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Belletti I. Troschel L. Pisani P. Berrino F.
Title
Retrospective assessment of exposure by experts: the example of formaldehyde, solvents and mineral oils among textile and metal workers.
Source
International Journal of Epidemiology. 22 Suppl 2:S127-33, 1993.

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International Journal of Epidemiology
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Vol. 22, No. 6 (Suppl. 2)
Printed in Great Britain

Retrospective Assessment of Exposure by Experts: The Example of Formaldehyde, Solvents and Mineral Oils among Textile and Metal Workers

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Belletti I (Epidemiology Division, Istituto Nazionale dei Tumori. Via Venezian, 1, I-20133 Milan, Italy), Troschel L, Pisani P and Berrino F. Retrospective assessment of exposure by experts: The example of formaldehyde, solvents and mineral oils among textile and metal workers. International Journal of *Epidemiology* 1993; **22 (Suppl. 2): S127-S133.**

The validity of retrospective assessment of occupational exposure greatly depends on the amount of detail in the available information, on the knowledge of the specific industrial process by the experts, and on the criteria adopted to define relevant exposure. These criteria are difficult to standardize and are rarely made explicit in published reports, which makes it difficult to interpret inconsistencies among different studies. In two ongoing case-control studies on kidney cancer and, respectively. malignant lymphomas, a detailed occupational history was obtained and supplemented by 19 additional questionnaires, specifically addressing industrial activities where the knowledge of job title alone would have been insufficient for reliable exposure assessment. One further questionnaire was used to collect details of task and environment for all the other activities. These data are used to establish probability, intensity and frequency of exposure to 30 substances known or suspected to be carcinogenic from previous studies. There are two basic steps in the exposure assessment procedure: firstly, general rules are defined for each job within each activity covered by specific questionnaires; secondly the judgement is modulated according to the detailed tasks, working conditions and environment. To illustrate the process and to facilitate comparison with other studies, examples are given for a few common exposures in the textile and metal industries—the two most frequent economic activities in the study area—namely exposure to mineral oils, formaldehyde, aromatic solvents, chlorinated solvents and other organic solvents.

In two population-based case-control studies on kidney cancer and malignant lymphomas, which are ongoing in the Varese province (Northern Italy). complete job histories were collected, and supplementary questionnaires for specific industrial activities were also used. These specific questionnaires (SQ) were designed to improve the expert assessment of exposure to a number of nuisances whose presence in the work environment cannot easily be determined from the job title alone and the economic activity of the establishment.) They have been developed in order to obtain a detailed description of any single task and work environment.* Beyond the qualitative assessment of the exposure, this detail helps to estimate its intensity and frequency. Even with SQ the validity of assessment greatly depends on the knowledge of industrial processes by the experts, on the information actually elicited with the questionnaires, and on the concept of what is individual exposure, namely the physical conditions and minimal dose of a compound regarded as a relevant exposure.[3] They also depend on the ability of the expert to translate anecdotal information into a quantitative assessment. All these determinants of classification may vary from study to study and are not usually described in detail when presenting results. In order to facilitate comparison with other studies this paper attempts to report explicitly.-with the help of a few examples, the criteria followed and uncertainties persisting in the process of retrospective assessment of exposure. Suggestions for improving the process are also given.

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MATERIALS AND METHODS

Substances and Industrial Activities Considered

Occupational exposure to all the substances belonging to **IARC** Monographs' groups 1, 2A, 2B (carcinogenic, probably and possibly carcinogenic substances) and related to malignant lymphomas or kidney carcinomas have been considered.[4,5] Some other substances have been added because of their mention in epidemiological studies or to validate a job exposure matrix constructed in a previous study.? In the end 30 substances or groups of substances have been included: acetamide, acrylonitrile, p-aminoazobenzene, aromatic solvents, arsenic, asbestos, atrazine, benzene, bitumens, 1,3-butadiene, cadmium, chlorinated pesticides, chlorinated solvents, chlorophenols and chorophenoxy compounds, chromium, coal tars and derived products, p-dichlorobenzene, ethylene oxide, formaldehyde, lead, mineral oils, nickel, nitrilotriacetic acid, N-nitrosodiethanolamine, other organic solvents (OOS), polychlorinated biphenyls, polynuclear aromatic hydrocarbons, styrene, tris (2.3-dibromopropyl) phosphate, vinyl chloride.

In order to exemplify the criteria used to assess exposure, this paper focuses on the textile and metal industries, because of their prevalence in the study area. Relevant substances present in both industries have been selected: mineral oils, formaldehyde, aromatic solvents, chlorinated solvents and OOS. Together with industrial hygiene reports from local industries a number of references have been **used.**[4,6,7,8-12]

Questionnaires

Specific questionnaires on the following **19** industries/operations have been used whenever the corresponding industry or job was mentioned in the occupational history: agriculture, breeding, slaughterhouses and meat processing, foundries, metal industry, welding, plating and coating metal products, body shops, chemical industry, paint manufacture, rubber industry, plastic manufacture, textile industry, wood industry, leather and footwear industry, building, transport, electricians, laundries. One further general questionnaire has been used for all the other activities.

The questionnaires have been designed following a detailed analysis of the relevant working areas, jobs and operations within an industry.[13] For instance, the metal industry questionnaire asks about which operations are performed in hot or cold metal rolling, in quenching and with different machine tools. It also enquires about the use of mineral oils as lubricants, as cutting or quenching fluids and for metal forming; about the presence *of* furnaces in hot metal rolling; about the use of specified or non-specified solvents; about the presence of different kinds of painting; about insulating operations and materials. All SQ enquire about company's activities, shift work, working environment (presence of fumes, dusts or vapours, use of exhaust fans), individual protection, job type (including temporary and occasional work), raw materials and final products.

Even if some direct questions about particular chemicals are present (formaldehyde in the textile industry, mineral oils and paints in the metal industry, solvents in different activities, etc.), the principal aim is to collect a detailed and complete description of each job, leaving to the experts the task of establishing exposure to specific chemicals. It has been shown, in fact, that a subject is more likely to remember operations and equipment than chemical names.[2,14,15]

Exposure Categories

The exposure categories chosen for this study have evolved from those used in previous studies. Pastorino *et al.*[16] assessed only the probability of exposure and classified subjects' exposure as certain or highly probable (+), uncertain (?), absent (-). No judgement of intensity and frequency of exposure is present in this classification. Ferrario *et al.*[1] developed a job exposure matrix in which the exposure was categorized with regard to both probability and intensity: 1) job-related exposure is not higher than for the general population; 2) job may entail a cumulative exposure slightly higher than for the general population; 3) job may entail exposure to levels definitely higher than for the general population, but available information is not sufficient *to* discriminate between exposed and not exposed; 4) job entails exposure to the specific agent; **5)** job entails exposure to the specific agent and exposure is known to be particularly high. Category 3) (uncertain exposure) was further divided into three levels according to the probability of exposure (<1/3, 1/3-2/3, >2/3) but did not give information about intensity.

In the present study, in order to retain most of the available detail, probability. intensity and frequency of exposure have been separately assigned for each job title and for each substance. Categories of exposure are:

- ***Probability:*** 1-not exposed; 2-exposure probability <33%; 3-exposure probability 33-66%; 4-exposure probability >66%; 5-exposed.
- ***Intensify:*** 0-not exposed; 2-very low intensity: groups of the general population can be exposed with this intensity for non-occupational causes;

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3–medium intensity: definitely higher than in the general population; 4–high intensity.

— ***Frequency:*** (within a working year) 0–not exposed; 2–frequency <5%; 3–frequency ***5–50%;*** 4–frequency >50% of the working time.

Exposure Assessment

The procedure is the following:

a) For each SQ general criteria of exposure assessment are decided. Criteria are mainly based on the principal working areas on which the questionnaire is structured (e.g. in the textile industry formaldehyde exposure is systematically considered in the finishing area and not in the spinning area), but might also include jobs in different departments (e.g. maintenance, room cleaning); jobs with possible exposure to all the chemicals present in the specific industry (e.g. warehouse, chemical deliveries to various working units); jobs with similar characteristics in different industries (e.g. transport, goods loading and unloading, etc.).

b) Exposure assessment of any single job period is decided on the basis of the general criteria and modified by the answers about the specific environment and task.

Further relevant information to modify the exposure assessment derives from the general questions present in all questionnaires. For instance:

— Description of the working unit has helped to specify the operations performed by other workers near the subject and thus any possible indirect exposure from the working environment. For example, in the metal industry, painting and cleaning operations have often been reported in the near surroundings of the work place. This led to a solvent exposure assessment for workers, such as some machine assemblers (International Labor Office—ILO code 84110),[17] for whom this exposure was not always expected.

— The presence of fumes, dusts or vapours, the use of an exhaust fan or of individual protection, have helped in estimating exposure intensity.

— A possible temporary move to other working units, for example to substitute other workers, has resulted in an evaluation of low frequency exposure. The issue of frequency, however, will not be considered here.

RESULTS

Exposure Assessment in the Textile Industry

Mineral oils. In the textile industry mineral oils can be used as:

— lubricants for all types of natural fibre spinning machines.

— fibre lubricants in the spinning of wool and jute (generally an aqueous solution of mineral oils is sprayed on the fibres).

— loom lubricants. In particular Sulzer looms which work at high speed and have 'projectiles' needing continuous lubrication; often the weaver has to operate in front of the loom where a box containing hot oil is situated.

Therefore, a high probability and a medium intensity of exposure to mineral oils have been estimated for the spinning and weaving of natural fibres; a higher intensity of exposure has been estimated for Sulzer weavers and for jute and wool spinners. Specific examples of exposure assessment are given in Table 1.

TABLE 1 *Examples of exposure assessment—Mineral oils in the textile industry*

Prob.	Int.	ILO[a]	Task[b]
2	2	97145	Warehouse porter: carries and stacks goods in warehouse; no indication of handling chemicals
2	3	75440	Weaver lubricating looms: possible use of graphite as lubricant instead of mineral oils
3	2	75430	Hand-operated machine weaver; other non-specified looms near the work place
4	2	79450	Cutting and sewing machine operator and ironer; spinning operations near the work place
4	3	70070	Supervisor and fibre preparing machine setter
4	3	75440	Weaving machine operator
4	4	75220	Wool spinner and non-specified loom weaver
5	2	75430	Hand-operated machine weaver; loom lubrication with mineral oils
5	3	85560	Maintenance electrician in the textile industry
5	4	75440	Sulzer loom operator

Prob. = Categories for probability of exposure.
Int. = Categories for intensity of exposure.

[a] The complete description of the working activity has been used for each exposure assessment; the ILO code" was not used for this purpose. It is present in the various Tables to facilitate comparisons (e.g. with job exposure matrices).

[b] Synthesis of information from questionnaires which led to exposure assessment is reported.

Solvents. A direct question concerning the use of solvents is present for printing and finishing, but solvent exposure is possible also for other operations. In

rayon acetate spinning, for example, some exposure to benzene. toluene, or dichloromethane is likely. In weaving, loom lubrication may involve exposure to solvents in loom cleaning and for hand cleaning. In sizing operations chlorinated solvents, such as perchloroethylene, instead of water, can be used. In dyeing. chlorinated solvents, such as perchloroethylene, trichloroethylene and 1,1,1-trichloroethane, can be used instead of aqueous solutions which are more frequently used. In colour mixing, solvent exposure can be due, in particular, to printing paste preparation because of the use of organic solvents as coadjutants. The use of this paste is then responsible for solvent exposure in printing. In finishing, solvents can be used in cleaning and sizing operations (in particular chlorinated solvents for wool and OOS solvents for all other fibres). A certain probability of exposure to solvents is also possible for operations on finished fabrics that could have been just cleaned by solvents, such as cutting, sewing, ironing, textile quality control and so on.

When no direct information on the class of solvents was available, a higher probability of exposure has been assigned for chlorinated and OOS solvents than for aromatic ones; the latter, in fact, were less frequently mentioned in the industrial hygiene reports from the study area that were available to us.

High probability and intensity of exposure have been frequently assigned for chlorinated and OOS solvents in printing, colour mixing and finishing.

Medium probability and usually low intensity of exposure have been estimated for chlorinated and OOS solvents in cutting, sewing, dyeing, and unspecified artificial fibre spinning; medium probability and usually high intensity exposure to aromatic solvents have been estimated for printing, colour mixing and artificial fibre spinning.

Low probability and medium–low intensity of exposure have been estimated for chlorinated and OOS solvents in sizing; for aromatic solvents in dyeing; for all solvents in warehouse-related activities. Low probability of exposure has also been estimated for workers in printing and finishing who claim never to have used solvents; it has been assumed, in fac ,that the operator may have been unaware of the presence of solvents in printing pastes or auxiliaries, which might involve medium intensity exposure ai least.

Specific examples of exposure assessment are reported in Table 2; the Table refers to OOS solvents, but it also comments on aromatic and chlorinated solvents.

Formaldehyde. In the textile industry formaldehyde may be present in corrosion printing (in printing paste additives) and in sizing operations (in crease-resistant agents such as formaldehyde resins). Exposure to formaldehyde is also possible for all operations related to direct contact–with finished fabrics that could have been previously treated with formaldehyde releasing agents, for example: cutting, sewing, ironing, packaging, textile quality control and so on.

TABLE 2 Examples of exposure *assessment—OOS* solvents *in the textile industry*

Prob.	Int.	ILO	Task
2	2	97145	Warehouse poner: opens packages. loads trolleys for dyeing operations
2	2	70070	Supervisor; occasionally machinery maintenance
2	3	75470 56060	Ironing and textile quality control; no direct use of chemicals
2	3	92950	Textile printer; says he has never used solvents (prob. 2, in . 3 for chlorinated and aromatic solvents)
3	2	79450	Cutting and sewing machine operator (prob. 4, int. 2 for chlorinated solvents)
3	4	75690	Textile cleaner (prob. 4, int. 4 for chlorinated solvcnts)
3	4	75220	Spinner of unspecified fibres; presence in the factory of acrylic, polyester and rayon fibres (prob. 3, int. 4 for chlorinated and aromatic solvents)
4	4	92950	Textile printer: use of unspecified solvents (prob. 4, int. 4 for chlorinated solvent-; prob. 3, int. 4 for aromatic solvents)
5	4	92950	Textile printer; use of turpentine (prob. 3, int. 3 for chlorinated and aromatic solvents)

N.B. See footnotes to Table 1.

Medium or high values of probability and intensity of exposure to formaldehyde have been estimated for printing, sizing, finishing (particularly for high temperature operations such as ironing and calendering).

Low probability and low intensity of exposure has been estimated for warehouse porters and goods distribution operators.

Specific examples of exposure assessment are reported in Table 3.

Exposure Assessment in the Metal Industry

Mineral oils. Mineral oils have different functions in the metal industry. They can be used, for example, for machine lubrication, friction reduction, metal cooling, corrosion and rust prevention and chip removal. With emulsifying agents they can also be used as aqueous solutions. Operations related to mineral oil exposures are, for example. rolling, pressing, drawing. quench-

TABLE 3 *Exa textile industry*

Prob.	Int.
2	2
2	3
3	2
3	3
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4	2
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5	3

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TABLE 3 *Examples of* exposure *assessment—Formaldehyde* in *the textile industry*

prob.	Int.	ILO	Task
2	2	97145	Warehouse porter: carries and stacks goods
2	3	75670	Calender operator who declared that fabrics were coming from bleaching (and so probably formaldehyde free)
3	2	39140	Storeroom clerk; yarn distribution and final product deliver); fabric cutting near the work place; vapour presence deriving from other rooms
3	3	92950	Textile printer
3	4	75690	Sizer; the worker said he used chemicals vapour presence
4	2	79550	Cutting and sewing machine operator
4	2	79510	Embroidered table cloth repairer
4	3	56060	Pressing machine operator: cutting and packaging operations near the work place
4	3	75670	Calender operator
5	3	75440	Weaving, cutting and finishing operator; use of formaldehyde and exhaust ventilation system presence

N.B. See footnotes to Table 1.

ing, machine tool working and machine lubricating. Mineral oils can also be used as antirust and anticorrosive coatings for parts which have to be stored for a long time.

Exposure to mineral oils has often been assessed in the metal industry because many subjects answered affirmatively to the direct question. If the question was not answered, a medium probability of exposure has been estimated for machine tool operators and for all the subjects working close to them.

High intensity of exposure has been estimated for operations using high temperatures such as forging or quenching and for the presence of many automatic machine tools in the working environment.

A lower intensity has been assessed for machine tool lubrication when this was the only possible source of exposure.

Specific examples of exposure assessment are reported in Table 4.

Solvents. Solvent exposure in the metal industry is possible in different working areas. For this reason in the questionnaire a direct question concerning the use of solvents is included, but without reference to any specific operation or department. So, for most subjects, direct information is available. When no answer is available, solvent exposure is assumed for the following operations: painting and surfacing; metal workparts degreasing; materials, machines and work place maintenance; any job entailing solvent manipulation (fuels included); hand cleaning for workers using lubricants or paints. Solvents can also be present in exhaust fumes from fuel engines or furnaces.

TABLE 4 *Examples of exposure assessment—Mineral oils in the metal industry*

Prob.	Int.	ILO	Task
2	2	84910	Engine maintenance with hand tools; similar operations near the work plac : no presence of vapours and fumes
2	2	85920	Security inspector for whole factory
3	2	99910	Scrap man also involved in cleaning of production departments
3	3	84175	Textile machinery assembler with hand tools and installer in place of use
3	3	99910	Metal-sawing machine operator; no direct use of mineral oil.; presence of different machine tools near the work place
3	3	99910	Apprentice: cleaning of mechanical equipment
4	3	70050	Machine assembler with hand tools; automatic lathes near the work place
4	3	97145	Warehouse porter: lathes, millers and other machine tools near the work place
4	4	84910	Machine tool operator: the interviewee (next of kin) could not respond about the use of mineral oils
5	3	83420	Lathe operator without cutting oils; machine lubrication; other machine tools near the work place
5	4	83420	Lathe and grinder operator; use of aqueous solutions of mineral oils and machine lubrication
5	4	84910	Oil quenching

N.B. See footnotes to Table 1.

Exposure to chlorinated solvents has been assumed for painting and for workers involved in machine tool lubrication, the latter because of cleaning of machines, metal work parts, work place and hands.

Aromatic and OOS solvents have been associated with the presence of exhaust fumes, with painting and with the use, for any purpose, of gasoline, naphtha, diesel oil, kerosene and white spirit.

Exposure graduation has been estimated as follows:

— OOS solvents. High probability has been assigned for any use of gasoline, diesel oil, kerosene, naphtha, white spirit; for the presence of exhaust fumes from gasoline or diesel oil; for painting operations. Medium probability of exposure has been assessed for machinery lubrication and for operators of non-specified furnaces.

- Aromatic solvents. Graduation of probability and intensity was very similar to those for OOS.
- Chlorinated solvents. High probability and low intensity of exposure havi' been assessed for gasoline use; medium probability and high intensity for degreasing and painting.

Specific examples of exposure assessment are reported in Table *5;* Table *5* refers to OOS solvents, but it also contains comments on aromatic and chlorinated solvents.

TABLE 5 *Examples of exposure assessment—OOS solvents in the metal industry*

Prob.	Int.	ILO	Task
3	3	83130	Pressing and forging; non-specified furnaces; fumes in the environment (prob. 3, int. 3 for aromatic solvents)
3	4	83970	Bending machine operaror: use of unspecified solvents for unspecified operations (prob. 3, int. 4 for aromatic and chlorinated solvents)
4	2	99940	Cleaning operations in painting unit (prob. 4, int. 2 for aromatic solvent.; prob. 3, int. 2 for chlorinated solvents)
4	2	84175	Machine assembler; painting near the work place but in an isolated room (prob. 4, int. 2 for aromatic solvents; prob. 3, int. 2 for chlorinated solvents)
4	2	85920	Safety control of machines; presence of painting operations (prob. 4, int. 2 for aromatic solvents; prob. 3, int. 2 for chlorinated solvents)
4	3	87370	Car body repairer; use of nitrocellulose stopping (prob. 4, int. 3 for aromatic solvents)
4	4	84110	Compressor assembler; spray painting; no information about solvent use (prob. 4, int. 4 for aromatic solvents; prob. 3, int. 4 for chlorinated solvents)
5	3	84110	Machine tool assembler; painting near the work plac ; nitrocellulose paint vapours in the environment (prob. 5, int. 3 for aromatic solvents)
5	3	83110	Fuel furnace operator (prob. 5, int. 3 for aromatic solvents)
5	4	84910	Machine tool operator; use of nitrocellulose solvents to clean machine tools and spray painting (prob. 5, int. 4 for aromatic solvents)
5	4	87350	Lathe operator; use of naphtha and trichloroethylene to clean both the machine and the work parts (prob. 5, int. 4 for chlorinated and aromatic solvents)

N.B. See footnotes to Table I.

TABLE 6 *Examples of exposure assessment—Formaldehyde in the metal industry*

Prob.	Int.	ILO	Task
2	2	84175	Textile machine assembler and installer in place of use
2	2	99910	Apprentice: cleaning operations in a mechanic unit
3	2	83130	Oil quenching
3	2	83130	Pressing with non-emulsified mineral oils
4	2	84985	Work pans controller; machine tools with emulsified mineral oils in the work place
4	3	83420	Lathe and grinder operator; use of aqueous solutions of mineral oils and machine lubrication

N.B. See footnotes to Table I

Formaldehyde. Mineral oils, in particular aqueous solutions, can release formaldehyde because of the addition of bactericides.

Formaldehyde exposure has been assessed for workers exposed to mineral oils, with a higher probability for those using emulsified ones.

Specific examples of exposure assessment are reported in Table *6.*

DISCUSSION

The use of specific questionnaires permits different exposure judgements to be given to subjects with the same job title and to solve many uncertainties that arise when only the job title is available. Sometimes the answer to a direct question is sufficient for a straightforward assessment: this occurred, for example. for mineral oils in the textile and metal industries. Exposure assessment from a direct question is possible. however, only for substances which are very common in a given activity; which are generally used with the awareness of the worker; which are easily recognized; which do not have ambiguous denomination (as has. for example, the word 'solvent', when it is not related to a specific operation). But also in these cases direct questions may be misleading. For example, if a machine-tool operator says he used mineral oils and his questionnaire is reliable (i.e. complete, without doubtful or contradictory information), it is quite easy to decide that he was exposed. Much more difficult is to decide that a machine tool operator was not exposed, if he denies the use of mineral oils. In fact, the reliable exclusion of the presence of mineral oils in the working environment requires a very detailed description of it.

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Such problems may be at least partially solved with standardized questionnaires and with better strategies of interview. In any case the adequacy of information does not depend only on the good quality of questionnaire, but also on subject recall and on interviewer ability.[18]

For these reasons, even when very detailed SQ are available. experts often have to express a subjective judgemen . So it is very important that the studies based on an expert assessment make as explicit as possible the procedure used in exposure evaluation.' The documentation should include:

- A description of the general criteria used in exposure assessment, which can also be done in the form of a job exposure matrix.
- A list of significant examples showing how the exposure judgements have been modified on the basis of the particular information contained in the questionnaire. Tables 1 to 6 show how such a list can be compiled.

This kind of procedure allows a comparison between experts on the minimum level of exposure that should be considered to define a subject definitely exposed and also helps to improve understanding of the sources of discrepancy between different studies.

ACKNOWLEDGEMENTS

This work was supported by the Italian National Research Council under contract No. 88.00524.44 and by the European Concerted Action on Retrospective Evaluation of Occupational Exposure in Cancer Epidemiology.

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