

7. FOSETYL-ALUMINIUM AND PHOSPHONATES

TWO NAMES, ONE SHARED STORY

Imagine a vineyard at the beginning of summer.

The vines are developing their grape clusters, but the weather is warm and humid. These conditions can favour the spread of downy mildew, one of the diseases most feared by winegrowers.

To protect the vines, the farmer can use different plant protection products, each with its own characteristics and mode of action.

Among the substances used to protect crops are fosetyl-aluminium and phosphonates.

At first glance, they might seem to be simply more fungicides, similar to those discussed in previous chapters.

In fact, they have some distinctive characteristics.

One is their ability to be absorbed by plants and move within them. Another, even more interesting, concerns what remains after they have been transformed.

Fosetyl-aluminium and several phosphonate salts can, in fact, give rise to the same substance: phosphonic acid.

This simple characteristic creates a surprising problem: when phosphonic acid is found in food, we cannot always tell which product was used to produce it.

But let us take things in order.

WHAT IS FOSETYL-ALUMINIUM?

Fosetyl-aluminium, often abbreviated to fosetyl-Al, is an organophosphorus compound used as a fungicide.

Its name may sound complicated, but it essentially describes a compound formed by the association of aluminium with fosetyl, a substance derived from phosphonic acid.

Fosetyl-aluminium became established in agriculture primarily to combat diseases caused by oomycetes.

Oomycetes are organisms that, although they resemble fungi in certain respects, belong to a distinct biological group.

They include the organisms responsible for numerous downy mildews and several species of the genus *Phytophthora*, which can cause serious damage to crops.

Consider grapevine downy mildew, but also certain diseases affecting citrus fruits, vegetables and ornamental plants.

Fosetyl-aluminium has been an important tool because, unlike many contact fungicides, it can penetrate plant tissues and move within the plant.

This is a property worth exploring further.

A FUNGICIDE THAT TRAVELS WITHIN THE PLANT

In previous chapters, we saw that many dithiocarbamates act mainly on the surface of leaves and fruit.

Fosetyl-aluminium behaves differently.

It is a systemic fungicide.

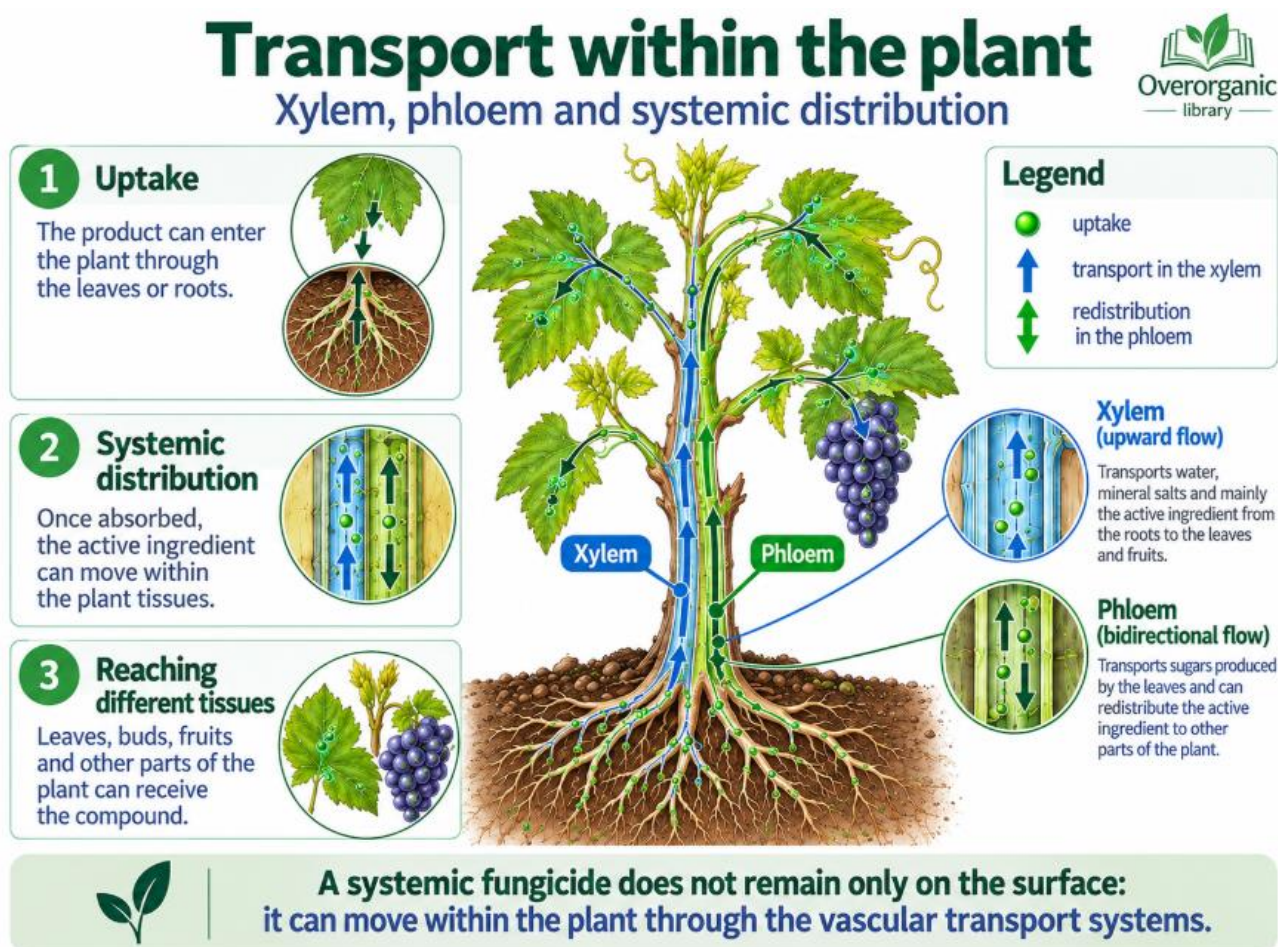
This means that, once absorbed, it can be transported through plant tissues.

To understand how this movement occurs, we must remember that plants have a genuine internal transport network.

The xylem mainly carries water and mineral salts from the roots towards the above-ground parts of the plant.

The phloem, on the other hand, distributes sugars and other substances produced or used in the plant's various organs.

We can imagine these tissues as two distribution networks linking roots, stems, leaves and fruit.



Fosetyl-aluminium and its transformation products can move within this system, reaching parts of the plant other than those directly treated.

This characteristic is useful from an agronomic perspective because it allows the active substance to provide protection that does not depend exclusively on surface deposits.

But it also has an important consequence for anyone studying residues in food.

A substance absorbed and transported within a plant cannot be regarded solely as a surface contaminant.

Simply washing a piece of fruit therefore does not guarantee the removal of residues that may be present within the plant tissues.

HOW DOES IT ACT AGAINST DISEASE?

The mode of action of fosetyl-aluminium differs from that of many conventional fungicides.

Part of its activity is associated with the effects of phosphonates on pathogens.

These compounds can interfere with various metabolic processes in oomycetes, limiting their development.

But there is another particularly interesting component.

Several studies have shown that fosetyl and phosphonates can stimulate plant defence responses.

Plants do not have an immune system identical to that of animals, but they are far from defenceless.

When plants recognise a potential pathogen, they can activate a series of biochemical reactions, produce protective substances and alter cellular activity to combat infection.

It is a kind of internal alarm system.

Phosphonates can contribute to the activation of some of these mechanisms.

The protection provided is therefore the result of a combination of actions that may include direct effects on the pathogen and stimulation of plant defences.

This explains why these substances differ from many fungicides that act solely by contact.

WHAT ARE PHOSPHONATES?

At this point, we need to introduce a chemical distinction.

Fosetyl-aluminium is a specific substance.

Phosphonates, by contrast, include various chemical compounds related to phosphonic acid.

Certain salts of this acid are particularly important in agriculture, including potassium phosphonates and disodium phosphonate.

Potassium phosphonates are used as active substances in plant protection products intended to protect various crops.

These compounds can also be absorbed by plants and transported within their tissues.

Despite some chemical differences, fosetyl-aluminium and phosphonates share one fundamental feature.

Once present within the plant, they can contribute to the formation or presence of phosphonic acid.

And it is this substance that represents the main residue of analytical interest.

IMPORTANT: PHOSPHONATES AND PHOSPHATES ARE NOT THE SAME THING

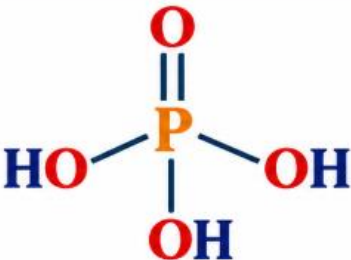
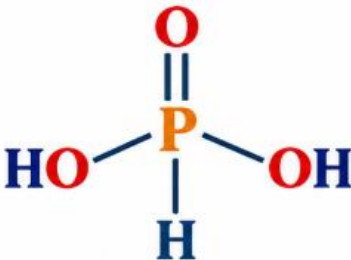
The two names are very similar, but they refer to chemically different substances.

Phosphates are compounds derived from phosphoric acid and are essential for life.

Phosphates and phosphonates compared

Phosphoric acid and phosphonic acid are not the same thing



Phosphoric acid (phosphate)	Key differences	Phosphonic acid
 H₃PO₄	1 Number of OH groups: 3 in phosphates, 2 in phosphonates.	 H₃PO₃ HP(O)(OH)₂
Phosphorus is in the oxidation state +5. Phosphates are the salts and esters of phosphoric acid.	2 Presence of the P-H bond in phosphonic acid.	Phosphorus is in the oxidation state +3. Phosphonates are the salts and esters of phosphonic acid.
	3 Different structure and chemical behaviour.	



In analytical practice and regulation, confusing phosphates and phosphonates can lead to incorrect interpretations.

The phosphorus in conventional fertilisers is commonly supplied to plants in phosphate forms.

Plants use phosphorus to produce essential molecules, including those involved in energy transfer and the formation of nucleic acids.

Phosphonates, by contrast, are compounds derived from phosphonic acid, in which phosphorus has a different chemical state.

In general, higher plants do not directly use phosphonates as a normal source of phosphorus nutrition in the same way that they use phosphates.

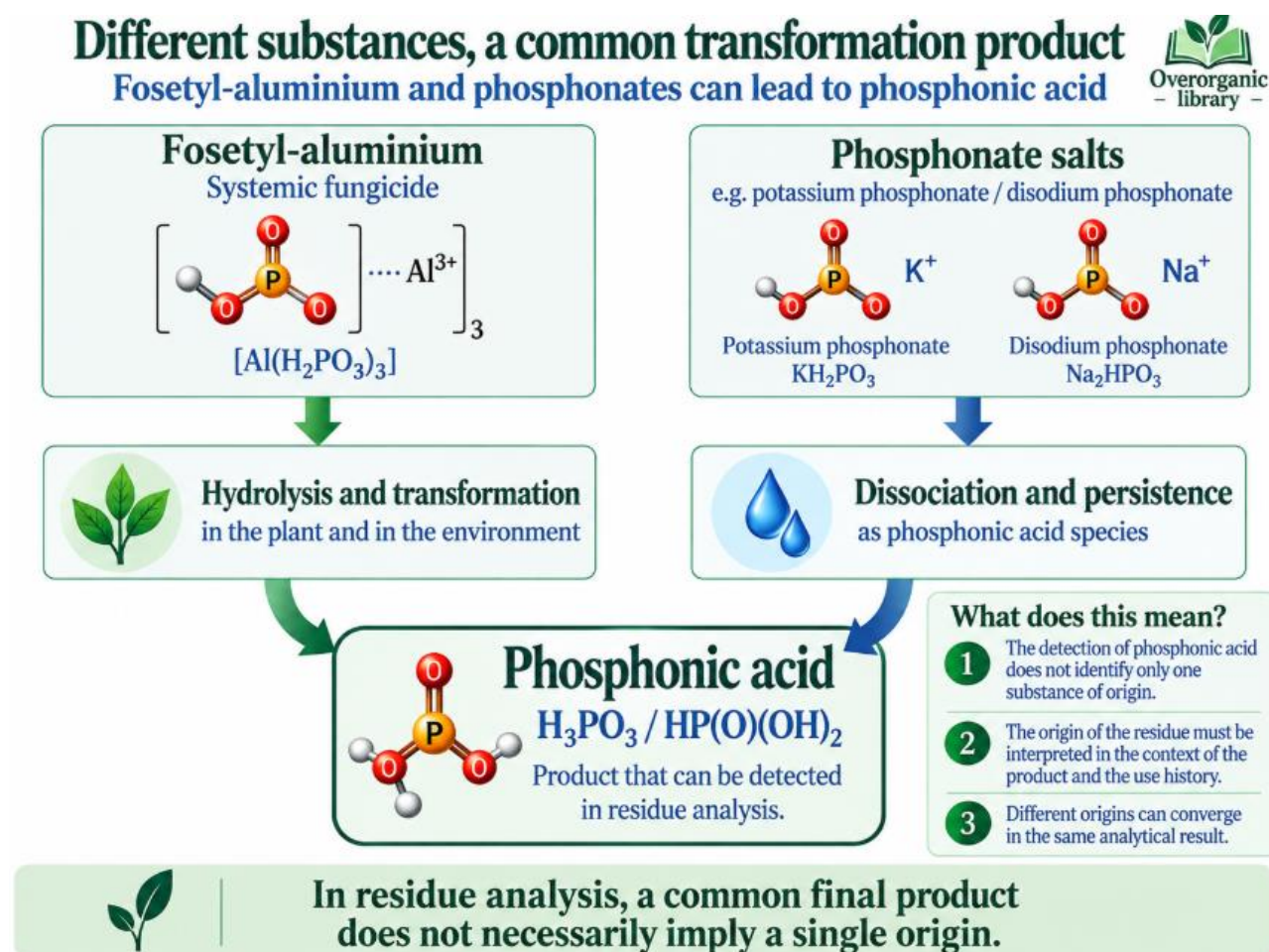
This difference is important because, in the past, some products containing phosphonates were also marketed for purposes related to plant nutrition or strengthening.

A product containing phosphorus is therefore not necessarily a phosphate fertiliser in the conventional sense.

The similarity of the names must not lead us to confuse the nutritional function of phosphates with the plant-protection activity that phosphonates can exert.

TRANSFORMATION INTO PHOSPHONIC ACID

Let us now see what happens when fosetyl-aluminium enters the plant.



The molecule can undergo chemical reactions that lead to the formation of phosphonic acid and ethanol.

The ethanol can subsequently be metabolised and incorporated into the plant's normal biochemical processes.

Phosphonic acid, on the other hand, can remain present in plant tissues.

The use of potassium and disodium phosphonates can also result in residues attributable to phosphonic acid and its salts.

This phenomenon has been extensively studied by EFSA.

In its scientific review published in 2021, the European Authority examined fosetyl, potassium phosphonates and disodium phosphonate together precisely because these substances share a particularly important residue.

The resulting situation is very different from the one encountered with dithiocarbamates.

In the case of CS₂, the analytical method converts different substances into a common indicator.

In the case of phosphonates, however, the common substance may actually be present in the food as a consequence of transformations within the plant or uptake from the soil.

It is therefore not the same analytical problem, although the final result may be similar: it becomes difficult to trace the origin of the residue with certainty.

WHEN A RESIDUE CAN HAVE DIFFERENT ORIGINS

Imagine analysing two apple samples from different farms.

In the first case, a product containing fosetyl-aluminium was used.

In the second case, a product based on potassium phosphonates was used.

Both samples could contain phosphonic acid residues.

Suppose the laboratory finds the same concentration in both samples.

Could we establish which product had been used simply by looking at the analytical result?

No.

Measuring phosphonic acid alone does not make it possible to distinguish between the two origins with certainty.

But the issue is even more interesting.

Phosphonic acid can also be associated with other products used in agriculture, which are not necessarily registered as fungicides.

EFSA itself has considered possible contributions from fertilisers, plant-strengthening products, soil improvers and other agricultural sources.

This does not mean that all these sources are always present or that their use is necessarily permitted in every circumstance.

It means that finding phosphonic acid is not, in itself, proof that fosetyl-aluminium was used.

Additional information is needed to reconstruct its origin, such as treatment history, soil characteristics and the possible presence of other substances.

A RESIDUE THAT CAN OUTLAST THE CROP

Another important characteristic concerns the persistence of phosphonic acid in soil.

As we saw in Chapter 4, not all chemical substances disappear at the same rate.

Fosetyl-aluminium can degrade rapidly, but the phosphonic acid produced from it may persist for much longer.

In studies reviewed by EFSA, the time required for 90% of phosphonic acid to dissipate in soil ranged from 91 days to more than 1,000 days, depending on experimental conditions.

This parameter is known as DT90.

Naturally, this does not mean that phosphonic acid remains in every soil for three years or that its concentration remains unchanged.

It means that, under certain conditions, it can persist for considerable periods.

And this gives rise to a particularly interesting phenomenon.

Imagine a field where one crop is grown and products capable of leaving phosphonic acid residues in the soil are used.

The following year, a different crop is grown.

Even without a new treatment with fosetyl or phosphonates, the second crop could absorb some of the phosphonic acid remaining in the soil.

This mechanism has been considered in studies on rotational crops.

A residue found in a food could therefore also be linked to treatments applied to a previous crop.

This is a scientifically documented possibility that makes reconstructing the origin of a substance even more complex.

A PARTICULAR CHALLENGE FOR TRACEABILITY

When a food is analysed, the laboratory can determine the concentration of phosphonic acid using sufficiently sensitive and selective methods.

The analytical result may be correct.

But knowing the concentration does not necessarily mean knowing the history of the product.

Phosphonic acid could originate from treatment with fosetyl-aluminium, the use of phosphonate salts or other agricultural sources.

In some circumstances, it could have been taken up from the soil following earlier treatments.

This is particularly important when attempting to reconstruct the origin of residues from farm records or when assessing products from different farming systems.

Knowing what was applied to a crop immediately before harvest is not always enough.

Sometimes it may also be necessary to know the agronomic history of the soil.

Chemistry thus shows us how complicated it can be to attribute a residue to a specific agricultural practice.

A CHANGE IN EUROPEAN LEGISLATION

The presence of a residue common to different substances has also had consequences for the European control system.

For many years, the regulatory residue definition included fosetyl, phosphonic acid and their respective salts, with the total concentration expressed as fosetyl.

EFSA's scientific review prompted this approach to be reconsidered.

With Regulation (EU) 2024/2619, the European Commission introduced a new residue definition for enforcement purposes, based on phosphonic acid and its salts, expressed as phosphonic acid.

The Regulation also provided specific provisions for residues of the parent substance fosetyl.

The change reflects the need to bring the residue definition more closely into line with knowledge of the substances' metabolism and their behaviour in food.

It is a significant example of how rules on contaminants can evolve over time following scientific assessments.

Legislation does not merely establish how much residue may be present: it must also define precisely which substance, or group of substances, is being measured.

WHAT HAVE WE LEARNT?

Fosetyl-aluminium and phosphonates have shown us an important aspect of residue chemistry.

Different substances can follow different pathways and give rise to the same compound.

In the case we have examined, that compound is phosphonic acid.

Its presence in food can be associated with plant protection treatments, other agricultural products or the uptake of residues remaining in the soil.

For this reason, an analytical determination can be very precise without allowing the origin of the substance to be established with certainty.

It is important to emphasise that this difficulty of attribution does not automatically make a residue harmless, nor does it prove that an unauthorised product was used.

These are different questions, to be assessed on the basis of the available information.

In the next chapter, we will follow phosphonic acid along its journey through food.

We will discover why it can still be found when fosetyl-aluminium is no longer present, what happens during food processing and what information an analytical certificate can really provide.

SCIENTIFIC REFERENCES FOR CHAPTER 7

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2. EFSA (2021). Modification of the existing maximum residue levels for fosetyl/phosphonic acid in citrus fruits resulting from the use of potassium phosphonates. EFSA Journal, 19(11), 6926. Study of potassium phosphonates, their use in plant protection and residues in citrus fruits. [Read the EFSA scientific publication](#)
3. EFSA (2022). Modification of the existing maximum residue levels for fosetyl/phosphonic acid in chards/beet leaves and honey resulting from the use of potassium phosphonates. EFSA Journal, 20(1), 6992. Assessment of residues and possible alternative sources of phosphonic acid. [Read the EFSA scientific publication](#)
4. European Commission (2024). Regulation (EU) 2024/2619 amending Annexes II and III to Regulation (EC) No 396/2005 as regards maximum residue levels for fosetyl, potassium phosphonates and disodium phosphonate in or on certain products. [Read the regulation on EUR-Lex \(Italian\)](#)