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AN APPROACH FOR ASSESSING TARGET LEVELS FOR INDUSTRIAL AIR QUALITY

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ABSTRACT

This paper considers methodologies how desired level, target level, of industrial air quality can be defined taking into account a feasibility issue. The method is based on the health-based risk assessment and the technology-based approach. Because health-based risk estimates at low contaminant concentration regions are rather inaccurate, the technology-based approach is emphasized. The technological approach is based on information on the prevailing contaminant concentrations in industrial work environment and the benchmark air quality attained with the best achievable control technology. The prevailing contaminant concentrations attained with a standard technology are obtained from a contaminant exposure data bank and the benchmark air quality by field measurements in industrial work rooms equipped with the advanced ventilation and production technology. As an example the target level assessment has been applied to most common contaminants in work room air. Target levels of air quality benefit ventilation designers, manufacturers of air handling equipment and end-users of ventilation systems.

KEYWORDS

Air quality, contamination sources, industrial buildings, target levels.

INTRODUCTION

Occupational exposure to airborne contaminants is regulated by the occupational exposure limits (OEL). The OEL's have been established to prevent adverse health consequences and, therefore, they indicate only the minimum air quality requirement based on the present understanding of acceptable risk. OEL's do not serve as suitable criteria for planning comfortable environment or as an incentive for developing future control technologies. In addition, the OEL's do not take into account combined effects. Because many companies have adopted the policy of continuous improvement of working conditions, it would be desirable to create target levels for those who want to pursue more efficient control by applying the best available control technologies. Therefore, if the desired indoor air quality goals could be clearly defined, they would greatly benefit the designers, health and safety professionals, manufacturers of control technology facilities, end-users and other experts who are responsible for maintaining good indoor climate.

The aim of this paper is to consider new approaches for air quality goals for the occupational environment.

METHODS

In order to assess target concentrations of air contaminants approaches based on both human risk assessment and technology can be used (Figure 1) (Niemelä and Rantanen 1995).

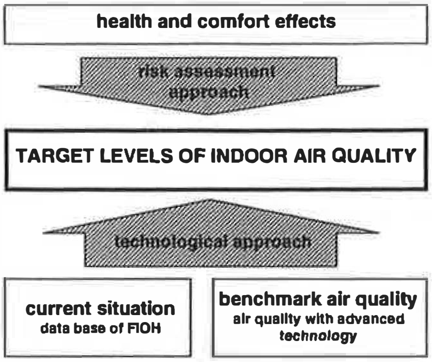

Figure 1 Approaches for the assessment of target level of air quality.

Risk assessments

The procedure of assessing health-based occupational exposure limits for chemical substances includes determination of the no-observed-adverse effect level (NOAEL) for the critical toxic effect and application of an appropriate safety factor based on expert judgement. The safety factor takes into account the uncertainties in toxicological data and exposure information (Kimmel and Gaylor 1998). In the case of a non-threshold effect, quantitative risk assessment is performed to establish the concentration level below which the risk is negligible. Such a procedure may entail remarkable uncertainties at low dose regions. Exposure limits are periodically revised in the light of new research information. In most cases, during the course of time the limits have been reduced. However, adequate toxicological data are available only for relatively few substances. Irritation and other effects considered mild and fully reversible may be ignored. A wide variation in human susceptibility may also go unheeded. A possible target level could be exposure that is indistinguishable from the general population exposure. However, adequate data even for this purpose exist for a few substances only and, consequently, the technology-based approach for the assessment of target levels is emphasised.

Control technology based approach

The control technology approach is based on information on exposure levels achieved by different control technologies from standard practices to the most advanced current designs.

Existing contaminant exposure data banks can be utilised to survey the standard practices. In the present study, the register of occupational hygiene measurements at the Finnish Institute of Occupational Health containing information on more than 150,000 determinations of airborne pollutants was used. Based on the data in the register, cumulative frequency distributions of contaminant concentrations were created. Although the register data mainly reflect relatively poor working conditions involving significant emission rates or inefficient controls, the lower tails reflect good air quality and are of particular interest. Nevertheless, the levels existing in the best occupational environments are unlikely to be included. As an example, the cumulative frequency distribution of concentrations of xylene is shown in Figure 2.

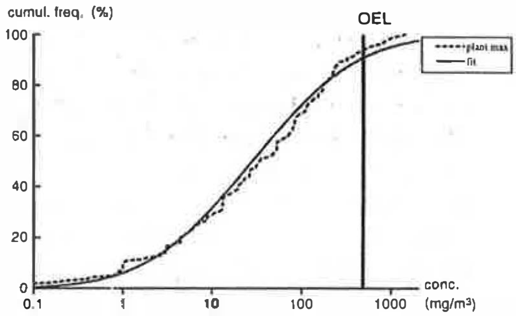

Figure 2 Plant maximum concentrations of xylene (number of plants = 139 , number of measurements = 865)

In recent years, benchmarking has proven to be a very successful tool in Total Quality Management (Watson 1992). Generally, benchmarking is the search for the best practices leading to superior performance. Basically, benchmarking is a target-setting and comparison process in which the current standard performance is compared with the best one. A typical feature for the benchmark process is up-grading of the targets periodically. When the benchmark philosophy is applied to air quality control, it means that the air quality level produced by the best available control technology must be defined. In this study, the benchmarked air quality is obtained by determining the contaminant concentrations in plants with advanced production and control technology. In the selection of the benchmark plants the following criteria were set:

- low contaminant emission rates due to the nature of a process, or the elimination of avoidable sources, and effective source control of unavoidable sources.
- balanced mechanical supply and exhaust ventilation equipped with an advanced air distribution strategy for the accurate control of flow patterns in a work space.
- air handling units equipped with heat recovery and sophisticated control of the key parameters of HVAC systems, i.e. temperature, air flow rate, pressure difference.
- new or renovated premises.

As an example, the measurement data of inorganic total dust collected benchmark factories and factories with the standard practices are shown in Figure 3.

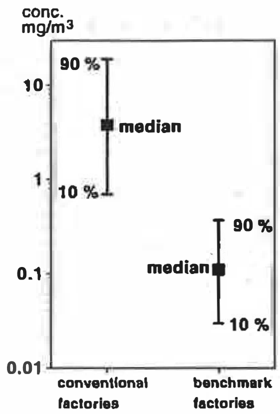

Figure 3 Concentrations of inorganic total dust in conventional and benchmark factories (median, 90 and 10 percentiles).

RESULTS

The target level procedure was applied to 16 single common air contaminants and combined effects of solvents. These are very common contaminants in the industrial environment and in many cases also the most critical compounds from the viewpoint of need for control measures. The prevailing concentration data for many of these compounds as well as the benchmark levels have been described elsewhere (Niemelä et al. 1994).

The representing of air quality classes in five categories seems to be practical (figure 4). In the following, tentative concentration bands are given for four quality categories. The first category, representing the cleanest air, refers to special requirements of processes (electronics industry, biotechnology etc.). The second category represents good occupational level achieved by using the best available controls. The upper concentration limit of the second category is below one tenth of the OEL of the corresponding compound implying that the employer is not liable for repeated air monitoring according to the recent European standard (European Committee for Standardisation 1995). The next two categories for the occupied spaces with notable contaminant sources cover the concentration range up to the OEL of a particular contaminant. It may be useful to set the fifth category for non-occupied zones or spaces.

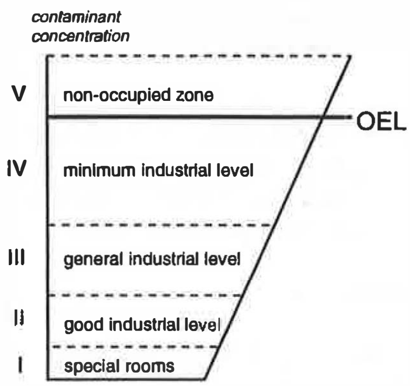

Figure 4. Target level classes of air quality

The tentative classification scheme for 17 common contaminants and a general model for assessing target values for other contaminants is presented in Table 1.

Table 1. A tentative classification of indoor air quality for common compounds .

	Air Quality Class			
Contaminant	**I. Special rooms** [1)]	**II. Good Industrial level**	**III. General Industrial. level**	**IV. Minimum Industrial level**
Inorganic dust (mg/m^3)	< 0.01	< 0.5	0.5 - 2.5	2.5 -10
Ch omium-(III)-compounds (µg/m^3)		< 10	10 -100	100 - 500
Ch omium-(VI)-compounds (µg/m^3)		< 2	2 - 10	10 - 50
Nickel compounds (µg/m^3)		< 5	5 - 20	20 - 100
Oilmist (mg/m^3)		< 0.2	0.2 - 1	1 - 5
Formaldehyde (mg/m^3)		< 0.1	0.1 - 0.4	0.4 - 1.2
Nitrogen dioxide (mg/m^3)	< 0.1	< 0.2	0.2 - 1.4	1.4 - 5.7
Carbonmonoxide (mg/m^3)		< 3	3 - 12	12 - 35
Ozone (µg/m^3)		< 50	50 - 75	75 - 100
Acetone (mg/m^3)		< 12	12 - 120	120 - 1200
Butanol (mg/m^3)		< 2	2 - 20	20 - 150
Aliphatic mineral spi its (mg/m^3)		< 10	10 - 100	100 - 1200
Isopropanol (mg/m^3)		< 5	5 - 50	50 - 500
Toluene (mg/m^3)		< 5	5 - 40	40 - 380
Xylenes (mg/m^3)		< 5	5 - 40	40 - 440
Styrene (mg/m^3)		< 1	1 - 20	20 - 86
Combined effect of solvents		< 0.02	0.02 - 0.2	0.2 - 1
General model for other contaminants		< 0.1*OEL	0.1*OEL - 0.25*OEL	< OEL

*) As an example of special rooms. Air quality requirements in electric rooms according to standard IEC 721-3-3.

**) The upper limit is the current OEL in Finland.

DISCUSSION

The target levels for seventeen common contaminants were determined into four categories in terms of concentration bands. The register of the occupational hygiene measurements revealed that the ratio of the current concentration levels to OELs greatly depends on the particular contaminant. Excluding ozone, the upper limit of 'Good industrial level' (category II) varies from 1 to 9 % of the corresponding OEL in Finland. The upper limit of category 'General Industry level' also varies from substance to substance. Apart from ozone the limit is 10-33% of the corresponding OEL. It is worth to be emphasized, however, that this scheme is still a proposal for further development. Particularly, we need more benchmark data to validate the upper limit of category II 'Good Industrial level'. Apart from total inorganic dust, chromium compounds, nickel, oil mist, formaldehyde, and styrene more benchmark data are needed

The previous procedure can be used for assessing target levels for a variety of substances in work rooms with notable contaminant emissions. A different set of target levels have already been proposed for non-occupied environments (Fanger 1990; Scanvac 1991; Commission of the European Communities 1992; Seppänen et al. 1995). At the present time, implementation of ventilation systems and other control measures is often based on experiences on earlier plants, i.e., on trial and error. This approach is not the most effective way of developing new efficient control measures for the improvement of industrial air quality. It is obvious that a more systematic approach is needed. A clear definition of the design goals is one key element in the systematic approach. Nowadays a vast majority of workplaces have airborne contaminant levels below the health-based OEL's. Nevertheless, air quality is often not satisfactory to the occupants. Therefore, the technology-based approach by determining levels achievable with the best available technology is more fruitful. Although the capital costs of advanced HVAC systems may be about 50% higher than the traditional ones, the energy economy of modern facilities is usually much better than that of the traditional ones. We can, therefore, conclude that the life-cycle costs of the benchmark ventilation facilities may be the same or even less than of the traditional ones in the same industrial category, at least in cold climates. The setting of quantitative goals for indoor air quality also supports an organisation's quality policy in the area of safety and health. We feel that the introduction of the target level concept for indoor quality will enhance the development of more advanced and efficient control technologies.

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