Comparison of formaldehyde exposure measurements stored in French and German databases

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Abstract Workplace formaldehyde measurements stored in the German MEGA database and the French COLCHIC database were studied. Industrial sectors in which formaldehyde is most often sampled were used to provide results in both countries. The results show that formaldehyde is often found in human health activities and in the manufacture of wood products, basic metals, rubber and plastic products, and textiles. MEGA and COLCHIC data for these sectors are presented by type of measurement (area and personal sampling). The results also show formaldehyde exposures in the major industrial sectors in both countries. The exposure data stored in MEGA and COLCHIC present similar magnitude. A broad picture of occupational exposure to formaldehyde in France and Germany was obtained by comparing the data from the two databases.

Vergleich der Daten zur Formaldehydexposition aus deutschen und französischen Datenbanken

Zusammenfassung Messwerte zur Exposition gegenüber Formaldehyd am Arbeitsplatz aus der deutschen Datenbank MEGA und der französischen Datenbank COLCHIC wurden ausgewertet. Dazu wurden die Branchen mit den höchsten Probenanzahlen für Formaldehyd in beiden Staaten herangezogen. Die Auswertungen zeigen, dass Formaldehydexpositionen häufig im Gesundheitswesen, in der Metallerzeugung und -bearbeitung und bei der Herstellung von Holzerzeugnissen, Gummi und Gummiprodukten sowie Textilien auftreten. Die Auswertungsergebnisse aus MEGA und COLCHIC werden differenziert nach der Probenahmestrategie (ortsfest und personengetragen) dargestellt. Zusätzlich werden die Ergebnisse in bedeutenden Branchen der beiden Staaten dargestellt. Die in MEGA und COLCHIC dokumentierten Werte liegen in einer ähnlichen Größenordnung. Der Vergleich der Auswertungen aus beiden Datenbanken spiegelt ein umfassendes Bild der Exposition gegenüber Formaldehyd am Arbeitsplatz in Deutschland und Frankreich wider.

1 Introduction

1.1 Context and background

Exposure databases have been developed for gathering workplace exposure measurement data, harmonizing practices and monitoring compliance. In the US, the Occupational Safety and Health Administration (OSHA) has gathered and stored measurement data for over 30 years in the Integrated Management Information System (IMIS) [1]. In Europe, the Institut National de Recherche et de Sécurité (INRS) and its COLCHIC database [2] and the Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung (IFA) (formerly known as BGIA) and its MEGA database [3] constitute the largest data sources.

Cross-border and comparative evaluations of exposure databases in Europe originate from a project promoted by the European Foundation for the Improvement of Living and Working Conditions at the beginning of the 1990s. The project involved the description of the common features of, and the differences between, the measured exposure values for samples of xylene, acetone and wood dust, and the establishment of comparability criteria and the scope of such comparisons [3; 4]. Among the institutes involved were the INRS and its COLCHIC database, and the IFA and its MEGA database. At the time, the European Union (EU) confirmed the project's considerable relevance as a means of obtaining valid and generally accepted data as the basis for European limit values and risk management.

This paper thus provides an overview of MEGA and COLCHIC data on formaldehyde exposures which is relevant in view of the growing EU-wide discussion on the substance owing to its carcinogenic effects. Data on formaldehyde have already been assessed by *Lavoue* et al. [5] whose study compared the US (IMIS) and the French COLCHIC databases.

1.2 Description of databases

The content and systematic structure of the data collected were developed for both databases in order to provide all the "core information" having a potentially significant effect on the measurement result, together with a comprehensive description and assessment of exposure [6 to 8]. This information is related to the industrial workplace, working and manufacturing methods, substances in use, risk management measures, exposure situation and sampling and analysis conditions. In this respect, one measured value can be assigned to dozens of different data items.

In relation to workplace air samples, both databases store hundreds of thousands of exposure measurement results involving hundreds of chemical and biological agents (**Table 1**). It should be noted that the number of results varies widely from one agent to another. There are several thousand results for certain agents and fewer than ten for others.

The COLCHIC database contains atmospheric measurements taken since 1985 by eight interregional laboratories of the French regional health insurance fund and the laboratories of the INRS. COLCHIC covers the workplaces under the authority of the French national insurance scheme which excludes state services (military, a major part of the education system, municipal services), agriculture, mining, energy production and national mass transit. The aim of COLCHIC is to provide assistance in the management of exposure data for laboratories, to respond to requests for data sources, and to contribute to the development of solutions for better understanding of chemical exposure assessment (modelling). Most measurements collected by labora-

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Table 1. Comparative summary of COLCHIC and MEGA databases.

	COLCHIC	MEGA
Start	1985	1972
Measured values	930,000	2,470,000
Facilities	16,500	61,000
Air samples	330,000	930,000
Product samples	87,000	119,000
Chemical agents	712	840
Code list for sectors of industry	NACE	German Office of Statistics
Code list for working areas	*Ad hoc* table	MGU code list
Code list for profession (job)	ROME code (convertible to ISCO)	German Labour Office
Code list for chemicals	COLCHIC and CAS	MEGA and CAS

tories are performed following expert evaluation of the workplace and for the most part upon suspicion of over-exposure ("suspicion of over-exposure" is the reason for more than 75% of the measurements stored).

The data stored in the MEGA exposure database are gathered within the framework of the "Messsystem Gefährdungsermittlung der Unfallversicherungsträger" (MGU) system of the German Social Accident Insurance Institutions [9; 10]. This measurement system is used for exposure risk assessment. All the processes within the MGU conform to the requirements of a quality management system according to DIN EN ISO 9001. The aim of the MGU is to gather and document valid data on exposure to hazardous substances and biological agents at workplaces through atmospheric measurements and material analyses. Workplace measurements may be part of the supervisory duties of the social accident insurers or, for example, be required during extensive measurement programs.

1.3 Formaldehyde

Formaldehyde is very widely used. It is an ingredient of disinfectants and is also used for fumigation. Its broad biocidal action covers bacteria, fungi, spores and certain viruses.

Formaldehyde presents a wide range of health hazards, including acute and chronic effects and carcinogenicity. Broad consensus exists that owing to its irritant effects on the upper respiratory tract, formaldehyde can cause nasopharyngeal tumours as a result of cell proliferation processes. Avoiding irritation by limiting formaldehyde exposure is therefore regarded as protection against an additional nasopharyngeal cancer risk. Whether formaldehyde may cause leukaemia is currently under discussion.

The International Agency for Research on Cancer (IARC), an entity of the World Health Organization (WHO), classified formaldehyde in Group 1 (carcinogenic for humans) in 2004 (confirmed in 2009), following the publication of epidemiological findings on tumours of the nose and on leukaemia [11]. In 2012, the Risk Assessment Committee (RAC) of the European Chemicals Agency (ECHA) followed a proposal by France to classify formaldehyde as a Category 1B carcinogen (presumed to have carcinogenic potential for humans; classification is largely based upon animal evidence) [12]. If the European Commission follows this recommendation, the classification will be legally binding.

In March 2008, the Scientific Committee on Occupational Exposure Limits (SCOEL) recommended an 8 h time-weighted average (TWA) limit of 0.25 mg/m³ and a short-term exposure limit (STEL, 15 minutes) of 0.5 mg/m³. Due to the classification of formaldehyde as a Category 1B carcinogen, these limits could be revised in the near future.

2 Method

To be stored in MEGA, a measurement must be compliant with the sampling and analysis standard EN 482. Sampling and analysis techniques are described in the loose-leaf collection entitled "IFA-Arbeitsmappe Messung von Gefahrstoffen" [13; 14]. Most of the data stored in COLCHIC are compliant with EN 482, the only exceptions being those measured on passive samplers (6.6% of all samples). These samples were not used in this study, in order to ensure comparability with MEGA. Finally, all the data used in this study (MEGA and COLCHIC) were obtained with active samplers employing 2,4-dinitrophenylhydrazine-impregnated silica gel and analysis was performed by high-performance liquid chromatography. Measurement results below the quantification limit were adjusted to half the value of this limit. For MEGA, the quantification limit is 0.02 mg/m³ for a sample air volume of 20 l. For COLCHIC, the quantification limit (LoQ) depends on the laboratory performing the analysis. For 2002 to 2011 data, 80% of LoQ values were 0.02, the remainder being 0.01 or less.

Table 2 provides a general overview comparing measured formaldehyde concentrations in MEGA and COLCHIC for the period from 2002 to 2011 according to the type of sample, area and personal.

In MEGA, the measurements are preferably carried out for two hours, as the standardized analytical method is adjusted to this duration. Within this constraint, the industrial hygienist attempts to cover the entire range of the employee's usual activities within the sampling period. In COLCHIC, the sampling duration is fixed at the industrial hygienist's discretion based upon his/her expertise. Conse-

Table 2. Overview of formaldehyde concentration measurements in COLCHIC and MEGA; GM = geometric mean.

	All		Area		Personal	
	COLCHIC	MEGA	COLCHIC	MEGA	COLCHIC	MEGA
N	8,211	7,238	4,555	4,148	3,656	3,069
GM in mg/m³	0.08	0.05	0.07	0.04	0.11	0.07
Median in mg/m³	0.08	0.04	0.06	0.03	0.11	0.07
75th percentile in mg/m³	0.27	0.18	0.22	0.14	0.31	0.24
90th percentile in mg/m³	0.73	0.56	0.68	0.52	0.78	0.61
95th percentile in mg/m³	1.50	0.92	1.45	0.84	1.60	0.99

Table 3. Number of formaldehyde measurements in databases (all types), according to the industrial sectors (*N* = number of measurements, % = percentage of all formaldehyde data).

Rank	COLCHIC			MEGA		
	Sector	N	%	Sector	N	%
1	Human health activities	1,804	21	Manufacture of wood, furniture and related	1,309	18.1
2	Manufacture of wood, furniture and related	1,167	13	Manufacture of basic metals	1,139	15.7
3	Manufacture of rubber and plastic products	1,097	12	Human health activities	931	12.9
4	Manufacture of textiles	469	5	Manufacture of rubber and plastic products	709	9.8
5	Manufacture of food products	410	5	Manufacture of other non-metallic mineral products	479	6.6
6	Manufacture of basic metals	392	4	Education	348	4.8
7	Specialised construction activities	376	4	Manufacture of fabricated metal products, except machinery and equipment	233	3.2
8	Manufacture of machinery and equipment	362	4	Manufacture of machinery and equipment	210	2.9
9	Manufacture of fabricated metal products, except machinery and equipment	316	4	Manufacture of chemicals and chemical products	165	2.3
10	Manufacture of paper and paper products	259	3	Manufacture of textiles	149	2.1
11	Manufacture of chemicals and chemical products	256	3	Manufacture of other transport equipment	100	1.4
12	Manufacture of other non-metallic mineral products	245	3	Manufacture of motor vehicles, trailers and semi-trailers	85	1.2
13	Scientific research and development	174	2	Manufacture of paper and paper products	84	1.2
14	Public administration and defence; compulsory social security	152	2	Land transport and transport via pipelines	71	1
15	Wholesale trade, except of motor vehicles and motorcycles	138	2	Repair and installation of machinery and equipment	59	0.8
16	Crop and animal production, hunting and related service activities	132	2	Specialised construction activities	50	0.7
17	Retail trade, except of motor vehicles and motorcycles	98	1	Manufacture of electrical equipment	43	0.6
18	Education	93	1	Water transport	38	0.5
19	Manufacture of other transport equipment	77	1	Veterinary activities	16	0.2
20	Manufacture of motor vehicles, trailers and semi-trailers	65	1			

quently, significant variations in exposure can occur. For the purposes of comparison, the present study considers data with sampling durations of between 30 and 240 minutes. This permits focusing on the chronic effects of formaldehyde; acute effects that can be triggered by short-term exposure peaks are outside the scope of the study.

A comparison focusing on industrial sectors was performed as defined by the EU NACE classification. The NACE code is a system by which sectors of the economy are divided into equivalent categories. The COLCHIC database uses NACE directly. The MEGA database uses its own MEGA codes. For the purpose of the study, these were converted as far as possible into NACE codes. This made it possible to consider 88.8% of MEGA data for the period from 2002 to 2011.

The NACE comparison was performed in two stages. First, the industrial sectors in which formaldehyde is most often measured were identified. In **Table 3**, these industrial sectors are ranked on the basis of the number of formaldehyde measurements performed in France and in Germany according to the databases. The rankings differ slightly, but general trends can be noted concerning the industrial sectors of interest that are to be investigated due to their importance in German and French industry. Limiting the discussion to the three main sectors in each of the two databases leaves only four sectors, namely manufacture of wood, furniture and related; human health activities; manufacture of basic metals; manufacture of rubber and plastic products. Taking both databases together, these groups contain the majority of the data. In addition, the example of the textile industry will be described because of historical relevance [15].

The comparison of formaldehyde data was performed with reference to these major industrial sectors. To obtain an indication of a possible health hazard resulting from formaldehyde exposure, the exposure data are presented in relation to the SCOEL limit value.

3 Results

3.1 Overview of the databases

The difference observed in **Table 4** between geometric means with the total set of data (Table 2) is moderate, in particular concerning personal samples. After filtering the short term personal measurement data, the geometric mean (GM) decreased for both the MEGA (from 0.07 to 0.06 mg/m³) and COLCHIC data (from 0.11 to 0.09 mg/m³).

With the exception of 2002, the median concentrations per year (**Figure 1**) for the MEGA data for formaldehyde exposure were largely stable at a level far below the SCOEL limit value.

However, at least 10% and in most years 15 to 18% of the measured values exceeded the SCOEL limit value. The 90th

Table 4. Overview of filtered formaldehyde measurements, i.e. sampling duration ≥ 30 minutes and ≤ 240 minutes; GM = geometric mean.

	All		Area		Personal	
	COLCHIC	MEGA	COLCHIC	MEGA	COLCHIC	MEGA
N	6,784	6,469	4,041	3,663	2,743	2,796
GM in mg/m³	0.07	0.04	0.07	0.03	0.09	0.06
Median in mg/m³	0.07	0.04	0.06	0.02	0.09	0.06
75th percentile in mg/m³	0.24	0.13	0.21	0.09	0.26	0.19
90th percentile in mg/m³	0.59	0.42	0.62	0.3	0.55	0.52
95th percentile in mg/m³	1.11	0.7	1.2	0.58	0.9	0.8
% ≥ SCOEL limit value (0.25 mg/m³)	24	16	23	12	26	21

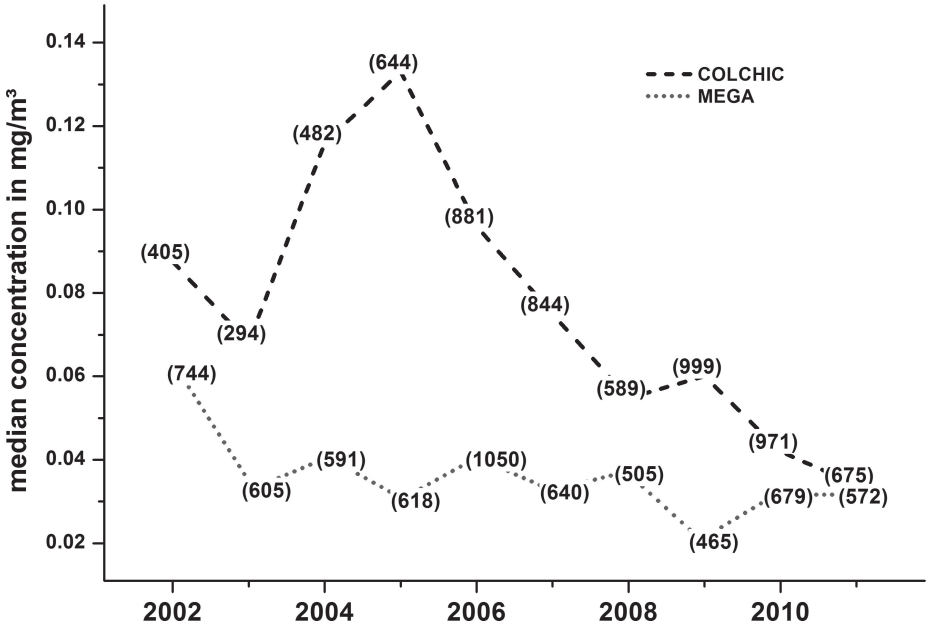

Figure 1. Formaldehyde median concentration of measurements per year (area and personal confounded, number of measurements per year in parentheses).

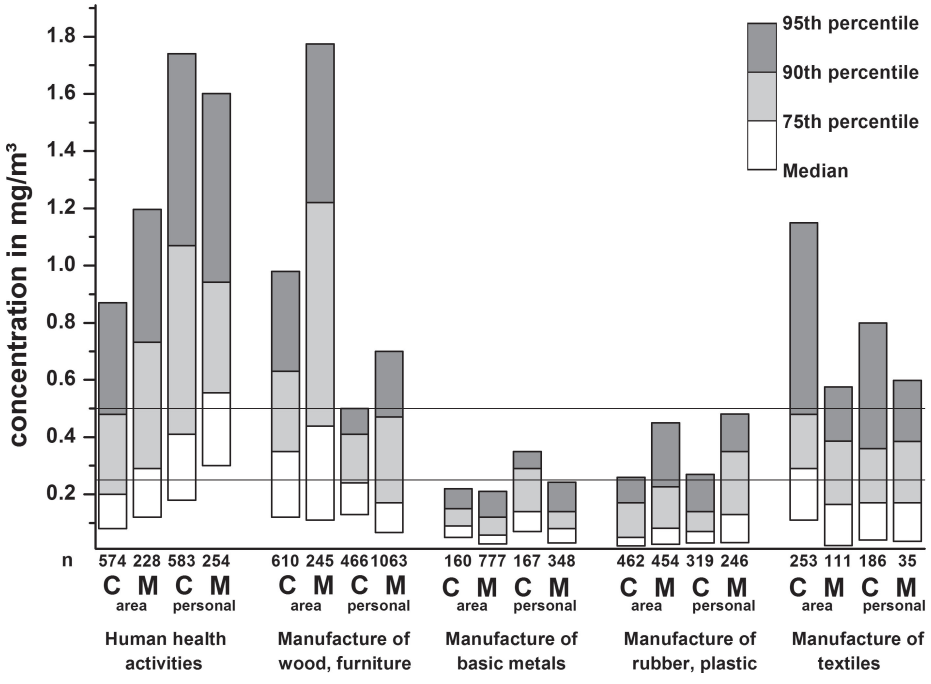

Figure 2. Formaldehyde measurements in the sectors of interest; *n* = number of measurements, C = COLCHIC data, M = MEGA data.

percentile is higher than 0.3 mg/m³ in almost all cases, and the 95th percentile is always higher than 0.55 mg/m³. Fluctuations, especially in high percentiles, can be attributed to time-limited measurement programmes within specific industrial sectors. The time trend for COLCHIC shows a peak in the years 2004 and 2005. The reason is related to the years 2002 and 2003, in which the industrial sectors under investigation were divided differently compared to subsequent years, resulting in a lower median concentration (over-representation of the rubber and plastic products sector with low concentrations, under-representation of the wood sector with high concentrations).

3.2 Analysis of sectors of interest

Figure 2 provides an overview of the selected exposure data from MEGA (M) and COLCHIC (C), area and personal, differentiated according to the selected industrial sectors. The white, light-grey and dark-grey boxes of the columns indicate the ranges of exposures between the 50th and 75th, 75th and 90th, and 90th and 95th percentiles, respectively. The horizontal line indicates the formaldehyde SCOEL TWA of 0.25 mg/m³ and STEL of 0.5 mg/m³.

3.2.1 Human health activities

The sector of human health activities (**Table 5**) is that which includes the largest number of measurements in COLCHIC (1,157), well over twice as many as in MEGA (482). Overall, the measurement values are similar but slightly lower in the COLCHIC database.

In the REACH regulation, the Risk Characterization Ratio (RCR) is defined as the ratio of "exposure" to the OEL [16]. In the following sections,

Table 5. Formaldehyde measurements in the human health activities sector; GM = geometric mean.

	All		Area		Personal	
	COLCHIC	MEGA	COLCHIC	MEGA	COLCHIC	MEGA
N	1,157	482	574	228	583	254
GM in mg/m³	0.11	0.15	0.07	0.09	0.16	0.23
Median in mg/m³	0.11	0.20	0.08	0.12	0.18	0.30
75th percentile in mg/m³	0.30	0.47	0.20	0.29	0.41	0.56
90th percentile in mg/m³	0.75	0.89	0.48	0.73	1.07	0.94
95th percentile in mg/m³	1.40	1.40	0.87	1.20	1.74	1.60
% ≥ SCOEL limit value (0.25 mg/m³)	29	44	20	29	39	58

Table 6. Formaldehyde measurements in the manufacture of wood and furniture sector; GM = geometric mean.

	All		Area		Personal	
	COLCHIC	MEGA	COLCHIC	MEGA	COLCHIC	MEGA
N	1,076	1,308	610	245	466	1,063
GM in mg/m³	0.12	0.08	0.13	0.13	0.12	0.07
Median in mg/m³	0.12	0.07	0.12	0.11	0.13	0.07
75th percentile in mg/m³	0.30	0.2	0.35	0.44	0.24	0.17
90th percentile in mg/m³	0.52	0.56	0.63	1.22	0.41	0.47
95th percentile in mg/m³	0.75	0.89	0.98	1.78	0.50	0.7
% ≥ SCOEL limit value (0.25 mg/m³)	30	23	34	37	25	19

this ratio provides an insight into the risk associated with the sectors of activity: the geometric mean is used as the exposure and the SCOEL limit value as the OEL. An RCR > 1 denotes a "poorly controlled" risk: this situation does not occur in the industrial sectors investigated. An RCR < 0.2 denotes a "well controlled" risk. Between these ranges, the risk is "controlled", but efforts should be made to reduce exposure. For human health activities, efforts to reduce exposure should be made in both countries (RCR = 0.44 in COLCHIC and RCR = 0.60 in MEGA). The proportions of area and personal measurements are similar in the two databases (50%/50% in COLCHIC; 47%/53% in MEGA). In both databases, statistical indicators of area concentration measurements are lower than those of personal concentration measurements.

The measurements were performed mainly in sectors of pathological activity (e.g. histological laboratories, dissection facilities), or were linked to cleaning and sterilization activities, in both cases in health facilities.

In this context, it should be mentioned that the MEGA database contains a further 348 measurements (geometric mean: 0.58 mg/m³, median: 0.57 mg/m³, 95th percentile: 4.78 mg/m³) obtained at laboratories and internship facilities in the pathology and anatomy departments of university medical and veterinary faculties. These are designated with the NACE "education" code. Among these, a collection of 138 data items was obtained by selection according to sampling period (30 to 240 minutes) and represented by a geometric mean of 0.45 mg/m³, a median of 0.56 mg/m³ and a 95th percentile of 2.04 mg/m³.

3.2.2 Manufacture of wood, furniture and related

If both databases are considered together, the industrial sector of manufacture of wood, furniture and related represents the majority of the data (**Table 6**), yielding 1,308 (largest sector in MEGA) and 1,076 values (COLCHIC) respectively.

Data from NACE divisions 16 and 31 were combined in this section due to overlap. Documented working areas predominantly concern hot pressing, sawing, gluing, grinding, milling, chipping and activities at machines for chipboard and furniture production. The RCR suggests that efforts should be made in both countries to reduce exposure in this sector (RCR = 0.48 in COLCHIC, RCR = 0.32 in MEGA). Overall, the statistical indicators differed slightly: the median and 75th percentiles were higher in COLCHIC, while the 90th and 95th percentiles were lower. This indicates that the measured concentrations were on average higher in COLCHIC but that high concentration values were found in MEGA. The proportions of area and personal measurements are almost balanced in COLCHIC (56%/44%), whereas they are quite unbalanced in MEGA (19%/81%). In both databases, the statistical indicators for area measurements were lower than those for personal measurements. For MEGA, the statistical indicators for area measurements were strongly influenced by high exposure during the manufacture of wood-based panels by hot-pressing.

3.2.3 Manufacture of basic metals

The manufacture of basic metals (**Table 7**) is the industrial sector with a much higher number of measurements reported in MEGA (1,132) than in COLCHIC (327).

The statistical indicators determined for the manufacture of basic metals are based on measurements during work at computerized numerical control machining facilities, core moulding, welding, soldering and grinding, and in foundries. The low RCR suggests that the sector is well controlled in both countries (RCR = 0.20 in COLCHIC, RCR = 0.12 in MEGA). Overall, the statistical indicators are very similar. The proportions of area and personal measurements are almost balanced in COLCHIC (48%/52%) whereas they are quite unbalanced in MEGA (68%/32%). In both databases, statistical indicators of area concentration measurements

Table 7. Formaldehyde measurements in the manufacture of basic metals sector; GM = geometric mean.

	All		Area		Personal	
	COLCHIC	MEGA	COLCHIC	MEGA	COLCHIC	MEGA
N	327	1,132	160	777	167	348
GM in mg/m³	0.05	0.03	0.04	0.03	0.07	0.03
Median in mg/m³	0.06	0.03	0.05	0.03	0.07	0.03
75th percentile in mg/m³	0.11	0.06	0.09	0.06	0.14	0.08
90th percentile in mg/m³	0.22	0.13	0.15	0.12	0.29	0.14
95th percentile in mg/m³	0.30	0.22	0.22	0.21	0.35	0.24
% ≥ SCOEL limit value (0.25 mg/m³)	9	4	3	4	14	5

Table 8. Formaldehyde measurements in the manufacture of rubber and plastic products sector; GM = geometric mean.

	All		Area		Personal	
	COLCHIC	MEGA	COLCHIC	MEGA	COLCHIC	MEGA
N	781	700	462	454	319	246
GM in mg/m³	0.03	0.03	0.02	0.03	0.03	0.04
Median in mg/m³	0.03	0.03	0.02	0.03	0.03	0.03
75th percentile in mg/m³	0.06	0.11	0.05	0.08	0.07	0.13
90th percentile in mg/m³	0.15	0.26	0.17	0.23	0.14	0.35
95th percentile in mg/m³	0.27	0.46	0.26	0.45	0.27	0.48
% ≥ SCOEL limit value (0.25 mg/m³)	5	11	5	9	6	14

Table 9. Formaldehyde measurements in the textile manufacturing sector; GM = geometric mean.

	All		Area		Personal	
	COLCHIC	MEGA	COLCHIC	MEGA	COLCHIC	MEGA
N	439	146	253	111	186	35
GM in mg/m³	0.07	0.04	0.08	0.04	0.05	0.05
Median in mg/m³	0.06	0.03	0.11	0.02	0.04	0.04
75th percentile in mg/m³	0.25	0.17	0.29	0.17	0.17	0.17
90th percentile in mg/m³	0.47	0.39	0.48	0.39	0.36	0.39
95th percentile in mg/m³	0.98	0.58	1.15	0.58	0.80	0.60
% ≥ SCOEL limit value (0.25 mg/m³)	25	17	31	18	17	14

are lower than those of personal concentration measurements.

3.2.4 Manufacture of rubber and plastic products

This industrial sector (**Table 8**) is measured at approximately the same frequency in COLCHIC and in MEGA, accounting for 781 and 700 values respectively.

The measurements were carried out mainly during the manufacture of moulded rubber parts, injection moulding and activities involving extruders. The low RCR suggests that the sector is well controlled in both countries (GM = 0.03 mg/m³ i.e. RCR = 0.12). Overall, the statistical indicators are very similar. The proportions of area and personal measurements are almost balanced in the two databases: COLCHIC 59%/51%; MEGA 65%/35%). In both databases, the statistical indicators for area concentration measurements are similar to those for personal concentration measurements.

3.2.5 Textile manufacturing

In this industrial sector, three times as many measurements are documented in COLCHIC as in MEGA. Working areas in which exposure to formaldehyde was determined are predominantly those of printing, chemical finishing, and non-woven production. The RCR observed (**Table 9**) differs slightly between the two countries: the COLCHIC value is higher than the MEGA value (RCR = 0.28 in COLCHIC, RCR = 0.16 in MEGA).

Overall, all the statistical indicators computed from the COLCHIC data show slightly higher concentrations than in the MEGA data. The proportions of area and personal measurements are almost balanced in COLCHIC (57%/43%), whereas they are unbalanced in MEGA (76%/24%). In COLCHIC, the statistical indicators of area measurements are always higher than those of personal measurements, whereas they are similar for MEGA.

4 Discussion

4.1 Industrial sectors

Human health activities and the manufacture of wood and furniture are industrial sectors in which a large proportion of the formaldehyde concentrations observed are above the SCOEL TWA (33% and 26% for each industrial sector, COLCHIC and MEGA combined). Moreover, the high number of measurements available for computing the values permits asserting that these values are reliable. Consequently, specific prevention measures to reduce exposure to

formaldehyde should be taken by enterprises and workers in these industrial sectors. However, it does not appear easy to put this into practice.
In healthcare, formaldehyde is used to fix and preserve tissues (pathology and anatomy laboratories) and to disinfect surfaces, particularly against multi-resistant germs. In both databases, these activities are recognized as generating high concentrations, and no completely equivalent alternatives exist. To minimize exposure, it is therefore necessary, for example, to minimize the formaldehyde content of the formulations used as far as possible, or to optimize ventilation systems and working processes. In certain circumstances it may also be indispensable for employees to use personal protective equipment temporarily.
Worrying exposures occur in the wood and furniture sector during the production and processing of wood-based materials (wooden panels). Wood products contain formaldehyde which is an important component of the resins used to bond them. Efforts are being made to reduce the formaldehyde content in these resins and to develop formaldehyde-free resins. However, the carcinogenic isocyanates used as a substitute for formaldehyde are also controversial.
The manufacture of basic metals and that of rubber and plastic products are industrial sectors in which concentrations are low. Three times as many data items are available in MEGA as in COLCHIC for the manufacture of basic metals. Although the RCR results are slightly higher in COLCHIC than in MEGA, their value remains quite low. For the manufacture of rubber and plastic products, the number of measurements and the concentration levels are remarkably similar. A detailed analysis of COLCHIC and MEGA data shows that the overall measured concentration is low, irrespective of the product used, the task performed or the job of the worker.
Exposure in the textile manufacturing sector is average compared to the overall data. Germany no longer has a major textile industry; the measurement data are therefore not comparable to those of "historical" working areas or those now found, for example, in Asia. The present data from this sector are derived from a small number of factories that produce textiles for special purposes (chemical finishing and non-woven production).

4.2 The time trend

Since 2002 and 2003, formaldehyde has been widely discussed and a topic of focus owing to discussion in the media on ambient air pollution, in particular relating to furniture. This is corroborated by the fact that fewer measurements were conducted in the wood industry before 2005. The median concentration peak of approximately 0.12 to 0.13 mg/m³ observed in 2004 and 2005 may be due to this focus. It is thus possible that since formaldehyde is a carcinogenic substance, it has been substituted in the interests of better acceptance of products and services, resulting in a reduction in occupational exposure.
For Germany, no general trend of falling exposure over the last decade can be discerned. This also applies to the individual sectors of industry. Annual fluctuations, especially at the higher percentiles, are a result of measurement campaigns in individual industrial sectors in which many measurements have been performed within short periods.

4.3 Comparing measurements by area and personal sampling

Workplace measurements should be performed by sampling close to the point at which the person breathes. Should personal sampling not be possible, area sampling systems may be employed. Sampling must then be conducted in consideration of the person (measurement at eye level and at a comparable distance from the source of exposure). In addition, area sampling systems are also used to estimate worst-case scenarios and determine contrast against background load.
From a general point of view (Table 2), the measured concentration based on area sampling is lower than that based on personal sampling. This does not hold true however for all sectors. In the wood and furniture manufacturing sector, the area concentration is similar (geometric mean) but with many more high values (percentiles and values exceeding the SCOEL limit value) than the personal concentration (Table 6). One reason for this is that industrial hygienists use the area sampler for measuring the emissivity of processes rather than the global area concentration. In the case of service tasks during the production of wooden panels, the workers are present for only a short time in the production halls. Since the sampling period is usually much longer than this activity, the resulting time-weighted averages are low. Nevertheless, the workers are subject to higher exposures for brief periods.

4.4 Additional data

For MEGA, the vast majority of the 769 data items excluded due to the sampling duration are attributable to the human health (449) and education (210) sectors which cover the same working areas described above. These collections are characterized by somewhat higher statistical parameters. The 50th and 95th percentiles are 0.3 and 2.15 mg/m³ in the case of human health activities and 0.58 and 9.45 mg/m³ in case of education. Most of these measurements (567) are referred to as task-related. Only 119 measurements relate to high peak or short-term exposures.
For COLCHIC, most of the 1,849 data items excluded were samples collected for less than 30 minutes (1,155 measurements), of which over 35% were also in the human health sector (411 measurements) and plastic and rubber sector (19%; 217 measurements). As in MEGA, these data were characterized by higher statistical parameters: the 50th and 95th percentiles were 0.34 and 3.33 mg/m³ for human health sector and 0.04 and 4.34 mg/m³ for plastic and rubber sector. The greater part of the remaining excluded data covers unspecified exposures. In the latter case, the explanation is the same as for MEGA.

5 Conclusion

Overall, the concentration values documented in the two databases do not differ significantly with regard to the conclusions on prevention that could be proposed. Workers' exposure in both countries is at a comparable level in the five major sectors of industry in which measurements are frequently performed. Seen globally, there is no fundamental difference between the industrial sectors studied for France and Germany or the prevention policies applied.
The major differences between the COLCHIC and MEGA databases concern the purpose of the measurements and

the sampling strategy. In France, industrial hygienists perform measurements only for preventive purposes and can use various devices and techniques (recommended in the MetroPol database [17]). In Germany, the measurements are not only performed for preventive purposes, but also for regulatory and social insurance purposes. The techniques and devices are stipulated by the MGU. Other differences include the coding systems used.

The COLCHIC and MEGA databases can be used in many ways to answer a range of questions (e.g. within REACH), based on chemical substance, the task, the sector, or any other determinant of exposure. Their relevance and reliability would improve still further if the data in the two databases could be merged, for example, in order for the data in one database to close any gaps in the other. However, for this to be possible, the comparability of the data must first be backed up by statistical methods. Specific shortcomings identified during work on these analyses could cause difficulties: the coding of the work areas in COLCHIC and MEGA are sufficiently different to make harmonization complex. Consequently, only industrial sectors were evaluated here. The use of a standardized European register could be a solution. Also of importance is accurate knowledge of exposure duration. Selection by sampling duration, as was the case in this paper, delivers good results for a general overview but does not address differences in short-term, task- and shift-related exposure scenarios.

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