

In-vitro characterization of failure related emissions of small batteries

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Keywords: battery emissions, in-vitro aerosol exposure, effect monitoring, toxicology
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The mechanical and thermal load on lithium ion batteries can lead to battery failure and an uncontrolled release of thermal energy, vapors and aerosols. This can pose a health risk to consumers which can be assessed by detailed analysis of the chemical compositions and/or toxicological investigations of the emitted fumes.

Cells are punctured by the so-called nail penetration test. A metallic nail intrudes into the battery causing a short circuit initiating a cascade of exothermic chemical reactions. The cell mantle is destroyed and compounds of the cell material as well as reaction products are released.



Figure 1. Destroyed cell after nail test. Electrical charge at test condition: 2.2Ah

The emissions are captured inside a 160 l box from which samples are drawn for aerosol analysis as well as for in-vitro exposure of human lung cells (A549). Gas phase analysis was carried out by infrared spectroscopy and gas chromatography. Particle emissions were measured using the Respicon followed by analysis of chemical elements of the filter deposits by plasma mass spectroscopy. For cell treatment the P.R.I.T.[®] ExpoCube[®] system allowing for exposure of air-lifted interface cultures was used. The exposure was carried out in the technical lab.



Figure 2. Experimental set-up: Test chamber in the rear, exposure unit and flow control in the front.

Typical emissions resulting from the puncturing of a completely charge battery consist of 3.3 kJ sensible heat, 6 l reaction gases and 700 mg respirable particles. Hydrogen, water vapor, carbon dioxide and carbon monoxide are the dominating compounds of the gas phase. Further gases are the vaporized electrolyte and combustion by-products. The particle emissions are characterized by the elements cobalt, nickel, manganese and lithium accounting for about one third of the total mass.

Cell exposures were conducted over an exposure period of 60 minutes using continuously sampling from the aerosol box and concurring clean air and non-exposure controls. Cells were analysed in an “acute toxicity” setup with respect to changes in cellular viability and interleukin secretion (IL-8) 24 hours after exposure.

In a first set of exposure experiments, aerosol from failure related emissions of small batteries led to a clear loss of cellular viability in a dose-dependent manner using the native aerosol from the box. Within this clearly cell-toxic dose-range IL-8 secretions from exposed cultures also decreased with the applied doses from the aerosol. Smoke aerosol from cigarettes was used in an equivalent testing setup for a relative comparison of dose-related effects. As a result, the toxic potential of aerosol from failure related emissions of small batteries was classified as similar or even more toxic as the mainstream aerosol from burning cigarettes.

As a conclusion, it was possible to set up a comprehensive experimental setup to conduct nail penetration testing using small batteries and to characterize the generated aerosols with respect to physical, chemical and toxicology related parameters. First results demonstrated a relevance for inhalation related toxicology as given by the respirability of the particulate phase of the generated emissions and a relatively high in vitro toxicological potential in an acute toxicity setting.

Correlated results from cell exposures and physico-chemical properties will be used to elaborate a strategy to draw conclusions with respect to safety assessment approaches from this kind of experimental data.