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Editorial

Identifying a role for human biomonitoring in incidents involving hazardous materials

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ABSTRACT

Human biological monitoring (HBM) is an established method for chemical exposure characterization. Over the past few years HBM complemented environmental modelling and measurement strategies in several large scale chemical incidents in Belgium and Germany. These applications showed biomarkers to persist in body fluids, allowing sample collection to start in the aftermath of the incident. In addition, integration of exposure over time and from different routes and sources of exposure were reflected in HBM results. Especially adducts to hemoglobin were used to study exposures of workers and of the general population in retrospect. HBM results confirmed the exposure, sometimes pointing to a-typical sources and routes of exposure, not foreseen in incident scenarios. As a next step in Belgium, Germany and The Netherlands guidelines were prepared to support a role for HBM in the response to chemical incidents. Current practices indicate that the interpretation of HBM outcome can still be improved, using refined sample collection strategies and reverse dose calculations to facilitate the use of available exposure standards in the interpretation of HBM results. Exchange of knowledge and experience as well as sharing technical resources will further strengthen the role of HBM in the response to public health incidents and disasters.

A chemical incident causing the emission of hazardous materials into the environment can lead to significant adverse health effects among first responders, emergency services, accidental bystanders, and the general public. As chemical incidents mostly have an unforeseen and thus urgent nature, preparedness and planning are essential. Throughout Europe, medical and other emergency services have been developed to quickly and effectively respond to incidents, yet public health issues have only received marginal attention.

When confronted with a chemical incident the primary task of emergency responders is to establish a safety perimeter, control the source of emissions, evacuate and treat immediate victims, and prevent propagation of the incident. Nevertheless, a toxic cloud may disperse across a wide area, causing potential adverse health effects among the general public as well as persistent contamination of the environment. Similarly, surface runoff may pollute surface or groundwater reservoirs, cause soil pollution, or may accumulate through the food chain, causing secondary exposures for humans or livestock.

Recognizing and addressing exposure of the general public to the emissions from chemical incidents has until now been grossly under-represented in emergency preparation. In 2002, a report from the World Health Organization (WHO) on "Environmental health in emergencies and disasters" highlighted that "*...public health plans to deal with chemical incidents are usually non-existent or poorly developed...*" Wisner and Adams et al., 2002. Also in its more recent "Manual for the Public Health Management of Chemical Incidents" (2009), the WHO again highlighted the need for a multidisciplinary, multi-sectorial and trans-boundary approach to the public health management of chemical incidents.

Determining the level of exposure during, and soon after chemical incidents is crucial for the assessment of public health risks and appropriate medical treatment, as well as for subsequent follow-up studies (WHO, 1997, 2009) and may contribute to effective disaster management. Yet, immediately after a chemical accident, exposure assessment is often restricted to a limited number of environmental measurements which are most often not sufficient to allow for a reliable exposure assessment of the population. The priority for environmental measurements is low (relative to other priorities such as evacuation and medical triage). The alternative to

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measurements is near-real time modelling of exposures during a chemical incident. This requires much input data and the outcome of this effort often results in low-resolution plots with large levels of uncertainty. Although these can be useful for interventions such as decision-making related to public health interventions, shelter or evacuation, they are not very valuable for estimating the impact on the health of the general public. Furthermore, the primary exposure is often of short duration. So there is only a small time window to collect field data: as the plume is passing by, some toxic products can disappear quickly in the environment. Even if measurements are carried out, the information on the identity of involved chemical substances in an early phase of an accident will be limited in terms of quality, quantity, and reliability.

HBM is an established approach to assess exposure to chemicals in an occupational setting or within general population studies, but is not routinely used in an incident or disaster setting. It is based on the measurement of chemical substances or products of biotransformation (e.g. metabolites or adducts to macromolecules) in body fluids (e.g. blood or urine) or other human matrices such as exhaled air. In the field of incidents, applications of HBM may offer advantages over presently used methods such as ambient air measurements and modelling. This will be further motivated below.

Since most biomarkers have a lifespan of several days or longer, HBM allows the collection of samples well after the acute phase of the incident is over, when air concentrations have fallen below the limit of detection (Tates et al., 1995; Bader and Wrbitzky, 2006). HBM integrates exposure from multiple uptake routes and sources over time and is therefore most suitable to quantify direct contact of humans with potentially hazardous chemical substances in the chaotic setting of a chemical incident with potentially complex exposure scenarios. It allows the targeted exposure assessment in identified susceptible subpopulations such as children, elderly, or individuals with previous illnesses. HBM will thus strengthen emergency medical care and support health risk assessment (Wolff et al., 2005; Scheepers, 2015 in press). It will also bring valuable information to improve health impact assessments and support epidemiological follow-up studies (Ackermann-Liebrich et al., 1992; Edelman et al., 2003; Roorda et al., 2004; Carrasco et al., 2007). The merits of HBM on an individual and group level will be further explained below.

HBM is a suitable tool to support follow-up and health risk management at an individual level by:

- confirming internal exposure to one or more chemical substances;
- relating an exposure to observed clinical symptoms;
- supporting optimal medical care (including decisions to be made for treatment);
- providing information to the patient about the relationship between the chemical incident, individual exposure and potential health effects (risk communication);
- helping to establish the cause of death in a post-mortem analysis.

HBM can also have a role in follow-up health surveillance studies at a group level by:

- providing quantitative individual exposure data that can be used for exposure classification in
- epidemiological studies related to the health impact of the incident;
- monitoring the need for medical attention and support (necessities of screenings, decontamination plans, et cetera);
- informing the general public with respect to concerns for health effects and the relationship of these health effects with the incident.

The individual and societal benefit of having well-prepared and fit-for-purpose plans and tools to recognize and address adverse public health effects from technological disasters is self-explanatory. Recently, guidelines have been prepared independently in several countries to facilitate the use of HBM in the management of chemical incidents, the identification and quantification of exposure, and the protection of the public and occupational health by targeted risk management. These national guidelines typically are adaptations of previously established protocols for either occupational or population-based surveillance studies that have been revised and adapted to meet the specific needs of emergency situations.

In this Special Issue of Toxicology Letters, the role of HBM in the response to a chemical incident is addressed in three papers describing current practices in Belgium, Germany and The Netherlands (Smolders et al., 2014; Müller et al., 2014; Scheepers et al., 2014a,b):

- In Flanders, the Dutch-speaking part of Belgium, a long history of HBM exists for population monitoring purposes, particularly driven by the Flemish Environmental Health Survey (Croes et al., 2014; Den Hond et al., 2013). As such, the inclusion of HBM in disaster management planning was obvious and built upon this previous experience. At the same time, the long-standing Flemish experience in environmental health research offered the opportunity to include other potentially valuable instruments besides HBM. Complementary approaches that focus more on effect assessment using in vitro toxicity testing, indirect exposures through the food chain, and parallel means of data collection (e.g. through ecosurveillance or public consultation), are integrated in the Flemish approach. As such, the Flemish guidelines have been developed into a decision support system (DSS) to aid public health officials in identifying the appropriate actions and instruments in case of incidents. While this DSS is set up to provide a flexible and structured decision tree, the value of expert opinion is deemed essential to account for the many uncertainties associated with the early phase of technological incidents (Smolders et al., 2014).
- The current Dutch approach is primarily based on previous experience in the aftermath of a fireworks explosion in a residential area in Enschede in 2000 (Roorda et al., 2004). Much attention is given to the question if HBM has added value and how to find out if it does. A practical issue is finding the proper motivation to involve biological sample collection in a certain incident setting. Two general motivations are given: (a) HBM outcome may impact on public health interventions (shelter, evacuation, hospitalization) including treatment of victims and (b) HBM may support risk communication even in cases were exposures are low and negligible. In the Dutch system a decision to start HBM in a small-scale incident is taken in the region by a public health hazmat advisor according to a national procedure. In complex or large-scale incidents an independent group of experts at a national level can provide a recommendation whether or not to engage in HBM within 24 h (Scheepers et al., 2011; Scheepers et al., 2014a,b).
- Germany has a long-standing tradition in HBM. Recently, HBM became part of an integrated civil protection program aimed at chemical, biological and radionuclear (CBRN) incidents. A compendium was published with a standard procedure for application of HBM during and following CBRN incidents, including fact sheets with basic toxicity information for 50 agents relevant to civil protection. Müller and co-workers compare the German approach to the Dutch system and find some interesting differences: in Germany HBM is embedded in an integrated response to CBRN incidents, whereas the Dutch approach is designed to respond to chemical incidents in particular. In Germany HBM can and will be used if demanded by health authorities and the