2009
Biological Exposure Indices

Adopted by ACGIH®
with Intended Changes

BEIs®

Contents

2008 BIOLOGICAL EXPOSURE INDICES COMMITTEE

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INTRODUCTION TO THE BIOLOGICAL EXPOSURE INDICES

Biological monitoring provides one means to assess exposure and health risk to workers. It entails measurement of the concentration of a chemical determinant in the biological media of those exposed and is an indicator of the uptake of a substance. Biological Exposure Indices (BEIs®) are guidance values for assessing biological monitoring results. BEIs® represent the levels of determinants that are most likely to be observed in specimens collected from healthy workers who have been exposed to chemicals to the same extent as workers with inhalation exposure at the Threshold Limit Value (TLV®). The exceptions are the BEIs® for chemicals for which the TLVs® are based on protection against nonsystemic effects (e.g., irritation or respiratory impairment) where biological monitoring is desirable because of the potential for significant absorption via an additional route of entry (usually the skin). Biological monitoring indirectly reflects the dose to a worker from exposure to the chemical of interest. The BEI® generally indicates a concentration below which nearly all workers should not experience adverse health effects. The BEI® determinant can be the chemical itself; one or more metabolites; or a characteristic, reversible biochemical change induced by the chemical. In most cases, the specimen used for biological monitoring is urine, blood, or exhaled air. The BEIs® are not intended for use as a measure of adverse effects or for diagnosis of occupational illness.

Biological monitoring can assist the occupational health professional detect and determine absorption via the skin or gastrointestinal system, in addition to that by inhalation; assess body burden; reconstruct past exposure in the absence of other exposure measurements; detect nonoccupational exposure among workers; test the efficacy of personal protective equipment and engineering controls; and monitor work practices.

Biological monitoring serves as a complement to exposure assessment by air sampling. The existence of a BEI® does not indicate a need to conduct biological monitoring. Conducting, designing, and interpreting biological monitoring protocols and the application of the BEI® requires professional experience in occupational health and reference to the current edition of the *Documentation of the Threshold Limit Values and Biological Exposure Indices* (ACGIH®).

DOCUMENTATION

BEIs® are developed by Committee consensus through an analysis and evaluation process. The detailed scientific criteria and justification for each BEI® can be found in the *Documentation of the Threshold Limit Values and Biological Exposure Indices*. The principal material evaluated by the BEI® Committee includes peer-reviewed published data taken from the workplace (i.e., field studies), data from controlled exposure studies, and from appropriate pharmacokinetic modeling when available. The results of animal research are also considered when relevant. The *Documentation* provides essential background information and the scientific reasoning used in establishing each

BEI®. Other information given includes the analytical methods, possible potential for confounding exposures, specimen collection recommendations, limitations, and other pertinent information.

In recommending a BEI®, ACGIH® considers whether published data are of reasonable quality and quantity, and may also consider unpublished data if verified. There are numerous instances when analytical techniques are available for the measurement of a biological determinant, but published information is unavailable or unsuitable for determining a BEI®. In those instances, occupational health professionals are encouraged to accumulate and report biological monitoring data together with exposure and health data.

Relationship of BEIs® to TLVs®

BEI® determinants are an index of an individual's "uptake" of a chemical(s). Air monitoring to determine the TLV® indicates the potential inhalation "exposure" of an individual or group. The uptake within a workgroup may be different for each individual for a variety of reasons, some of which are indicated below. Most BEIs® are based on a direct correlation with the TLV® (i.e., the concentration of the determinant that can be expected when the airborne concentration is at the TLV®). Some of the BEIs® (e.g., lead) are not derived from the TLV®, but directly relate to the development of an adverse health effect. The basis of each BEI® is provided in the *Documentation*.

Inconsistencies may be observed between the information obtained from air monitoring and biological monitoring for a variety of reasons, including, but not limited to, work-related and methodological factors. Examples are listed below:

- Physiological makeup and health status of the worker, such as body build, diet (water and fat intake), metabolism, body fluid composition, age, gender, pregnancy, medication, and disease state.
- Occupational exposure factors, such as the work-rate intensity and duration, skin exposure, temperature and humidity, co-exposure to other chemicals, and other work habits.
- Nonoccupational exposure factors, such as community and home air pollutants, water and food components, personal hygiene, smoking, alcohol and drug intake, exposure to household products, or exposure to chemicals from hobbies or from another workplace.
- Methodological factors, which include specimen contamination or deterioration during collection and storage and bias of the selected analytical method.
- Location of the air monitoring device in relation to the worker's breathing zone.
- Particle size distribution and bioavailability.
- Variable effectiveness of personal protective devices.

Specimen Collection

Because the concentration of some determinants can change rapidly, the specimen collection time (sampling time) is very important and must be observed and recorded carefully. The sampling time is specified in the BEI® and is determined by the duration of retention of the determinant. Substances

and determinants that accumulate may not require a specific sampling time. An explanation of the BEI® sampling time is as follows:

Sampling Time	Recommended Collection
1. Prior to shift	16 hours after exposure ceases
2. During shift	Anytime after 2 hours of exposure
3. End of shift	As soon as possible after exposure ceases
4. End of the workweek	After four or five consecutive working days with exposure
5. Discretionary	At any time

Urine Specimen Acceptability

Urine specimens that are highly dilute or highly concentrated are generally not suitable for monitoring. The World Health Organization has adopted guidelines for acceptable limits on urine specimens as follows:

Creatinine concentration: > 0.3 g/L and < 3.0 g/L
or
Specific gravity: > 1.010 and < 1.030

Specimens falling outside either of these ranges should be discarded and another specimen should be collected. Workers who provide consistently unacceptable urine specimens should be referred for medical evaluation.

Some BEIs® for determinants whose concentration is dependent on urine output are expressed relative to creatinine concentration. For other determinants such as those excreted by diffusion, correction for urine output is not appropriate. In general, the best correction method is chemical-specific, but research data sufficient to identify the best method may not be available. When the field data are only available as adjusted for creatinine, the BEI® will continue to be expressed relative to creatinine; in other circumstances, no correction is recommended, and the BEI® will be expressed as concentration in urine.

Quality Assurance

Each aspect of biological monitoring should be conducted within an effective quality assurance (QA) program. The appropriate specimen must be collected, at the proper time, without contamination or loss, and with use of a suitable container. Donor identification, time of exposure, source of exposure, and the sampling time must be recorded. The analytical method used by the laboratory must have the accuracy, sensitivity, and specificity needed to produce results consistent with the BEI®. Appropriate quality control specimens should be included in the analysis, and the laboratory must follow routine quality control rules. The laboratory should participate in an external proficiency program.

The occupational health professional should provide known blind challenges to the laboratory along with worker specimens (e.g., blanks, purchased or spiked specimens containing the determinant, or split specimens). These blind challenges will enable the occupational health professional to assess the ability of the laboratory to process, analyze, and report results properly, and to

have confidence in the laboratory's ability to accurately measure the worker's BEI®. When blind challenges are used, the spiked determinant should be in the same chemical form and matrix as that being analyzed by the laboratory.

Notations

"B" = Background

The determinant may be present in biological specimens collected from subjects who have not been occupationally exposed, at a concentration which could affect interpretation of the result. Such background concentrations are incorporated in the BEI® value.

"Nq" = Nonquantitative

Biological monitoring should be considered for this compound based on the review; however, a specific BEI® could not be determined due to insufficient data.

"Ns" = Nonspecific

The determinant is nonspecific, since it is also observed after exposure to other chemicals.

"Sq" = Semi-quantitative

The biological determinant is an indicator of exposure to the chemical, but the quantitative interpretation of the measurement is ambiguous. These determinants should be used as a screening test if a quantitative test is not practical, or as a confirmatory test if the quantitative test is not specific and the origin of the determinant is in question.

Note:

It is essential to consult the specific BEI® *Documentation* before designing biological monitoring protocols and interpreting BEIs®. In addition, each BEI® *Documentation* now provides a chronology that traces all BEI® recommended actions for the chemical substance in question.

Application of BEIs®

BEIs® are intended as guidelines to be used in the evaluation of potential health hazards in the practice of occupational hygiene. BEIs® do not indicate a sharp distinction between hazardous and nonhazardous exposures. For example, it is possible for an individual's determinant concentration to exceed the BEI® without incurring an increased health risk. If measurements in specimens obtained from a worker on different occasions persistently exceed the BEI®, the cause of the excessive value should be investigated and action taken to reduce the exposure. An investigation is also warranted if the majority of the measurements in specimens obtained from a group of workers at the

same workplace and workshift exceed the BEI®. It is desirable that relevant information on related operations in the workplace be recorded.

Due to the variable nature of concentrations in biological specimens, dependence should not be placed on the results of one single specimen. Administrative action should not be normally based on a single isolated measurement, but on measurements of multiple sampling, or an analysis of a repeat specimen. It may be appropriate to remove the worker from exposure following a single high result if there is reason to believe that significant exposure may have occurred. Conversely, observations below the BEI® do not necessarily indicate a lack of health risk.

BEIs® apply to 8-hour exposures, 5 days per week. Although modified work schedules are sometimes used in various occupations, the BEI® Committee does not recommend that any adjustment or correction factor be applied to the BEIs® (i.e., the BEIs® should be used as listed, regardless of the work schedule).

Use of the BEI® should be applied by a knowledgeable occupational health professional. Toxicokinetic and toxicodynamic information is taken into account when establishing the BEI®; thus, some knowledge of the metabolism, distribution, accumulation, excretion, and effect(s) is helpful in using the BEI® effectively. The BEI® is a guideline for the control of potential health hazards to the worker and should not be used for other purposes. The values are inappropriate to use for the general population or for nonoccupational exposures. The BEI® values are neither rigid lines between safe and dangerous concentrations nor are they an index of toxicity.