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MEETING REPORT

A EUROPEAN MEETING HELD TO DISCUSS DERMAL EXPOSURE MONITORING AND RELATED ISSUES, BRUSSELS, BELGIUM, 21–23 JUNE 1994

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Abstract—Recognizing the significance of dermal exposure, the European Commission funded and convened a consultative meeting on dermal exposure and related issues, with the objectives of identifying gaps in knowledge, discussing future research requirements and exploring the possibility of establishing a research network for the purpose of stimulating collaborative European R&D projects. The meeting began with a series of keynote review lectures covering a range of issues associated with dermal exposure. Participants from the United States outlined the prevailing situation and likely future developments in dermal exposure assessment in the United States, and representatives of participating European states then presented a brief summary of regulatory position regarding dermal exposure in their respective countries. The prevailing position in skin and surface contamination monitoring was discussed and gaps in knowledge identified; areas of work which would result in the development of standardized methodologies were debated. The meeting resulted in the formation of five syndicate groups, these include: (i) occupational exposure assessment–risk assessment; (ii) biological monitoring; (iii) skin and surface contamination; (iv) *in vitro* models (skin penetration); and (v) source apportionment (dermal vs air exposure). Each syndicate group discussed and identified the R&D requirements in its area of interest and reported its findings to the meeting. There was a consensus that a need exists for the establishment of a European network on dermal exposure to co-ordinate efforts in this field. Preparatory work for the establishment of the network is currently underway.

INTRODUCTION

It has generally been realized that evaluation of the health risk in the occupational environment caused by chemicals which have multiple exposure routes cannot be effectively carried out by air monitoring alone. Published studies have shown that for numerous substances dermal absorption can contribute significantly to the total body burden, and in some cases it can play the determining role in workers' exposure. In addition to direct dermal absorption, contaminated skin can contribute to the ingestion by inadvertent transfer from hand to mouth. Another aspect of dermal contamination is its role in occupational skin disease, a major cause of workers' ill health in diverse occupations. As a result of increasing awareness of the issues related to dermal contamination, occupational health and safety regulatory bodies across the world are concerned about the implications of dermal exposure, and are aware of the need to establish methods for its quantitative monitoring for health risk assessment.

Although there are well-defined methods for the assessment of inhalation exposure, the situation with respect to dermal exposure is markedly different. With the exception

of biological monitoring, existing methods provide only a qualitative measure of the potential contribution of the dermal pathway. In order to develop a comprehensive risk assessment strategy for exposure to chemicals in the workplace it is essential that quantitative methods for the assessment of total dose received via all exposure pathways be developed and standardized. Within Europe, concerns regarding the prevailing situation in dermal exposure monitoring led the European Commission Directorate General XII and Directorate General V, in consultation with the Health and Safety Laboratory, Health and Safety Executive, U.K., to organize a 3-day European consultative meeting on dermal exposure and related issues in the context of measurement for occupational health and safety. The meeting was held from 21 to 23 June 1994, in Brussels, Belgium. This report summarizes the discussions during the meeting and its outcome.

OBJECTIVES

The problems involved were considered in the context of measurements for occupational health and safety, and clear objectives of the meeting were: (i) to bring together technical experts and others involved in the study of dermal exposure, to focus upon the present state-of-the-art in the field with a view to identifying gaps in knowledge, and to discuss research requirements; (ii) to discuss the initiation of collaborative European research projects to develop and test standard methodologies for monitoring skin and surface contamination, and other measurement techniques relevant to the evaluation of dermal exposure; and (iii) to discuss the establishment of a network on occupational dermal exposure assessment and related issues. The objectives were designed to contribute to the technical definition of the future EC Measurement & Testing (M&T) 4th Framework Programme in the field of workplace monitoring (occupational hygiene).

DERMAL EXPOSURE ASSESSMENT: STATE-OF-THE-ART

The meeting began with a series of keynote review lectures to focus upon the state-of-the-art in dermal exposure, in order to initiate the debate on the various facets of the problem encountered in assessment and to identify requirements for further work. In addition, representatives of participating states submitted a brief summary of the regulatory position in their countries.

Dermal exposure pathways (Chairperson: Dr J. Auffarth, BIA, Germany)

Dr J. J. van Hemmen (TNO, The Netherlands) discussed dermal exposure pathways and the significance of dermal exposure in health-risk assessment. Exposure pathways were identified as direct deposition on the skin from a source or the ambient environment, or exposure resulting from contact with contaminated surfaces. The contribution of dermal contamination to ingestion exposure was known to be difficult to estimate, but could significantly contribute to the total body burden. The

relationship between the dermal exposure potential and total dermal uptake was complex, involving such variables as the physiochemical nature and concentration of dermal contaminant, the area and duration of dermal contact, and the structural and biochemical factors associated with the skin, all of which affect penetration and ultimate body uptake. In addition to systemic effects arising from dermal exposure, the importance of assessing dermal exposure and its role in dermal disease, such as dermatitis, was discussed. The main obstacle to taking dermal exposure into account for assessing exposure was seen to be the lack of practical and validated methods of assessment, including lack of validated methods for the assessment of penetration through human skin. In the absence of validated methods, it was difficult for the industry to carry out its obligation for risk assessment for compliance with the Community's legislation regarding occupational health and safety. In situations where the dominant route of exposure has been shown to be dermal, the setting of dermal occupational exposure limits (DOELs) was discussed. The basis for setting DOELs either for surface or for skin contamination or uptake as determined by bio-monitoring and related to effects on health, needs to be examined.

Skin absorption and biological monitoring (Chairperson: Dr K. Wilson, Health and Safety Laboratory, U.K.)

Professor H. Savolainen (Switzerland) and Dr G. D. Nielsen (Denmark) discussed skin absorption and biological monitoring. The complex nature of dermal penetration phenomena for chemicals results directly from the heterogeneous nature of the skin barrier (epidermis, dermis, lipid layers, etc.), from the different available pathways for penetration, and from the dynamics of interaction of the various components of the 'barrier layer' with the penetrating chemical. Thus a conditional equilibrium which may exist *in vitro* is non-existent *in vivo*, and further complexities arise when considering the penetration of a given substance in the presence of solvents. Identification of important parameters affecting the dermal penetration function, such as the hydrophilic and hydrophobic nature of chemicals, partition coefficients and lag coefficients, etc., through *in vitro* and *in vivo* models was considered necessary. The conflicting guidance (OECD vs U.S.A.) available for chemical penetration studies needs to be resolved and a standardized approach developed in order to compare and utilise data effectively. Consideration needs to be given to cell design, receptor fluid, effective skin membrane life, membrane integrity and prioritization of substances for penetration studies. Similarly the role of animal models for providing reliable penetration data and their relevance to humans needs to be examined in greater depth. Also reference substances with well-defined skin penetration characteristics need to be developed for use in studies of penetration for existing or new substances; this will greatly facilitate inter-laboratory data comparison. Dr B. Forslind (Sweden) pointed out that prior to the development of any dermal exposure assessment strategy a detailed understanding of the skin's barrier functions is crucial. The variation of lipid classes and their influence on the barrier properties, and the differences in lipid content of atopic skin compared to normal skin, need to be understood. The role of biological monitoring in dermal exposure assessment was illustrated by the results of a study of workers' exposure to phenoxy acid herbicides and atrazine. The skin contamination evaluated from patch samples was shown to correlate well with urinary monitoring. However, it was noted that the dermal dose–excretion relationship needs to be

carefully evaluated and compared with the respiratory dose-excretion relationship for a range of substances if biological monitoring is to quantify exposure.

Prevention and control (Chairperson: Professor ***G.*** Scansetti, Italy)

Mr L. Morris (HSE, U.K.) discussed prevention and control of dermal exposure. The dependence of dermal exposure upon the nature of the task being performed was illustrated by visualization by fluorescence of exposure in work with metal-working fluids and in sheep-dipping operations. Localized penetration through protective clothing under working conditions was used to demonstrate that laboratory test methods for Personal Protective Equipment (PPE) do not always indicate the actual performance in the workplace. A strategic approach should be taken in preventing and controlling exposure, for example, starting with measures taken to minimize emissions at source, and then measures to prevent transfer of contamination, with PPE being the final resort in achieving control. Strategies to reduce reliance on PPE were shown to include elimination or substitution of the material with a safer one or changing its physical form, engineering containment of sources, closed or remote handling systems, and improvement in workplace and personal hygiene practices. A hierarchy of measures to prevent dermal exposure, assigning their relative importance as an aid to a risk reduction strategy, is needed and it should reflect the cost-effectiveness of the various measures. Effective utilization of PPE by workers and their approach to the reduction of personal exposure are crucial components in a comprehensive strategy. The development of worker educational programmes for dermal exposure and related issues was considered to be of prime importance. The evaluation of the risk of dermal exposure requires that simple and reliable methods be developed for risk assessment, without which the effectiveness of control measures and of PPE cannot easily be ascertained.

Skin contamination and skin disease (Chairperson: Dr B. Forslind, Sweden)

Professor J. Lachapelle (Belgium) discussed skin contamination and skin disease. It was noted that workers in diverse operations are affected by skin disease. The fact that the majority of reported cases of occupational disease are skin-related confirms the urgent need to understand the role of dermal contamination in causing dermal ill-health. On the basis of the evidence of studies of clinical cases presented for dermatitis caused by direct deposition of airborne contamination on the skin (Occupational Airborne Contact Dermatitis, OACD), it was argued that in addition to other mechanisms responsible for dermatoses OACD could be responsible for a greater number of cases than previously thought. In case studies skin-surface biopsy has identified the presence of particulate and fibrous contaminants on affected areas. In addition to the chemical nature of contaminants, particle size and morphology were also envisaged to be important factors in skin irritation. The barrier function of the irritated or sensitized skin would be dramatically altered and affected areas may facilitate penetration. Owing to the individual-specific dermatological response to a given dermal contaminant, a dose–effect relationship for dermal contamination cannot be visualized as in systemic poisoning. However, the potential for dermal ill-health associated with a given substance and patch tests tailored to a given occupational environment should be considered. It was argued that 'barrier creams' do not prevent contact with fibres and particulates.

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The U.S.A. experience (Chairperson: Dr P. Kerklaan, The Netherlands)

Dr M. Boeniger (NIOSH, U.S.A.) discussed "Dermal issues in the U.S.A.; experiences, present position and likely future developments". Several regulatory and advisory agencies and institutions in the United States have issued standards or recommendations, or have programmes which relate to dermsl exposure issues. The Occupational Safety and Health Administration (OSHA) has promulgated several comprehensive occupational health regulations that in part address dermal exposure. In 1992, OSHA promulgated a standard to regulate exposure to 4,4′-methylenedianiline (MDA)in the workplace. It was acknowledged that for MDA >90% of exposure could be through the skin. Measures to prevent excessive skin exposure are limited to visual inspection of gloves and the skin; designation of regulated areas, and biological monitoring was suggested as a potential monitoring tool but no specific guidelines on dermal related issues were provided. Specific requirements were issued to limit air concentrations to below 10 ppb and to provide medical surveillance. Several new regulatory standards are currently under review. A comprehensive standard on glycol ethers is also not likely to contain any procedures for measuring skin exposure. A draft revised standard on PPE is also performance-based and requires employers to develop a programme suitable for their particular needs and which includes the selection, use and maintenance of PPE. **Also** under review is OSHA's generic exposure assessment standard, which would require several general provisions that could encourage comprehensive exposure assessments in the workplace, including the extent of skin exposure. The employers' responsibility to address potential dermal exposures would be increased by requiring him/her to collect quantitative as well as qualitative data, to determine and document the adequacy of control measures, and to research the harmful effects of exposure. Non-regulatory governmental activities have recently involved creation of a NIOSH–EPA–OSHA working group on dermal exposure whose aim is to develop a criteria document that would include ranking and categorizing skin hazards according to the absorption potential and toxicity of each chemical on the revised OSHA PEL list: quantitative skin expsoure limits would be recommended, and as part of this effort EPA is acquiring dermal penetration data on 58 chemicals on the PEL list. The Interagency Testing Committee has drafted a skin penetration study protocol that is intended to standardize the test results.

In February 1994, the EPA sponsored a workshop on dermal exposure monitoring methods for a proposed National Human Exposure Assessment Survey programme. The topics identified as requiring investigation were: (i) activity pattern data to relate surface contamination monitoring data to potential skin contact; (ii) a solvent that emulates perspiration to be used as a wetting agent for surface and skin wipes; (iii) a sampling strategy to relate to human activity pattern data; (iv) characterization and refinement of walk-off mat sampling methods to track contaminants from outside homes; (v) a passive dermal sampler that monitors chronic accumulation exposure (in hours) and which mimics the characteristics of real skin; and (vi) a multifaceted approach to monitoring skin exposure. In conclusion, in the United States increasing importance is now being attached to chemicals that penetrate the skin. However, there is a lack of validated and standardized methods and strategies for screening or measuring skin exposure. Improved methods and strategies to reduce occupational skin disease are also required.

Di T. Klingner (CLI Inc., U.S.A.) continued with a paper on "Dermal exposure

assessment–biological action limits: a performance-based standards program". A urine monitoring programme for assessing industrial exposure to MBOCA (methylene-bis-chloroaniline) has been in place since 1978. Recognition that skin absorption was the primary route of exposure led to the development of a range of new dermal exposure assessment techniques including surface–skin wipes and glove–clothing permeation indicators. A series of workplace surveys utilizing these colorimetric indicators resulted in identification of work practices that contributed to dermal exposures. After significant dermal exposure routes were identified, modifications to work practices, protective clothing and housekeeping were implemented. Significant reductions in dermal exposure were documented via biological monitoring. Dr Klingner suggested that a performance-based 'biological action limit' process was the most efficient and effective method for reducing dermal exposure.

Skin notation criteria

Dr J. Jackson (Belgium) outlined the European Centre for the Ecotoxicology and Toxicology of Chemicals (ECETOC) Document No. 31 which is concerned with issues related to the assignment of skin-notation for substances. The criteria that lead to a 'skin-notation' are generally not specified, an exception being the provisional approach of the Dutch Expert Committee on Occupational Standards (DECOS) which has since 1989 been assessing a semi-quantitative approach to gain experience before committing to a particular method. ECETOC document No. 31, reviews the factors underlying the criteria for assigning skin-notation and puts forward proposals, summarized in a "Decision tree for skin notation", to assist the achievement of a harmonized approach. It is recommended that this approach be reviewed in the light of experience in use, of any formal validation undertaken and of scientific and technical progress. Factors taken into account include the physical form of the substance, local vs systemic effects, systemic toxicity, potential for percutaneous absorption, and the combination of toxicity and skin penetration data. It was pointed out that skin notation relates specifically to skin penetration (toxicokinetics) and not to dermal toxicity (toxicodynamics). Criteria for dermal toxicity are also described in Annex VI of Directive 67/548/EEC.

MEASUREMENT METHODOLOGIES FOR THE ASSESSMENT OF DERMAL EXPOSURE

Mr J. Cherrie (IOM, Edinburgh, U.K.) focused on considerations which are important in the assessment of skin exposure and the absorbed dose. These included the concentration of contaminant on the skin, the area and location of contaminated skin, duration of exposure, whether the skin exposure was occluded and the vehicle of contaminant. An exposure index was proposed, combining the contaminant concentration on the skin, the surface area exposed and the duration of exposure. Dr C. Dary (EPA, U.S.A.) (Chairperson: Professor J. Kangas, Finland) discussed the monitoring of surface and skin contamination. Occupational and incidental dermal exposure may be monitored through the combined measurement and analysis of the biomechanics of exposure and the rate of disappearance of residues from environmental media, in reltion to the rate of transfer of residues from surface to the skin. Studies were described which attempt to quantify dermal exposure. The biomechanics

of exposure were examined by measuring the contact and transfer of residue of an organic surrogate pollutant, the insecticide malathion, from a carpet to the surface of a cotton whole-body dosimeter. A close correlation was found between the frequency and the duration of localized contact with the contaminated surface and the concentration ($\mu g\ cm^{-2}$) of malathion transferred to that part of the suit. The results indicated that videotaping and ergonomic analysis can be used to monitor the biomechanics of exposure when validated against whole-body dosimetric measurements.

Surface contamination monitoring methods

(Chairperson: Dr A. Robertson, IOM, U.K.)

Dr T. Schneider (NIOH, Denmark) discussed surface contamination monitoring methodologies. Among the exposure pathways, the role of surface contamination in dermal exposure was considered to be of special significance. Although numerous sampling methods and on-site analysis tools have been developed for monitoring surface contamination, they provide at best only a qualitative picture. The variables associated with the surface, the nature of contaminant and those inherent in the sampling techniques need to be evaluated in order to assess their effect on sampling efficiency and reproducibility. The spatial variation of contaminants in the occupational environment has an important bearing on sampling strategy and geostatistical methods can be employed for the purpose. An important feature of surface contamination is related to its ability to be re-entrained and to contribute to airborne exposure. This aspect needs to be further evaluated and the dependence of re-dispersion on work activity and wind conditions better understood. The use of reference samples to assess sampling efficiency and reproducibility, for example using well-defined surface contaminants on typical surfaces found in the occupational environment, and the definition of true surface contamination on porous and other surfaces such as carpets, should be considered. Other research areas identified include:

—the development of fraction conventions (re-suspendable and dermal fraction of surface contamination);
—fraction-specific sampling methods;
--surface to skin transfer coefficients;
—work on reference surfaces;
—methods for generating reference contaminated surfaces in laboratory and field spiking;
—well-defined sampling strategies for occupational environments with reference to the contamination source; and
—ultimately the need to carry out inter-laboratory comparisons of the techniques.

As an example of application of the wipe sampling method, Mr K. Korhonen (IOH, Finland) presented results of a study of wipe sampling methods for polychlorinated biphenyls (PCBs). Occupational exposure to PCBs can occur as a result of handling PCBs, of accidental spillages or of accidents involving transformers containing PCBs. Revised EC Directive 76/403/EEC requires the progressive reduction of the use of PCBs and their elimination from the work environment no later than 1 January 2000. For surfaces, limits of 100 $\mu g\ m^{-2}$ for PCBs, 50 $\mu g\ m^{-2}$ for PCDF and 5 $\mu g\ m^{-2}$ for 2, 3, 7, 8, TCDF and 2, 3, 7, 8, TCDD was suggested for purposes of clearance after accidents.

Direct dermal deposition from the ambient environment
(Chairperson: Dr A. Robertson, IOM, U.K.)

Professor A. Goddard (Imperial College, U.K.) discussed assessment of direct dermal deposition on the skin from the ambient environment. By using labelled surrogate aerosols and Neutron Activation Analysis (NAA) it was demonstrated that by generating monodisperse aerosols in a test chamber with known concentration and well-defined particle size it is possible to estimate the deposition velocities for various particle sizes and then calculate the relative deposition rates for various surfaces including various regions of the human body such as hair, face, hands, arms, etc. Studies carried out to examine the deposition of particulate contaminants have shown that it is possible to provide data regarding the potential dermal dose received on different parts of the human body and clothing, in a given concentration of aerosol under turbulent flow conditions. It was also pointed out that the total amount of particulate matter deposited on the skin (face, hands, forearms), could be significantly higher than the inhaled dose. Using suitable test contaminants, the NAA techniques could be used to validate the sampling methods for particulates and droplets to provide indication of the variability and accuracy of the sampling methods. The dynamics of particle–skin interaction can be studied under controlled conditions to determine the effects of variables, such as air flow around the worker's body and worker activity on particle residence time. The non-invasive fluorescent technique also offers much scope for future work in this area. Studies to examine re-suspension, mechanical transport and the effectiveness of cleaning practices, with reference to understanding their effect on total particle cycling in the work environment, would yield valuable data for providing an insight into the complex processes that determine dermal exposure.

Skin contamination sampling methods (Chairperson: Dr **A.** Robertson, IOM, U.K.)

Mr D. Brouwer (TNO, The Netherlands) reviewed skin exposure sampling strategies. Exposure via the dermal pathway is a complex and dynamic process and consideration needs to be given both to adsorption and to absorption. Thus on the surface of the skin interfacial forces are responsible for retaining or removing the contaminant and beyond the skin surface factors related to penetration, such as diffusion, and the kinetics of body uptake would govern exposure. Since there exist a number of mechanisms by which dermal exposure can occur, such as immersion, direct deposition on the skin and contact with contaminated surfaces, its evaluation becomes even more complex.

The methods for determining dermal exposure include taking skin wipe or swab samples, the use of surrogate skin, direct-reading instruments, use of surface sampling and biological monitoring. These methods represent different approaches and, when compared, they give differing results. There seems to have been no effort devoted to assessing these methods with a view to understanding the factors responsible for the differences. The surrogate skin method can provide information on the skin loading and thus measure the potential for dermal exposure, however, retention characteristics of the surrogate surface may not resemble those of the actual skin. Removal methods give the actual skin exposure if the penetration rate is low and the removal efficiency is known. Direct-reading instruments, utilizing the natural fluorescence of a substance or of added exposure tracers, can be used to monitor dermal contamination. However, background skin fluorescence has to be corrected for, and the technique may

underestimate the exposure for rapidly penetrating chemicals. Biological monitoring integrates skin exposure over the whole body but also includes other exposure routes, and pharmokinetic models can be used to assess the dermal component. Areas which need to be examined for the development of suitable dermal exposure assessment methods are the use of tracers and wipes to identify the areas exposed, their location and their surface area; work activity pattern observations; the determination of the source strength; skin-contaminant contact and transfer processes; and the evaluation of surface sampling procedures. There is a pressing need for the validation and comparison of methods.

Dr M. Boeniger (NIOSH, U.S.A.) discussed the application and limitations of surface and skin monitoring methods. In addition to providing information on exposure, methods for monitoring dermal exposure are needed in order to select appropriate PPE, to evaluate work and cleaning practices, and for the justification of costs involved in placing controls. Wipe sampling of inanimate surfaces has been the most extensively used approach for the purpose of identifying locations and sources of exposure. If the work activity patterns and the efficiency of transfer of contaminants from the surface to the skin are known, skin contact exposures can be estimated. Skin surfaces can also be wiped but the ability to assess skin contamination level accurately and quantitatively is limited unless the collection efficiency is known. Furthermore, where Contaminants can penetrate or bind to the skin, recovery from the skin has been shown to be very low, underestimating actual contact. When sampling from the skin confounding factors such as excretion of substances in the sweat also need to be borne in mind. Whole hand washing has been used as a preferable method to remove contaminants from the skin because trapped material is more likely to be recovered and ail surfaces are available for cleaning. However, this approach is subject to limitations as hand washes are unlikely to recover bound or asorbed contaminants from the skin effectively. For chemicals that penetrate the skin rapidly it is unlikely that the amount recovered will represent the received dose. The solvent should be selected on the basis of effectiveness, safety and frequency of intended use. Surrogate skin monitoring, placing a passive collection medium next to the skin or clothing, is sometimes used to determine direct contact with, or the aerosol deposition of, contaminants. For screening purposes, there are commercial collection pads that change colour upon contact with the contaminant, and charcoal pads may be used to collect some volatile compounds, When surface collectors like these are used, it is important to determine the likely anatomical sites of contact or deposition so that the extent of contamination can be appropriately detected. NIOSH are currently developing a direct dermal dosimeter using a reconstituted pig-skin stratum corneum on charcoal backing in an attempt to mimic human skin behaviour and permeation characteristics. Observations to determine worker activity patterns and practices, and any decontamination procedures which may be used, should be made before using this approach. Visualization techniques have been used to detect the presence and distribution of contaminants over surfaces and on workers, and with sophisticated visual imaging equipment and a computer quantitative measurement of exposure is possible. Such techniques are also excellent training tools for demonstrating the effects of poor work practices or inadequate protective measures.

There are various ways in which penetration of contaminants through PPE can be checked. Cotton or polyethylene gloves can be worn under normal polymeric gloves as

a collection medium or the inside of the glove can be rinsed with an appropriate solvent. The selection of a method will depend primarily on the level of quantitative reliability needed, on the sensitivity needed to prevent false negatives, and on the analytical method proposed. If only source detection is required, sensitivity and potential interferences are of primary concern, but if estimates of dose are needed, parameters such as collection efficiency, recovery from the sampling media, sample stability, presence of interferences, and sampling and analytical precision and accuracy should be known. Also, if true 'dosing' estimates are desired, the collection media should present capture and retention characteristics similar to those of the skin, or at least the ratios of these characteristics comparing the sampling media and skin should be known. Areas where further work is needed include: demonstrating the significance of dermal exposure for substances other than pesticides; development of sampling methods and their validation; a survey to provide a profile of skin exposure potential in different jobs; and the creation of a regulatory environment which encourages dermal exposure monitoring.

PREVAILING REGULATORY POSITION IN EUROPE

Representatives of each participating European state gave an account of the prevailing regulatory position in their respective countries in the field of dermal exposure monitoring.

Belgium

The Belgian regulations on occupational skin disease is listed under two headings: skin disease related to exposure to listed chemical substances; and skin disease related to the handling of products. Skin disease is recognized as related to occupation if the specific allergic skin patch test is positive and the chemical substance is on the proscribed list, or if there is a positive patch test with the industrial product used. Other than this no guidance is available on the methods for the assessment of dermal exposure to chemicals in the occupational environment.

Denmark

The Danish OEL list contains 556 substances and among these 170 have skin notation, 50 for the particulate phase. The regulations specify that for substances with skin notation, the OEL value for inhalation of airborne contaminants can be used only if skin absorption does not take place. 'Skin' denotation is included in the official lists of occupational exposure limits. However, this denotation is not based on any independent evaluation of the skin penetration potential and the associated risk of adverse effects. Similar lists from other countries have been utilized, i.e. from other Nordic countries and ACGIH as well as German and Dutch evaluations.

France

With the exception of the problem of dermal exposure to pesticides during agricultural treatments, there are no specific regulations concerning the prevention of dermal exposure in France. All regulations on industrial chemicals in general are based on atmospheric thresholds, but some have been assigned a skin notation.

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Germany

Basically, occupational contacts with hazardous substances are regulated by the Hazardous Substances Order: "Verordnung zum Schutz vor gefahrlichen Stoffen (Gafahrstoffverordnung—GefStoffV)". The German list of occupational exposure limits (TRGS 900 "Grenzwerte") provides a 'skin notation' ('H': Haut = skin) for industrial chemicals that are known to penetrate the skin in significant amounts. Criteria for assigning a 'skin notation' are not yet specified. Technical Rule: TRGS 150 "Unmittelbarer Hautkontakt mit Gefahrstoffen" ("Direct Dermal Contact with Hazardous Substances") and direct contact with skin penetrating chemical agents (i.e. 'H — notation according to TRGS 900 or listed carcinogens) elicits specified protective health and safety measures, as is mandatory in case of exceeded occupational exposure limits.

The regulatory position in Germany regarding dermal exposure is not laid down scientifically and quantitative aspects are not mentioned. Dermal exposure to chemical substances at the workplace are regulated by indirect methods using the BAT-concept, which monitors exposure biologically using internal parameters. The MAK-Committee in Germany is interested in changing this situation and moving towards the quantitative assessment of dermal exposure. However, since the scientific basis for the monitoring of dermal exposure is inadequate it is difficult to envisage the formulation of regulations for its control.

Ireland

The current regulatory position regarding dermal exposure in Ireland includes the fact that certain chemicals will be assigned a skin notation which must be taken into consideration when carrying out the risk assessment which is required in respect of chemicals in the workplace. Risk assessment for certain carcinogens and other chemicals requires an assessment of all routes of exposure and absorption into the body.

Italy

Currently, with the exception of the production and use of aromatic amines **(AA),** there are no regulations regarding dermal exposure. The recommendation Rec. 46—12 June 1979 subdivides AA into three categories, namely: (1) carcinogenic; (2) suspected; and (3) not adequately tested. Consequently two different working areas are instituted, named controlled areas (for carcinogenic AA) and areas under surveillance (for the remaining AA). Different levels of preventative measures are adopted, to limit skin contamination and/or absorption, according to the area classification. Protective clothing, personal hygiene facilities, and surface and clothing contamination control are mandatory. Skin notation is used, but there is no legislative requirement for dermal exposure assessment.

The Netherlonds

For registration procedures dermal exposure to pesticides and new chemicals is considered in great detail. A project has been initiated in which an outline for a possible dermal occupational exposure limit is conceived, applied to two chemicals and

indicatively evaluated for one compound in the workplace. So far skin notation is the only warning given of possible uptake of a substance through the skin at work.

The Ministry of Social Affairs and Working Conditions is involved in preparing and enforcing regulations concerning occupational exposure to toxic substances. The existing regulations state that, if exposure to substances occurs at the workplace, the employer should assess the level of exposure to each of these substances, taking into account all possible exposure routes (inhalation, dermal, ingestion). Based on the outcome of their assessment the employer should control the exposure adequately in order to prevent health effects and nuisance. In practice a safe exposure level is reached if exposure is (well) below an OEL and OELs are set only for respiratory exposure. In 20 cases a skin notation has been assigned to these legally binding OELs. Recently, strict criteria as defined by ECETOC (see section on "Skin notation criteria", p. **246)** were introduced for assigning a skin notation. Around 700 administrative MAC-values (Maximally Accepted Concentrations) have been published and these values (of which **136** have a skin notation) have been taken mainly from the ACGIH. The establishment of health-based ***Dermal Occupational Exposure Standards (DOESs)*** could offer a tool for taking adequate and quantitative account of the dermal route in exposure assessment and the usefulness and feasibility of DOESs is being investigated in The Netherlands. Feasibility depends mainly on the availability of practical and standardized methods for measuring skin contamination and skin absorption.

Spain

There are no direct regulations regarding dermal exposure in Spain, but there are some references to this issue in different fields: occupational disease, personal protection, chemical protective clothing, gloves, etc. However, no guidance is provided for the assessment of dermal exposure for risk assessment purposes.

United Kingdom

The Control of Substances Hazardous to Health Regulations (COSHH), 1988, apply. Under Regulation 7(1) there is a general duty on employers to ensure that the exposure to substances hazardous to health by any route (e.g. inhalation, ingestion, absorption through the skin or contact with the skin) is either prevented or, where this is not reasonably practicable, adequately controlled.

The Approved Code of Practice accompanying the COSHH Regulations explains the terms 'adequately controlled' for exposure by inhalation and other routes. Exposure to any substance which can be hazardous by ingestion, absorption through the skin or mucous membranes, or contact with the skin or mucous membranes (e.g microbial infection, dermatitis and chemical burns), should be controlled to a standard such that nearly all the population could be exposed repeatedly without any adverse health effects. Information about appropriate standards of control may be sought from manufacturers, suppliers and other sources. Aspects to consider include the design and construction of the plant, the cleanliness of the workplace, personal hygiene practices, the layout of the workplace and equipment, working practices and use of personal protective equipment. In the published list of Occupational Exposure Limits (EH **4/94)** certain substances are marked in the table with an 'SK' notation. This indicates that the substance can penetrate the intact skin and thus become absorbed in the body.

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Finland

In Findland, there are no regulations concerning dermal exposure. In the case of PCB accidents (with PCDDs and PCDFs), the authorities have used the Nordic recommendations when evaluating the effect of cleaning operation by use of the surface wipe sampling method.

Switzerland

Skin contamination is not regulated by the Swiss authroties except that for the most notorious skin penetrating agents a notation 'skin or H(aut)' is given in the VME (MAK) listing. In this way, if the exposure by the skin exceeds the permitted total exposure as determined by urinalysis results, enforcement action is taken.

FUTURE PRIORITIES

Dr A. Dost (HSL, U.K.) commented on the resources and effort currently being devoted to the assessment of respiratory exposure through the development of refined methods for measuring the inhalation dose, and compared this with the situation prevailing in relation to dermal exposure monitoring, it is difficult to consider in quantitative terms because of the absence of well-characterized and validated methods. In order to develop for the European Community a comprehensive and harmonized risk assessment strategy in the workplace, the Commission was asked specifically to examine and address this imbalance in its future calls for proposals. It was pointed out that it was essential to encourage collaborative European projects in this area in order to pool the research capabilities of different laboratories and regulatory bodies interested and engaged in this work in the Community.

Mr P. Buchanan (EC, DG V) chaired the concluding session and organized the participants into five discussion groups initially to identify requirements in the key areas: (i) occupational risk assessment; modelling–risk assessment; (ii) biological monitoring; (iii) percutaneous penetration; (iv) skin and surface contamination measurement; and (v) source apportionment; relative contributions. Following the discussions, each group produced a summary report and also identified a 'post-box' to act as a focus for interaction between members of the group. It was noted that the groups could be expanded in the future to include those not present at the meeting and others who wished to be included in more than one group.

Risk assessment

The key items identified for future work were improved methodology for dermal exposure assessment, including the development of a model to categorize exposure, and validation of the model in the occupational environment. Also the development of harmonized risk assessment procedures for the purpose of hazard evaluation, exposure estimates and other information about circumstances, such as climate. In addition localized effects such as those due to sensitizers and skin damage need to be evaluated. The individuals involved in the work would include competent authorities, industry and research institutions, and the disciplines would include toxicologists, hygienists and physicians. [Post-box—Dr Joop van Hemmen (TNO), Rijswijk, The Netherlands.]

Biological monitoring (BM)

The key items identified for future work were: (a) prioritization of substances for which BM can provide information on dermal exposure; (b) development of criteria for validating methods and guidelines for measurement procedures; and (c) validation of methods for inter-laboratory comparisons and for quality assurance. The way forward was thought to be the inclusion of this subgroup within the dermal exposure network and to continue the dialogue between the European Community and the United States. [Post-box—Dr K. Wilson, HSE, Sheffield, U.K.]

Percutaneous penetration

It was noted that the group was concerned with skin penetration and not skin irritation. The key items identified for future work were: (a) the need to obtain internationally accepted penetration rates for the purpose of assigning a skin notation for substances. This will require the development of a standard test which can assess lag time, metabolism, reservoir effect and penetration; (b) the test would be an ***in vitro*** one but would be standardized against ***in vivo*** systems; (c) a choice needs to be made on whether to use human skin, animal skin or artificial skin and also in relation to the application matrix and the receiving substance; and (d) a range of classes of compounds need to be studied to try to understand the factors governing penetration with a view to developing predictive techniques. [Post-box—Dr G. Nielsen, Odense University, Denmark.]

Skin and surface contamination measurement

The key items identified for future work were: (a) the development of methodologies for the measurement of skin and surface contamination, and the selection, characterization and standardization of the existing methods for screening, for transfer, and for skin contact and if necessary the development of an artificial skin for sampling and for re-suspendability measurement; (b) validation of methodologies, correlation with biological monitoring, morbidity, standardization and validation of sampling methods, worker educational material related to skin contamination, development of strategy guidelines, and the identification and prioritization of industries and of compounds to cover. [Post-box—Dr A. Dost, HSE, Sheffield, U.K.]

Source apportionment

It was pointed out that when a person is moving about at a steady rate up to three times as much of a substance can be deposited on the surface of the individual as is inhaled. The key items identified for future work were: controlled studies of the direct deposition of airborne substances onto skin, which would involve the development of a measurement method; studies of the deposition onto other surfaces; and studies of re-suspension. [Post-box—Dr J. Roed, Riso National Laboratory, Denmark.]

European network

The meeting agreed that a network on dermal exposure should be established under the EC 4th Framework programme and the application and other related matters should be progressed by a co-ordinator. It was proposed that Dr J. Firth (Robens Institute, University of Surrey, U.K.) should have the role of the co-ordinator and the

meeting accepted this. In addition, it was decided that mea while the individual sub-groups should continue to progress their own interests through the post-boxes and these would be brought together by the co-ordinator at a later stage. Work is currently under way to identify parties interested in the formation of the network.

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