Chapter 4 – MONITORING OF AIR IN CONFINED AND OPEN SPACES

by

M.A.E. Mol, M.M. van Deursen, F.R. Groeneveld and H.C. Trap
TNO Defence, Security and Safety, Rijswijk, Netherlands

Recent military operations have highlighted the problem of possible chemical hazard exposure in troops. A risk assessment process is especially important for military forces deployed in chemically contaminated environments, and measurement of exposures will help in preventing or reducing incapacitation during deployment or development of disease after deployment [1 – 4]. Therefore, a need exists in operational military settings to rapidly detect a wide range of chemicals with potential adverse health effects for exposed personnel. Exposure to airborne contaminants that arise from occupational military activities and local environmental pollution is a major contributor to health problems. Inhalation of gases, vapors, aerosols, and mixtures of these can cause a wide range of adverse health effects, ranging from simple irritation to debilitating systemic diseases. In operational military settings, monitoring of levels of hazardous air pollutants at deployment sites occurs before and during deployment. Insight into the quality of the air at the deployment location is of particular importance, since whereas one may choose to import drinking water and food from the homeland one has to breathe the air that is locally present. It is unlikely that military missions of several months will be fulfilled while continuously wearing respiratory protection.

Pre-deployment screening of air will give a first impression of the quality of the ambient atmosphere for a variety of toxic industrial compounds at a future camp site. Data collected during this quick scan contribute to the choice for the best location for future settlement. An inventory of equipment fit for performing of quick scans was made recently by van Deursen et al. [5]. Performance of such scans is limited by transportation opportunities to the survey site, time available to be spent there, and the type of equipment which can be used. The gas detection instruments should be portable (10 – 15 kg) at least, but ideally hand-held (max. 2 kg). Various hand-held instrumentation to detect toxic air hazards are commercially available, based on different technologies such as electrochemical cells, detector tubes, photo ionization detectors or ion mobility spectrometry. Hand-held devices are easy to use and have a fast response; they detect most of the immediately irritating gases. Often only single gases can be detected at a time, but with some multiple-gas analyzers four or five components can be detected simultaneously. The detection limits of hand-held devices are in the low ppm-range. This type of device is suitable if one wants to screen roughly for known toxic compounds.

More detailed information on airborne contaminants can be obtained by using portable devices based on infra-red technology (e.g. Miran SapphIRe and HazMatID Portable Chemical Identifier), and on gas chromatography-mass spectrometry (GC-MS). Instruments based on the latter technology have the largest potential for identification of a broad range of chemicals at ppb or even lower levels. The HapSite is a good example of portable GC-MS equipment that can be used in field situations such as the pre-deployment quick scan.

During the quick scan, additional environmental air samples can be collected for off-site analysis in a (mobile) laboratory at a distance, yielding more sensitive analyses with sophisticated laboratory facilities. Sampling techniques and transport conditions are key factors that determine the outcome of off-site analyses. To cover most air contaminants three ways of sampling are recommended [6]. Adsorption on solid adsorbent cartridges, e.g. Tenax, is the best way to catch volatile organic compounds (VOC), whereas gases can be sampled best in Tedlar gas bags. For analysis of particulate matter, air should pass through filters to collect the particles.

Compounds collected in this way remain stabile when stored at refrigerated temperatures for not longer than 7 days.

At a laboratory, air samples can be analyzed by one-dimensional gas chromatography (GC) coupled to various detectors such as a flame ionization detector (FID), a flame photometric detector (FDP) or a nitrogen phosphor detector (NPD). Direct identification of the compounds may occur by GC-MS. Furthermore, a Fourier Transform Infra Red (FT-IR) gas-analyzer and NOx analyzer with chemiluminescence monitor may be supplementary to perform standard analyses for gases and vapors [7]. However, airborne mixtures often are complex, such as atmospheres produced by combustion – e.g. diesel exhaust and residual oil fly ash – and the analysis of VOC is a challenge. VOC are associated with adverse effects to human health; at low concentrations they can cause cancer, immunological and neurological damage, as well as reproductive and endocrine disorders. However, it is often difficult to determine these toxic compounds at trace concentrations due to lack of resolution and sensitivity in single-column GC analysis. The toxicants have to be separated from an excess of other compounds present at many orders of magnitude of higher concentrations. Therefore, the analytical procedures employed have to be highly selective and sensitive. Comprehensive two-dimensional gas chromatography (GC×GC) may offer a solution to that problem, because it offers enhanced resolution for complex mixtures containing trace level environmental toxicants. Several studies demonstrated that GC×GC is a promising technique for analysis of complex environmental toxicants [8].

During deployment, air quality sampling can be done on-site at the camp in a mobile lab with portable devices or with appropriate equipment as previously described. The acute toxicity of many organic vapors means that close to real-time air monitoring is desired to minimise risk to human health. In addition, samplers to measure the presence of coarse particulate matter (PM10) at the campsites and outside the camps during patrols are required. Dust exposure is a primary disease and non-battle injury threat in countries where natural ambient air levels for PM10 (265 to over 670 $\mu g/m^3$) exceed by far the safety standard of western countries (70 $\mu g/m^3$) [9 – 10].

Although suitable analytical methods are available to identify numerous individual contaminants in air, meaningful risk assessment of a complex mixture such as polluted inhaled air is a major challenge [11 – 12]. Individual risk assessment of the constituents of air pollution disregards possible combinatory effects. Risk assessment of a complex mixture of air pollutants on the basis of individual compounds is not yet possible since no adequate procedures are available to integrate toxicity data of complex mixtures.

As an alternative for the measurement of the toxicological effects of mixtures of gases, vapors, and particles that actually occur in environmental air, a biologically-based toxicity monitoring system might be used. Using a biological sentinel, toxicity caused by unsuspected materials as well as by the interactions of chemicals in complex mixtures can be detected. Several field portable monitoring systems are available, but they are exclusively designed to observe the quality of aqueous samples. They are whole-cell- or organism-based and monitor the biological effects of contaminants. Recently, the US Army Center for Environmental Health Research has developed an aquatic biomonitoring system based on bluegills for real time toxicity detection of toxic conditions caused by a wide range of chemicals or chemical mixtures. They are also involved in studies showing that the ECIS biosensor (Agave BioSystems) can be used to observe toxic conditions in aqueous samples. The ECIS biosensor is currently being adapted for use as a field portable system for real-time air toxicity monitoring [13] .In cooperation with the University of Montana, USACEHR is exploring the potential of using bees for real-time air monitoring. In this study, volatile and semivolatile chemicals in the air inside beehives are detected and the responses of honeybee colonies to harmful substances are observed in electronic beehives [14].

On a laboratory scale, other systems are under development to detect the toxic effects of chemical mixtures in air on a biological system. Two commercial exposure chamber devices, the Harvard/Navicyte horizontal diffusion chambers and the CULTEX system are used for monitoring the response of cultured cells to complex air exposures like polluted ambient air, cigarette smoke and diesel exhausts [15 – 18]. To achieve a continuous direct exposure to gases, cells are cultured at the air-liquid interface on microporous membranes. These bio-based systems can rapidly provide information on air toxicity caused by gases and vapors as well as by aerosols.

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