BOHS
British Occupational Hygiene Society

The Chartered Society for Worker Health Protection

Biological monitoring

A tool for helping to assess workplace exposure.

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1. Who is this guide for?

This guide is primarily intended to help employers and individuals with delegated responsibility for health and safety to set up and manage a biological monitoring programme. It may also be useful for occupational health professionals, safety representatives and individual employees.

It will refer to some Great Britain (GB) legislation of particular relevance for biological monitoring; specifically, the Control of Substances Hazardous to Health (COSHH) Regulations 2002 (as amended), but readers should also be familiar with wider legislation and regulations relevant to workplace exposure. Furthermore, any local regulations should be considered if applying this guidance to non-GB-based operations[1].

The information contained in this guide covers the key aspects to consider for setting up a new monitoring programme or if you are taking over responsibility for running an ongoing programme. In most cases, a competent person should be able to use this guide to help them run a biological monitoring programme, but further advice as required can be obtained by contacting a specialist laboratory service provider or a competent occupational health professional with specialist knowledge in biological monitoring.

2. What is biological monitoring?

Biological monitoring, also commonly referred to as biomonitoring, is the measurement of a substance in a biological media obtained from an individual. The most common sample types are blood or urine but several others have been used including saliva, hair, sweat, exhaled breath and tissue biopsy. The type of sample is primarily determined by the substance being monitored, but where multiple options exist then their collection will present different levels of invasiveness and they are likely to reflect different timeframes of exposure (this will be discussed in more detail later).

Often, biological monitoring quantifies the substance of interest in a sample, but sometimes it is more appropriate to measure a metabolite (breakdown product). The choice of test compound, or biomarker, is largely determined by biochemical behaviour of the substance in the body. Ideally, a good biomarker should be sensitive to detect relevant levels of exposure and specific to an individual substance (or a group of closely related substances). Biological monitoring is most commonly used to assess exposure to chemicals but it also has some applications for non-chemical exposures[2].

Biological monitoring is a type of exposure assessment so it sits alongside other occupational hygiene measurement techniques including air sampling, surface wipes, skin contamination or professional competence and observation. Results give information about whether exposure controls are adequate and are working properly but they are not indicative of potential ill-health. Elevated biological monitoring results should be treated as an early indication that exposure control could be improved, before irreversible health consequences might begin to appear in workers. Some biomarkers do give information about early health effects – biological-effect monitoring – but even these tests only provide information about

[1] Northern Ireland has its own regulator although standards are similar to GB (http://www.hseni.gov.uk/)

[2] Biomarkers of non-chemical exposure can be useful, but they are typically of wide specificity, such as oxidative damage or stress, which can be difficult to link to a specific exposure.

early, reversible effects that would not be expected to lead to clinical disease so long as exposures are brought under control. Some high-hazard exposures require additional health surveillance, which will not be covered by this guidance.

Biological monitoring is uniquely useful for situations where exposure control relies on respiratory or other personal protective equipment (RPE or PPE). In these situations, it is the only objective test that protective equipment is effective and being used properly[3]. Similarly, biological monitoring is strongly advised for operations that have potential for significant skin exposure. In addition, because it is a personal measurement, biological monitoring can be helpful for identifying and improving behavioural factors. Levels of a biomarker reflect total systemic uptake over a time period specific to a particular substance. This can be useful as a quick check for any exposure issues in a workplace. However, it is usually not possible to distinguish the exact route, source and time or duration of exposure[4].

Many industrial substances are also present in the environment, in food or other products so there may be a background level, although typically this is far below levels that would be of concern for health. Often, non-occupational exposures have minimal impact on workplace monitoring but it might mean that biological monitoring results will never be zero, even with excellent exposure control. For some substances, exposure sources outside the workplace can be a significant contribution to total uptake so it may be necessary to employ strategies to help isolate occupational exposure such as pre- and post-work sampling or collecting an 'unexposed' background sample away from work.

Due to the personal nature of the sample, you are required to obtain informed consent from individuals before collecting samples. This will be discussed in more detail later, but essentially this involves workers understanding what is being tested and who will see the results. Results should be treated as personal data under the General Data Protection Regulations (GDPR) [6].

The development of biological monitoring tests requires a large amount of information before they can become routinely available for workplace exposure assessment. While suitable tests are available for many occupationally relevant substances, speciality or novel chemicals are unlikely to be available, although new biomarkers are constantly being developed. The availability of suitable workplaces with potential samples can often significantly aid biomarker development, so discussion with your laboratory or occupational health provider is encouraged.

Biological monitoring is intended to be a simple tool for use in helping to establish and maintain good exposure control. Using biological monitoring as a tool requires no specialist skills (although, for example, blood sampling requires an appropriately qualified professional) and it can usually be administered by any competent person who understands the principles outlined in this guide. For less experienced users, some sources of further information are suggested, which should be accessed as required. Where appropriate, urine sampling enables straightforward collection. The availability of guidance values for many

[3] Biological monitoring can inform how well all control measures are working, not just PPE or RPE.

[4] Collecting good contextual information, such as what specific tasks individuals were doing and when, in addition to any exposure control measures being used can help to identify these factors.

analytes aids the interpretation of results. Testing can identify areas that may require further attention and a continued programme of monitoring can provide assurance that exposure controls remain adequate.

3. Who should be monitored?

Employers must comply with the Control of Substances Hazardous to Health Regulations 2002 (COSHH) as amended, to protect the health of workers ([1]). Aside from lead, which has its own separate legislation (CLAW, [2]), quantification of occupational exposure using biological monitoring is not mandatory. However, biological monitoring can help employers demonstrate compliance with assessing the risks to employees' health arising from their work with chemicals and decide what precautions they need to take (COSHH regulation 6) whilst preventing or controlling risk (regulation 7). It can make a valuable contribution to exposure monitoring (regulation 10), where necessary; particularly in circumstances where air sampling alone may not give a reliable indication of exposure. Biological monitoring may also form part of a health surveillance programme under regulation 11 of COSHH, where it is possible to link results from biological monitoring to an adverse health effect.

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. Biological monitoring is especially useful for situations where

- there is likely to be significant skin absorption; and/or
- there is likely to be significant uptake following ingestion of the chemical; and/or
- control of uptake depends on the correct selection and use of personal protective equipment.

4. How do I set up and manage a biological monitoring programme?

Biological monitoring can be a simple, easy to use tool to help employers to assess exposure to their employees. However, it is underpinned by a substantial amount of technical knowledge, so you might wish to seek specialist advice – particularly if you haven't used biological monitoring before. A specialist laboratory that offers a biological monitoring service will be happy to discuss your requirements, or you might choose to use an occupational health provider as an intermediary. The British Occupational Hygiene Society (BOHS) and the Faculty of Occupational Medicine (FOM) are useful resources who can facilitate access to their members if you require specialist advice. Trade associations or other contacts in your industry might also be able to help. With some appropriate knowledge, a biological monitoring programme can be set up and managed by a non-specialist. This section details the essential steps that you need to consider.

Each of these steps should be thought through before embarking on any sampling or testing, and you should plan for how you might access specialist advice should it be required.

Step 1 Define the purpose of the programme
Step 2 Appoint a competent person to manage the programme

Step 3 Define the monitoring strategy
Step 4 Consult on the programme with employees or their representatives
Step 5 Discuss and agree the programme with the individual employees concerned
Step 6 Establish procedures for sample collection, storage, transportation, analysis and quality assurance
Step 7 Establish procedures for feedback, including interpretation or results
Step 8 Ensure arrangements are in place for acting on the results and evaluating the effectiveness of the programme

Step 1 Define the purpose of the programme

Before considering any exposure measurements, a competent person should have completed COSHH health risk assessments for all of the processes using hazardous substances in your workplace. These assessments will inform whether biological monitoring could be helpful for your circumstances, in identifying whether controls are adequate to control exposure below reference values. COSHH regulations outline two applications for biological monitoring, for either exposure assessment or health surveillance[5]. While the process of monitoring is the same for both applications, there may be some subtle differences in how they are managed and in how the results are interpreted.

Step 2 Appoint a competent person to manage the programme

If you are carrying out exposure assessment, then any suitably competent person can manage the programme. The person should have appropriate knowledge and experience to carry out their duties. They will need to discuss results with individual employees and, depending on the size of your organisation; the role may involve interacting with other managers. It is not a requirement, but you might choose to engage an occupational health or other suitably competent professional to provide these services.

If blood samples are necessary, you will need an appropriately qualified phlebotomist to take them.

If you are using biological monitoring for health surveillance (under COSHH regulation 11), then you will need to appoint a suitably qualified medical professional[6].

Step 3 Define the monitoring strategy

The monitoring strategy depends on what you are measuring, but it essentially covers who, what, when and how often to take samples. For well-established biological monitoring tests, this information is widely available. But many other tests are available, so it is advisable to discuss your needs with your laboratory or occupational health provider; they should advise on whether biological monitoring is possible and appropriate as well as how the results can be interpreted.

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[5] Most biological monitoring is for exposure assessment. Its use for health surveillance is only relevant where there is a clear link to a health-effect. Lead is covered by separate legislation (CLAW). Please refer to individual regulations for more information.
[6] https://www.hse.gov.uk/doctors/about.htm

Who to monitor?
What sample to collect?
When to take it?
How often to sample?

Discuss your requirements with your laboratory or occupational health provider

A substantial amount of technical knowledge is required to inform these parameters but it is not necessary for the end user to consider the detail. However, a basic familiarity with these concepts might be helpful to users, so further information is available in Appendix A – Technical Advice: A sampling strategy for biological monitoring.

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. Because of individual variability and the impact of behaviours on uptake, it is preferable to sample all relevant workers. However, where this is not possible (perhaps due to worker numbers) a "similarly exposed groups" approach can be taken, as is often done for air monitoring for example [3].

Step 4 Consult on the programme with employees or their representatives

It is helpful to discuss any plans to implement a monitoring programme with employees, or their representatives, and obtain their agreement. Consultation should include discussions of:

- gaining employees' consent to provide samples;
- what the sample is going to be tested for (and what is not going to be tested e.g. drugs, alcohol, pregnancy, genetic testing etc.);
- who will see the results;
- what the results mean – usually they inform about exposure but are not directly related to risk of developing ill-health;
- what might happen if a result indicates that exposure is not being properly controlled;
- periodic review of the programme;
- how employees can provide feedback;
- informing new starters.

Employees are not obliged to participate in a biological monitoring programme[7]; however, if reasonable steps are taken to consult and involve them in the process then they will hopefully see the benefits and are more likely to ensure successful implementation.

Step 5 Discuss and agree the programme with the individual employees concerned

[7] Employees using lead may be obliged under CLAW to cooperate. If the programme is part of health surveillance, refusal to participate might mean that an individual has to be redeployed.

Biological monitoring involves measurements on an individual's body fluids, so their rights must be protected. Before collecting a sample, the employer must obtain informed consent from the individual. It is the employer's responsibility to maintain records of consent and to store data in compliance with relevant data protection laws.

Before an individual can give their informed consent, they must be provided with information about the intended monitoring (including the points from step 4), how results will be used, any specific individuals that will see the results[8], the benefits to themselves and what the result means. It is important to note that most biological monitoring can only inform about exposure and whether it is being adequately controlled. Results cannot be interpreted in terms of individual risk of ill-health.

In some circumstances, it may be possible to display anonymised group data, such as average or min-max range, but only if doing so would not compromise the ethical rights of individuals to not be identifiable. But generally, it is most useful to have individual data. Variability between individuals makes direct comparison of individuals complicated.

An example consent form is provided at Appendix B.

Step 6 Establish procedures for sample collection, storage, transportation, analysis and quality assurance

Your laboratory should provide detailed information about sample handling, analysis and quality assurance. The following general guidance might be useful.

Sample collection

The type of sample required, and when to collect it, depends on what is being tested. In the UK, wherever possible, urine is preferred over blood as it is less invasive and does not require specialist collection. If an individual is collecting their own sample (i.e. urine or most other samples apart from blood), they should wash their hands and remove overalls so as not to contaminate it with material from the workplace. Samples should be collected at specified times – relative to when potential exposure occurred. Typically, samples will be collected at suitable break times such as end of shift or occasionally pre-work the next day. For some substances that can accumulate over consecutive days, sample collection towards the end of the week (or shift pattern) is preferred. Other substances may be short-lived in the body, so it is important to collect sample soon after end of exposure.

If sample containers have been supplied, it is important to use these as they may have been screened to ensure no contamination or sometimes they may contain an additive to help stabilise the sample (clear information should be provided by the laboratory). Sample bottles should be labelled - usually a name[9] (or other unique identifier) and sample date is sufficient but the time of the sample might be needed if collecting multiple samples.

Essentially, it is important to follow the advice from your laboratory.

[8] Aside from the programme manager, other specified individuals such as supervisors or managers might need to know individual results to enable any necessary further action.

[9] Personal details should be minimised and must comply with appropriate data protection regulations.

Storage

Mostly, samples should be sent to the laboratory on the day that they are collected, where they will be stored appropriately until analysis. In some circumstances where this is not possible, you should seek advice from your laboratory or occupational health provider. It may be acceptable, for example, to store samples refrigerated overnight before arranging dispatch. Any deviations from your normal procedure should be noted as it may affect sample viability, potentially leading to false results.

Transportation

Most samples are designed to be sent via first class post from mainland UK locations. Sample stability over one or two days at room temperature is assessed as part of test validation. The date of collection should be recorded on the sample request form so that any postal delays can be identified. If you prefer, you could use a courier service.

It is your responsibility to ensure that samples are transported safely and in compliance with applicable regulations (see UN3373[10]). Your laboratory or occupational health provider can provide advice and in most cases will provide appropriate packaging.

Analysis and quality assurance

It is essential that sample analysis is performed using properly validated test methods using quality assurance procedures. When choosing a laboratory, you should discuss what procedures are in place to ensure long-term reproducibility, so that your results are comparable with past data. Some factors to consider when evaluating a laboratory include: a laboratory's undertaking of internal quality assurance and performance in external proficiency testing where available; knowledge and experience of the staff; whether the cost of analysis includes advice on interpreting the results; how long it will take to get your results. A good laboratory will be happy to discuss these and any other issues of specific relevance to your circumstances.

Step 7 Establish procedures for feedback, including interpretation of results

You should inform employees being monitored of their individual results and what this means. This should be done by a person who is competent to explain the results. Remember that most biological monitoring informs us about exposure (not health), so typical feedback might be whether the current result indicates that exposure is being adequately controlled, or not. You might compare the current result with any previous data to establish a trend in exposure – it may take several rounds of monitoring to gradually improve elevated exposure. In some circumstances, it might be helpful to compare different individuals who are doing broadly similar tasks – but, as noted previously, be aware that some variability in results is normal even if the group are all exposed to identical levels.

Many substances are present in food, consumer products, pharmaceuticals or the environment. Since biological monitoring assesses total systemic uptake via all routes, it may be necessary to exclude the possibility that elevated results may be due to non-

[10] https://www.un3373.com/category-biological-substances/category-b/

occupational exposure. In some situations, hobbies or side-jobs could be significant contributors to exposure. Where appropriate, such factors should be discussed with individuals, whilst taking care not to infringe their rights to confidentiality and data protection. Timing of the sample can sometimes help to minimise the impact of these external factors. You may wish to seek specialist advice in rare situations where elevated results appear to be inconsistent with your understanding of workplace exposure.

Many routine biological monitoring tests have well-established guidance values which help to interpret the results; HSE publishes its guidance values [4]. There are a few different approaches for setting guidance values and you may wish to seek specialist advice from your laboratory or occupational health provider about their interpretation. Usually, occasionally exceeding a guidance value is unlikely to have long-term consequences for health, but it probably suggests that exposure controls could be improved.

Step 8 Ensure arrangements are in place for acting on the results and evaluating the effectiveness of the programme

To get the most value out of your monitoring, you should assess each individual's result and take any required action. Depending on the size and structure of your organisation, monitoring results may need to be shared with specific individuals to enable effective action. Any disclosure of data beyond the programme manager needs to be in accordance with the ethical rights of the individual being tested and should have been established prior to collecting sample, as previously discussed. It is usually advisable to check any elevated results by re-sampling at an appropriate time so that you can establish whether the exposure is on-going or was an isolated, one-off, event. You can then relate the effort and resources required to the extent of the problem. This also highlights the usefulness of recording contextual data (such as tasks undertaken, PPE used) at the time of sampling.

In addition to generally available guidance values, some workplaces find it helpful to establish their own in-house 'action' levels. This approach can be useful if your exposures are generally very well-controlled so you might want to take some corrective action at levels below a guidance value. It also enables the use of contemporary data to set an appropriate level for your individual workplace, rather than relying solely on data that may be rather dated. But, in the absence of other data, guidance values still offer a useful starting place for interpreting your results.

You should periodically evaluate your monitoring programmes to ensure that they continue to meet your needs. If results indicate exposure is not being adequately controlled, it would be good practice to re-sample after carrying out any corrective actions to help evaluate their effectiveness. You should continue this cycle of testing and improvement until exposure-control can be considered adequate or as low as reasonably possible[11]. Once monitoring indicates that good-control has been established, annual testing might be adequate. In some

[11] The mode of action of the hazard determines whether it is appropriate to control exposure below an acceptable threshold or, for substances such as carcinogens or sensitisers, you are obliged to reduce exposures to as low as reasonably practicable (ALARP).

circumstances, where repeated monitoring has consistently demonstrated no or very low (background environmental levels), it might be appropriate to end the programme.

In most circumstances, any competent person who understands the principles outlined in this guide can manage a biological monitoring programme, including providing feedback on the results. However, some applications including conducting biological monitoring of lead under CLAW regulations or when using as part of health surveillance (COSHH reg. 11) may require appointment of an appropriately qualified person (refer to relevant regulations for up to date information).

5. Further advice

Links to specific regulations or guidance of relevance for occupational exposure (COSHH, CLAW, EH40) can be found on the HSE website (HSE.gov.uk). Direct links are provided in the references section.

The World Health Organisation has produced guidance. WHO Biological monitoring of chemical exposure in the workplace: guidelines.
https://apps.who.int/iris/handle/10665/41856

Guidance values are prepared by various national and international bodies. They are useful for providing context and helping to interpret biological monitoring results. Please be aware that guidance values from other countries may relate to different exposure limits than apply in Great Britain. Guidance values are derived using several different approaches and therefore interpretation may vary. Some older guidance may no longer accurately reflect current best-practice exposure control. A specialist laboratory or an appropriately qualified occupational health professional will be able to provide suitable guidance.

US Biological Exposure Indices:
https://www.acgih.org/forms/store/ProductFormPublic/2020-tlvs-and-beis

German Biological Tolerance Values:
https://onlinelibrary.wiley.com/page/book/10.1002/3527600418/homepage/access_to_the_list_of_mak_and_bat_values.htm

European Scientific Committee on Occupational Exposure Limits (SCOEL):
https://ec.europa.eu/social/BlobServlet?docId=12629&langId=en

European Chemicals Agency: Occupational exposure limits substance evaluations:
https://echa.europa.eu/oels-activity-list

6. Glossary.

Background level – Many substances are present in the environment; in food, consumer products, tobacco etc. so they are detectable in non-occupationally exposed people. The typical non-occupationally exposed range of biomarker can help to provide context for the interpretation of monitoring results.

Biological monitoring / biomonitoring – Quantification of total systemic uptake by measuring a substance (or metabolite) in a biological sample obtained from an individual. It can be helpful as part of exposure management and control.

Biological effect monitoring – Quantifying an early, reversible, indicator of toxic effect.

Biomarker – A substance that can be quantified and correlates with exposure to a substance, or a biological effect.

COSHH – Control of Substances Hazardous to Health; some key legislation in Great Britain governing the responsibility of employers to manage exposure to chemicals and some other exposures.

Guidance value – Produced to help interpret results. Usually set by regulatory agencies, or appointed scientific expert committees, they relate a level of biomarker to a known exposure level (usually in air) or a level judged to not cause adverse health effects. They tend to be only available for commonly used industrial substances and can become dated.

Half-life – The time for a biomarker level to reduce by half following end of exposure.

Individual variation – The expression of biological variation between individuals, both genetic and physiological, that leads to a range of biomarker levels in response to an identical exposure.

Informed consent – An essential part of biological monitoring where an individual receives information about the planned monitoring, understands it and gives their agreement to provide a sample and who can see the results.

Metabolite – Either an intermediate or an end product produced by enzyme-mediated conversion in the body. Usually excreted in urine. Some substances undergo little or no metabolism, while others have multiple complex pathways.

Matrix – A biological material used as the sample. Usually biological monitoring used blood or urine, but other samples including breath, sweat, hair and saliva may be used.

Occupational Health Professional – A doctor, nurse or hygienist with experience of understanding work-related exposure and health issues. They should be appropriately qualified and experienced and a faculty member of the relevant professional society (Faculty of Occupational Medicine, https://www.fom.ac.uk/; Faculty of Occupational Health Nursing, https://www.fohn.org.uk/; British Occupational Hygiene Society, http://www.bohs.org/).

P90 level – A statistically generated guidance value that can be produced from any suitable data set, including in-house data. Set at the 90th percentile, it is an exposure-based guidance value that may not necessarily relate to a ‘safe’ exposure. But it can be helpful for identifying individuals or processes that require improvement and periodic review can help to drive a cycle of continuous improvement.

Appendix A – Technical Advice: A sampling strategy for biological monitoring

This appendix contains further technical detail that will be useful to help set up biological monitoring for substances that do not already have well-established guidance. It is not necessary to have a comprehensive understanding of this information – we would encourage you to seek specialist advice as necessary. But a basic appreciation of this information will help you to better understand the rationale underpinning biological monitoring.

Biological monitoring can be applied to quantify a wide array of exposures, usually but not exclusively chemical exposure. However, we would normally consider what other approaches are already available as part of assessing the benefit of developing a new biomarker. As previously discussed in the main document, biological monitoring complements other exposure assessment methods that you may be more familiar with and different methodologies will have their own individual strengths and limitations. Generally, biological monitoring would not be considered for substances that have primarily irritant effects or where very acute exposures can be catastrophic; often real-time monitoring is more appropriate here.

While a range of sample types, or media, are potentially applicable for biological monitoring, urine has traditionally been preferred in the UK due to the ready availability of this matrix and ease of collection[12]. The best sample media is dependent on the individual substance of concern – not all biomarkers can be measured in all sample types. The other key feature of biological monitoring is that biomarkers are dynamic – they will begin to respond at onset of exposure, increasing during continued exposure and 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 sample relative to an exposure event, which is substance specific.

Route of exposure can affect the time taken for a substance to enter the body. Biological monitoring assesses total systemic 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. In practice, when comparing inhalation versus dermal exposure we observe distinct absorption profiles over time[13], so some prior consideration of likely exposure route can help to determine the best time to collect sample.

The rate of elimination is equally important. Again, this is a substance-specific parameter and can vary hugely. The rate of elimination is 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

[12] Elsewhere blood samples are preferred as it often gives a closer estimate of the dose at target-site for toxicity.

[13] In practice, where dermal absorption is the major exposure route, we often observe higher levels of biomarker in pre-shift samples the following day compared to immediate post-shift samples.

the initial level. Largely dependent on the physico-chemical nature of the substance, half-life can range 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 biological monitoring impractical as biomarkers are so rapidly eliminated. As half-life increases you may be advised 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, we can begin to observe accumulation over consecutive days of exposure and it can be appropriate to collect sample towards the end of the week (or consecutive shift pattern). As we move towards very long half-life substances, accumulation becomes more obvious. Such substances are described as bio-accumulating or persistent. Nowadays, highly persistent chemicals are generally not in widespread use due to their potentially damaging effects on the environment, so where possible they are replaced with shorter half-life compounds. But many inorganic elements (metals and metalloids) exhibit long half-lives[14]. In these cases, sample collection time becomes less critical as a sample will reflect combined exposure over several weeks, months or even years. However, you should also consider 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.

Half-life can be a difficult concept and we would not expect a non-specialist end-user of biological monitoring to have detailed understanding. But it does underpin the rationale for recommending when to collect a sample, relative to exposure, so it is important to follow specialist advice or you could end up with misleading results. 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). Once you have a sampling strategy that fits your requirements, it is advisable to maintain consistency so that you are minimising sampling variability and so we can be confident that any variations in your biological monitoring results are reflecting changes in exposure.

Developing a new biomarker requires some knowledge of any potential metabolism. The importance of metabolism is, again, substance specific. The choice of matrix also has an influence – the unchanged substance is often measured in blood whereas urine is more likely to contain metabolites. 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. Occasionally, different laboratories may offer different tests for the same chemical – your laboratory should be happy to explain the rationale behind their recommended biomarker. Whilst using metabolites can add a further layer of potential variability, they can be useful in eliminating sample contamination.

[14] Some elements have complex mixtures of short and long half-life components.

It is important to be aware of the variabilities outlined here, but by taking some fairly simple precautions you can minimise their impact on your biological monitoring results. It is also true that the biological variations outlined here have equal relevance to other exposure measurement methods. Some of the strengths and limitations of biological monitoring are listed below to help you to decide whether it might be helpful for your exposure management requirements.

Summary of benefits and limitations of biological monitoring.

Strengths	*Limitations*
Integrates all routes of exposure – can give an overview of total exposure	Integrates all routes of exposure – sometimes difficult to identify source of exposure (potential for non-workplace exposure).
Personal measurement – can be very useful in influencing behaviours.	Suitable tests not always available
When using exposure controls (RPE, PPE, gloves, overalls etc.) BM can demonstrate correct use and effectiveness.	Biomarkers are dynamic (levels change over time) so sampling time relative to exposure is important.
Urine sampling enables simple collection and no specialist expertise required on-site. Can reduce costs. Accessible to all workplaces.	Intensive data requirement for toxicokinetics can be a barrier to new substance method development
Measurement of metabolites (where appropriate) can reduce potential for contamination.	Interindividual variability means results between individuals may not be directly comparable.
Reflects actual exposure (absorbed dose).	Situations where the half-life (t1/2) is either extremely short (less than an hour; biomarkers only present for short time) or long (several months or years; unresponsive to changes in exposure) can be problematic
	Storage stability of biological samples – can be a problem if samples can't be sent to lab promptly

Data interpretation, including P90 approach.

While some commonly used substances have extensive guidance available to aid the interpretation of results, many others lack the required detailed scientific knowledge to set a level based on either an equivalent environmental level or a health basis. But it is still possible to have an effective biological monitoring programme. In-house guidance levels are simple to establish, once you have collected sufficient data that you are confident reflects typical exposure in your workplace. Alternatively, pooled data is often available from your laboratory, regulatory agencies or perhaps trade organisations that can help to put your data into context. One approach that has been shown to be effective is to establish a 90th percentile level from a suitable set of data – sometimes referred to as a P90 guidance value

[5]. Whilst it has no relationship to potential health consequences of exposure – there are no guarantees that being below a P90 is protective to health – this type of guidance value is entirely exposure-based and represents what is achievable. By definition, only 1 in 10 results will exceed the P90 and, in most cases, this would indicate that improvements to exposure control are possible. Therefore this approach is in line with the principles of COSHH – namely to control exposure as low as reasonably practicable (ALARP[15]). Furthermore, periodically reviewing the P90 can help to drive a cycle of improved exposure control by highlighting areas that can be targeted for improvement.

Alternatively, in the absence of any other data it can be helpful to compare occupational exposure data with unexposed, background levels. These could be taken from your own workplace, for example unexposed office workers, or your laboratory may be able to help. Many biomarkers have detectable levels in the general population. If your workplace results are within, or close to, the background level then this would suggest that exposure is being well-controlled. Conversely, exceeding the background level by several orders of magnitude would indicate significant workplace exposure, although we could not make any inference about the potential (or not) for adverse health consequences.

[15] https://www.hse.gov.uk/risk/theory/alarpglance.htm

Appendix B – Example consent form.

It is the employer's responsibility to obtain informed consent before taking samples for biological monitoring and to keep records appropriately and in compliance with all relevant regulations. There is no standardised approach, but the example form below contains all the required details.

Many jobs involve the use of chemicals which can harm your health if they are not used properly. As your employer I have to identify the risks to your health and ensure that they are properly controlled. Where control relies on personal protective equipment (PPE, such as masks, overalls and gloves) or where the chemical(s) can be absorbed through your skin, biological monitoring can be used to indicate how much of a chemical you are exposed to at work has entered your body.

You can find out more about biological monitoring in the free HSE leaflet *Biological monitoring in the workplace: Information for employees on its application to chemical exposure*.

A biological monitoring programme is about to begin in your workplace. The results will be used to check that your exposure to [enter chemical name] at work is being adequately controlled. You do not have to take part in this programme. If you decide not to take part, this will not affect your conditions of employment. Similarly, if you do take part, the result of your test will not affect your conditions of employment.

You will be offered a copy of your results. They will be used by [enter name of responsible person] to assess whether your exposure to [enter chemical name] needs to be reduced. Your permission will be sought before results are passed to any other person.

If you require more information at any time, or have any concerns about the programme or your results, you can contact [enter name of responsible person] on [contact details].

Section A: To be completed by the employee

The purpose of this biological monitoring programme and the actions which might be taken to control my exposure have been explained to me by [enter name of responsible person]. I, [worker name], agree to provide a sample of blood/urine/breath* for the measurement of [enter chemical name] under the following conditions:

1. The sample I provide will **only** be analysed for [enter chemical name] and related tests.
2. The result of my test will be sent to [enter name of responsible person].
3. Further access to my results will be restricted to the following persons in the indicated forms:

Person to receive results**	Individual results (not anonymised)	Individual results (anonymised)	Group results (anonymised)

4. I would/would not* like to receive my own result and have it explained to me.

Signature of employee: …… Date: …….

Section B: To be completed by the biological monitoring programme manager

I agree to abide by the above conditions.

Signature of biological monitoring programme manager:
……

Name (print)…… Date: …….

Notes

Completion of this form

Section A should be completed by the employee.

Section B should be completed by the biological monitoring programme manager.

Note: A signed copy of the form should be held by the employer and employee.

Note: You may need to simplify this form, particularly question 3, to suit individual circumstances.

*Delete as appropriate

**This box should be completed by the programme manager following discussion and agreement with employees or their representatives. Recipients may be supervisors, employers, health and safety managers, trade union representatives or occupational health staff not involved in running the programme.

References

1. HSE. *The Control of Substances Hazardous to Health Regulations 2002 (as amended). Approved Code of Practice and guidance*. 2013 19/05/2020]; Available from: http://www.hse.gov.uk/pubns/priced/l5.pdf.
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3. Vincent, R.Y., *1717a En 689: the new european standard on testing compliance with occupational exposure limit values.* Occupational and Environmental Medicine, 2018. **75**(Suppl 2): p. A199-A200.
4. HSE. *EH40/2005 Workplace exposure limits*. http://www.hse.gov.uk/pubns/priced/eh40.pdf 2020 19/05/2020]; Available from: http://www.hse.gov.uk/pubns/priced/eh40.pdf.
5. Cocker, J. and K. Jones, *Biological Monitoring Without Limits.* Annals of Work Exposures and Health, 2017. **61**(4): p. 401-405.
6. GDPR. https://ico.org.uk/for-organisations/guide-to-data-protection/guide-to-the-general-data-protection-regulation-gdpr/