Molecular study shows unexpected effects of toxin

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Scientists from the University of Birmingham studying the effects of the widely-used pesticide fenitrothion, have discovered unexpected cell damage in a common freshwater fish, roach, exposed to the toxin.

With colleagues from the universities of Exeter and Sussex the researchers exposed male roach to the pesticide for 28 days then studied the metabolites in their cells. Metabolites include fats, sugars and thousands of other natural chemicals – substances that can indicate whether a cell is healthy.

The results did not show the expected neurological effects of fenitrothion on the roach, but revealed a host of other effects, including changes to the way steroids are metabolised. This suggests that fenitrothion is an endocrine disruptor – a so-called gender-bender which can affect an organism's sexual characteristics.

The work reveals the range of effects this kind of exposure can have on non-target organisms, and it could help scientists develop effective 'environmental biomarkers' or indicators that show when toxic substances have found their way into the wider environment.

This area of research – called metabolomics – has developed over the last decade as a new way of investigating the links between metabolic changes and an organism's health – for example, measuring cholesterol can provide an indication of heart disease in humans.

'It's a discovery technique,' says Professor Mark Viant from the School of Biosciences at the University of Birmingham, one of the lead authors of the report, published in Environmental Science & Technology. 'Instead of measuring just one molecular response to a toxin, in metabolomics you measure many hundreds of metabolites and get much more and richer information about what's actually going on inside a cell in response to external stress.'

Surprisingly fenitrothion appeared not to have the expected neurological effects on the roach – in fact the opposite seemed to be the case. Instead of an increase in the chemical acetylcholine, which responds to the toxin's neurological action, the researchers saw a significant decrease.

And they found a range of other molecular responses in the fish, in particular in energy metabolism as well as unexplained effects on the metabolism of the amino acid phenylalanine, which the body uses to create proteins.

The unexpected neurological changes could mean the fish adapted to the presence of the pesticide. If this is the case it could be good for the roach, as it means they've developed a way of dealing temporarily with the primary mechanism of the toxin.

But such adaptation could come at a cost, as it may use energy that would otherwise be invested in growth and reproduction.

'We don't know yet whether this is what happened,' says Viant. 'But we do know that the energy levels in the fish were affected.'

The Environment Agency classifies fenitrothion as a 'red list' pollutant, one of the most dangerous substances to the aquatic environment. Once used on crops it can be washed off the soil and find its way into surface water.

'But our purpose wasn't purely to discover the toxic effects of fenitrothion,' Professor Viant explains. 'The point was to evaluate this still relatively new technique as a tool for discovering novel biochemistry and environmental biomarkers.'

The report highlights the complexity of the roaches' response to the toxin. Viant emphasises that a more traditional investigation, purely to check for the expected neurological effects on acetylcholine in the roach, would have turned up counterintuitive results that revealed nothing about the wider effects of the toxin.

'We need to be careful not to make simple assumptions about how organisms will respond to environmental stress,' he concludes.

The advantage of this metabolomics approach is that these metabolic changes happen long before the organism's health is compromised, so potentially the technique could be used to detect harmful effects of toxins and other environmental stresses and do something about them before it's too late.

Andrew D Southam, Anke Lange, Adam Hines, Elizabeth M Hill, Yoshinao Katsu, Taisen Iguchi, Charles R Tyler and Mark R Viant. 'Metabolomics reveals target and off-target toxicities of a model organophosphate pesticide to roach (Rutilus rutilis: implications for biomonitoring. Environmental Science & Technology, 45, 3759-3767. Online publications: dx.doi.org/10.1012/es103814d