

## SAND, CALCIUM AND HIGH SOIL pH – A HIGH RISK COMBINATION FOR ENHANCED BIODEGRADATION

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Enhanced microbial biodegradation is a phenomenon that does not functionally affect methyl bromide, but it is a well-documented process that can occur to most non-halogenated soil-applied pesticides. There are many examples of severely reduced pesticidal efficacy resulting from enhanced biodegradation. Once induced, there are no cures and recovery times can be measured in years.

Potential alternatives or stop-gap replacements for methyl bromide, notably metham (metam) sodium and 1,3-dichloropropene (1,3-D), are susceptible to enhanced biodegradation. As enhanced biodegradation is a potential production issue likely to be foreign to traditional methyl bromide users, they and their advisers need to be aware of this phenomenon, and key factors that may expose production systems to the risk of its onset or exacerbate it.

There is a crucial need to ensure use efficacy and sustainability of such less forgiving alternatives to methyl bromide. Our recent research has identified some new aspects and key interacting factors that bear strongly on the development and scale of enhanced biodegradation of metham sodium specifically, but we suspect that the principles will apply broadly to pesticides susceptible to enhanced biodegradation.

Severe examples of enhanced biodegradation of metham sodium (sodium *N*-methyldithiocarbamate) occur in Australia, particularly at sites of intensive horticultural production characterised by sandy soils. Bacteria, notably very environmentally resilient and therefore highly persistent spore-forming *Bacillus* and *Actinomycetes*, were found to be the causative organisms. They achieved the enhanced biodegradation effect by metabolising the methyl isothiocyanate (MITC) toxin that is rapidly produced when metham sodium is applied to moist soil.

MITC persistence in affected soil was reduced to around seven hours, compared to around 15 days in soil from the same region that had never been exposed to metham sodium and in affected soil sterilised by autoclaving. There was a c. 95% reduction in the concentration x time product estimated from the area under each of the decay curves, and reduced efficacy of pest control was demonstrated.

In much of the literature on enhanced biodegradation of soil-applied pesticides, a positive correlation has been observed between the risk of the phenomenon's onset or its degree and soil pH. As preponderance of bacteria over fungi and greater bacterially mediated biological transformations in more alkaline soils is an ecological maxim in soil microbiology, the observed effects are not unexpected.

In addition to these observations, however, reference to bacteriological first principles reveals that calcium is an important nutrient for bacteria, particularly spore-forming types. It plays a crucial role in the development of a stronger and therefore more resistant spore coat, in turn favouring the development and persistence of such bacterial populations in the soil.

Elevated soil pH may often be naturally associated with greater calcium concentration from limestone, or artificially through the common agricultural practice of adding lime (calcium carbonate) to soils where their pH is below agronomically desirable levels. Addition of lime to soil is known to increase abundance of bacteria, notably actinomycetes, and overall microbial activity. As a consequence of this knowledge, there appeared to be the likelihood of a confounded or interactive effect of soil pH and calcium content in relation to the development of enhanced biodegradation.

We conducted studies on the effects of soil pH, calcium concentration and frequency of pesticide application on the induction of enhanced biodegradation of MITC in a sandy and a loam soil. It was only under the combination of high soil pH ( $> c. 6.5$  (in  $\text{CaCl}_2$ )) and elevated calcium concentration in sandy soil that severe levels of enhanced biodegradation were rapidly induced.

We conclude that the development of enhanced biodegradation of metham sodium is a complex interplay between soil pH, calcium concentration, soil type factors that mediate the types or activity of microorganisms with the capacity to metabolise such xenobiotics, and the number and frequency of pesticide applications. The same principles are very likely to apply to other soil-applied pesticides.

For producers using relatively fast-acting fumigant-like substitutes for methyl bromide, such as metham sodium or 1,3-D, the news is both good and bad. The development of enhanced biodegradation at levels that interfere with pest control in mineralogically more complex soils appears unlikely even where pH and calcium content is high. In contrast, sandy soils with similar pH and calcium content attributes are at very high risk.

Armed with this knowledge, producers considering the use of metham sodium, 1,3-D or other labile pesticides as a substitute for methyl bromide will be more aware of the risk of inducing enhanced biodegradation through repeated applications to the same area of soil in their production system. They will also be in a much better position to take action to decrease the risk through management of practices such as liming. These pesticides are useful products, but being less forgiving than methyl bromide they require stewardship for sustainable, effective use.