

4. PERSISTENCE, DEGRADATION AND METABOLITES

THE DISAPPEARANCE OF A SUBSTANCE IS NOT ALWAYS THE END OF ITS STORY

Imagine applying a fungicide to a tomato crop.

The product reaches the leaves and fruit, where it protects them against fungal diseases. Over the following days, however, it begins to undergo a series of transformations.

Sunlight, water, oxygen, temperature and microbial activity can gradually alter the chemical structure of the substance.

As time passes, the amount of the original fungicide decreases.

We might think the problem has been solved: the product breaks down and eventually disappears.

But environmental chemistry teaches us something very important: when a molecule degrades, it does not necessarily disappear. Often, it is transformed into other molecules.

And these new substances may have properties very different from those of the original compound.

Some are less persistent or less toxic. Others, however, may remain in the environment longer, move through it more easily, or have toxicological properties that require specific assessment.

To understand the behaviour of dithiocarbamates, therefore, we must follow not only the original substance but also the products of its transformation.

WHAT DOES PERSISTENCE MEAN?

In environmental chemistry, persistence is the ability of a substance to remain in the environment before being transformed or removed.

Not all molecules behave in the same way.

Some are rapidly broken down by soil microorganisms. Others persist for weeks, months or even years, depending on their structure and environmental conditions.

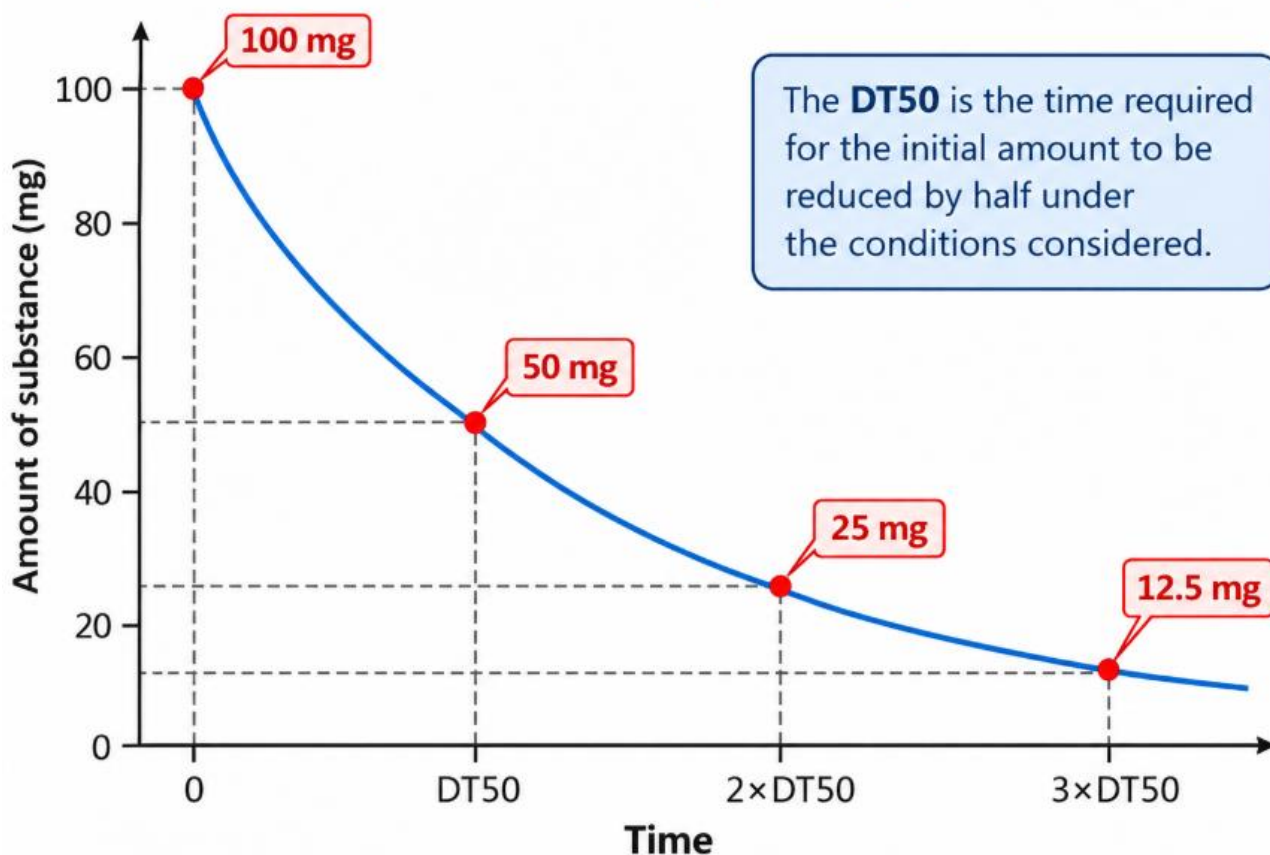
The rate of degradation is often described using a parameter called the half-life, denoted DT_{50} in environmental studies.

The concept is simple.

Suppose we start with 100 milligrams of a substance. If its half-life is five days, after five days, under the conditions considered, approximately 50 milligrams will remain.

After another five days, approximately 25 milligrams will remain, and so on, assuming degradation follows an exponential pattern.

Half-life (DT50)



The half-life, therefore, is not the point at which a substance disappears completely, but the time required for its quantity to fall by half.

It is important to add that this value is not an absolute, unchanging property: it can vary with temperature, moisture, pH, biological activity and soil characteristics.

In the case of dithiocarbamates, some active substances, such as mancozeb, can degrade relatively quickly under certain environmental conditions.

But this does not mean that all their transformation products will meet the same fate.

THE CASE OF MANCOZEB

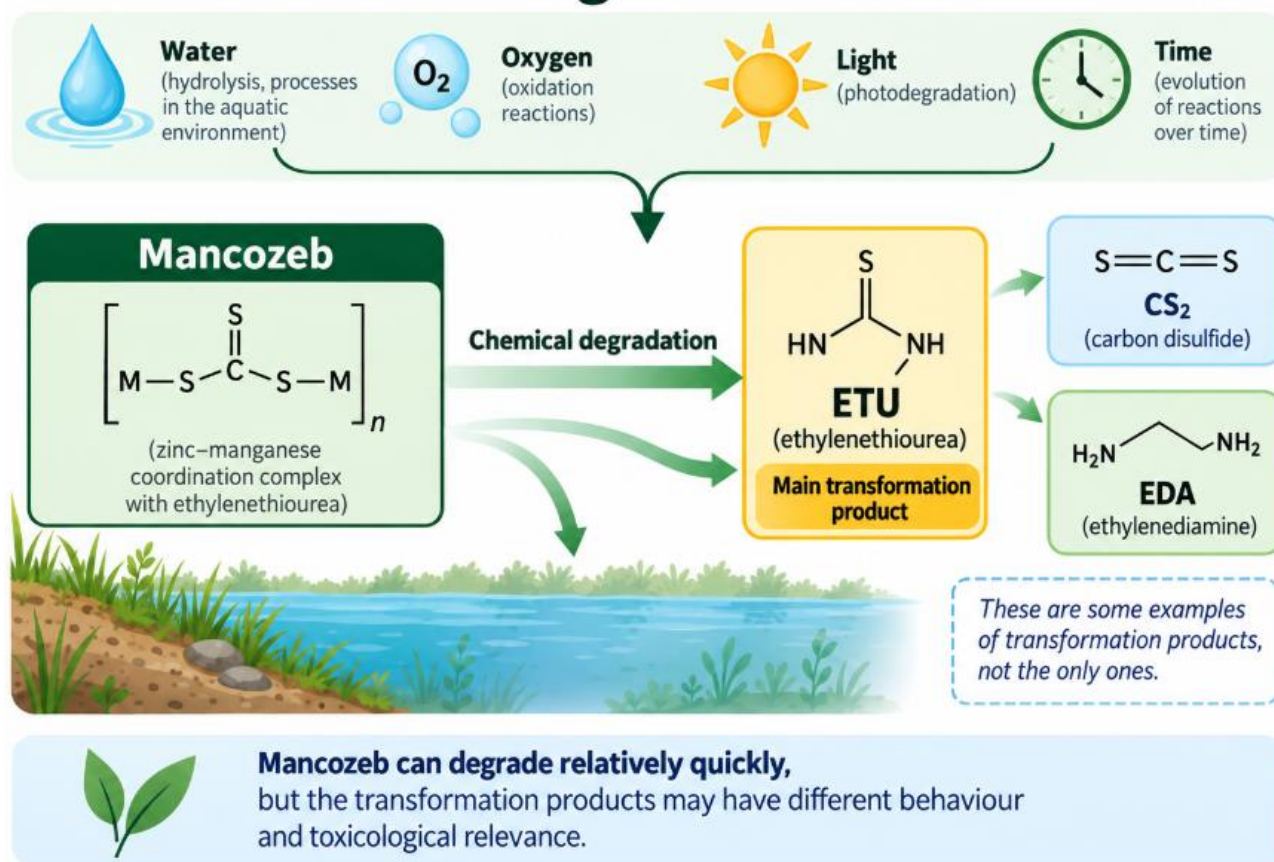
Mancozeb has been one of the most widely used fungicides in the dithiocarbamate family.

Its structure contains manganese and zinc, and it is relatively unstable in the presence of certain environmental factors.

When it comes into contact with water and oxygen, it can undergo chemical transformations that produce numerous degradation products.

Among these, one of the most important from a toxicological perspective is ethylenethiourea, commonly abbreviated to ETU.

The chemical degradation of mancozeb



According to data reported by FAO, mancozeb may have soil half-lives of just a few days, while the fate of ETU depends on environmental conditions and the processes governing its formation and degradation.

This brings us to a fundamental concept.

A substance with low persistence does not necessarily produce degradation products that are equally short-lived.

To assess the environmental consequences of an agricultural treatment correctly, therefore, it is not enough to measure how quickly the original fungicide disappears.

We must also know which substances it turns into.

ETU: A SMALL MOLECULE THAT DESERVES ATTENTION

Ethylenethiourea is a relatively simple molecule, but it is highly significant in toxicological assessments of certain dithiocarbamates.

It can form during the degradation of fungicides belonging to the ethylenebisdithiocarbamate group, including mancozeb, maneb and metiram.

It is important to clarify that not all dithiocarbamates produce the same degradation products.

The family includes chemically different substances, and it would be incorrect to attribute ETU formation indiscriminately to all of them.

Why does this molecule attract so much interest?

Because its chemical structure and biological effects differ from those of the substances from which it originates.

Toxicological studies have highlighted possible effects on the thyroid as one of the main concerns.

The thyroid is a small gland at the front of the neck, but it plays an essential role in the body: it produces hormones that regulate metabolism, contribute to growth and take part in numerous physiological processes.

Disruption of thyroid hormone production may therefore have consequences that depend on the intensity and duration of exposure.

The toxicological effects of ETU will be explored in greater detail in the next chapter, devoted to health.

For now, the key point is this: when assessing residues of certain dithiocarbamates, we must consider ETU as well as the fungicide from which it may derive.

WHAT HAPPENS IN THE SOIL?

When a plant protection product is applied to a crop, not all of the quantity applied necessarily remains on the vegetation.

Some may reach the soil, either directly during treatment or through runoff and wash-off caused by rainfall.

In the soil, dithiocarbamates may encounter conditions very different from those on the surface of a leaf.

Soil, after all, is not an inert material.

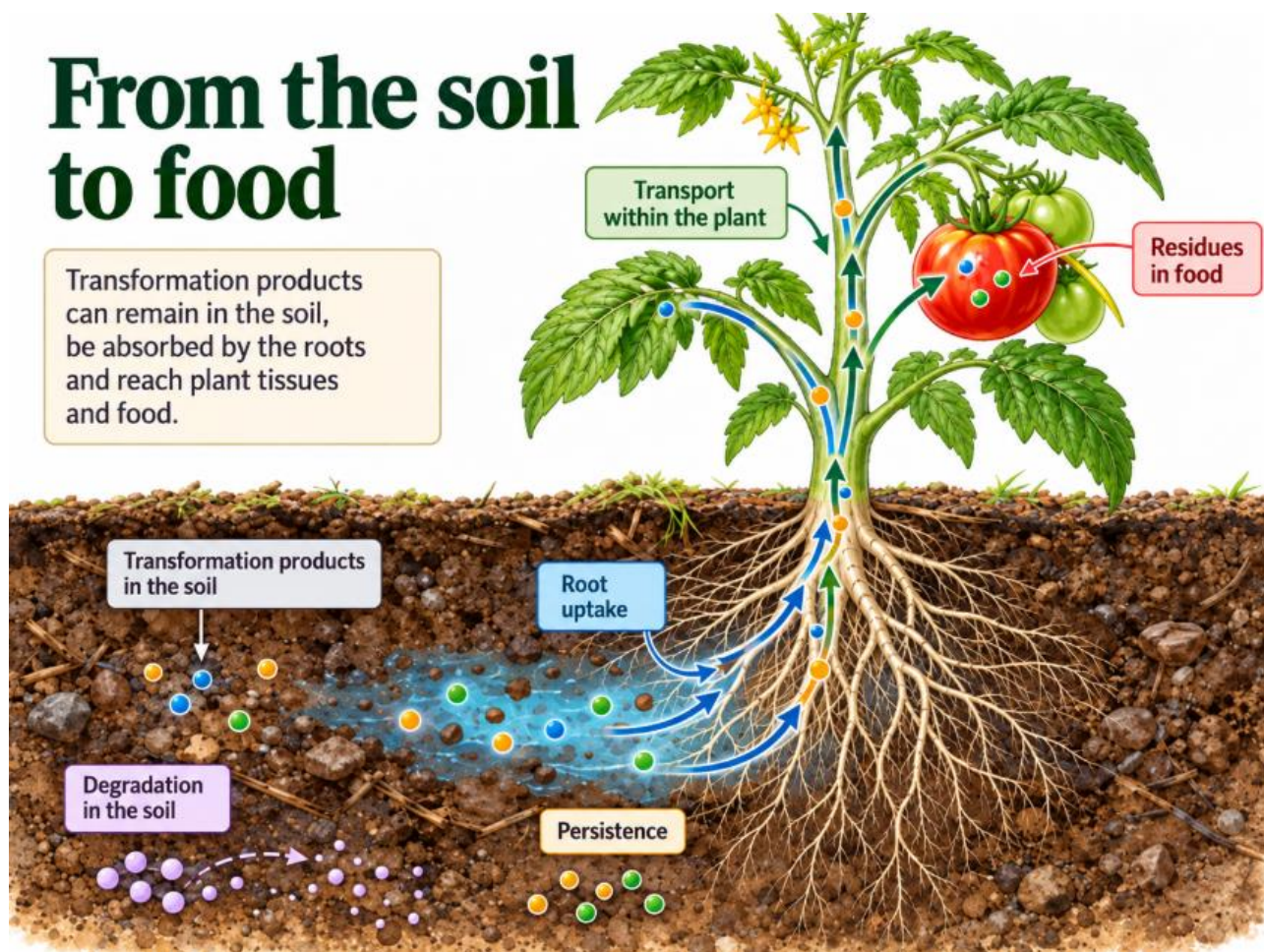
It is a complex system made up of mineral particles, organic matter, water, air and an enormous community of living organisms.

Bacteria, fungi and other microorganisms continuously participate in the transformation of organic substances and numerous compounds introduced into the environment.

Residues of plant protection products can also be involved in these processes.

Degradation can occur through chemical reactions, biological processes or a combination of the two.

From the soil to food



Some substances bind to soil particles, reducing their mobility. Others may dissolve in the water within soil pores and move more easily.

Degradation products may behave differently from the original molecule.

For example, ETU has solubility and mobility characteristics that differ from those of mancozeb.

This means that, to understand the environmental fate of a fungicide, we need to follow the entire sequence of transformations, not just the molecule originally applied.

FROM ENVIRONMENTAL DEGRADATION TO RESIDUES IN FOOD

So far, we have considered what happens in the environment, but the issue also concerns food.

A substance may degrade directly on the plant surface, within plant tissues or during subsequent storage and processing.

These processes can give rise to metabolites and other degradation products.

In general terms, a metabolite is a substance produced by a metabolic process. In pesticide studies, the term is also used to describe compounds formed as the original substance is transformed within living organisms.

Not all degradation products, however, are necessarily metabolites in the strict sense: some transformations can also occur through simple chemical reactions, without the involvement of living organisms.

This distinction is important for understanding the terminology used in scientific assessments.

For food, the main issue is establishing which substances may actually be present at the time of consumption.

For this reason, residue assessments do not always consider only the molecule applied in the field; they may also include certain transformation products.

The choice depends on the chemical and toxicological characteristics of the substances concerned.

HEAT CAN TRANSFORM RESIDUES

Consider a freshly picked tomato.

It can be eaten raw, but it can also be processed into tomato purée, concentrate or sauce.

During industrial processing, it may be exposed to high temperatures.

In many cases, heat promotes the degradation of certain molecules.

We might therefore expect food processing always to reduce the problem of residues.

But that is not necessarily the case.

Studies reviewed by EFSA have shown that, during laboratory-simulated heat treatments, metiram can degrade to form ETU.

In particular, significant transformations were observed under experimental conditions simulating processes such as pasteurisation, boiling and sterilisation.

In some experiments, the proportion of the original material converted into ETU increased substantially as the intensity of the heat treatment rose.

This finding does not mean that every cooked food containing metiram residues automatically develops dangerous concentrations of ETU.

The quantities actually present depend on numerous factors, including the initial residue, the characteristics of the food and the processing conditions.

It does, however, demonstrate a very important principle:

A reduction in a residue during cooking does not necessarily mean that all substances of toxicological concern have disappeared.

Some of the original compound may be transformed into other molecules, which must be considered separately.

This is precisely why studies of industrial food processing play an important role in food safety assessment.

HOW ARE THESE TRANSFORMATIONS STUDIED?

Tracking the fate of a chemical substance is not straightforward.

Researchers use several techniques to understand how a molecule is distributed, degraded and transformed.

One particularly interesting approach involves the use of substances labelled with radioactive isotopes.

In these studies, certain atoms in the molecule are replaced with isotopes that make it possible to trace their path during transformation.

It is rather like attaching a tiny tracking device to part of the molecule.

This makes it possible to identify which degradation products form and how the material derived from the original substance is distributed.

Of course, identifying transformation products is not enough.

Their quantities must also be determined and, where necessary, their toxicological properties studied.

EFSA assessments of dithiocarbamates have used precisely this type of information to distinguish the original substances from their metabolites and degradation products.

Nevertheless, not every step is always fully understood.

In some cases, unidentified products, insufficient information or uncertainty about the conditions under which particular transformations occur may remain.

Scientific assessment must therefore also take account of what we do not yet know.

THE TRUE MEANING OF DEGRADATION

We began with an apparently simple question: what happens to a fungicide after it has been applied to a crop?

We have discovered that the answer can be very complex.

Some of the product may be removed by rain. Some may bind to the soil. Certain molecules are transformed by microorganisms, while others react with water or oxygen.

During these processes, new substances may form, sometimes with characteristics very different from those of the original compound.

The case of mancozeb and ETU is a particularly instructive example.

A fungicide may degrade relatively quickly, but some of its transformation products may require specific assessment, both environmentally and toxicologically.

For this reason, when discussing the persistence of a substance, it is not enough to ask how long it takes to disappear.

We must also ask what it transforms into, where the degradation products end up and what effects they may have.

That is the difference between simply observing the disappearance of a molecule and understanding its fate.

In the next chapter, we will examine the consequences that certain dithiocarbamates and their transformation products may have for human health, distinguishing scientific evidence from the uncertainties that remain.

SCIENTIFIC REFERENCES FOR CHAPTER 4

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