that purpose are needed.

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DISCUSSION

R. Baars
Ministry of Public Health and Environmental Protection NL

Following on Mr. Andersen's discussion of the effects on human health of formaldehyde present in the air inside buildings and hus remarks on the establishment of standards, I can tell you that in the Netherlands we recently introduced a maximum level for formaldehyde concentrations indoors.

I should like now to outline developments in the Netherlands and to indicate why we examined the formaldehyde problem in the broadest possible context.

Problems initially arose because of the presence of formaldehyde inside buildings following the insulation of external cavity walls. If the mixture of components in the urea formaldehyde foam used for this purpose is not right, free formaldehyde gas may be released through cracks into the air inside the house; out of the 180.000 homes insulated, this was a problem in 48 cases. Since central government was providing grants for the insulation work it could exercise a measure of control, and by tightening up its supervision it was able to solve this problem quickly.

In order to minimize construction costs, we in the Netherlands have been working for many years now to develop building materials and systems which require as little labour as possible. As part of this approach it was decided some years ago to use chipboard for internal walls and roofing slabs, since this made possible the use of prefabricated boards. The first problems developed in schools and adult-education centres, since the buildings involved were mostly tem-

porary and had therefore to be built as cheaply as possible. Of the 40 buildings where problems arose, 20 were closed on the orders of the Health Surveyor, who has the power - under the Education Act - to take this step.

Chipboard also came to be used in house-building, and it is estimated that there are 4.000 homes in the Netherlands, built since 1974, where it is the source of high concentrations of formaldehyde.

High formaldehyde concentrations resulting from the use of unsuitable construction materials were found in a large number of buildings, and since the problem was clearly widespread the Government set up an official working group to advise them on how to tackle it.

This committee, which consists of representatives of the Ministries of Health and Housing and of the Factory Inspectorate, has looked into the current situation in a large number of countries.

In Germany, for example, the Federal Office of Health (Bundesgesundheitsamt) assembled a group of experts who proposed - in 1977 - a maximum level of 120 micrograms per cubic metre. We understand that indoor air pollution by formaldehyde is to be covered by a Poisons Act, and that there is a DIN standard which - while it includes no exact figures - lays down that chipboard must not give off formaldehyde in significant quantities.

In Sweden the problem arose mainly in homes, and a maximum content of free formaldehyde is prescribed for chipboard used in floors. The measures taken in existing buildings depend on the concentrations found.

We also received valuable information from Denmark, which Mr. Andersen has already covered.

In the United Kingdom work is being done to establish a standard for chipboard, laying down the maximum content of free formaldehyde.

The approach chosen in Australia involves stringent regulations for the use of chipboard: it must always be covered by a layer of veneer which is impermeable to formaldehyde.

Little information has reached us from France or the United States beyond the fact that the problem has been found in American mobile homes.

After consulting the foreign literature and taking account of medical recommendations, the working group came to the conclusion that 120 micrograms per cubic metre* is acceptable as a standard inside buildings. This level generally produces no irritation of the mucus membranes, an effect from which we in the Netherlands think that the general public should be protected. As regards the olfactory threshold, the working group felt that the information in the literature was inconsistent, notably because there is no very clear distinction between smell and irritation of the mucus membranes.

The working group's report, together with a number of policy recommendations, was submitted to the Ministers of Housing and Health in January of this year. In July the Ministers submitted it to Parliament, adopting the maximum level recommended by the working group as the basis of their policy for the solution of the formaldehyde problem in homes. We have provided a translation of the Ministers' letter to Parliament; in addition to covering the working group's rapport, it sets out a number of basic aspects of their policies: measures are proposed to prevent formaldehyde problems arising in new houses, together with recommendations regarding existing homes where concentrations exceeding 120 micrograms per cubic metre are found.

I should like to deal with the second of these topics first. Under the Dutch Housing Act, a municipal authority may require the owner of a dwelling which is not in a satisfactory state for habitation to take steps to improve it. If he fails to do so the authority itself may undertake improvement work; the costs incurred in this way are then recovered from the owner, usually with a surcharge of 10 % to cover the State's additional expenses. The municipality may not take these steps if the costs are likely to be so high as

*according to the working group the best estimation of the no-effect level

to make the property economically unviable or if they are out of proportion to its value.

Research has shown that the treatment of chipboard with two coats of paint of a particular specification brings the formaldehyde concentration in the air below the maximum permitted level. In the Netherlands this treatment costs an average of 3,000 to 6,000 guilders (6,500 to 13,000 Danish crowns) per dwelling, depending on the amount of chipboard involved. This means that minicipal authorities can reasonably demand that measures be taken to resolve the problem. I would add that the municipalities' powers extend to all dwellings, including low-cost housing, housing in respect of which a state subsidy is payable, and owner-occupied homes.

The other question to be answered is: how do we in the Netherlands try to prevent the same problems arising in new houses? Under the Housing Act a local authority may issue building regulations, a model for which has been prepared by the Union of Dutch Municipalities. The model text is regularly updated in line with social and technical developments. The most recent amendment proposes an article which would allow municipal authorities to make the issue of a building permit subject to the requirement that the materials used should be such as not to damage the health of the building's occupants.

In the past the absence of such an article made preventive action impossible and municipal authorities could not take the steps that I have outlined until an actual health hazard arose; in future, however, they will be able to require the use of satisfactory chipboard. There are over 800 municipalities in the Netherlands, and since it is not possible for them to check the quality of building products for themselves, we have a standards institute - known as KOMO - for construction materials. The institute issues marks and certificates of approval where the manufacturing process is such as to ensure that the material will satisfy the relevant requirements; random samples are then taken to ensure that standards are being maintained. KOMO has now established provisional standards limiting the amount of formaldehyde given off by chip-

board, and after 1 January 1979 only approved chipboard may be used in construction work. The standards have already been enforced for the construction of low-cost housing, and the Ministry providing the subsidy has agreed to bear any extra costs which may be involved.

Where the problem relates to buildings other than homes - schools, for instance - it is still the subject of consultations between Ministries; however, we may expect the same line to be followed here.

The ministry of Health is currently drafting a Chipboard Decree with a view to ensuring that chipboard used outside the construction industry - in furniture manufacture and do-it-yourself work, for example - is also of such a quality that virtually no formaldehyde is given off.

This, then, is how we in the Netherlands are endeavouring through a complex of formal regulations to ensure that construction materials have no adverse effects on human health, a field which, according to the recommendations of the World Health Organization, should constitute a major element in government policy.

B.Seifert
Inst. für Wasser-, Boden- und Lufthygiene, D

The Federal Health Office in Germany has recently published an indoor air standard for formaldehyde, namely 0.1 ppm. This was after having detected very high formaldehyde concentrations in schools due to building materials. In this case, no ambient air standard has been available. In all cases where such ambient air standards are set, I would not think it necessary to have special indoor air standards; ambient air standards may do the work as they are already fixed according to possible health effects on the most sensitive groups of the population, e.g. pregnant women, children or old persons. Furthermore, controlling such indoor standards will be quite an impossible work, as the respectation of the standard can strongly depend on the behaviour of the persons living in the room in question. In a room with chipboard-made furniture, the standard of 0,1 ppm may be respected at 20 ^{o}C, but it may not if the people in this room want to live at a temperature of 25 ^{o}C with less ventilation.

But, what should be given to the public in any case, is an information about the risk that may exist under the different comditions. This kind of proceedings would be comparable to the anti-smoking campaign. Using standards and regulations should be restricted to all those cases where the individual has not the possibility to decide upon the quality of his environment, e.g. in public places, be they indoors or outdoors.

I. Andersen

When an outdoor air standard for a substance is available, this also can be used as an indoor air standa d. The reason is that the outdoor standa ds are fixed according to possible health effects on the most sensitive subjects of the population. However, only very few outdoor air standards exist (in. U.S.A. there are six only), and this number is not going to increase rapidly.

For the indoor generated pullutants I, therefore, feel that the authorities responsible for the safety of the indoor invironment will have to initiate investigations for development of standards for the many substances, which represent a health risk in the indoor enviroment, but not in the outdoor environment. The scientific basis for these standards could be identical to that used for outdoor pullutants.

I do not believe that information to the public about the risk that may exist under different conditions is sufficient to protect the health of the inhabitants. In any developed country the ranges of temperatures, humidities and ventilation rates in the home environment are known, for which reason the concentration in the indoor air of the emanated substance in question could easily be calculated provided the emanation of the substance per unit surface area at these climatic conditions is known. This information is available for the emanation of formaldehyde from chipboard (1). If an indoor air standard for formaldehyde is set, therefore, the maximum amount of eg. m^2 chipboard to be used in a room could be calculated. A procedure like this would rapidly result in the in-

troduction of new types of chipboard with a low emanation of formaldehyde!

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G.H.Green
University of Saskatchewan, CDN

Does the concentration of formaldehyde decrease with time in the building?

Can you predict the levels that will occur in a new building?

What ventilation rate in air changes per hour will reduce the level to a safe one?

I. Andersen

The concentration of formaldehyde decrease with time in a building made of formaldehyde emitting construction materials. After a period of 2-3 years the emanation is constant at the lower level.

The levels of formaldehyde may be predicted using the mathematical model published in the above mentioned reference.

The ventilation rate necessary to reduce the level of formaldehyde to a safe concentration may also be predicted from the same mathematical model.

E.Rødahl
Technical University of Norway

Dr. Andersen is discussing setting of standards. Setting of standards involves balancing economical and technical benefits against social and health risks. Thus this setting is not a problem for the scientist alone. As a matter of fact it is a political question.

Do you have any code advising how to set standards for indoor air pollution?

The answer would be of interest to all commissions trying to establish ventilation codes.

I. Andersen

The setting of standards is more art than science, no doubt about that. I feel that the indoor air quality standards should be set in a way that all subjects - except the allergic subjects, are protected against adverse health effects. Further the majority of the subjects should not experience any discomfort or de-

crease of performance. The threshold of allergic subjects is much lower than the threshold of healthy subjects. The only practical way to protect the allergic subjects will by to construct special living quarters for them with a very low content of pollutants in the indoor air.

I. Andersen

Y.Kobayashi
Toyohashi University of Technology, JAP

As for the influence upon human body, I think behaviour of pollutants along the time must be investigated in the living situation.

Dr. Baars found that the concentration of the formaldehyde in the room increases until two years and then decays, because the pollutant comes from the inside layer of the chipboard. I did not even imagine that behaviour. The tendency of the concentration depends, of course, upon the ventilation rate. Setting standards for pollutants should have two aspects: one is for the case of building design and the other is for maintenance of houses.

P.O.Fanger
Technical University of Denmark

B.Berglund
University of Stockholm, S

On what assumptions have you chosen ethylvaleriat for the odor threshold test? I am asking because numereous compounds may be candidates for such a test, and which compound is the best depends on its sensory cross-effect relative to the pollutant of interest (in this case formaldehyde).

I. Andersen

Ethylvaleriat was chosen after the advice of a scientist with many years experience in odour research. We did not have the capacity to test more than one compound.

H.U.Wanner
Eidg. Techn. Hochschule, CH

Did you expose subjects to formaldehyde in combination with particles? I expect that in this case there will be an increase in the votes about discomfort.

Another source of formaldehyde in the air is disinfectants: in hospitals we measured concentrations up to 1 mg/m^3, in the air of respirators up to 4 mg/m^3. Have you done similar observations? Do you propose special standards for hospitals?

I. Andersen

I. Andersen

No. The subjects were exposed to formaldehyde in clean air. The air in the inlet to the chamber contained less than 100 condensation nuclei per cm^3, and no dust particles were present in the air. Formaldehyde is widely used as a desinfectant in hospitals and, therefore, it will be present in the indoor air in hospitals. I see no reason for having special indoor air standards for hospitals, except for the very, very few rooms with highly specialized functions.

P.O.Fanger
Technical University
of Denmark

As a basis for standard setting you are stating that all (but the sensitized) should be protected against adverse health effect and that the majority of the subjects should not experience discomfort.

1. At 0.3 mg/m^3 you observed a decreased nasal mucuciliary flow and 20 % of your subjects suffered from eye and airway irritation. Could you be sure that the above-mentioned observations would not be present in <u>any</u> of your subjects at 0.15 mg/m^3?
2. In your general basis for the setting of any standard you are accepting that up to 50 % of the occupants experience discomfort. This figure seems high and would cause massive complaints in practice. For the thermal environment it is usual to accept 5-10 % dissatisfied.
3. Why have you used the 50 % odour threshold as the 50 % discomfort limit, when you have measured discomfort directly? On one hand, a limit where half of the occupants can smell the formaldehyde seems high. On the other hand, fig. 2 indicates that only a small percentage would find it uncomfortable.

I. Andersen

No, these physiological changes may also be present at 0.15 mg/m^3, for which reason I suggest that this or a lower concentration is used as an indoor air quality standard.

There are no studies of the effects of such low concentrations. Also these studies will be very costly and difficult to perform, as the number of subjects

will have to be very large. However, the result of animal experiments indicates that the threshold for objective biological response (odour response as a subjective response is not included here) is about 0.3-0.4 mg/m^3. At 0.15 mg/m^3 less than 50 % of the subjects will be able to smell the formaldehyde at an acute exposure, but after a few minutes they will not notice this smell any longer. Therefore, they will not be dissatisfied. You should not consider a 50 % odour threshold as identical to a 50 % discomfort limit. Discomfort was defined as irritation of the airways (feeling of dryness etc.).

H.J.Asp Hansen
Technological Institute, DK

Is it possible to tell how much formaldehyde the body may detoxify per hour and in that way set a standard for prolonged exposition to formaldehyde.

I. Andersen

From animal experiments it is known how much formaldehyde the body may detoxify per hour, but this has not been studied in human subjects.

T.Lindvall
Swedish Environment Protection Board

Impressed by the work by Dr. Andersen and his colleagues. I have two questions:

1. Amdur's data on airway resistance in quinea pigs on formaldehyde exposure are key information to the setting of limit values. Do you think her data are reliable, and transferable to humans in view of your own studies?
2. Do you think the safety margin of your suggested limit value of formaldehyde is enough considering the possibilities of interaction between formaldehyde, particulate matters, other sensory and respiratory irritants?

I. Andersen

I consider the data from Amdurs studies as reliable, as they were performed with a well-established technique by a trained scientist. Also they fir nicely to the results of a very recent study (1) and to the results of the human exposure study I have reported today.

1) Kane, L.E. & Alarie, Y.: Am. Ind. Hyg. Ass. J. 1977, 38: 509.

I have suggested a standard for continuous exposure to formaldehyde at 0.15 mg/m^3 or less. However, I would be satisfied with a standard of 0.15 mg/m^3 as this value is 50 % of the threshold for biological response. Interaction between formaldehyde and other airborne substances is a possibility, but at present we have no indication of such an occurrance. It should also be remembered that 0.15 mg/m^3 is only 3-4 times higher than the formaldehyde concentration in rural air.