THE USE OF HUMAN BIOLOGICAL MONITORING IN ENVIRONMENTAL HEALTH PROTECTION

UPOTREBA BIOLOŠKOG MONITORINGA KOD LJUDI U CILJU ZAŠTITE ŽIVOTNE SREDINE

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Various natural phenomena, such as earthquakes, volcanic activity, or floods, but also changes due to human activity, can influence the health of human beings. The inability of humankind to, using basic principles of ecology, reduce their negative influence on the living environment can be considered one of the biggest failures of the 21st century. Having in mind that the human factor is one of the biggest causes of changes in biological systems, managing this influence requires thorough assessment and control, which is most easily done using biological monitoring. The aim of this paper is to present the basic principles of biological monitoring, as well as demonstrate the most useful methods and examples of their use in health impact assessment.

Key words: environmental protection; biological monitoring; toxicology

Različiti prirodni fenomeni, kao što su zemljotresi, vulkanska aktivnost, ili poplave, ali i promene koje su posledica aktivnosti čoveka, mogu imati uticaj na zdravlje ljudi. Nesposobnost čoveka da, upotrebom ekoloških principa, smanji svoj negativan uticaj na životnu sredinu može se smatrati jednim od najvećih neuspeha 21. veka. Imajući u vidu da je ljudski uticaj jedan od najvećih pokretača promena u biološkim sistemima, upravljanje ovim uticajem zahteva procenu i strogu kontrolu, što je najlakše postići biološkim monitoringom. Cilj ovog rada jeste predstaviti osnovne principe biološkog monitoringa, i prikaze najčešće korišćene metode i primere njegove upotrebe kod procene uticaja na zdravlje čoveka.

Ključne reči: zaštita životne sredine; biološki monitoring; toksikologija

1 Introduction

There is a large number of natural events, such as tornados, storms, or floods, as well as events precipitated by human activities, able to negatively influence the health and well-being of people living in the society. The impact of natural events is impossible to prevent, but there is room for minimizing this effect. Unfortunately, human kind has failed, especially in the 20th and 21st century, to use the ecological principles in order to minimize the negative impacts of human activities on the environment and health of the human population [1].

A "disaster" is usually defined as an unforeseen event that causes great damage, destruction, and human suffering what overwhelms local capacity, often requiring external assistance. This definition includes civil unrest, warfare, economic crisis, hazardous material or transportation incident (most often chemical spills), explosion, nuclear incident, building collapse, hurricane, drought, epidemic or a pandemic, earthquake, fire, flood, or volcano eruption.

Following the United Nations' International Strategies for Disaster Reduction classification, all disasters can be broadly classified into three categories: natural disasters, technological disasters, and manmade disasters. Natural disasters are usually divided into hydrometeorological disasters (floods, storms, and droughts), geophysical disasters (earthquakes, tsunamis, and volcanos), and biological disasters (epidemics and insect infestations). Technological disasters are composed of industrial accidents (chemical spills, collapses of industrial infrastructures, fires, and radiation) and transport accidents by various means of transportations. Finally, a separate group is composed of manmade disasters, divided into two groups: economic crises (economic collapse, hyperinflation, currency crisis or financial crisis) and violence (terrorism, civil unrest, riots, and war) [2].

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*Figure 1. Damage caused by the “Kobe” earthquake in Minatogawa
(Photo by 松岡明芳)*

Natural disasters are those able to generate most serious consequences, and we can surely remember some of the most recent disasters hitting both developed and developing countries. Among them, people tend to remember those causing the largest number of lives lost, such as the Pakistan earthquake, Great Hanshin-Awaji (Kobe), the Indian Ocean tsunami, and of course Hurricane Katrina. Beside natural disasters, modern society has recently been exposed to manmade disasters, from economic crises, terrorism, and wars, to industrial incidents, which could have enormous influence on the environment as well as human health. It is “old news” to underline the apparent increase in the natural disasters, mostly due to the increased number of hydro meteorological disasters. In the last 20 years, floods have been identified as the most commonly occurring natural disaster in the world, followed by droughts, epidemics, earthquakes, and tsunamis.

*Figure 2. The “sarcophagus containment structure” around the Chernobyl power plant
(Photo by Carl Montgomery)*

Two of the largest economic disasters in history are the Great-Hanshin (Kobe) earthquake and the Hurricane Katrina. The Kobe earthquake happened on January 17, 1995, in the Hyogo prefecture in Japan. It reached 6.9 points on the moment magnitude scale, and the tremors lasted for more than 15 seconds. **Figure 1** shows the damage in the Minatogawa, Kobe. More than 6,000 people lost their lives in this earthquake.

400,000 buildings were irreparably damaged, 300 fires were started, water and electricity were disrupted [3]. Hurricane Katrina was a Category 5 major hurricane, which was extremely destructive and deadly. In August 2005, it caused catastrophic damage along the Gulf coast. It was estimated that more than 1200 people died in this hurricane, and the total property damage was estimated at more than \$120 billion [4].

Nevertheless, not all disasters need to be as deadly in the moment of their occurrence. Industrial disasters, such as the Bhopal and Chernobyl represent only famous examples of human and environmental risk from technological development. **Figure 2** shows the Chernobyl power plant with its sarcophagus containment structure (taken in 2006). The contamination of food, water, and air has had adverse effects on human health and lives, and the “slow” disasters, such as air pollution, chemical spills, radiation, and heavy metals, asbestos are able to compromise human intellectual, behavioral and physical development. Some authors state there are hazards present in almost every industrial activity, and it is considered impossible to remove completely [5]. Still, the risks can be reduced by understanding the technological processes, as well as methods to identify the potential vulnerabilities in the environment and human health.

Biological monitoring represents one of the widely used methods for exposure and risk assessment. It could represent the most useful tool for identifying exposures and risk when a disaster occurs, as well as to prevent “slow” disasters by identifying even minor changes in the biological system [1]. The aim of this paper is to present the basic concepts of biological monitoring for environmental health protection, as well as to describe several cases when biological monitoring has been used in this context.

2 Biological monitoring

Considering that activities of the humans represent a dominant force in the changes of the biological community, it is necessary to understand much better the pattern and process in biological systems, and possibly develop procedures which could facilitate assessment, evaluation and protection of biological resources. There are three main tools used to assess the levels of exposure in various human studies. The first tool are questionnaires, which tries to describe the exposure using information such as the proximity to the exposure source, job title, description of food eaten. Environmental monitoring is the second option, and it includes personal monitoring, which depends on the measurements of the concentrations of various toxic substances in the air (the breathing zone of the exposed person), water, or on the skin. The third option is biological monitoring. Each option has its advantages and disadvantages. Questionnaires are a useful tool to quickly, and with almost no financial cost, evaluate a person’s potential exposure levels. They have been used in various studies around the world, especially in occupational exposure assessment, as well as in environmental exposure to quantify the exposure through the diet or distance from the exposure source.

Table 1. The advantages of human biological monitoring

Advantage	Explanation
Proof of exposure	The ability to detect a (verified) biomarker in a biological specimen confirms that exposure has actually occurred.
Dose estimate	The levels measured are proportional to the internal dose of the chemical, thus integrating exposures from all sources and pathways.
Surveillance	Measuring levels of biomarkers in the general population can help identify vulnerable populations and sub-populations and alert that a higher-than-usual exposure is occurring for some reason.
Pre- and post-exposure	Biomonitoring before and after a specific event can show the difference between a baseline and “after-exposure” concentrations, or even follow the time trend.
Effectiveness of measures	Through monitoring biomarker levels before and after a specific risk management measure it is possible to evaluate the effects of the said measure.
Prioritize research/interventions	These methods can help define research needs, but also the most important points in which to develop interventions

Human biological monitoring or biomonitoring represents the measurement of the concentration of various biomarkers (original chemicals, their metabolites, and/or products of the interaction between the chemicals and the body) in different biological specimens. Biological monitoring requires the collection of biological material, such as blood, urine, saliva, breast milk, meconium, toenails, and hair. In many exposure scenarios, the exposure occurs through different routes of exposure, such as inhalation, dermal exposure, ingestion, or even pre-natal exposure in children. The most valuable fact about human biological monitoring is exactly that – it reflects exposures and disposition, considering absorption, distribution, metabolism, and

elimination (ADME) from all exposure routes, and is indicative of exposure really occurring [6]. If a biomarker is an indicator of exposure, it is called exposure biomarker. Such biomarkers are heavy metal levels in blood, for example blood lead levels. If a biomarker represents a biochemical effect, it is called biochemical effect biomarker, and if it represents a biological effect – a biological effect biomarker.

There are many positive sides of performing human biological monitoring, and **Table 1** presents the main advantages of this approach. Knowing that a measured amount proves an exposure had occurred, ability to estimate the dose and connect it to the potential effect, opportunity to identify vulnerable groups and their exposure levels, as well as to estimate the impact of an event, or even risk management measured strongly promote this approach [7].

On the other hand, as any method, there are some common problem with biological monitoring. **Table 2** underlines some of the most common problems and their influence on the decision to perform human bio-monitoring. When using human biological monitoring it is necessary to know well the exposure scenario, the laboratory procedure, as well as the ADME of an active substance in order to be able to interpret correctly the results.

Table 2. Issues to consider in human biological monitoring

Disadvantage	Explanation
Non detection	The detection of a biological biomarker in a human biological specimen depends on many factors, and the non-detection does not necessarily mean the exposure had no occurred. It is therefore necessary to know the biomarker characteristics, and follow a strict procedure in order to claim that non-detection is actually due to no or low exposure.
Health effects	Even when a biomarker of exposure is detected, it does not necessarily mean that health effects would occur, or that the detected levels should be considered dangerous to human health.
Ignorant of the exposure pathway	Having in mind that human biological monitoring provides an integrated estimate of exposure, it is necessary to keep in mind that all pathways of exposure are included, and it is in the majority of cases impossible to identify the most important pathway of exposure. This makes the definition of necessary health interventions extremely difficult. Nevertheless, knowing the exposure sources, the environmental and/or occupational exposure scenario, as well as the ADME help resolve this issue.

3 The use of biological monitoring in exposure assessment

The exposure to chemicals and the toxicological, even medical, evaluation of the potential impact of said exposure on human health is not only an issue in regular exposure, such as that at work. So-called “un-scheduled” exposures, such as peak exposures during some more specific work not occurring every day, or in chemical incidents, can be extremely important to evaluate. In addition, low-level chronic exposure, higher than normally evident in the environment, can cause serious effects in the end, but could be detected much earlier. Human biomonitoring has been used in emergency responders, such as paramedics, remediation workers, firefighters, but also in residents living close to the site of a chemical incident.

3.1 Case-study: Lead exposure of children

Lead contamination can be considered of special interest as a slow technological disaster. In occupational settings, the exposure to lead is usually easily detectable, requiring clear preventive actions to safeguard the health of the exposed workers. On the other hand, environmental lead can usually be attributed to several sources, of which petrol and paint have been of interest in the past, but canned foods, toys, traditional medicine, and industrial sources of lead remain of interest nowadays [8]. Children are especially susceptible to health effects due to lead exposure as their gastrointestinal tract absorbs lead better, and one of the main targets for lead toxicity, the neurological system, is still in development. In Serbia, the most famous lead exposure site was the lead battery recycling plant in Zajača, where many of the children living in this village had blood lead levels much above the Centre’s for Disease Control recommendations of 5 micrograms per deciliter of blood [9].

The above mentioned study and the results of biological monitoring in lead-exposed children have underline the use of biological monitoring in detecting and preventing potential (slow) chemical disasters. In the said case, the results have brought on an impressive pressure of the public to monitor the working and living conditions in the two villages near the lead battery smelter, finally leading to the closure of the factory. Unfortunately, it is unknown how many similar lead smelting plants exist in Serbia conducting work under similar conditions and posing a health hazard to the workers and general population. Biological monitoring,

as a screening method, could help identify these areas, as well as similar areas where chemical exposure could present a health hazard.

3.2 Case-study: Obrenovac floods

In the second half of May 2014, a low-pressure system named “Yvette” caused heavy rains to fall on Serbia. More than 200 mm of rain fell on Western Serbia in a week, which was equivalent to 3 months of rain under normal conditions, causing a rapid and substantial increase in water levels of main rivers in this area, among which Sava River. Sava river basin received the most of the rainfall, which resulted in flash floods in the tributaries where water levels rose almost immediately after the onset of the rain. The widespread flooding affected the rural areas around Šabac, but also the urban areas, particularly in Obrenovac. It was estimated that the floods had affected around 1.6 million of people living in 38 municipalities/cities mostly located in central and western Serbia, among which the municipality of Obrenovac was most severely impacted.

Figure 3. The flooded primary healthcare Centre in Obrenovac

The effects of the 2014 floods in Obrenovac on the environment and the health of the population living in this city is extremely difficult to estimate. Although, in total, the floods have affected more than 1.5 million people in various parts of Serbia, and caused millions of euros in damage and money needed for reconstruction, the effect on the water, land and air in the air remains yet to be investigated. Knowing that the water had engulfed the industrial zone of Obrenovac, old and new buildings, as well as the landfill could indicate that contamination is highly likely. Although, to our knowledge, no biomonitoring campaign has been conducted to date, such a campaign, monitoring for example the exposure to heavy metals, could help set the priorities for more detailed studies and preventive actions in the affected areas.

4 Conclusions and future work

In order to perform adequate biological monitoring it is necessary to have a biomarker for which there is reliable human data on kinetics, or in extreme cases, animal data can be used to help interpretation. It is necessary to collect the biological material early on after the incident, or according to the expected exposure timeline in exposures other than incidents. It is extremely important to keep in mind when the exposures have occurred if the data is available. The biomarker should be persistent enough to allow for the timely collection of the biological sample and the analysis of the biomarker. An often forgotten issue is the ethical approval and the real need to collect biological samples, and finally the price of the whole procedure, from sample collection to analysis and interpretation must be acceptable.

Having in mind the underlined issues, biological monitoring remains an important and useful method for environmental health protection, especially when potential chemical exposure is at hand.

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