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Application of the Maximum Cumulative Ratio (MCR) to chemical mixtures in indoor air

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Background

Indoor air contains a varied and diverse mixture of chemical substances to which people may be simultaneously exposed. Cumulative risk assessment - taking into account the toxicity of each and every substance - is resource intensive. Therefore, in this study we have adopted the Maximum Cumulative Ratio (MCR) approach which determines when cumulative risk assessments are most required. We used the Maximum Cumulative Ratio (MCR) to assess whether the risk of an indoor air mixture is dominated by one single compound or by the contribution of many chemicals. The MCR is applied to a Tier 1 cumulative risk assessment where the assumption of dose addition is made for all compounds.

For each chemical in the mixture, the Hazard Quotient (HQ) is calculated as

$$HQ_{ij} = \frac{C_{ij}}{RV_i}$$

where C_{ij} is the concentration of chemical i in mixture j and RV_i the reference value for chronic non-cancer effects of chemical i.

The Hazard Index (HI) of the mixture is then calculated as

$$HI_j = \sum_i HQ_{ij}$$

Finally, the MCR is then equal to the ratio of the HI of the mixture to the maximum HQ in that mixture.

$$MCR_j = \frac{HI_j}{\max(HQ_{ij})}$$

Using the HI and the MCR, mixtures can be classified into four groups:

- Group I: concern for effects caused by individual chemicals, and concern for combined effects
- Group II: no concern for combined effects or for individual chemical effects
- Group IIIa: concern for combined effects dominated by one chemical
- Group IIIb: concern for combined effects and no one chemical dominates

Materials and methods

Monitoring data

Three databases containing results of measurements of chemicals in the indoor air of buildings and of personal exposure were used for exploration of the MCR concept to indoor air chemical mixtures

- EXPOLIS databases (1996 – 2000): total of 416 indoor air samples (dwellings) and 382 personal monitoring samples from Helsinki, Athens, Milan, Basel, Prague and Oxford
- French IAQ survey (2003 – 2005): indoor air samples from 567 dwellings in France
- Flemish IAQ survey (2008 – 2011): indoor air samples from 360 dwellings and 90 classrooms in Flanders (Belgium)

Risk values

MCR calculations are based on chronic reference values (RV) for each compound in the mixture for non-carcinogenic effects in the general population. As no list of chronic reference value (RV) covering all chemicals is available, RVs and the basis of their derivation were collected from selected sources for each chemical. A decision tree approach was followed to select the most appropriate RV. Key elements in the decision tree, included: 1) only transparently derived health based RV ; 2) preference to recent (≤ 5 years) evaluations; 3) first priority to RV derived by WHO, 4) second priority to values derived by US EPA, ATSDR, INDEX and OEHHA, 5) third priority to values derived by Health Canada, RIVM and standalone scientific publications.

Results and Discussion

Across the three study databases, 43 substances (mainly VOCs and NO_2) were measured; only 4 compounds (benzene, ethylbenzene, toluene and xylenes) were common in the three studies. Health based RVs were identified for 28 out of 43 substances.

The average MCR value (1.9) is small compared to the average N value (15), which is the number of chemicals detected in the mixtures.

Nearly half of the samples (48 %) had MCR values less than 2, indicating that for half of the mixtures, one chemical dominates the toxicity of the measured mixtures.

The upper bound of the range of MCR values declined with increasing HI (Figure 1).

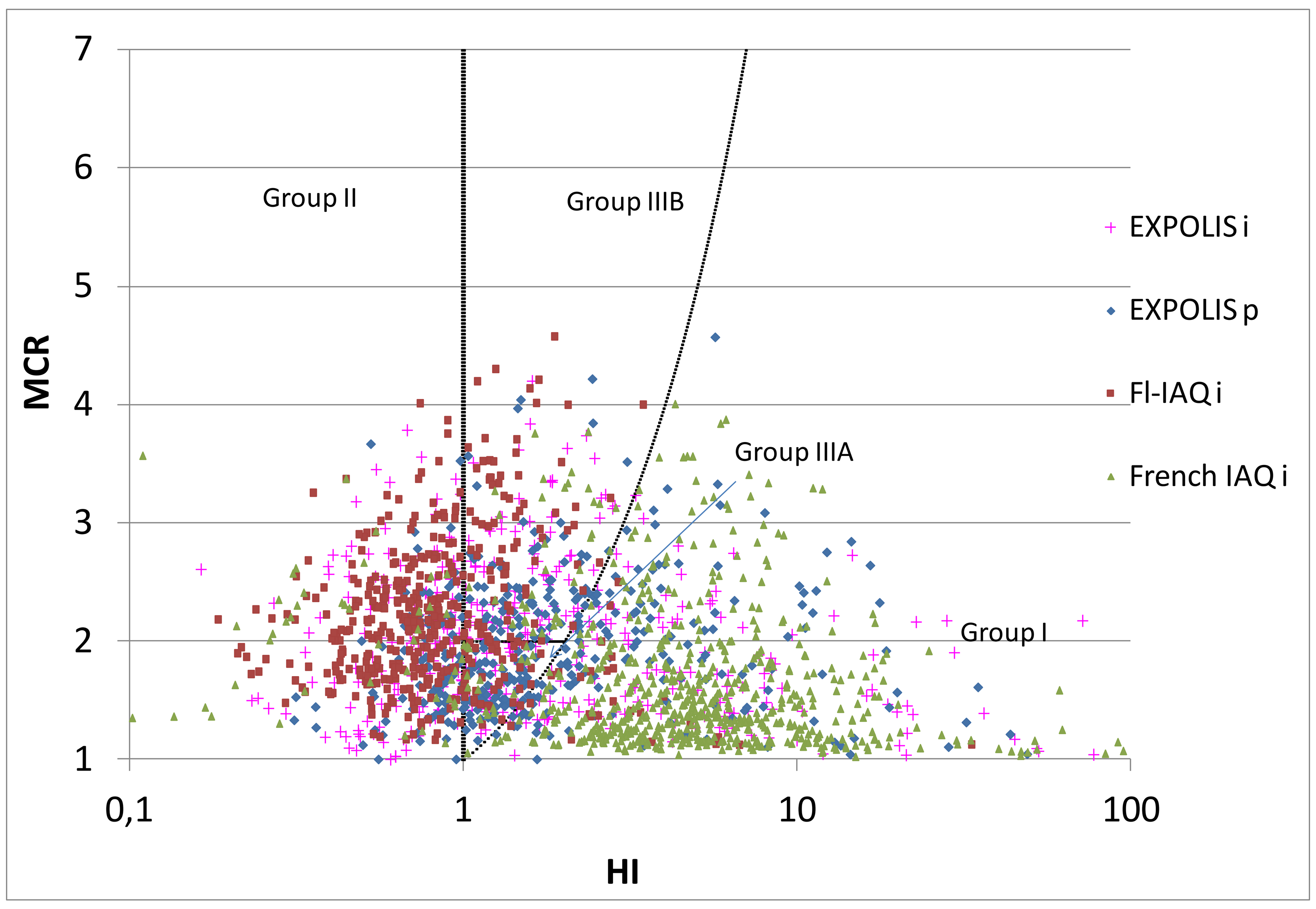

Figure 1: Scatter plot of the Maximum Cumulative Ratio (MCR) versus Hazard Index (HI) for indoor (i) and personal (p) air mixtures of the Expolis database, Flemish IAQ survey (i) and French IAQ survey (i)

Table 1:percentages of mixtures in group I, II, III A and III B, and compound with the largest contribution to MCR

% mixtures per *MaxHQ compound*	group I	group II	group IIIA	group IIIB
EXPOLIS i	33% *Trichloroethene*	36% *NO_2*	9% *NO_2*	22% *NO_2*
EXPOLIS p	38% *NO_2*	23% *NO_2*	19% *NO_2*	20% *NO_2*
Flemish IAQ survey	6% *Trichloroethene*	67% *Formaldehyde*	9% *NO_2*	18% *NO_2*
French IAQ survey	85% *Acrolein*	7% *Benzene*	3% *Trichloroethene*	5% *Benzene*

Whereas the majority of the Flemish IAQ indoor mixtures (67 %) are situated in group II (no concern), the majority of the French indoor mixtures (85 %) seem to be in concern group I because of a HQ > 1 for acrolein. For the EXPOLIS i & p mixtures, more or less equal fractions of samples are situated in group I and group II (Table 1).

The discrepancy in % of mixtures in groups I, II and III between the three datasets might be partly explained by the difference in substances monitored in the three datasets. Whereas the high HQ for acrolein drives the risk (group I) for majority of the French IAQ mixtures, acrolein was not measured in the Expolis and Flemish IAQ surveys. In contrast, NO_2 seems to be the highest contributor to the HI of the mixtures in group III A & B of Expolis (i & p) and Flemish IAQ, while NO_2 was not measured in the French IAQ survey.

The fraction of mixtures situated in group III (A and B) – varying from 8 % (French IAQ) to 39 % (Expolis p) represents the group of mixtures which would have been evaluated as 'no concern' in a substance by substance assessment. However, for these group III mixtures, the MCR analysis indicates that a cumulative risk assessment is needed.

Further steps will focus on the evaluation of the impact of the choice of the RV on the MCR, the sensitivity of MCR values to limits of quantification for different pollutants monitored and the progress towards a Tier 1.5 evaluation where local and systemic effects are separated.

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