BIOLOGICAL MONITORING AT WORK:

GUIDANCE FOR OSH EXPERTS AND WORKPLACES

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Introduction

This guide is for occupational hygienists, occupational health (and safety) professionals and managers who are considering setting up and/or managing a biomonitoring programme for chemical exposure in the workplace. It may also be helpful to worker representatives and health and safety representatives. It was developed by the European Agency for Safety and Health at Work (EU-OSHA) on request of the European Commission and sets out common principles for occupational biomonitoring.[1] However, it is important that users check the national occupational safety and health (OSH) legislation that applies to them, which may be more detailed or stringent.

The guide is based on national and international guidance documents that are listed in the references section. It gives practical advice on setting up a programme and how to protect workers' rights, explains what EU legislation says and the role and use of biological monitoring guidance values and biological limit values, and provides information on how occupational biomonitoring is to be used to improve prevention at workplaces rather than for research purposes or development of biological monitoring methodologies. There may be more detailed guidance available at the national or sectoral level. It is therefore recommended to check for any national regulations, standards or guidance that detail the national requirements.

Since biomonitoring involves measurements on biological samples collected from individuals, it is essential that the rights of the individual providing the sample are safeguarded. The guide explains how to set up an effective biomonitoring programme in the workplace context while protecting the rights of individual participants.

The guide covers the use of biomonitoring for exposures to chemicals in the workplace for the purposes of exposure assessment and health surveillance, including in case of accidents and chemical spillage. It is not intended to give detailed advice on its use in other areas, for example, overdose research or pre-employment screening and environmental surveys. However, some of the principles and technical information are common to these other uses.

Definitions

In the following section, some terms used throughout the document are defined.

Health surveillance

Health surveillance in the context of this guidance means monitoring of a person to identify changes in the person's health status because of exposure to certain substances. Health surveillance of workers is strongly linked to the results of the workplace risk assessment, which will give indications of the possible exposures as well as the potential health risks of these exposures. Health surveillance at work should be carried out by or be done under the supervision of a competent medical practitioner with experience in occupational health surveillance. There are different types of health surveillance procedures used to assess exposure to hazardous chemicals, including:

- Interview questions: This involves asking the worker questions about previous occupational history, medical history and about symptoms related to exposure. It may also involve questions about how workers carry out their work, their personal hygiene, personal protective equipment (PPE) use at work or where they eat in the workplace. All of these questions provide information to assess current or previous exposure to hazardous chemicals and identify any health effects in exposed workers.
- Medical examination: This involves the use of standard clinical and medical assessments, tests and techniques to assess the presence of early, acute or long-term health effects, often at set intervals. It can include an assessment of medical history and a clinical examination. This can also include tests like spirometry (for testing lung function) and radiography, for example, a chest X-ray.

[1] Directive 98/24/EC of 7 April 1998 on the protection of the health and safety of workers from the risks related to chemical agents at work. Available at https://osha.europa.eu/en/legislation/directives/75

- Workers should also be informed whom they can report any symptoms to, which should be followed up by the doctor responsible for health surveillance to assess any connection with workplace exposures.

Health surveillance in the context of this guidance means the assessment of an individual worker to determine the state of health of that individual, as related to exposure to specific chemical agents at work or as related to exposure to, including specific work processes, carcinogens, mutagens or reprotoxic (CMR) substances at work. Provisions for health surveillance are set it out in EU directives[2] and more detailed provisions may be included in national legislation, codes of practice or guidance. Suitable health surveillance can include biological monitoring. It should be ensured that workers receive health surveillance that is appropriate to the risks they incur at work and the requirements and responsibilities are laid out in national legislation. Health surveillance may be provided by the national health system.

Biological monitoring/biomonitoring

The term biomonitoring is used in both occupational and environmental health. In the following, biomonitoring is defined in the context of occupational monitoring. Screening tests for the detection of psychoactive substance consumption are excluded from the scope of these guidelines. Biological monitoring is most commonly used to assess exposure to chemicals, but it also has some applications for non-chemical exposures.

- **Biological exposure monitoring**, commonly referred to as biomonitoring, is the measurement of a substance or its metabolites (breakdown products) in a biological specimen obtained from an individual. The most common sample types are serum, blood and urine, but several others have been used, mainly in research, including saliva, hair, sweat and exhaled breath. The type of specimen is primarily determined by the substance being monitored, but, where multiple options exist, their collection will present different levels of invasiveness and may reflect different time frames of exposure. Often, biomonitoring quantifies the substance of interest in a sample, but sometimes it is more appropriate to measure a product of biotransformation (metabolite or a reaction product with DNA or a protein, a so-called addition product or adduct).[3] Ideally, a good biomarker should reflect the internal dose, be sensitive enough to detect relevant levels of exposure, and be specific to an individual substance (or a group of closely related substances).


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- **Biological effect monitoring** is the measurement and assessment of early biological effects caused by absorption of chemicals before health impairment occurs in exposed workers. It normally involves measuring biochemical responses — for example, measuring plasma and erythrocyte cholinesterase activity in workers exposed to organophosphorus pesticides; or measuring increases in urinary protein following exposure to cadmium. These responses may have potential health implications for the individual and may arise from non-occupational

[2] Council Directive 89/391/EEC of 12 June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work (Framework Directive), Directive 98/24/EC of 7 April 1998 on the protection of the health and safety of workers from the risks related to chemical agents at work (fourteenth individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC) – CAD; Directive 2004/37/EC of 29 April 2004 on the protection of workers from the risks related to exposure to carcinogens, mutagens or reprotoxic substances at work (Sixth individual Directive within the meaning of Article 16(1) Directive 89/391/EEC) – CMRD.

[3] These metabolites and addition products have added value because they reflect bioavailability and activation of the substance of interest.

exposure. Consequently, biological effect monitoring in an occupational context should always be carried out under the supervision of an occupational physician. Effect biomarkers are mainly used in research or clinical assessments.

The choice of test compound, or biomarker, is largely determined by the biochemical behaviour of the substance in the body The goal is to assess the exposure and health risk posed to workers. This is generally done by comparing the analysis results with appropriate biological assessment values. Based on the assessment, suitable prevention measures (improvement of technical, organisational and personal prevention) for reducing the risks posed to health can be proposed.

Biological limit value

Biological limit value (BLV) means the limit of the concentration in the appropriate biological medium of the relevant agent, its metabolite or an indicator of effect.[4] BLVs are reference values for evaluating potential health risks in the practice of occupational health. A BLV is a guideline for the control of such risks and should not be used for other purposes. If the biological levels repeatedly exceed the BLV, or if several measurements obtained from a group of workers at the same workplace exceed the BLV, the cause of the excessive values must be investigated and proper action taken to reduce the exposure.

Binding BLVs may be drawn up at EU (for example, lead and its ionic compounds) or national level on the basis of a toxicological evaluation and of the availability of suitable measurement techniques and shall reflect feasibility factors while maintaining the aim of ensuring the health of workers at work. Such BLVs can be set out in directives based on the available information, including scientific and technical data, together with other relevant health surveillance information.[5] For any chemical agent for which a binding EU BLV is established, Member States have to establish a national binding BLV based on, but not exceeding, the EU limit value.[6]

Biological guidance value

Where toxicological data cannot support a health-based BLV, a biological guidance value (BGV) might be established. BGVs represent the upper concentration of the chemical agent or one of its metabolites in any appropriate biological medium corresponding to a certain proportion (generally the 90th or 95th percentile) in a defined reference population, usually the general population or working adults (representing the population of workers not occupationally exposed to the substance). If background levels cannot be detected, the BGV may be equivalent to the limit of detection (LOD) or the limit of quantification (LOQ) of the biomonitoring method, which then is to be specified in the document.

They may be useful for workers, employers and occupational physicians when dealing with worker protection issues in the absence of BLVs, as, if they are exceeded, this may be indicative of an exposure at work. Unlike BLVs, BGVs are not health-based and therefore do not set a limit between absence or presence of adverse health effects.

Background

Employers have to assess any risk to the safety and health of workers arising from the presence of chemical agents at work and identify preventive measures to be taken to eliminate or reduce the risks to a minimum. Results of any health surveillance need to be taken into account and the workplace risk assessment has to be revised if it reveals any risk to workers.

Health surveillance is currently mostly carried out on an individual basis. Requirements for health surveillance and biomonitoring are set in national legislation when there is a risk to health for workers. Health surveillance is appropriate where:

- the exposure of the worker to a hazardous chemical agent is such that an identifiable disease or adverse health effect may be related to the exposure;
- there is a likelihood that the disease or effect may occur under the particular conditions of work; and

[4] Council Directive 98/24/EC (CAD), Article 2(e); Directive 2004/37/EC (CMRD), Article 2(d).
[5] CAD, Article 3(6-7); CMRD, Article 16(3).
[6] CAD, Article 3(5).

- the technique of investigation is of low risk to workers.

Furthermore, there should be valid techniques for detecting indications of the disease or effect.[7]

Individual characteristics (e.g. pre-existing medical conditions and specific health characteristics) that might increase the likelihood that a worker may contract the exposure-related health effect or disease may also be assessed.

There are requirements laid down in the EU directives that foresee mandatory health surveillance under specific circumstances. Where a binding BLV has been set at EU level,[8] health surveillance is mandatory for working with the hazardous chemical agent, process or the CMR substance in question. Workers have to be informed of the requirement for health surveillance before being assigned to the task involving the risk of exposure.[9] Member States have to include these requirements in the national legislation. Biomonitoring will be required in these instances.

The doctor or authority responsible for the health surveillance of workers must be familiar with the exposure conditions or circumstances of each worker. In some instances, the doctor or authority responsible for the health surveillance of workers may indicate that health surveillance must continue after the end of exposure for as long as they consider it to be necessary to safeguard the health of the worker concerned.[10]

Relation to air monitoring[11]

Biological monitoring may be applied for exposure assessment alongside other occupational hygiene measurement techniques, including air sampling, surface wipes or the assessment of skin contamination, or professional competence and observation. Biomonitoring can make a valuable contribution to exposure monitoring in circumstances where air sampling alone may not give a reliable indication of exposure, for example, when skin contamination is possible through direct contact or contaminated clothing/surfaces. It can also be used to support prevention measures taken, by contributing to workplace risk assessment and the evaluation of prevention measures.

Biomonitoring of occupational exposures and the surveillance of external exposure are different and complementary approaches to assessing occupational exposure to chemical agents. They are both integral parts of the assessment of chemical risks.

Occupational exposure limits (OELs) and BLVs usually, but not necessarily (e.g. in the case of irritants or corrosive substances), address the same critical health effects but can also address different health effects and therefore be derived differently; and they are complementary in the sense that air monitoring covers the inhalational route of uptake only, whereas biomonitoring covers all routes of uptake (inhalational, transdermal, oral) but do not replace each other. A BLV can be derived based on a toxicological assessment, such as the relationship between the concentration of the biomarker and the critical effect of the chemical agent, but another option is to derive the BLV from the OEL on the basis of established correlations between the airborne concentration of a substance and its biomarker level. This is usually carried out at EU or national level. In the latter case, the comparison of the biomonitoring results with a BLV informs primarily about the compliance with the OEL.

Criteria for the application of biomonitoring

This section explains the advantages or disadvantages of applying biomonitoring and the circumstances under which it is particularly useful. It also explains that biomonitoring may be a part of the assessment of aptitude/fitness for work, which is foreseen by legislation in some EU Member States.

Strengths and limitations of biomonitoring

Biomonitoring is particularly appropriate for activities:

[7] CAD, Article 10 (1).
[8] In Annex II of the CAD or in Annex IIIa of the CMRD.
[9] CAD, Article 10(1); CMRD, Article 11(2).
[10] CMRD, Article 14(1).
[11] Air monitoring to determine a worker's exposure involves measuring the level of an airborne contaminant in the breathing zone of workers using a personal sampler during their usual work activities, including routine breaks.

- where there is potential for direct skin contact with hazardous substances that can be absorbed through the skin in toxicologically relevant amounts (for instance, organic solvents such as DMF, DMA and toluene); these substances may be marked with a skin notation[12] in OEL lists;
- where the oral route of uptake of hazardous substances may be relevant;
- where there is exposure to hazardous substances with long biological half-lives, meaning substances that are only eliminated from the body slowly after uptake or substances that may accumulate in the body;
- in which the hazardous materials or substances are difficult to detect in terms of air measurement (repair work, maintenance services, outdoor work, fluctuating indoor air concentrations, frequently changing substances in batch operation, restrictions prohibiting the introduction of air sampling equipment in work areas such as in clean room settings and infection-free zones);
- under (working) conditions that promote skin absorption (for example, higher temperature, mixtures of substances, skin diseases and occlusive work clothing);
- where the internal exposure to hazardous substances may be modified by physical work with an increased breathing volume/frequency;
- with non-standard working time arrangements (for example, more than eight hours per day, more than five days a week);
- where exposure assessment cannot be done by external (sensor) measurements; and
- where one is dependent on personal protection measures to reduce exposure.

The advantages of biomonitoring are that it takes into account:

- All the absorption routes of the chemical agent: inhalation, skin (dermal) absorption, and ingestion.
- The characteristics of exposure (workers' ventilatory flow, ambient temperature, physical effort, use of PPE, personal hygiene, etc.) and of the individual particularities of persons exposed (skin integrity, hepatic or renal pathology, metabolisation phenotype, etc.).[13]
- All sources of occupational and extra-occupational exposure. In some cases, however, exposure from the general environment may contribute significantly to occupational exposure, making it difficult for OSH experts to identify sources of exposure and interferences.

There is however a limited number of validated biomarkers of exposure and/or of associated BLVs or BGVs. A limited but growing number of chemicals have values that can be used to interpret the measured biomarker concentrations in the context of health risk or external exposure guidance values.

Biomonitoring of occupational exposure to chemicals should not be considered for assessing and monitoring health risks if the chemical agent has critical effects that are solely local and/or have an irritative or allergic mechanism of action or whose effects result from peak exposures rather than average or cumulative exposure.

Accidental exposures

Biomonitoring can also be used following accidental exposures to hazardous substances, for example, solvent spillages, especially if measurements of the workplace atmosphere are not available. Results may have to be assessed on a case-by-case basis, as the conditions of exposure may not be the same that are underlying the BLV, which is set for an average exposure of eight hours per day, five days a week.

Fitness/aptitude for work, health surveillance and biomonitoring

In some countries, baseline health surveillance may be legally required for workers before they start work with a chemical. The tests required may vary and may involve biomonitoring, typically in urine or

[12] The purpose of a 'skin notation' is to indicate the need to prevent skin contact with a substance present as a gas, solid or liquid that can be absorbed through the skin. Substances may be marked with a skin notation, for example, in national lists of occupational exposure limits.

[13] It should be however noted that for workers with skin and especially with hepatic or renal diseases, occupational exposure to any chemical needs thorough consideration.

blood. There may be cases where occupational physicians recommend not to allow the worker to work with a specific chemical because of pre-existing health conditions (e.g. renal insufficiency and cadmium exposure). Renal and hepatic diseases may impair the elimination of chemicals and/or their metabolites from the body. Therefore, the results of measured biomarkers may be misleading — moreover, some normally not bioaccumulative chemicals may also accumulate in the body.

Health surveillance and biomonitoring may also be part of a regular check on aptitude/fitness for work and there may be cases where aptitude/fitness for work is not confirmed or only granted under conditions. In these cases, for instance, if a BLV or a certain threshold is exceeded, the frequency of biomonitoring may be increased, the worker removed from work or further medical examinations carried out. Removal from work is mainly applied in cases where biomonitoring results of highly bioaccumulative substances (such as lead or cadmium) exceed the BLV.

Conclusions drawn from biological monitoring

Biomonitoring may allow conclusions to be drawn as to:

- the quantities of hazardous substances absorbed by the worker by inhalation, by the skin (dermal) or by ingestion (oral);
- specific biochemical and biological effects of hazardous substances;
- individual differences in metabolism of hazardous substances;
- the effectiveness of preventive measures to protect the worker; and
- individual hygiene when handling hazardous substances.

Implementing biomonitoring of occupational exposure to chemicals enables:

- assessment of the health risks for each of the workers exposed or for a group of workers;
- identification of at-risk groups in a workshop, company, profession or activity sector;
- assessment of the effectiveness of technical, organisational and personal (individual) protection measures implemented to reduce exposure; and
- traceability to be ensured of individual and collective occupational exposure.

Ethical issues

Ethical guidelines for occupational health have been developed by the International Commission on Occupational Health (ICOH).[14] According to the ICOH code of ethics for occupational health professionals, biological tests and other investigations must be chosen for their validity and relevance for protection of the health of the worker concerned, with due regard to their sensitivity, their specificity and their predictive value. Occupational health professionals must not use screening tests or investigations that are not reliable or which do not have a sufficient predictive value in relation to the requirements of the work assignment.

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Where a choice is possible and appropriate, preference should always be given to non-invasive methods and to examinations that do not involve any danger to the health of the worker concerned. Non-invasive testing like urine sampling is preferred over invasive methods like blood sampling if they are appropriate and provide the same degree of reliability and accuracy. However, for some chemicals, like inorganic lead, a blood sample may be required. An invasive investigation may only be advised after an evaluation of the benefits to the worker and the risks involved. As for any other biomonitoring, such an investigation is subject to the worker's informed consent and must be performed according to

[14] The International Commission on Occupational Health (ICOH) is an international non-governmental professional society whose aims are to foster the scientific progress, knowledge and development of occupational health and safety in all its aspects. It was founded in 1906 in Milan as the Permanent Commission on Occupational Health. The ICOH is recognised by the United Nations as an NGO and has close working relationships with the International Labour Organization and the World Health Organization.

the highest professional standards. It cannot be justified for insurance purposes or in relation to insurance claims (ICOH, 2014).

Biomonitoring involves analysis of samples collected from workers. There are sensitive ethical issues involved in the collection, analysis and reporting of results from such samples. Occupational physicians and occupational hygienists play a crucial role in handling such sensitive issues and they should be consulted in setting up a biomonitoring programme, particularly in establishing procedures for reporting results. An occupational physician should also be available to offer medical interpretation of results.

As personal data, the results of the analyses and their assessment are subject to medical confidentiality. Individual results should be treated as personal data under the General Data Protection Regulation (GDPR).[15] The anonymity of the worker(s) must not be jeopardised by information on special circumstances surrounding the analysis (for example, unique workstation) or measurements.

Occupational hygienists, occupational physicians and nurses are bound by ethical obligations imposed by their professional bodies, whose role is to ensure that these principles are adhered to. However, this may not be the case with other people involved in a biomonitoring programme. It is therefore important to make sure that everyone involved with the biomonitoring programme is aware of and operates in accordance with the principles given in this guide.

Consent

The occupational health objectives, methods and procedures of health surveillance and any biomonitoring, whether for health surveillance or exposure assessment purposes, must be clearly defined with priority given to adaptation of workplaces to workers who must receive information in this respect. The relevance and validity of these methods and procedures should be consistent with available scientific evidence and relevant good practice. Surveillance and tests should be carried out with the non-coerced informed consent of the workers. They must be fully informed in advance of the conduct and objectives of the test and of the use of the analytical results. The potentially positive and negative consequences of participation in screening, biomonitoring and health surveillance programmes should be discussed as part of the consent process. Health surveillance and biomonitoring must be performed according to national laws and practices, usually by an occupational health professional approved by the competent authority.

When biomonitoring is performed, the procedure must be explained and acceptable to the workers concerned (informed consent).

It is unethical for an occupational health professional to perform additional tests on the biological specimen other than those specified when taking the sample without the knowledge and consent of the relevant worker. Workers should be informed that the biomonitoring is voluntary, although in some cases it may be foreseen by law, and for their benefit, and about what exposure is being assessed, what sample they will need to provide, what will be analysed in the sample(s), and when and how the results will be reported.

Workers should be encouraged to talk about concerns they have regarding their biomonitoring programme. If a worker still doesn't want to be subjected to biological monitoring, employers must comply with their duties under the national legislation, which may include stopping them from working with the hazardous chemical, and they should inform workers about any consequence if they refuse to participate in the biomonitoring programme. There may be more detailed requirements on consent of workers in national legislation and in agreements at the sectoral levels, which must be considered by employers.

In some instances, there may be a case for making the results known to an individual's family practitioner. In this case, the worker should first be offered the opportunity to see them and must provide consent. The right for workers not to know and be informed about the results that may be stipulated at national level in some countries should also be addressed and respected.

[15] Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (General Data Protection Regulation - GDPR), in particular Article 9: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02016R0679-20160504&qid=1674485543249

Requirements on those who carry out health surveillance and biological monitoring

Occupational biomonitoring should be carried out by or be done under the supervision of a trained medical practitioner with experience in occupational health surveillance and exposure assessment, preferably an occupational physician. National requirements may be in place for training and accreditation of trained medical staff and/or occupational physicians who carry out and supervise health surveillance and biological monitoring. For instance, practitioners may be single practitioners in a medical practice, occupational physicians who work for specialist occupational health organisations, or they may provide specialist services and testing in certain areas of health surveillance.

Laboratories that carry out the analysis of samples may also be subject to authorisation or certification and may have to fulfil certain requirements, for example, regarding quality assurance, Principles of Good Laboratory Practice, and/or compliance with ISO standards such as the ISO/IEC 17025 standard for testing and calibration laboratories. It is therefore important to check the national regulations or guidance. Lists of accredited physicians and laboratories may also exist at the national level or may be established by the national authorities.

How to set up a biomonitoring programme

Several actors may be involved in setting up a biomonitoring programme: the employer, the occupational physician or occupational health service, the occupational hygienist, OSH professionals, laboratories that carry out analysis, and the workers or their representatives. They have different roles and responsibilities and different access to data generated by biological monitoring. Employers, their representatives, occupational physicians and occupational health services, or occupational hygienists may be initiating a biomonitoring programme. This section explains how to set up a biomonitoring programme and outlines some processes that should be followed, for instance, consultation of workers.

For the biological monitoring challenges to be understood by each person concerned by its implementation (workers, employers, health and safety committee or staff representative(s), laboratory, etc.), it is recommended that the occupational health team or the occupational physician provide clear, appropriate information to all the partners involved.

A competent person should be responsible for biomonitoring. Employers should seek advice from their occupational physician or occupational health service. Requirements may be laid down in national legislation or standards on when biomonitoring must be carried out and on the persons who set up, manage or implement a biomonitoring programme, as well as on laboratories that carry out the analysis. It is therefore recommended to check the national legislation for any compulsory biomonitoring and for any requirements on the experts involved.

Information for employers who want to set up a biomonitoring programme

For each worker subjected to the biomonitoring programme, it is recommended that employers provide the occupational physician or other occupational health or health and safety expert, as determined by national requirements and practices, undertaking or supervising the health surveillance or exposure assessment including biomonitoring with the following information:

- The name, date of birth, gender at birth and current residential address of the worker.
- A list of the hazardous chemicals that the worker is or will be potentially exposed to and the dates that the worker last used or may have been exposed to the chemicals.
- A list of previous chemicals worked with.
- The work the worker is, or will be, carrying out and what has triggered the requirement for health surveillance or biomonitoring.

- If the worker has started that work, how long the worker has been carrying it out.
- The safety data sheets for the chemical(s), or any other useful documentation.
- Relevant workplace risk assessment reports and results of any air monitoring carried out at the workplace. This information is critical for the practitioner to understand all of the situations where workplace exposure could occur. Note that the workplace risk assessment reports should contain information about likely exposures at the workplace, including prevention measures that are in place to reduce exposure and investigations of results where workplace exposure standards, such as OELs, have been exceeded.

Defining the purpose of biomonitoring

National legislation may define the purpose of biomonitoring, and it may be linked to health surveillance or to exposure assessment. They are not mutually exclusive, but national legislation may define one or the other purpose as priority and biomonitoring may be carried out in fulfilment of these requirements.

The key issue to consider is whether biomonitoring will be of practical value in assessing risks from, and/or controlling exposure to, chemicals. In addition to the criteria mentioned in the previous sections, using biomonitoring for exposure assessment should be considered when all of the following apply:

- it will give information in addition to that already available through complying with the regulations and air monitoring;
- it will provide useful information on exposure assessment that will assist in evaluating prevention measures;
- there is an appropriate sampling strategy and analytical technique that preferably involves non-invasive sampling (i.e. in urine or breath rather than blood if this leads to comparable effectiveness); and
- there are clear criteria for interpreting the results, for example, a BLV or a reference value (where no reference value is available, it may be sensible to use standards from other countries).

The goal of the biomonitoring should also be consistent with the goal of any occupational hygiene intervention or the obligation that prompts the investigation, such as a legislative requirement for health surveillance or assessment of the worker's aptitude/fitness for work. The goal could be varied: using periodic measurements to ensure the traceability of workers' exposure; assessing exposure relating to new working conditions; identifying workplaces or tasks that require priority action in terms of prevention; assessing the need to implement surveillance of effects; and documenting medical files to issue notification of an occupational disease. Is the goal to measure exposure or is there an obligation for health surveillance that includes biomonitoring?

Consultation on the programme with workers or their representatives

It is important to consult with workers directly or with elected representatives before the biomonitoring programme starts or when major changes are introduced. There may be specific requirements set out in the Member States and therefore it is important to check national legislation for any specific obligations, which may differ depending on whether the specific biomonitoring in question is compulsory for the employer. In any case, it is recommended that consultation include all elements of the programme. For example, to discuss and agree arrangements for:

- gaining workers' consent to provide samples and their processing by occupational health or hygiene staff;
- gaining specific consent for further disclosure of the results;
- giving assurance on how workers will be affected if results suggest their exposure should be reduced;
- briefing new workers; and
- the periodic review of the programme.

It needs to be decided whether to use group data, individual data or both in the biomonitoring programme, and appropriate consent needs to be sought from the workers. Group results can provide an overall picture of a group of workers with similar exposure. This may be useful in assessing general controls in the workplace. However, benefit in ensuring exposure control can also come from the use of individual data.

It is recommended that employers discuss with workers the details and the most appropriate approaches for the particular circumstances. They will also need to explain under which circumstances biomonitoring is compulsory under national legislation and at which intervals and how biomonitoring needs to be carried out. They may also seek the support of the occupational health services or physicians for the explanations. Workers or their representatives will be able to provide valuable input in all of these areas and help ensure the programme is implemented successfully.

Discussing and agreeing on the programme with the individual workers concerned

As mentioned before, as biological monitoring involves measurements of an individual's body fluids (or other matrices), it is important to ensure that individuals' rights are protected. To do this it should be ensured that:

- workers give informed consent before samples are taken;
- samples are only analysed for the substances for which informed consent was given (strict controls will be needed to guarantee that this is adhered to);
- individual measurements are treated as confidential and results available only to people for whom consent has been given and who are required or authorised by law to receive such results; and
- workers are offered their result(s) and an explanation of what it/they mean(s) by a competent and authorised person, normally the occupational physician or health service, before passing it/them on to anyone else.

It is essential to make sure that workers understand what is being done and how the results will be used. When seeking informed consent from individual workers it is important to provide information on:

- the purpose of the programme (and whether it is a legal requirement);
- whether it is linked to an assessment of aptitude/fitness for work;
- what will be involved (taking a sample of blood/urine/breath or other, the frequency of testing and which tests) and any associated risks;
- what a programme of biomonitoring aims to achieve and its benefits;
- their rights on consenting to sample taking and use of results;
- interpretation of the results – emphasising, when appropriate, that the results may not have direct significance for their health, but do provide information on the effectiveness of prevention measures;
- who pays for the health surveillance including biomonitoring;
- the record-keeping requirements;
- what action might be taken on the basis of the results (including how the worker will be affected if results suggest their exposure should be reduced); and
- the benefit to the individual in taking part and the possible consequences to the individual in not taking part.

It is important that any consent form is in simple and clear language and is understood by the individual who is being asked to give consent (mindful of any literacy or language barriers). Provide two copies of the consent form, a copy for each person who signs the form. Each person will need to sign both copies.

If a worker consents to give a sample, it is implicit that the person authorised to run the programme, usually the occupational physician or responsible expert in the occupational health service, will have access to the individual's result. Specific confidentiality requirements may be laid down at national level. However, individual results should always be treated as personal data under the GDPR and medical confidentiality respected.

In some countries there may be additional rights for workers (right to withdraw consent at any moment and stop participating in a biomonitoring programme, right not to know the results of biomonitoring). It is therefore important to check national regulations and guidance, for both workers regarding their rights and employers regarding their obligations.

Managing a workplace biomonitoring programme

The person or service responsible for the biomonitoring programme (usually the occupational physician or occupational health service in cooperation with one or several laboratories) needs to set out the methodology and processes. The establishment of procedures should involve the occupational physician or occupational health services and ideally the programme should be managed or supervised by them.

Who should be subjected to biomonitoring?

It should be clearly determined who (which workers) should undergo the biomonitoring, based on the results of the workplace risk assessment and following any legal requirements. Any individuals who are potentially exposed to substances that may be hazardous to health can be considered for biological monitoring. Infrequent tasks that could lead to high exposures such as maintenance and cleaning should also be considered. Sampling should generally focus on those workers with the potential for direct and significant exposure. Bystanders and other workers may need to be considered when investigating elevated or unexpected exposures but are not usually part of routine monitoring programmes.

In cases of subcontracting or the use of temporary work, it is important that the occupational physicians or occupational health services of those companies be in contact with the occupational physician or health service of the upstream user company.

Selection of biomonitoring methods

The occupational health professional and the laboratory usually decide on appropriate methods so that the test results are interpretable and relevant to the exposure situation. Some approved or certified methods already exist with a documentation that includes many of the issues (for example, sampling time, interferences) discussed below. The World Health Organisation (WHO), for example, and the German MAK commission have published guidance on sampling and analytical methods for various substances and their metabolites or adducts. It is important that the person responsible for the biomonitoring programme is aware of any national requirements or legal obligations for health surveillance and biomonitoring, as well as any guidance or approved methodologies for biomonitoring and exposure assessment.

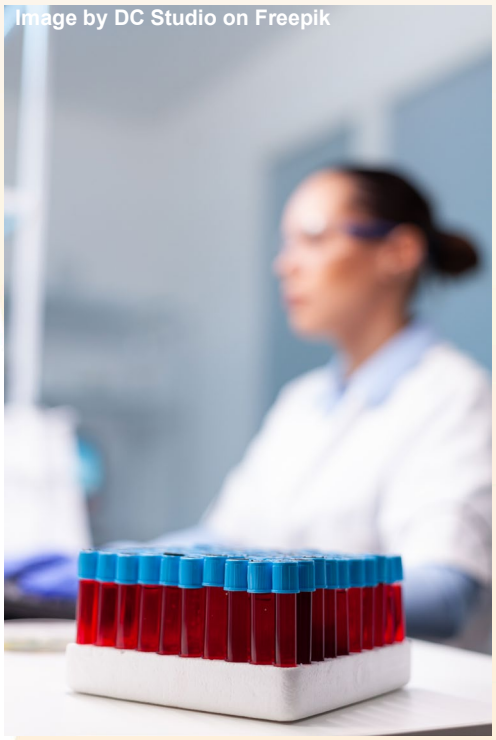


Image by DC Studio on Freepik

The methods applied need to be evaluated at least for the required sensitivity, specificity, biological relevance and feasibility. It is recommended to obtain detailed information about sample collection, storage, transportation, analysis and quality assurance from the laboratory selected to perform the analysis and establish clear procedures.

Choice of test parameter

The test parameter is the chemical substance, a metabolite or biological indicator (biomarker) and its content is determined in the biological material. A test parameter suitable for biological monitoring must be required to indicate reliably, sensitively and as specifically as possible the exposure to and/or effect of the hazardous substance. Usually, methodological and reference documents are available and may be referred to in national legislation, in particular where biomonitoring is addressing the control of

adherence to a BLV. Information can also be sought for instance from occupational medicine or hygiene associations or OSH institutes. However, some fundamental considerations apply:

It is recommended that the choice be made of a test parameter that best meets the following criteria:

- good specificity in relation to the chemical agent under consideration;
- sensitivity that is tailored to expected levels of exposure;
- low intra-individual variability;
- biological sampling that is non-invasive or slightly invasive;
- controlled sample stability;
- validated method of analysis that is routinely accessible;
- known relationships with health effects (dose–response or dose–effect relationships), or, failing that, with external exposure;
- appropriate elimination kinetics, meaning that the biomarker should be measurable over a shift and representative of the exposure; and
- existence of a BLV or appropriate guidance values (BGVs) (in a population that is subject to occupational exposure and/or in the general population).

When several test parameters are available for a single chemical agent, they sometimes provide different information on exposure and/or the internal dose. The choice is determined by the nature of the information sought, and it can be useful to use several simultaneously.

Occasionally, different laboratories may offer different tests for the same chemical — the laboratory should be able to explain the rationale behind their recommended biomarker.

More information on the criteria for choosing parameters to be assessed through biomonitoring is provided in the annex.

Sampling

Sampling is a critical step, and a procedure should be established to avoid contamination of samples (for example, avoiding contamination with solvents by using hydrogen peroxide instead of alcoholic disinfectants) and to perform all sampling in a standardised way. In the methodology, in particular for the control of any BLV, it should be indicated when the sample should be collected (for example, at the end of the shift, at the end of the work week, etc.). It is important to follow specialist advice, for instance, from the laboratory that will conduct the analysis, or there could be misleading results. Sampling will be part of any methodological guidelines for biological monitoring, and it is important to check the national requirements, for instance, whether they prescribe or recommend specific methodologies. More detailed information about the criteria for defining the sampling methodology is provided in the annex.

Once a sampling strategy that fits requirements has been set out, it is advisable to maintain consistency to ensure that biomonitoring results are reflecting changes in exposure rather than changes in the sampling methodology.

Sampling time

Since the concentration of some substances can change rapidly, the specimen sampling time is very important and sampling date and time must be recorded. The description should include instructions for the timing of specimen collection, that is, whether specimens should be obtained during the work shift, at the end of the shift or at some other time during the work week. Pre-shift samples at the beginning of the work week can be compared to post-shift samples to detect increases during the working week.

Route of exposure can affect the time taken for a substance to enter the body. Biological monitoring assesses exposure via all routes, but inhalation leads to almost instant absorption into the body while ingestion can take around an hour. By contrast, skin (dermal) absorption typically takes several hours. Some prior consideration of likely exposure route, for example, in the workplace risk assessment, can therefore help to determine the best time to collect samples.

Sampling times are also determined by the retention times of the chemical within the human body. The rate of elimination is important and can vary hugely, from a few minutes to months or years. Most of the time, it is advisable to collect a sample soon after end of exposure (for example, within an hour). For many other substances, the elimination rate allows sample collection at the end of the shift. However,

there can be an accumulation over consecutive days of exposure, and it can be appropriate to collect a sample towards the end of the week (or consecutive shift pattern).

Some substances are described as bioaccumulating or persistent, such as some inorganic elements (metals and metalloids, for instance, lead). A sample will reflect combined exposure over several weeks, months or even years. Therefore, it may be necessary to take a baseline measurement of the biomarker concentration prior to the start of the work week or workday to determine if the biomarker concentration increased over the time frame of investigation. It should be considered that these persistent substances will take a long time to reduce following end of exposure. It might be more important to take early action as biomarker levels of bioaccumulating substances begin to increase, rather than waiting until they begin to exceed guidance values.

Sample specificities according to medium

There are specificities that should be considered depending on the medium from which the sample is collected.

For urine sample collection, the following is important:

- Use the correct type of contamination-free container and ensure the required volume is collected at the time determined by the biomonitoring strategy.
- Ask workers to change out of their work clothes and wash their hands before providing a sample, otherwise there is the possibility of inadvertent contamination of the sample. This is especially important when the exposure biomarker is the chemical used (for instance, in the case of metals).


Image by freepik

The WHO has adopted guidelines for valid urine specimens for occupational monitoring. Some biological monitoring guidance values for chemicals, whose concentration is dependent on urine production levels, are expressed relative to creatinine concentration to correct for variable dilutions in spot samples, as urine concentration can vary widely due to changes in fluid intakes and fluid losses, through sweating for example. The specific limits are explained in the annex to this guideline.

Urinary biomonitoring is not suitable for individuals with severe renal disease affecting renal clearance.

Blood sample collection involves the puncturing of a vein and therefore must be carried out by someone qualified to do so (a physician, suitably qualified nurse or venepuncture technician). Again, consideration needs to be given to the type of container and the volume needed. Advice on the procedures to be followed includes the use of protective measures to guard against needlestick injuries, spillage or splashing of blood, and the need to properly label samples.

Pathogens such as hepatitis B and human immunodeficiency virus (HIV) may be present in blood, saliva, semen and other body fluids. Pathogens can be transmitted by an accidental nick with a sharp object, exposure through open cuts, skin abrasions, and even dermatitis or acne, and indirectly through contact with a contaminated environmental surface. There are five major ways to reduce the potential for exposure to biological pathogens:

- Engineering controls that include mechanical or physical systems can be used to eliminate biological hazards. Examples include biosafety cabinets and self-sheathing needles.
- Good housekeeping procedures, which involve clean-up of the work area, are essential to avoid contamination.
- Appropriate work practices are essential to minimise exposure to pathogens, including good personal hygiene procedures and avoidance of needle recapping.
- PPE, such as gloves and masks, should be used.
- Appropriate vaccination should be offered to workers carrying out blood sampling and handling blood samples.

Standard precautions should be practiced with every biological specimen collected or received into the laboratory. It is not possible to know if a particular specimen contains pathogens. Therefore, each sample should be treated as if contaminated.

Because of the additional risks associated with taking blood, it is recommended that urine or breath (i.e. non-invasive techniques) are used for biomonitoring wherever possible.

In relation to exhaled breath specimens, these must be taken in an area free from the chemical being measured. In general, samples should be taken in a non-contaminated area to avoid contamination from the air, work clothes, hands and other sources.

Sample labelling

Sample containers or vacutainers should be labelled — usually, a name (or other unique identifier) and sample date are sufficient, but the time of the sample might be needed if collecting multiple samples. Sample containers may also have been supplied by the laboratory that carries out the analysis. Sometimes they may contain an additive to help stabilise the sample or may be specifically prepared to avoid contamination. Information should be provided by the laboratory.

Sample pretreatment and storage

The transportation, pretreatment and storage of samples prior to sending to the laboratory should be outlined in a protocol or procedure, as samples may require fractionation, conservation, and/or preservation, for example, at low temperatures, prior to analysis.

When the sample cannot be sent to the laboratory immediately, the samples should be stored properly while awaiting dispatch. Advice on pretreatment and storage conditions can be obtained from the analysing laboratory and from national guidance, where available. If samples are regularly being stored and awaiting dispatch with a risk of exceeding recommended storage time, use of a different test parameter with a different sampling time should be considered.

Sample transportation

The transport of biological materials, including infectious substances, is covered by international, regional or national regulations that are updated on a regular basis and are widely accessible via the Internet and the carriers. Advice can be sought on this from the analysing laboratory, which in most cases will provide appropriate packaging. The packaging of samples sent by post must comply with the rules laid down by the carrier in relation to the transportation of biological material. These are usually intended to prevent the sample container from breaking in transit and to contain any sample leakage that may occur. It is important to maintain the integrity of the sample (correct temperature, etc.) so it can be transported safely and in compliance with applicable regulations (see UN3373[16]) within the test parameters for storage time to analysis.

Analytical methods

Analytical methods may be recommended already in legislation or in codes of practice or standards. There may be requirements set out for the analysis of the biological samples. It is therefore recommended to check any national legislation or guidance, for instance, guidance provided by national occupational hygiene or medicine associations. The sensitivity of the analytical method that will be implemented must be tailored to the levels of exposure of the workers concerned, and, in particular, it is recommended that the quantification limit is always less than one-tenth of the biological interpretation values chosen for interpretation, in analogy to air monitoring practices.

It is also recommended that in the report on the results, the laboratory specify the analytical method used, the uncertainty of measurement, the quantification limit, and the relevant biological interpretation values that enable the results to be interpreted (for instance BLV or guidance values).

[16] Biohazardous agents are classified for transportation by UN number. Category B, UN 3373 refers to a biological substance transported for diagnostic or investigative purposes.

Quality assurance

All aspects of a biomonitoring programme should be subject to a quality assurance programme.

Specific requirements may be in place for laboratories that perform sampling or analysis of biological samples. Employers and those who coordinate biomonitoring programmes in the enterprises are advised to check national requirements. There may be lists of accredited laboratories available at national level.

All analytical testing should be carried out by an appropriately accredited laboratory or a laboratory that can demonstrate quality assurance according to national requirements. It is recommended that an analytical laboratory that has put in place a quality-based approach of a level that is equivalent to the standards of accreditation, or, when a regulatory BLV exists, that has obtained accreditation for the measurement is chosen to carry out the analysis of biological samples.

What elements must be taken into consideration to interpret the results of occupational biomonitoring?

Biomonitoring results require medical interpretation by experienced medical practitioners. The results of biomonitoring should be interpreted by a physician who has the ability to take into account the individual's physiology, health status and lifestyle and who is used to assist the occupational health professional to detect exposure to the chemical agent and to determine the extent of absorption through the skin, gastrointestinal system or by inhalation to assess overall body burden.

The occupational physician may receive a report with a first interpretation provided by the analysing laboratory but is usually responsible for the interpretation in terms of health risks, as well as for individual and collective presentation of results. However, if results can be provided in anonymised or pseudonymised form, (group) results could also be interpreted by an occupational hygienist as regards exposure levels and the need to adapt prevention measures. The interpretation consists of comparing the levels measured to BLVs or, if not applicable, guidance values, and to the previous results of the same worker and those of similarly exposed workers. It is recommended that the overall interpretation of the results be done relative to:

- the appropriate biological interpretation values, such as for example background levels;
- the values available in the same activity sector and/or at the same type of workplace;
- the company's similarly exposed groups of workers; and
- the previous results for the same groups.

In order to interpret the results as best as possible, certain elements must be taken into account by the occupational physician on the one hand (as regards medical issues) or the occupational hygienist on the other, such as the conditions relating to exposure (representativeness, routes, chronology, protective equipment, etc.), the characteristics of the indicators chosen (specificity, toxicokinetics, intra- and inter-individual variability, etc.), the terms of sampling, transport and analysis, the parameters relating to the individual (gender, age, pathologies, smoking, medication, co-exposure sources, other than work-related, etc.), and the overall results of a group of similarly exposed workers to which the worker belongs and that person's previous checks, as well as the existence of limit or reference values validated and adapted to exposure.

Due to the variable nature of concentrations in biological specimens, conclusions on the exposure or health risk of workers may be difficult to be drawn based on a single sample. It may be necessary to collect multiple or repeated samples. Action should be based on the results of multiple sampling. Furthermore, a single biomonitoring value should never exceed a threshold for acute toxic effects.

When there is a possibility of non-occupational exposure to a chemical (for example, through the exposure of solvents in do-it-yourself materials), it may be necessary to compare a sample obtained after work exposure with a pre-work level. Mixed exposures to a number of different chemical substances may also affect how a chemical is handled by the body and may therefore affect the levels recorded by biological monitoring.

Biomonitoring results are not necessarily indicative of potential ill health. Elevated biomonitoring results even below limit values should be treated as an early indication that exposure control could be improved, before health consequences might begin to appear in workers.

Biomonitoring for prevention

When results are used for exposure assessment, it is important to ensure they are interpreted by someone competent in occupational health and hygiene. It may be useful to consult other sources such as the results of workplace risk assessments and workplace air measurements.

The analysis will help identify the groups most at risk, check whether the exposure conditions are acceptable and whether preventive measures are adequate. Occupational physicians and occupational hygienists provide support for suggesting improvements, both technical and organisational, that aim at reducing exposure and, in the long term, preventing the diseases linked to the exposures. Where available, cooperation with the occupational hygienist or safety engineer as well as with the health and safety representatives or committee is recommended. National legislation or guidance may specify who will be involved in the analysis of results and their interpretation and who needs to be informed, for example, when occupational hygienists have to be involved.

An occupational physician should be available to give advice and to discuss their significance with workers, if necessary, in particular also group results. The circumstances under which it will be appropriate for workers to be consulted should be discussed with the occupational physician at the beginning of the biomonitoring programme. These may include:

- where levels for an individual are above the BLVs or guidance value (or other interpretation criteria) despite good occupational hygiene practice; or
- where an individual reports symptoms of ill health that may be related to the exposure; or
- where medical interpretation is requested by an individual; or
- where there is concern, based on reliable information, that the levels recorded may be associated with harm.

There is no point in carrying out a biomonitoring programme unless:

1. it is clear what action to take in response to the results;
2. appropriate action is then taken; and
3. the effectiveness of this action is evaluated.

Where the results indicate a need to reduce exposure (for example, where a BLV or guidance value is exceeded, or where accumulated data or group data show a trend towards this), there will be a need to look at how the substance is being handled. This will include looking at current prevention measures and work practices, in particular:

- whether current prevention measures and handling methods are working effectively and properly; and
- whether additional measures need to be introduced.

Follow-up monitoring or increasing the frequency of monitoring will need to be considered, to ensure that any changes made to control measures have been effective. Where specific guidance is available for a chemical, this may contain further information on what action is necessary.

It may be required to keep records of the biomonitoring results. There are legal obligations set for record-keeping, which are further described in a dedicated section in this document, for instance, in the case of CMR substances.

Action in case of a health problem or exceedance of a BLV

The EU legislation lays out specific obligations for employers when limit values are exceeded or health problems are identified in workers.[17] Where, as a result of health surveillance:

- a worker is found to have an identifiable disease or adverse health effect that is considered by a doctor or occupational health professional to be the result of exposure at work to a hazardous chemical agent, or
- a binding BLV is found to have been exceeded,

[17] CAD, Article 10(4).

the worker shall be informed by the occupational physician or other suitably qualified person of the result that relates to him/her personally, including information and advice regarding any health surveillance that the worker should undergo following the end of the exposure.

The employer has to:

- review the workplace risk assessment;
- review the prevention measures provided to eliminate or reduce risks;
- take into account the advice of the occupational healthcare professional or other suitably qualified person or the competent authority when implementing any prevention measures required to eliminate or reduce risk, including the possibility of assigning the worker to alternative work where there is no risk of further exposure;
- arrange continued health surveillance, which may include biomonitoring; and
- provide for a review of the health status of any other worker who has been similarly exposed. In such cases the competent doctor or occupational health professional or the competent authority may propose that exposed persons undergo a medical examination.

There may be more specific or stringent actions set out in national legislation. Therefore, it is important to check national legislation, guidance or codes of practice.

The rotation of workers to counteract high exposures of specific workers should be avoided. In general, the aim should be to reduce exposure to all workers, and not to aim at averaging out exposures by rotating workers on specific tasks until exposure at a certain level (for instance at the level of the BLV) is reached. This is where group results and trends in exposure of workers who carry out similar tasks are important to consider, as exposure should be minimised as much as possible. According to EU legislation, the risks to the health and safety of workers at work involving hazardous chemical agents shall be eliminated or reduced to a minimum by reducing to a minimum the number of workers exposed or likely to be exposed and reducing to a minimum the duration and intensity of exposure.[18]

Health surveillance and biomonitoring after the end of exposure

In cases of exposure to CMR substances, the doctor or authority responsible for the health surveillance of workers may indicate that health surveillance must continue after the end of exposure for as long as they consider it to be necessary to safeguard the health of the worker concerned.[19] This may include biomonitoring. In some cases, for instance, for highly cumulative substances with long half-life, such as lead or cadmium, biomonitoring after the end of exposure may be recommended to monitor whether the biomarker levels decrease with time. This applies to highly bioaccumulative substances with long half-life, such as lead or cadmium.

Record-keeping

EU directives foresee obligations for record-keeping when workers are exposed to specific substances at work. These obligations are transposed into national legislation. Employers and those managing a biomonitoring programme should therefore check national regulations and guidance regarding these obligations, as they could be more detailed or more stringent.

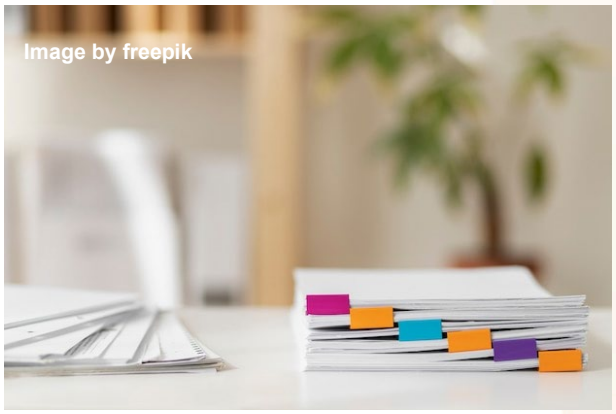
Individual records

In cases where health surveillance is carried out, an individual health and exposure record must be kept and the doctor or authority responsible for health surveillance shall propose any protective or preventive measures to be taken in respect of any individual workers. Health and exposure records shall contain a summary of the results of health surveillance and of any monitoring data representative of the exposure of the individual. Biomonitoring and related requirements may form part of health surveillance. Health and exposure records shall be kept in a suitable form so as to permit consultation at a later date, taking into account any confidentiality.[20] With regard to carcinogens and mutagens, the medical record shall be kept for at least 40 years following the end of exposure and with regard to reprotoxic

[18] CAD, Article 5(2).
[19] CMRD, Article 14(1).
[20] CMRD, Article 14(4); CAD, Article 10 (2) and (3).

substances, it shall be kept for at least five years following the end of exposure, in accordance with national law or practice.[21] As mentioned above, employers should check national legislation for any additional requirements on record-keeping and the content of records or their format, in particular on records of biomonitoring results, including any confidentiality issues regarding personal health data, and inform and instruct their OSH services and those responsible for the occupational biomonitoring programme accordingly. Workers shall have access to the results of the health surveillance that concern them. Individual workers should have the right to access their own health and exposure records.

The record will not contain details of medical conditions disclosed to or diagnosed by the medical practitioner conducting the health surveillance if these have no relevance or bearing on the work being performed. The report should only contain information relating to the health surveillance programme for the chemical(s) being used. It should not contain other confidential health information on workers, unless there is an obligation that the employer should know. If the worker has a pre-existing medical condition that may exacerbate the health effects of chemicals, it may be useful if this is brought to the attention of the OSH experts at enterprise level so appropriate prevention measures can be put in place, for example, in the case of sensitising substances. However, details of pre-existing medical conditions should only be transmitted and included in the report with the worker's written permission. Individual results should be treated as personal data under the GDPR.



The worker's biomonitoring results should be incorporated into her/his medical record on occupational health/health surveillance record. This can provide useful data for:

- the chronological monitoring of a worker's occupational exposure;
- an estimate of the risk incurred by the worker at a given moment;
- checking that the individual and collective protective measures are suited to actual working conditions;
- setting up preventive actions, then assessing their effectiveness;
- argumentation of the occupational nature of symptoms or illnesses arising in workers; and
- justification for setting up post-occupational monitoring.

Records may be consulted by occupational physicians or occupational health services at a later stage to assess exposure over time and check whether changes in prevention measures have also had an impact on internal exposure. Record-keeping and storage of data should therefore be set out when designing a biomonitoring programme. Ideally, it should be discussed with occupational hygienists or safety engineers how to organise biomonitoring and air monitoring programmes and how to ensure that group results can be utilised for the improvement of prevention, for example, organising simultaneous air measurements and biomonitoring. Records should be cross-referenced to the task performed and any other occupational hygiene information, for instance, records of air measurements.

Where an undertaking ceases to trade, the health and exposure records shall be made available to the competent authority.[22]

Collective results

It is recommended that occupational physicians or occupational health services keep collective data relating to similar exposure groups (groups of workers who are deemed to have similar exposure, minimal number of measurements representing the group, approach for interpreting results, etc. and the results of measurements). The summary of the results should be documented and added to any health and safety documentation at the enterprise level (such as air measurements). The information

[21] CMRD, Article 15(1).
[22] CAD, Article 10(3).

can be used to implement better prevention. However, the similar exposure groups should be regularly reassessed, for instance, annually and when any changes occur, for example, in task assignment or in the technical measures applied, or when new technology, equipment and/or machinery is introduced, to determine whether the workers considered for an exposure group are still similarly exposed. In addition to measures to protect the individual worker, a reassessment should also be done when the results of biomonitoring for one or several workers deviate notably from the average.

The benefits of keeping collective level results can be:

- assessing the risk incurred by subjects belonging to a group of workers with similar exposures: same industrial sector, same occupational task, etc.;
- drawing up collective mapping of exposure of those groups (by chemical agent, sector, job, task, etc.) at a given moment;
- comparing exposure of similar exposure groups from one activity sector to another or from one workplace to the other, for a single period;
- identifying activities or sectors that are most at risk, and determining priority groups for setting up intensified medical surveillance and/or carrying out targeted preventive actions;
- characterising the change in exposure over time within a group of workers with similar exposure, and, in that context, assessing the effectiveness of preventive actions and/or that of the consequences of modifications to industrial procedures;
- enriching job-exposure matrices useful for epidemiological studies and for retrospective documentation on exposure affecting workers who have not personally benefited from tailored biomonitoring (to determine the usefulness of post-exposure surveillance, or whether an illness can be attributed to past occupational activity);
- providing support for drawing up biological interpretation values (or BGVs) and regulations to prevent risks in some activity sectors; and
- providing help to assess the effectiveness of new regulations that are put in place.

Data at a group level could be useful, for instance, to epidemiologists. The anonymised/pseudonymised input of biomonitoring data into a database (or into interoperable databases) may permit the pooling of related information at regional or national level, thus allowing comparisons to be drawn between regions or activity sectors, workplaces and so on, to identify priorities in collective preventive actions and to assess their effectiveness. Individual results, however, should be treated as personal data under the GDPR and consent sought from workers for the use of their data. The prior agreement of data protection authorities needs to be sought.

Information about biomonitoring results to the concerned parties

Release of results is best handled by an occupational physician and will need the worker's consent.

The occupational physician should inform the employer of the anonymous and overall biomonitoring results.

Even with the worker's agreement, access to individual results is usually prohibited to the employer, the latter's representatives and non-medical preventionists, as it would be in breach of medical confidentiality. Individual results should be treated as personal data under the GDPR.

When the number of samples is low, especially in the case of a single worker, particular care must be taken when communicating the results, whether to the worker him/herself or to the employer, including when communicating group results.

Where this is defined by law and the assessment of aptitude/fitness for work includes biomonitoring, the occupational physician or occupational health service may also have to inform the employer about the worker's aptitude/fitness for work. The aptitude may be confirmed, denied or confirmed under conditions, for example, conditioned to more frequent checks.

Worker information

As mentioned before, if employers are required to provide health surveillance or biomonitoring to a worker who will, or is likely, to use, handle, generate or store a hazardous chemical in the business or undertaking, they should give them information about the health surveillance and biomonitoring requirements before they start work or before the health surveillance/biomonitoring programme is started and ensure the worker gives informed consent. This also applies where a biomonitoring programme is set up, for instance, for exposure assessment without a legal requirement.

Workers should be informed about:

- possible health effects from exposure;
- how to report symptoms;
- any requirement for them to see a doctor or specialist;
- if and how monitoring results may affect their work tasks, for example, explaining circumstances where the worker may need to move to other tasks; and
- that biomonitoring results are confidential and can only be disclosed to another occupational physician involved, unless their consent is otherwise given.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Workers being monitored should be informed of their own results and what they mean. This needs to be done by someone who understands the results and can explain what they mean. The person authorised to run the biomonitoring study should also be mindful of any additional rights of workers set out at national level in some countries, for instance, the right not to know his/her own result or the right to withdraw their consent at any time.

Where this is a legal requirement, the determination of aptitude/fitness for a given job that includes biomonitoring, when required, must be based on a good knowledge of the job demands and of the work site and on the assessment of the health of the worker. The workers should be informed of the opportunity to challenge the conclusions concerning their aptitude/fitness in relation to work that they feel contrary to their interest. An appeals procedure should be established in this respect.

It is recommended that the occupational physician hand over in person to each worker his/her interpreted results. A medical interview is essential and should be organised as quickly as possible when the result is higher than the selected biological interpretation value, or when it is clearly different from the results of a group of similarly exposed workers, to seek the causes of that result and, where appropriate to define the prevention measures to be taken to reduce or eliminate exposure to the chemical agent. When the results are presented, it is recommended that the worker be informed of the risks associated with exposure to the chemical agent concerned, the means of prevention and the schedule of upcoming measurement campaigns.

In cases of subcontracting or if temporary work is used, the occupational physician or occupational health service of the user company who has implemented biomonitoring should present the results thereof to the workers concerned as well as to their respective occupational physicians and health services.

Information and advice must be given to workers regarding any health surveillance that they may undergo following the end of exposure in case of exposure to CMR substances and when a BLV for any substance has been exceeded or a disease or health effect linked to exposure has been identified.[23]

Information to the employer

The person responsible (usually the occupational physician) must analyse the results of biomonitoring. Where these provide indications that the preventive OSH measures taken regarding the worker or

[23] CMRD, Article 14(5); CAD, Article 10(4).

workers are not sufficient, the physician should inform the employer and make recommendations regarding appropriate prevention measures. The employer must check the workplace risk assessment and the prevention measures in place, immediately set required OSH measures and re-evaluate the improvements in a reasonable time frame. To this end, the results must be anonymised or pseudonymised. Reporting of biomonitoring results to the employer should be done in accordance with national regulations and practices. It is therefore recommended to check national legislation, standards and guidance.

The results of the examinations prescribed by national laws or regulations, particularly those relating to health surveillance, should only be conveyed to management in terms of fitness for the envisaged work or of limitations necessary from a medical point of view in the assignment of tasks or in the exposure to occupational hazards. Specific report templates may be required to be used by national legislation, for example, to certify aptitude/fitness for work of workers and they may contain parts that are available to different stakeholders (for instance, feedback on aptitude/fitness for work may go to the employer, while other data should not be disclosed). If not mandatory to use, however, they may be helpful when preparing information for the occupational physician who is undertaking or supervising biomonitoring. Occupational physicians or occupational health services may have their own preferred templates, and specific requirements should be discussed with anyone involved in the biomonitoring programme.

Reports for employers may contain:

- the name and date of birth of the worker;
- the name, registration number and signature of the occupational physician/health service;
- name and address of the business or undertaking;
- the date biomonitoring was carried out;
- where applicable, a certification of aptitude/fitness for work or aptitude/fitness for work under certain conditions (for example, increased frequency of testing);
- any recommendation that remedial measures be taken, including whether the worker can continue to carry out the type of work that triggered the requirement for biomonitoring; and
- whether medical counselling is required for the worker in relation to the work that triggered the requirement for biomonitoring.

Reporting of group results could also be considered, in particular where biomonitoring is used for exposure assessment (see above section on record-keeping). The results should be aggregated before any dissemination. Preferably, all executives and OSH experts involved in the establishment (employers, health and safety committee, occupational hygienist, etc.) as well as the entire workforce concerned (workers) should receive the information.

Occupational physicians may have to recommend a temporary or permanent removal of some workers identified as being over-exposed or who may have a particular susceptibility to the effects of the chemical agent (pathological state, pregnancy, etc.), although this option should be used with caution and the emphasis should clearly be on the minimisation of exposure rather than moving workers. If a change of job is recommended, the employer should assign the worker another activity in accordance with OSH or labour law regulations. In providing such information, the emphasis should be placed on proposals to adapt the tasks and working conditions to the abilities of the worker. General information on work fitness or in relation to health or the potential or probable health effects of work hazards may be provided with the informed consent of the worker concerned, in so far as this is necessary to guarantee the protection of the worker's health.

The doctor or authority responsible for health surveillance of workers may indicate that health surveillance, possibly including biomonitoring, must continue after the end of exposure for as long as they consider it to be necessary to safeguard the health of the worker concerned.[24]

Where appropriate, occupational physicians or health services could also be asking employers to assess the contamination of environments (atmospheric and surface sampling: worktops, door handles, sanitary facilities, workers' hands and gloves, etc.), so that they can implement tailored prevention measures.

[24] CMRD, Article 14(1).

Costs

The costs of biomonitoring are borne by the employer if they are not covered by another body (e.g. accident insurance providers). Workers should not be charged the costs.

Unless otherwise foreseen in national regulations and agreements, employers must pay for the worker's biomonitoring including:

- appointment fees;
- testing and analysis costs;
- time to attend appointments and testing procedures; and
- reasonable travel costs.

Information for workers

This section is intended for workers who may be subject to health surveillance and biomonitoring.

Health surveillance is meant to help protect your health. It is aimed at detecting changes in your health because of the hazardous chemicals you work with.

Biomonitoring will measure the level of these chemicals in your body or how your body responds to exposure to these chemicals.

Your health surveillance may include:

- talking with a doctor with experience in occupational health surveillance, about the type of tests and how often you will need to have them, as well as about the results from these tests;
- questions about your work history, medical history or lifestyle, for example, diet, smoking and drinking habits;
- some of these things may change how your body responds to a hazardous chemical;
- if this matters in your job, the doctor may ask you questions and talk with you about how your work and what you eat, drink and smoke could affect your health;
- a physical check including looking at your skin; and
- tests of your urine, blood or lungs, or X-rays.

When do I need health surveillance including biomonitoring?

Under the occupational health and safety laws, your employer should monitor your health and assess your exposure at certain times. This includes if you:

- use, handle, generate or store certain hazardous chemicals that could be a risk to your health and there are:
  - ways to see if the chemicals have affected your health; or
  - ways to see if you have been exposed to the chemicals, but it's not clear how much you have been exposed to.

There are specific hazardous chemicals that, if you are working with them, may trigger health surveillance including biomonitoring.

Health surveillance is compulsory for work with a chemical agent for which a binding biological limit value has been set at EU level. In this case, you should be informed of this requirement before being assigned to the task involving risk of exposure to the hazardous chemical agent.

An individual health and exposure record should be made and kept up to date for every worker who undergoes health surveillance. You must have access to your personal record.

Where, as a result of health surveillance, you are found to have a disease or adverse health effect associated with exposure at work to a hazardous chemical agent or a binding biological limit value is found to have been exceeded, or if you may be exposed to a carcinogen, mutagen or reprotoxic substance you must be informed by the doctor, who will provide you with information and advice regarding any health surveillance that you should undergo following the end of the exposure.

Who carries out biomonitoring and monitors my health?

Biomonitoring should normally be carried out or supervised by an occupational physician (doctor) with experience in occupational health surveillance.

The doctor may supervise other suitably qualified people to do some of your tests and procedures. For example, an occupational nurse may ask you general questions about your medical history, check your skin, and collect samples of your urine or blood.

Your employer will consult with you about who will do any biomonitoring or health surveillance.

Who pays for biomonitoring or health surveillance?

Your employer or the social accident insurance organisation or other responsible body should pay for all biomonitoring or occupational health surveillance including:

- appointment fees,
- testing and analysis costs, and
- your time and travel costs.

Your employer should give you paid time to go to the related medical appointments and tests.

What is a biomonitoring report and what is in it?

The occupational physician or occupational health service may give a report to your employer that may contain:

- the dates of blood, urine or other sampling;
- the date of the tests;
- limited information about your test results, for example, this could be when you need to undergo the next test or, where this is required by law, regarding aptitude/fitness for work, but not your test results;
- recommendations about your work;
- what your employer should do in the workplace because of your results; and
- how they recommend your employer address a risk to your health, for example, if you can continue the work that triggered the health surveillance/biomonitoring.

The occupational physician uses your test results primarily to inform your employer if the exposure levels to the hazardous chemicals at your workplace are too high and there needs to be improvement in the protection measures. Where this is foreseen in your country's legislation, the occupational physician may also use your test results to inform your employer whether

- you are fit for work with the hazardous chemical;
- you are fit for work with the hazardous chemical with certain restrictions;
- you are fit to start work again with the hazardous chemical; and/or
- if you should stop working with the hazardous chemical.

The occupational physician or health service may also write a report based on your and other workers' test results, but the employer should not be able to identify your results based on this report.

The occupational physician or occupational health service will keep data that may contain confidential information about you, your health and the outcomes of your health surveillance tests, and biomonitoring results. The doctor will keep a part of your report confidential and won't show it to your employer, unless they must be told something under law. If you already have a medical condition that could make the health effects of chemicals you are working with worse, you or the occupational physician, with your permission, should tell your employer so they can minimise your risk. No one must use the health surveillance report, blood or tissue samples, X-rays, questionnaires or other tests for anything else than what is mentioned above and the assessment of your exposure to the hazardous substances at your workplace through biomonitoring.

The occupational physician should give you the results of tests and explain them, unless you have indicated otherwise.

Some of your records may have to be kept for a specific period of time after the record is made, even if you move to another workplace. This is normally specified in national legislation.

You have the right to access any of your records that are kept following health surveillance and biomonitoring. How this access is organised may be specified in legislation in your country.

Do I have to undergo health surveillance and biomonitoring?

Some hazardous chemicals can cause serious illness and disease. Health surveillance and biomonitoring may show if a workplace hazardous chemical has harmed or may harm you. It is there to help keep you safe.

- You must follow, as far as you can, any work health and safety instructions from your employer.
- You should also follow any policy or procedure including biomonitoring or health surveillance foreseen by law.

Your employer should ensure you are informed about health surveillance or biomonitoring procedures before you start working with the chemical. Often information may be given to you by the occupational physician or occupational health service, in particular:

- possible health effects from exposure;
- where offering health surveillance or biomonitoring is a legal requirement;
- what a programme of health surveillance or biomonitoring aims to achieve and its benefits;
- what is involved in the programme, for example, how often you would be tested and which tests, such as blood tests, may be needed;
- how you will be informed of your results;
- any requirement for you to see a doctor or specialist;
- how to report symptoms;
- who pays for the health surveillance, biomonitoring and the tests;
- if and how monitoring results may affect your work tasks, for example, explaining circumstances where you may need to move to other tasks;
- how your medical records will be kept, including after you leave the enterprise; and
- that health surveillance and biomonitoring results are confidential and should only be disclosed to another physician involved in the programme if you give your consent.

Your employer or occupational health doctor should listen to you about your doubts and think about what you say.

However, your employer must consider if you need health surveillance or biomonitoring for your job. They must do this under occupational safety and health legislation and may be sending you for tests to comply with legislation. They should also inform you about the consequences if you refuse to undergo biomonitoring.

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ANNEX 1

Further details on methodological issues are provided in this annex for reference.

Choice of test parameter

Using a new biomarker requires some knowledge of any potential metabolism, which is substance-specific. A key feature of biomonitoring is that biomarkers are dynamic — they will begin to respond at onset of exposure, increasing during continued exposure and usually decline once exposure ends. The exact rate of these processes is specific to each specific exposure/biomarker and is known as biokinetics — processes of absorption into the body, distribution around the blood and tissues, any metabolism (where relevant) and, finally, elimination of the substance or its metabolite. In addition, physiological processes can influence the behaviour of a substance in the body; factors such as body size, breathing rate, physical activity, amount of body fat and co-exposure to other substances (including pharmaceuticals). As a consequence, it is important to understand that there is an optimal time to collect samples relative to an exposure event, which is substance-specific. Often human metabolism data is unavailable, so we may have to infer from toxicity studies. The recommended biomarker for monitoring exposure to a substance may change over time, as scientific understanding develops or better instrumentation enables more sensitive detection of minor, but more reliable, metabolites or even unchanged compound.

For a single chemical agent, when it is possible to measure the agent itself and one or more of its metabolites, the parent compound is often a more specific indicator. However, using metabolites helps to avoid errors resulting from the external contamination of samples. Other reasons for preferring one biomarker of exposure over another are its lower volatility or better stability, or its direct responsibility in the occurrence of critical effects.

At equal performance for assessing exposure and if the metabolite is specific to the chemical agent concerned, it is recommended that preference be given to the metabolite measurement rather than that of the parent compound if:

- toxicity occurs after metabolic activation, and/or
- there is a real risk of contamination during sampling, and/or
- the chemical agent is unstable or volatile.

The choice of matrix also has an influence — the unchanged substance is often measured in blood or exhaled air whereas urine is more likely to contain metabolites.

Sampling is a critical step, and a procedure should be established to avoid contamination of samples (for instance, decontamination/hand washing and change of work clothes to street clothes) and to perform all sampling in a standardised way in a non-contaminated area.

Sampling

Different strategies/protocols may be used when sampling. In general, recommended sampling times are designed to fit into routine work patterns so, for example, a sample could be collected at break times or at the end of work (sometimes towards the end of the week or shift pattern).

- **Sampling time**

Since the concentration of some substances can change rapidly, the specimen sampling time is very important and must be recorded. Sampling times are determined by the retention times of the chemical within the human body. Measurements are made either on samples of breath, urine, blood or hair, or any combination of these depending on the properties of the substance being monitored.

The rate of elimination is equally important and often represented by the term half-life, defined as the time taken for the amount of biomarker in a given sample type to decrease to half of the initial level. Again, this is a substance-specific parameter and can vary hugely, from a few minutes to months or years. Knowledge of the half-life largely determines the optimal sample collection time. Extremely short half-lives can make biomonitoring impractical as biomarkers are so rapidly eliminated. As half-life increases it may be advisable to collect sample soon after end of exposure (e.g. within an hour). For many substances, the half-life allows sample collection at the end of the shift.

Most of an absorbed dose (97%) is eliminated after five half-lives, so for slightly longer half-life substances, there can be an accumulation over consecutive days of exposure, and it can be appropriate to collect sample towards the end of the week (or consecutive shift pattern).

For very long half-life substances, accumulation becomes more obvious. Such substances are described as bioaccumulating or persistent. Nowadays, highly persistent chemicals are not in widespread use due to their effects on the environment, so where possible they are replaced with shorter half-life compounds. But many inorganic elements (metals and metalloids) have long half-lives. In these cases, sample collection time becomes less critical as a sample will reflect combined exposure over several weeks, months or even years. In that case, it may be deemed better to start with establishing a baseline, for example, by collecting pre-shift samples. However, it should be considered that these persistent substances will take a long time to reduce following end of exposure.

Half-life can be a difficult concept, so it is important to follow specialist advice, or there could be misleading results.

- **Sample acceptability for urine samples**

Some biomonitoring guidance values for chemicals, whose concentration is dependent on urine production levels, are expressed relative to creatinine concentration to correct for variable dilutions of the substance of interest in spot samples, as urine concentration can vary widely due to changes in fluid intakes and fluid losses, through sweating for example. Specimens must have a creatinine concentration of >0.3g/L and <3.0g/L or a specific gravity of >1.010 and <1.030. Specimens falling outside of these ranges should be discarded, as urine samples that are very diluted or very concentrated are usually not suitable for monitoring.

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This guide was developed at the European Agency for Safety and Health at Work (EU-OSHA) based on existing guidance documents.