

Science for Environment Policy

New hazard index tool to aid risk assessment of exposure to multiple chemicals

Evaluating the level of danger to human health from exposure to multiple chemicals in contaminated sites is a complex task. To address this difficulty, researchers have developed a new screening tool that can be incorporated into public health risk assessment, which may include polluted former industrial plants, waste dumps, or even land where pesticides have been used. This 'hazard index' approach indicates when risk to health is high, which organs are most affected, and where further evaluation should be conducted in the context of environmental or occupational exposure at such sites.

Contaminated sites typically contain a variety of chemicals that vary in toxicity. A number of approaches to assessing risk to human health in these cases have been proposed. For example, guidance from the US Environmental Protection Agency (EPA) on assessing risk from multiple chemical exposure recommends the use of 'hazard quotients' for each chemical in the mixture, which, when combined, give a single hazard index. However, the EPA acknowledges that limitations of this approach include that it is not specific to any particular organ and nor does it consider that more extreme effects can result from the interaction of substances. Meanwhile, the US Agency for Toxic Substances and Disease Registry¹ has developed mixture-specific 'interaction profiles' to indicate the health risk from certain mixtures — however, only 11 of these profiles have been finalised.

In this study, researchers propose a new standardised framework to allow assessment of organ- or bodily system-specific risk from exposure to mixtures of chemicals. Building on the US EPA's cumulative health risk assessment of multiple chemicals, the basic hazard index mixtures screening (BHIMS) methodology identifies target organ toxicity doses (TTDs), and provides a hazard index based on the target organ or system.

Based on anatomy texts, the researchers first identified a hierarchy of anatomical organs that can be affected by toxic chemicals, dividing these into 12 target systems (e.g. respiratory system) and target organs that sit within these systems (e.g. lungs). Some organs are part of more than one system — for example, the ovaries and testes are part of the reproductive and endocrine systems. Specific toxicity effects of a substance can then be linked to one or more of these target organs and systems, or to the whole organism, where effects are general (such as weight loss).

Drawing on existing literature on toxicity and EPA reference dose values (based on critical effects from chronic exposure), chemicals are subsequently categorised according to the target organs they affect. The hazard index for each target organ is then calculated by reference to exposure level and reference dose.

For a defined set of chemicals, the researchers explain that the hazard index for a target system is equal to the total sum of the individual chemical hazard quotients for each system; a hazard quotient is the reasonable maximum exposure level in milligrams per kilogram (mg/kg) of body mass, per day, divided by the oral reference dose (maximum safe intake defined by the US EPA) for a toxic chemical.

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1. See: <https://www.atsdr.cdc.gov/substances/index.asp>

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The study demonstrates the approach with a set of eight chemicals that may be present in contaminated soil, at hypothetical concentrations. The toxicity and reference dose value for each chemical is given, as well as its critical effects and targets. Amongst the chemicals are the pesticide Norflurozan, which affects the liver and thyroid (therefore alimentary and endocrine systems), and has a reference dose of 0.04 mg/kg per day. Other chemicals in the set, 1,1,2-trichloropropane, Dacthal and ethylbenzene, also affect the liver, resulting in a hazard index for the liver of 0.81 from this set. The hazard index for the urinary system, however, is 1.63, due to the effects of 1,1,2-trichloropropane, Dacthal and hexachloroethane.

This approach allows the simultaneous evaluation of large numbers of substances, which may typically be present in contaminated sites. It offers a screening tool for risk assessors, indicating the probability of (non-carcinogenic) negative health impacts. Although the method does not explicitly indicate the interaction effects of chemicals, if the hazard index for a target system or organ is high (greater than 1, the researchers recommend), then this can highlight the need to carry out further investigations to evaluate any known interaction effects between the chemicals. This can be especially important with regards to the endocrine system, note the researchers.

The researchers acknowledge that the hazard index is not necessarily a fully accurate indicator of risk, as it is based on toxicity values and reference doses that are subject to uncertainty. Nevertheless, it provides a low-input, straightforward risk-assessment tool, which can indicate whether further investigations are necessary.

