It rains pesticides from greenhouses

The end of a myth, greenhouses are releasing pesticides into the environment

Pesticide Action Network Europe

Contents

It rains pesticides from greenhouses

Contents

It rains pesticides from greenhouses

Executive summary

The EU makes exceptions for the use of very toxic pesticides in greenhouses. To do this EU Regulators presume these are closed places, with no release of pesticides into the environment. This report shows that greenhouses are not closed systems. They do leak toxic substances into the environment. We tested rain and surface water samples for greenhouse areas in Belgium, Germany, The Netherlands and Spain. The results are alarming: we found 62 different pesticide residues. We found a cocktail of up to 35 pesticide residues in a single sample. These residues often exceeded the proposed EU water standard many times over.

The EU Regulation (EC) 1107/2009 defines greenhouses as *"a walk-in, static, closed place of crop production (....,) which (...) prevents the release of plant protection products into the environment"*. The European institutions therefore allow active substances in greenhouses that do not meet the conditions established by the Pesticides Regulation. However, greenhouses are not closed spaces. This report re-examines this statement and illustrates that the opposite is true.

In the frame of the water residue testing, one sample in Belgium had a very high total of 90 µg/L of pesticides in surface water and another one 35 µg/L. The EU proposed standard is 0.5 µg/L. A sample in Spain showed tenfold this norm. High levels of pesticides were also detected in the rainwater samples collected from Belgium (21.3 µg/L), Germany (1.25 µg/L) and the Netherlands (1.2 µg/L).

In all surface water samples in the four countries, we found the PFAS active substance fluopyram. We also measured 2,6-dichlorobenzamid, a metabolite of dichlobenil, banned since 2008. We found the endocrine disruptor boscalid that is authorised for use mainly in greenhouses. Dimethomorph, known to damage fertility and an endocrine disruptor, the PFAS substance fluopicolide, and fluxapyroxad were detected in all countries. Metalaxyl-M, which is restricted for treated seeds to greenhouse use only at the European level and has been associated with thyroid cancer, was detected in the water in all countries except Germany. Boscalid and the two greenhouse PFAS pesticides fluopyram and flupicolide were also detected in rainwater samples across all countries.

A literature review further emphasises that greenhouses are not closed places. PAN Europe has not found, in the public domain, any information on any technology enabling greenhouses to prevent any release of pesticides or other chemicals into the environment.

Finally, a legal analysis demonstrates that special legal practices to use otherwise banned substances in greenhouses are against EU pesticide law.

We, therefore, ask the EU institutions to protect health and the environment and to:

- stop allowing the use of otherwise banned pesticides in greenhouses, permanent or not;
- develop and provide an adequate pesticide risk assessment on all types of greenhouses to assess their emissions into the environment.

1. Introduction

In April 2022, the EU approval of the insecticide active substance sulfoxaflor, toxic to bees, was updated with a restriction of use to permanent greenhouses, by the European Commission (EC) and EU Member States at the Standing Committee of Plants, Animals, Food and Feed (SCoPAFF). In May 2022, the EU approval of the insecticide active substance bifenazate, toxic to birds and mammals as well as bees, was also renewed for use in permanent greenhouses only. In March 2023, a similarly restricted approval was decided for the insecticide active substance abamectin, toxic to birds, bees, earthworms, and aquatic and soil organisms. Currently, discussions are ongoing in the SCoPAFF on the renewal proposal of active substance captan, which poses long-term high risks to birds, mammals, aquatic organisms, bees and other non-target arthropods other than bees; its approval is expiring this year and is proposed to be renewed with a similar restriction of use.

As we can see, following the EU regular (re)approval procedure for these active substances, the risk assessment concluded that, under normal conditions of use, these substances did not meet the (re)approval criteria established by Regulation (EC) 1107/ 2009. In other words, it was shown that their representative uses would have harmful effects on human and animal health and/or unacceptable effects on the environment.

Nevertheless, instead of deciding against the approval of these harmful active substances, EU regulators have renewed their approval by restricting their use in greenhouses, assuming that these are closed structures and will resolve all the identified risks. However, this is done without properly assessing whether such use in greenhouses is, indeed, safe for the environment. In this report, we show that the opposite is true.

What is a Greenhouse?

Greenhouses, from a technical point of view, are defined as *"structures, primarily of glass or sheets of clear plastic, in which temperature and humidity can be controlled for the cultivation or protection of plants"*[1].

Greenhouses can be categorised by different types of structures and technology used:

- Low-technology: usually less than 3 metres in total height, structures are tunnel houses, or "igloos", with poor ventilation.
- Medium-technology: vertical walls more than 2 metres tall but less than 4 and a total height usually less than 5.5 metres, often accompanied by a roof or side wall ventilation or both, and with varying degrees of automation.
- High-technology: a vertical wall height of at least 4 metres, with the roof peak being up to 8 metres above ground level, roof ventilation and side wall vents, with a high degree of automation.

[1] See Dictionnary definition <https://www.thefreedictionary.com/Greenhouse+technology>

Introduction

This categorisation, however, is arbitrary, approximative, and does not rely on any legal or technical base.

Yet, Regulation 1107/2009, Article 3(27) gives greenhouses a different and very specific definition: *"walk-in, static, closed places of crop production with a usually translucent outer shell, which allows the controlled exchange of material and energy with the surroundings and prevents the release of plant protection products into the environment"*.

Therefore, based on this definition pesticides that are very toxic to the environment and/or human health such as abamectin and sulfoxaflor, end up getting reapproved under the restriction of use in (permanent) greenhouses.

Greenhouses and pesticide use

Greenhouses in crop and floral production are used for multiple reasons, mostly because they create optimal climate conditions needed for plant growth. Depending on their structure, they may accommodate growing more plants per square foot than growing crops in an open field, thus allowing profit maximisation. While some would think that greenhouses would prevent pests from entering, this is not the case as the warm and humid conditions are favourable for fungi, insects and other organisms. This results in pesticides being used extensively inside greenhouse structures, in conventional farming.

As greenhouses are considered a closed system by EU law, it is assumed that the emissions into the environment will be controlled and prevented and pesticide use within these structures will have limited to no impact on the environment and its species.

In fact, EU regulators are approving harmful substances by triggering Article 6(e) and (i) of Regulation 1107/2009, which states that approval may be subject to conditions and restrictions *"including, manner and conditions of application"*, in this case being a restriction of their use to (permanent) greenhouses.

Nevertheless, empirical studies (see point 3.1) have shown that pesticides have been leaking into the environment from greenhouses for many years. Consequently, pesticides that have been approved with "restriction and conditions", because they are too dangerous to be used in open fields (e.g. toxic to bees and/or birds), are continuously escaping from greenhouses into the environment without enough control, putting non-target species at risk.

Even more alarmingly, greenhouse production has increased steadily since its commercial introduction about half a century ago, and for some, greenhouses are the future of food production. As of today, *'covered production systems are now estimated to represent about half of the total production of fresh vegetables worldwide'*[2].

Therefore, given their significant role in global and European food production, the approval and use of toxic substances in greenhouses, whether they are low or high-technology structures, is putting the environment and human health at risk.

The pesticide approval procedure under EU Law

The procedure for placing pesticides on the EU market is governed by Regulation 1107/2009, which is a two-step procedure. Both steps are initiated by a pesticide company interested in placing their products in the market.

- First, the active substance is assessed and approved at the EU level.
- Second, once the active substance is approved at the EU level, pesticide products, also called Plant Protection Products (PPPs), which have this substance as their active ingredient, are assessed and authorised at the national level, where they will be sold.

Regulation 1107/2009 acknowledges that the use of pesticides can cause harm to humans, animals and the environment and has set strict rules for their approval to ensure a high level of protection. Under these rules, the active ingredients of pesticides (active substances) and pesticide product formulations can only be approved if it is demonstrated that their use does not adversely affect human, or animal health or the environment. In this respect, the applicants (the pesticide companies who have an interest in placing their product on the market) have to submit a range of studies that prove that their active substance and a representative formulation (pesticide product) are safe. Based on these studies and the ones available from scientific literature the Member State(s) in charge, followed by the European Food Safety Authority, carry out an assessment. This must consider the potential toxicity of all the pesticide product ingredients and metabolites, the whole product formulation, as well as the resulting residues on food, drinking water and the environment (box 1), taking into account cumulative and synergistic effects. Based on this assessment the European Commission in agreement with Member States decides on the approval or non-approval of the active substance in question.

[2] Schäffer A. et al (2018,Diskussion Nr. 16), 'Der stumme Frühling – Zur Notwendigkeit eines umweltverträglichen Pflanzenschutzes' <https://www.leopoldina.org/uploads/tx_leopublication/2018_Diskussionspapier_Pflanzenschutzmittel.pdf>

The Regulation is also underpinned by the precautionary principle, which both Member States and the European Commission are encouraged to evoke to ensure a high level of protection from pesticides if the assessment identifies risks and scientific uncertainties remain.

Box 1: Regulation 1107/2009 on the conditions to fulfil, in a nutshell:

- **Articles 1(3) and (4)**: the provisions of the Regulation are underpinned by the precautionary principle to ensure that pesticide-active substances and products placed on the EU market do not adversely affect human and animal health or the environment.

- **Article 4(1) to (3)**: An active substance shall be approved in accordance with Annex II [...] in the light of current scientific and technical knowledge. A pesticide active substance and its residues *"shall not have any harmful effects on human health, including that of vulnerable groups, or animal health"*, nor *"have any unacceptable effect on the environment"*. For pesticide products, it is stated that both *"immediate and delayed harmful effects on human health"* should be prevented, *"directly or through drinking water, food, feed or air, or consequences in the workplace, or through other indirect effects"*. Furthermore *"no unacceptable effects on the environment"* regard the impact on *"non-target species"*, and their behaviour as well as the impact on *"biodiversity and the ecosystem"*

According to Article 6 of the Regulation, the approval of an active substance can come with "conditions and restrictions", namely to ensure that the approval criteria laid down in Article 4 are met when the products that contain the substance are used in agriculture. These encompass a diverse range of measures, from the method of application to limitations on where and how these pesticides can be used (e.g. risk mitigation measures). This is the article that the Commission and Member States refer to when they restrict the application of the substance exclusively to greenhouses to prevent external exposure. Despite the wide range of greenhouse structures that result in different levels and types of emissions in the environment, it is assumed that this restriction will result in the "safe use" requirement of Article 4, without a proper and adequate risk assessment. As a result, active substances that do not meet the approval criteria end up getting approved under such a use restriction.

For instance, in the recent re-approval of the active substance bifenazate, a high risk to birds and mammals via long-term exposure was identified for all representative uses, as well as the chronic risk to mammals, non-target arthropods and bees for some of the representative uses. The European Commission in its Implementing Regulation (EU) 2022/698 proposes a restriction on its use of permanent greenhouses and states that *"in light of the current scientific and technical knowledge, it is necessary to provide for certain conditions and restrictions. It is, in particular, appropriate to restrict the use of plant protection products containing bifenazate to non-edible crops in permanent greenhouses and to require further confirmatory information"*. With this restriction to use bifenazate only on non-edible crops cultivated within permanent greenhouses, the European Commission and Member States may prevent bifenazate residues in food, but the prevention of their release into the environment, as demonstrated later, is an assumption that has not been proven through risk assessment.

In Table 1 we provide a list of substances for which a risk has been identified during EFSA's risk assessment peer-review but they were nevertheless authorised for use in greenhouses by the European Commission and Member States.

Table 1. *List of pesticides approved in greenhouses and their identified areas of concern*

Active substances	Regulations	Critical areas of concern identified EFSA
Bifenazate	Regulation (EU) 2022/698 of 3 May 2022	1) A high risk to birds and mammals via long-term exposure was concluded for all the representative uses 2) A high risk to non-target arthropods
Etoxazole	Regulation (EU) 2020/2105 of 15 December 2020	1) The available evidence cannot exclude that etoxazole might be considered a persistent (P), bioaccumulative (B) and toxic (T) or PBT substance 2) High risk was concluded for aquatic invertebrates for all representative uses 3) High risk was concluded for non-target arthropods for all representative uses evaluated 4) High risk was concluded for soil mites for representative uses in tomato, cucurbit, ornamentals, pome/stone fruits, grapes, strawberries and cotton
Sulfoxaflor	Regulation (EU) 2022/686 of 28 April 2022	No critical areas of concern but two risk assessments could not be finalised 1) The chronic risk assessments (adult and larvae) for bumble bees could not be finalised 2) The acute and chronic risk assessments for solitary bees could not be finalised in the absence of any data and risk assessment
Abamectin	Regulation (EU) No 2023/515 of 8 March 2023	1) A chronic risk to aquatic invertebrates (Peer Review 2020)
Captan	To be decided	1) A high risk to wild mammals, fish and aquatic invertebrates 2) A high risk to non-target arthropods* ** the condition for the approval regarding the ecotoxicological risk assessment (walk-in tunnels must remain closed from the time of application until harvest) is not implemented*

Active substances	Regulations	Critical areas of concern identified EFSA
Metalaxyl-M (when used for seed treatments)	Regulation (EU) 2020/617 of 5 May 2020	For seeds treatments: 1) High acute and long-term risk was identified for birds and mammals for all representative use Other uses: 1) The technical specification is not supported by the toxicological assessment due to one relevant impurity CGA226048 that has been shown to be potentially clastogenic and that was not tested at appropriate levels in the toxicological studies. 2) The relevant groundwater metabolite NOA409045 has a high potential to exceed the parametric drinking water limit of 0.1µg/L in groundwater as represented by the 80th percentile annual average concentration moving below 1m depth, in geoclimatic situations represented by 20 out of 21 crop FOCUS scenario combinations for the representative uses assessed. Only use as a sunflower seed treatment in situations represented by the Sevilla FOCUS scenario was predicted not to exceed the parametric drinking water limit.
Methoxyfenozide	Regulation (EU) 2020/2105 of 15 December 2020	1) Potential groundwater contamination above the parametric drinking water limit of 0.1lg/L by methoxyfenozide and toxicologically relevant metabolite RH131154 (M08).
8-Hydroxyquinoline incl. oxyquinoleine	Regulation (EU) 2017/2065 of 13 November 2017	1) Hydroxyquinoline has a harmonised classification and labelling as toxic for reproduction category 1B and a critical area of concern is identified. 2) Hydroxyquinoline is classified as toxic for reproduction category 1B, and toxic effects were observed in endocrine organs.
Fenazaquin	Regulation (EU) No 540/2011 of 25 May 2011	1) A high risk to aquatic organisms was indicated.

Aim and Objectives

a) Aim of the report

This report aims to provide information and demonstrate that greenhouses, even when permanent, are not closed spaces, which prevent the release of pesticide products into the environment. Therefore (re)approving active substances – known to be toxic – with a restriction "to (permanent) greenhouses" does not ensure environmental protection and therefore disregards the provisions of the EU law.

b) Objective

PAN Europe, together with its members and partners Ecologistas en Acción, PAN Germany, PAN Netherlands, Natuur en Milieufederatie Zuid-Holland and Bündnis für eine enkeltaugliche Landwirtschaft e.V. sought to examine the European Commission's assumption that greenhouses operate as closed systems and whether harmful pesticides are in fact leaking, resulting in emissions into the environment and exposure of ecosystems to dangerous pesticides. In doing so, PAN Europe and the participating organisations reviewed the scientific literature on the impact of greenhouses and carried out a pilot field study, by collecting surface and rainwater samples near greenhouse fields. Finally, we discuss the legality of the reapproval decision of an active substance to permanent greenhouses only.

2. What is the framework on greenhouses at the EU and national levels?

2.1. Contradicting consideration of greenhouses at the EU level

Despite the significant rise in crops and floral production within greenhouses in recent years, references to greenhouses within Regulation 1107/2009 remain minimal (Box 2).

Box 2: Regulation 1107/2009 references to greenhouses:

- **Article 3(27)** *"a walk-in, static, closed place of crop production with a usually translucent outer shell, which allows the controlled exchange of material and energy with the surroundings and prevents the release of plant protection products (PPPs) into the environment".*
- **Article 3(17)** adds that in the process of the approval of a product PPP *"For the purpose of use in greenhouses, as post-harvest treatment, for treatment of empty storage rooms and for seed treatment, the zone means all zones defined in Annex I".*
- **Article 40(1)(c)** on the principle of mutual recognition, identifies greenhouses as a case under which this principle applies.
- **Annex II points 3.6.3 to 3.6.5 and 3.8.2**, briefly define the case of negligible exposure, as the condition where the product is used in "closed systems", which "exclude contact with humans", that can be perceived as a greenhouse.

What is the framework on greenhouses at the EU and national levels?

While Regulation 1107/2006 considers greenhouses as "a closed space" that controls and prevents the release of pesticides into the environment, the EFSA explains the opposite. In its two scientific opinions on emissions of pesticides from cover crops (including greenhouse) published in 2010 and 2012, and a guidance document published in 2014, it contradicts such a definition. Indeed, the latter notes that *"There are indications from research reports and other literature [...] that emissions occur also in systems commonly recognised as -greenhouses."* (p.6). It also recommends *"to further develop representative exposure scenarios for greenhouses and walk-in tunnels"* (p.24). Furthermore, EFSA explicitly acknowledges that, currently, most systems considered to be greenhouses, do not control and prevent emissions of pesticides into the environment and therefore do not meet the definition of Reg. (EC) 1107/2009.

The EFSA guidance document (2014) was adopted by the European Commission and Member States. In the process of its adoption, the member states expressed several concerns such as the differences between the EFSA's definition and that of Regulation 1107/2009, the absence of available models to carry out such a risk assessment and the lack of clarity on how such a definition should be applied at the national level e.g. within the principle of mutual recognition across European agricultural zones.

The gradual change in the interpretation of the definition of Reg. 1107/2009 is likewise reflected by the European Commission, in its 2015 draft guidance document on negligible exposure. According to the draft, *"it is not possible to demonstrate 'closed systems' throughout the entire life-cycle of a plant protection product"* (p.9) and highlights that *"high-tech greenhouses, usually perceived to be 'closed systems', may still result in [...] leakages into the environment are also possible"* (p.9).

2.2. National legislation, greenhouses an inharmonious concept

Table 2. *National legislation on greenhouses and pesticides*

	Size greenhouse fields	Type of greenhouses	National legal framework	Risk Assessment	National definitions
The Netherlands	Very common. In 2021 there are 3707 greenhouse companies with a total of 10.555 hectares.	The majority are high-technology and walking structures. Localisation: the majority are in the province of South Holland and most commonly the greenhouse structures are connected with surface waters and are located close to villages.	Well-developed national legal framework in complement to the implementation of Regulation 1107/2009. E.g. Mandatory water purification measures specific to greenhouses, a model for concentrations in surface and groundwater from greenhouses (GEM Model) -> limited to high-technology greenhouses. 'Outline agreement on water purification in greenhouse horticulture': If (chemical) plant protection products are used, these must be removed by at least 95% from the water to be discharged.	The risk assessment conducted by the Ctgb -> However, there is no special risk assessment for closed systems like greenhouses.	Translated definition from Regulation 1107/2009

What is the framework on greenhouses at the EU and national levels?

	Size greenhouse fields	Type of greenhouses	National legal framework	Risk Assessment	National definitions
Belgium	Fairly common, especially in Flanders. In 2020, the area covered by greenhouses in Flanders was up to 2381 ha. In 2022, there are 697 holdings which grow vegetables in greenhouses.	Mainly high-technology, although low-technology greenhouses are also still frequently used. Localisation: Given the high population density in Flanders, greenhouses are often located in or around cities, municipalities and villages, in the vicinity of houses, and next to or in the vicinity of small streams or larger waterways.	Greenhouse production in Flanders is regulated by VLAREM II in addition to the implementation of Regulation 1107/2009. Chapter 4.2 concerns the control of surface water pollution: discharge of industrial wastewater in general, and industrial wastewater. Chapter 4.3 concerns the discharge of industrial wastewater into groundwater.	The main document is the Belgian guidance document on the emissions from protected crops to the environment. For greenhouses, the exposure is not considered relevant for birds, mammals, bees (with the exception of introduced pollinators), non-target arthropods and non-target plants. For soil, only a risk assessment for persistent substances is needed. Groundwater is regarded as negligible. Surface water, no exposure is considered.	SPF Santé Publique, Sécurité de la Chaîne Alimentaire et Environnement does not have a specific definition of greenhouses. However, it defines *"A protected crop is a crop that is covered when the plant protection product is applied and remains covered until the end of the crop, by a structure that is large enough to walk on and whose roof and sides are impermeable"*[3]. In other terms, a general definition of 'covered crops' is provided, which includes greenhouses. Therefore, unlike the EU law definition, it is not assumed that greenhouses are 'closed spaces'.

[3] Translated from French via Deepl. Original *"Une culture sous protection est une culture qui est couverte lors de l'application du produit phytopharmaceutique et qui le reste jusqu'à la fin de la culture, par une structure suffisamment grande pour marcher à l'intérieur et dont le toit et les côtés sont imperméables"*.

What is the framework on greenhouses at the EU and national levels?

	Size greenhouse fields	Type of greenhouses	National legal framework	Risk Assessment	National definitions
Germany	It is common practice but less intense. In 2022, the area covered by greenhouses represented a total of around 1,271 hectares.	Explanations of the BVL definition of greenhouses details and technical requirements. Often references of "Hohe begeh-bare Schutzab-deckungen" (High walk-on protective covers made of glass, solid plastic or foil). Localisation: No official information was found and compared to other countries localisations seem more disparate.	The main law is the transposition of Regulation 1107/2009 and the Sustainable Use Directive applies such as the German Plant Protection Law.	The German UBA carries out emission assessments for use in greenhouses. The German authorisation authorities have modified and concretised the definition of greenhouses. It also often refers to the EFSA 2014 Guidance Document on greenhouses.	The "Definition des Anwend-ungsbereichs "Gewächshaus" defines greenhouses as *"a walk-in, stationary, self-contained production location for cultivated plants with a transparent outer shell. The type of translucent materials used (glass, plastic, foil, etc.), the nature of the floor (concrete ceiling, foil or grown soil) and the exchange of air via ventilation between the greenhouse and its surroundings are not relevant"*[4] Again, in contrast to the EU law definition there is no mention of 'closed space'.
Spain	Very common (especially in Almeria). In the whole of Spain, the figure rises to almost 65,000 hectares.	Low-technology greenhouses are the most common structure. Localisation: near the coast and close to towns and cities. In Almeria, they are supplied by aquifers and groundwaters.	Neither the Spanish nor the regional governments have established specific rules for greenhouse production -> Transposition of the Sustainable Use Directive 128/2009 and Regulation 1107/2009.	No specificities for greenhouses.	Translated definition from Regulation 1107/2009.

[4] Translated from German via Deepl. Original *"Der Anwendungsbereich «Gewächshaus» wird bestimmt als ein begehbarer, ortsfester, in sich abgeschlossener mit transparenter Außenhülle versehener Produktionsstandort für Kulturpflanzen. Die Art der verwendeten lichtdurchlässigen Materialien (Glas, Kunststoff, Folie, etc.), die Beschaffenheit des Bodens (Betondecke, Folien oder gewachsener Boden) sowie ein Luftaustausch über die Lüftung zwischen Gewächshaus und Umgebung sind dabei unerheblich".*

What is the framework on greenhouses at the EU and national levels?

The legal framework on greenhouses in addition to being quite limited, presents different interpretations around what can be defined as a greenhouse. Indeed, as established by EFSA and as reflected by some national regulations, the capacity of greenhouses to prevent the release of pesticide products into the environment remains uncertain and questioned. Nevertheless, active substances, which do not meet the conditions laid out by Regulation 1107/2009 are approved, hidden behind the definition available in the pesticide regulation. Considering the identified toxicity of these substances, their release into the environment is very alarming and directly violates EU law.

3. Greenhouses: closed space or not?

3.1. Pesticide emissions from greenhouses, what does science say?

3.1.1. Greenhouses and surface water pesticide emissions, period up to 2010

A study written by Roseth et al. in 2010, analysing surface water bodies in Norway concluded the (water) pollution caused by greenhouses to be worse than the pollution from open-field crops. The study detected 18 pesticide active substances in water samples collected downstream from greenhouse fields: 9 fungicides, 5 herbicides and 4 insecticides. Ten compounds from flower and vegetable productions were frequently found to exceed environmental risk levels considered in the analysis, and with a few exceptions the compounds were found in higher concentrations than those typically found in agricultural runoff. Therefore, this study showed not only that there are pesticide emissions from greenhouses into surface waters but also that their concentrations are such that they are harmful to the environment.

Moreover, a report published by Dutch water authorities in 2005 had already drawn similar conclusions. This report illustrated that pesticides were found in surface waters near greenhouses at levels exceeding the aquatic quality standards (MAC-EQS)[5]. The report focuses on the Dutch greenhouse sector (9,000 growers, 10,000 hectares, 60% ornamentals, vegetables 75% soil-less, ornamentals 25% soil-less). Many aquatically toxic pesticides are applied, essentially fungicides and insecticides. The report identifies that crop culture in greenhouses often uses more pesticides per hectare than most other agri-sectors: ornamentals 28 kg/ha, and vegetables 18 kg/ha at the time. Near those greenhouse fields in the Netherlands, up to 27 different pesticides are reported in surface waters. In several such areas, 15 or more pesticides analysed were exceeding the Dutch quality standard MTR (maximum risk level)[6]. Such examples are the pesticides[7] carbendazim, imidacloprid, parathion-methyl and pirimicarb. Some pesticides like dichlorvos, imidacloprid and parathion-methyl exceeded the MTR by a factor of 100, despite being already banned under Regulation 1107/2009. Incidentally, the MTR standards were exceeded 1000 times in surface water for the pesticides abamectin, chlorothalonil, dichlorvos (banned), imidacloprid, parathion-ethyl (banned), parathion-methyl, permethrin, tolclofosmethyl and vinclozolin.

[5] The Dutch standards at that time, MTR, maximum risk level, are to be compared to the MAC EQS in the Water Framework Directive 2000/60/EC.

[6] The standard is called "MTR", the maximum allowed level of a substance from an ecotoxicological point of view.

[7] Only one of the four, pirimicarb, is currently approved as a pesticide.

The report also registers some atmospheric deposition. One is particularly memorable, the decades-ago banned substance endosulfan[8]. The Dutch water authorities concluded that the greenhouse sector is the most polluting agri-sector in the Netherlands compared to other agricultural sectors. The report identifies several emission routes: drained water and condensed water (according to a study by the Ministry of Agriculture). At that time, water authorities[9] called these surface waters 'ecologically dead'.

Finally, most high-tech greenhouses producing vegetables are soil-less and have many pipes that directly discharge surplus feed water into the ditches and canals. A practice, prohibited by the previous Water Directive 76/464/EEG in the case of 'black list' substances[10]. Yet, several of these pesticides coming from greenhouses were qualified as 'blacklist'. Court cases in the Netherlands forced the government to prohibit the discharge of polluted water into the surface waters. In the Netherlands, the pipes had to be closed and excess feed water was either recycled (by bringing it to a rainwater basin and re-entering it to the feeding of plants) or discharged into the community sewers. This practice of discharging polluted water into sewers however is a questionable approach. Indeed, the water from the sewers will also ultimately end up in surface water, as there is no established method to remove entirely pesticides during wastewater treatment[11], therefore these active substances used in greenhouses will be released into the environment.

It, therefore, can be concluded that for the past decades, surface water was heavily polluted with a range of pesticides from greenhouses. These substances were recorded as exceeding the safety standards to a large extent, despite some of them being banned under Regulation 1107/2009. While being an environmental crisis at the time, this also provides strong proof that greenhouses are not a closed space and that emission through surface water has been a recurring issue.

3.1.2. Greenhouses and surface water pesticide emissions, recent data

A recent study from Sweden analysed surface water downstream 7 professional greenhouses (vegetables, ornamentals) every 14 days during one year. Of the 28 allowed pesticides in the greenhouses (based on monitoring of the growers), 25 were still detected in surface water bodies: acetamiprid (max. 9.4 µg/L), aclonifen, azoxystrobin (max 9.2 µg/L), boscalid, carbendazim, cyprodinil, fludioxonil, hexythiazox, imazalil, imidacloprid, mandipropamid, metalaxyl, paclobutrazol, penconazole, pirimicarb, propamocarb

[8] Duyzer, J. et al. De blootstelling van omwonenden van kassen aan gewasbeschermingsmiddelen via de lucht . TNO MEP. Rapportnr. 2004/517. Apeldoorn, 2004.

[9] Bas van de Wal, Hoogheemraadschap van Delfland, in: 'Leve de sloot', H.Muilerman & E. Matser, Stichting Natuur en Milieu, 1994.

[10] The Directive was withdrawn in 2013 because of its success in protecting surface water, and protection is postponed to the future Water Framework Directive.

[11] A fourth treatment stage in sewage treatment plants can eliminate approx. 70% of pesticides.

(max. 107 µg/L), propiconazole, pymetrozin (max 9.2 µg/L), pyraclostrobin, pyrimethanil, thiacloprid, thiophanate methyl.

Remarkably, for several of the PNEC – the (predicted) no-effect concentration[12] determined by Food Authority EFSA based on industry-delivered toxicity data – was exceeded in several occurrences: acetamiprid 391 times, imidacloprid 1444 times, and pirimicarb 41 times.

The study concludes that most pesticides from greenhouses could be detected in surface waters outside the fields and lead to potential toxicity to aquatic organisms.

Additionally, in a study conducted in Norway analysing run-off of greenhouses (in a creek), it was found that 44 out of 74 pesticides analysed could be found in the sampled creek:

Table 3. *Ketil Haarstad et al, "Pesticides in Greenhouse Runoff, Soil and Plants: A Screening", The Open Environmental & Biological Monitoring Journal, 2012(5): Maximum Concentrations (µg/l) of Pesticides Found in the Creek or in the Wells in Norway*

Pesticide	Maximum Concentration	When	Where
2,4-D	0.03	May-05	Creek
2,6-dichlorbenzamid	0.60	July-00	Creek
aclonifen	0.78	June-08	Creek
alfacypermethrin	0.01	June-04	Creek
AMPA	0.38	August-03	Creek
Azinphosmethyl	0.01	October-04	Creek
azoxystrobin	0.58	August-08	Well
bentazone	6.90	June-95	Creek
cyprodinil	0.31	November-10	Well
DDT	0.06	June-04	Creek
diazinone	0.49	April-02	Creek
dichloroprop	8.90	June-95	Creek
Dimethomorph	0.05	November-10	Well
esfenvalerate	0.06	July-04	Creek
ETU	3.00	July-95	Creek
fenhexamid	1.4	July-08	Creek
fenmedipham	2.2	May-08	Creek
fenpropimorph	12.0	July-98	Creek
fluazinam	2.2	June-04	Creek
fluroxipur	0.34	May-07	Creek
glyphosate	0.14	November-06	Creek
imazil	0.64	July-02	Creek
iprodion	4.3	July-04	Creek
isoproturon	0.06	August-05	Creek
clopyralid	2.4	October-09	Creek
Kloprofam	0.20	June-99	Creek

[12] According to the regulatory standard derived by EFSA.

Pesticide	Maximum Concentration	When	Where
kresoxim	1.5	June-04	Creek
linuron	24.0	June-96	Creek
MCPA	8.8	May-97	Creek
mecoprop	0.52	August-02	Creek
metalaxyl	1.62	August-95	Creek
metamitron	42.0	June-03	Creek
metribuzin	12.0	June-96	Creek
penconazole	0.28	June-06	Creek
pirimicarb	0.47	August-04	Creek
prochloraz	0.07	September-07	Creek
propachlor	68.0	May-00	Creek
propiconazole	7.7	July-98	Creek
prothioconazole	0.50	November-10	Well
pyraclostrobin	0.55	November-10	Well
simazine	0.35	July-96	Well
terbutylazine	0.09	June-96	Creek
tiabendazole	0.08	September-96	Creek
trifloxystrobin-methyl	0.08	October-08	Creek

Furthermore, another recent monitoring delivered by the Dutch water authorities gave a similar outcome. The study identified massive pollution of surface waters coming from greenhouses, every year, providing data up to 2021. The study was conducted in areas composed of 3000 greenhouses with hardly any other activity present near the site (apart from houses). Besides, the water pumped into the area was qualified as free from pesticides ("Brielse Meer", water originating from the rivers Rhein and Meuse), which, after passing through the greenhouses area, is being released into the North Sea. This choice of this specific site to conduct the analysis made it beyond any doubt what was the origin of the pesticides found in the samples.

Indeed, in 2021, 11 pesticides were detected exceeding the water safety standards (EQS and MAC-EQS)[13]. In the past 7 years, the number of pesticides exceeding safety standards fluctuated between 11 and 28. Far from being a closed and controlled system, greenhouses appear to be emitting pesticides and damaging aquatic life consistently.

The table below perfectly illustrates that throughout the year, the emission of pesticides to surface water happens on a regular basis. How this can be brought in line with the rules that emission was forbidden 25 years ago and a complete connection of the growers to the community sewer system was established[14] is highly questionable.

[13] The authorities compared the level with the standards of the EU Water Framework Directive 2000/60, both available standards, the (chronic) year standard, and the acute standard (MAC, maximal acceptable concentration). If such a standard doesn't (yet) exist, the (90-percentile) level is compared to the MTR (Maximum Allowed Risk, a Dutch standard).

[14] A 2017 ruling, "Besluit van 23 juni 2017 tot wijziging van het Activiteitenbesluit milieubeheer in verband met de vermindering van emissies van gewasbeschermingsmiddelen in de glastuinbouw en open teelten" provides that growers either apply a purification system on their excess water that is 95% effective or discharge polluted water on the sewers of the community.

***Table 4.** A number of pesticides analysed in surface water, and a number of pesticides exceeding standards[15] (note that pesticides 1 – 18 are banned, while pesticides 19 – 46 are approved).*

	Totaal aantal verschillende gemonitorde bestrijdingsmiddelen		195	120	220	187	198	214	254
	Totaal aantal verschillende normoverschrijdende bestrijdingsmiddelen per jaar		28	23	18	17	11	20	11
Nr	Stof	Merknaam (o.a.) jaar:	2015	2016	2017	2018	2019	2020	2021
	Niet meer toegelaten stoffen:								
1	ethylazinfos	Niet meer toegelaten (1995)	yellow	yellow	yellow	yellow	yellow	red	yellow
2	diazinon	Niet meer toegelaten (1998)	red	red	red	red	yellow	yellow	yellow
3	methylazinfos	Niet meer toegelaten (1999)	yellow	yellow	yellow	yellow	yellow	red	yellow
4	mevinfos	Niet meer toegelaten (1999)	yellow	yellow	red	yellow	yellow	red	yellow
5	triazofos	Niet meer toegelaten (2000)	yellow	yellow	yellow	yellow	yellow	red	yellow
6	methylparathion	Niet meer toegelaten (2003)	yellow	yellow	yellow	yellow	yellow	red	yellow
7	chloorfenvinfos	Niet meer toegelaten (2007)	red	green	green	green	green	green	green
8	dichloorvos	Niet meer toegelaten (2012)	red	red	red	yellow	yellow	yellow	yellow
9	carbendazim	Niet meer toegelaten (2016)	red	red	red	red	red	red	red
10	fenoxycarb	Niet meer toegelaten (2017)	yellow	red	yellow	yellow	yellow	yellow	yellow
11	linuron	Niet meer toegelaten (2017)	red	green	green	green	green	green	green
12	iprodion	Niet meer toegelaten (2018)	red	green	green	green	green	green	green
13	dimethoaat	Niet meer toegelaten (2019)	red	red	red	red	green	green	green
14	ethylchloorpyrifos	Niet meer toegelaten (2019)	red	red	red	green	green	green	green
15	lufenuron	Niet meer toegelaten (2019)	grey	grey	grey	grey	grey	red	yellow
16	pymetrozine	Niet meer toegelaten (2019)	red	green	green	red	red	green	green
17	methiocarb	Niet meer toegelaten (2020)	red	red	red	red	red	yellow	red
18	thiacloprid	Niet meer toegelaten (2020)	red	red	red	yellow	yellow	red	yellow
	Toegelaten stoffen:								
19	imidacloprid**	Admire	red	red	red	red	red	red	red
20	esfenvaleraat	Sumicidin Super	red	red	red	red	red	red	red
21	pendimethalin	Stomp, Malibu	red	yellow	red	red	yellow	red	red
22	cyprodinil	Switch	green	red	green	green	green	red	red
23	dodemorf	Meltatox	green	green	green	green	green	red	red
24	cypermethrin	Talisma	grey	grey	grey	red	red	yellow	red
25	methylpirimifos	Actellic 50	red	red	red	yellow	red	yellow	red
26	deltamethrin	Deltasect, Decis	red	red	yellow	red	yellow	yellow	red
27	chlorantraniliprole	Altacor	grey	grey	grey	red	green	green	red
28	abamectine	Vertimec Gold	red	red	red	red	red	red	yellow
29	pirimicarb	Pirimor	red	red	red	red	red	red	green
30	spinosad	Tracer, Conserve	red	red	red	red	red	red	yellow
31	emamectin-benzoaat	Affirm	grey	grey	grey	grey	grey	red	yellow
32	etoxazool	Borneo	grey	grey	grey	grey	grey	red	yellow
33	pyridalyl	Nocturn	grey	grey	grey	grey	grey	red	yellow
34	pyrethrinen	Spyro	grey	grey	grey	grey	grey	red	yellow
35	pyriproxyfen	Admiral	red	yellow	yellow	red	red	yellow	yellow
36	methoxyfenozide	Runner	red	red	red	red	green	green	green
37	diethyltoluamide	biocide	green	green	green	red	green	green	green
38	thiamethoxam	biocide	red	red	red	green	green	green	green
39	spiromesifen	Oberon	grey	grey	red	yellow	yellow	yellow	yellow
40	alfa-cypermethrin	biocide	red	red	yellow	grey	grey	grey	grey
41	indoxacarb	Steward	red	red	yellow	yellow	yellow	yellow	yellow
42	fipronil	biocide	yellow	red	yellow	yellow	yellow	yellow	yellow
43	azoxystrobin	Ortiva	green	red	green	green	green	green	green
44	etridiazol*	Aaterra ME	red	red	green	green	green	green	green
45	lambda-cyhalothrin	Karate, Ninja	red	yellow	yellow	yellow	yellow	yellow	yellow
46	pyraclostrobin	Signum, Bellis	red	grey	yellow	yellow	yellow	yellow	yellow
	* Sinds 31-05-2021 niet meer toegelaten								
	** Opgebruiktermijn tot 1-1-2022								

- green: below standards,
- yellow: cannot be assigned,
- red: exceeding standards
- grey: no testing

[15] These standards are the regulatory standards applied by the NL authorities to authorise pesticides; the standards from the Water Framework Directive that will be applicable by 2027 are far more strict, many times with a factor of 100.

To conclude, currently, pollution of surface waters with pesticides originating from greenhouses is worse than it was 10 or 20 years ago. Indeed, a large range of pesticides are detected in surface water and – in several cases – exceed national surface water standards every year. Moreover, despite being banned, a couple of pesticides remain in surface water bodies. This recent round of analysis conducted in several member states across the European Union therefore attests that greenhouses are anything but closed systems and that emission occurs frequently through diverse routes in surface water.

3.1.3. Greenhouses and pesticide soil emissions

Unfortunately, there is hardly any data on the topic of soil pollution in and around greenhouses. Yet, there is little doubt that crops that are grown within the soil in greenhouses have a risk of polluting the soil and possibly the groundwater, just like it happens in open fields. This, however, depends on the structure of the soil. On the topic of pesticide soil contamination, a study conducted on a number of 317 (agricultural) topsoil samples across the EU concluded that 83% of the soils contained at least one pesticide and 56% mixtures of pesticides. One might thus expect the situation in soil-bound greenhouses to be similar or even worse, given the higher volumes of pesticides used in greenhouses, especially flowers (see 2.2.1).

It, therefore, can be concluded that no data could be found on the specific topic of pesticide soil pollution in greenhouses. However, in the case of soil-bound crops in greenhouses, it can be expected that emissions through the soil occur similarly to open fields.

3.1.4. Greenhouses, air emissions and atmospheric depositions

Numerous reports have demonstrated that pesticides can be found in the air. A recent German study based on air samples, detected pesticides in the air all over Germany, all the way to nature conservation areas. For instance, glyphosate was recovered in every sample while more than half contained the pesticides chlorothalonil, metolachlor, pendimethalin, terbuthylazine, prothioconazole-desthio, dimethenamid, prosulfocarb, flufenacet, tebuconazole, aclonifen, chlorflurenol, hexachlorobenzene (HCB), and γ-hexachlorocyclohexane (γ-HCH). It was identified that the intensity of agricultural practices was directly related to the number of substances detected in ambient air. Medium- and long-range transport likely account for these findings. However, no specific reference to greenhouses was made.

Another study conducted by J. Socorro et al (2016) further challenges the current view of the half-lives of pesticides in the lower boundary layer of the atmosphere and their impact on air quality and human health. The study demonstrated that semivolatile pesticides – mostly adsorbed on atmospheric aerosol particles – are very persistent with respect to the highly reactive hydroxyl radicals (OH), the self-cleaning agent of the atmosphere. The half-lives in the particulate phase of difenoconazole, tetraconazole, fipronil, oxadiazon, deltamethrin, cyprodinil, permethrin, and pendimethalin were identified for several days and even exceeding one month. This implies that these pesticides can be transported over long distances, reaching remote regions all over the world. It thus appears that these pesticides shall be further evaluated in regard to their properties as Persistent Organic Pollutants (POPs).

Greenhouses: closed space or not?

Furthermore, a Spanish study also detected 40 pesticides (mainly insecticides and fungicides) with average concentrations in air samples ranging from 8 to 30,000 pgm^{-3}. The samples (PM10 filters) were taken in areas with citrus and vineyards around Valencia. Abamectin, Omethoate, Tebuconazole, Spinosad, Diphenylamine, Dichlorvos, Buprofezin, and Thiabendazole were among the pesticides detected at the highest levels. The levels of Carbendazim and Hexythiazox were considered harmful to infants. These data thus give an impression of 'dry deposition' in contrast to wet deposition (rainwater).

A Swedish study further demonstrated widespread air contamination with pesticides such as lindane, prosulfocarb, propamocarb, endosulfan-alpha, chlorpyrifos, terbuthylazine-desmethyl, MCPA, metazachlor, terbuthylazine, boscalid, endosulfan-sulfate, prothiochonazole-desthio, clomazone, endosulfan-beta, isoproturon, metolachlor, fluazinam, epoxiconazole, diflufenican, azoxystrobin, fenpropimorph, ethofumesate and flufenacet. It is essential to note that half of these substances are not even used in Sweden.

It thus appears obvious that a blanket of pesticides covers the EU, without the source being identified. It seems that a wide range of sources could be the origin of such emissions. On the topic of greenhouses, a few studies near greenhouse fields provide some evidence that greenhouses are not closed spaces nor controlled systems and contribute to pesticide air pollution.

The study by Ngoc et al., conducted in Belgium, is one of the few that investigated the volatilisation of pesticides in (vegetable-grown) greenhouses. The study stated that overviews of the available volatilisation rate data demonstrate that they range from 0% of the applied dose to more than 90% for very volatile substances such as lindane. It concludes that greenhouse temperature, ventilation rate, the substance vapour pressure as well as the rate of competing processes were important factors influencing the volatilisation of pesticides in greenhouses.

Moreover, already, thirty years ago, it was well-known that pesticides escaped from greenhouses into the air, even from high-technology greenhouse structures. This can be logically explained since greenhouses are generally much warmer than the surroundings and a range of pesticides has low vapour pressure. Additionally, specific spraying methods (like 'fogging') play a role in the volatilisation of these pesticides. A report from Regional Authorities[16] (Province Zuid-Holland) published in 1994, samplings of rainwater in the Netherlands, detected around 20 pesticides in rainwater collectors. Amongst these sampling points, one was the village of Naaldwijk which is surrounded by greenhouse fields for miles.

[16] Provincie Zuid-Holland (1994). Bestrijdingsmiddelen in neerslag in Zuid-Holland. Dienst Water en Milieu.

Table 5. *Levels of pesticides in rainwater, glasshouse area Naaldwijk, 1992 (03/06 until 21/10); only organochlorine- and organophos-substances were analysed.*

Pesticide	Average level (ng/L)	Maximum level (ng/L)
Gamma-HCH	12.8	31
b-Endosulfan	12.2	23
Vinchlozolin	20.3	55
Dichlobenil	10.0	19
Iprodion	11.3	37
Procymidone	11.4	43
Diazinon	15.8	40
Dichlorvos	92.0	240
Heptenophos	21.1	180
Malathion	4.4	20
Methylparathion	5.6	40
Ethylparathion	10.0	40
Tolclofos-methyl	20.9	50
Triazophos	1.1	10
Pirimiphos-methyl	1.1	10

The levels of these pesticides are such that for several pesticides analysed, the water quality standard for surface water was exceeded, even up to a factor of 100 times the standard[17]. The maximum monitored outcome is up to 1000 times the water quality standard (dichlorvos and malathion). Finally, a publication from the National Institute for the Purification of Water (RIZA)[18] identified the emission from greenhouses into the air at 51-52% of the volume of the pesticides applied.

[17] De Poorte, J. and C.J. Van Leeuwen. How toxic is rain? H2O 30 (1997) 168-171.

[18] R. Faasen, RIZA, Landbouwbestrijdingsmiddelen in oppervlaktewater, een situatieschets, H2O (25) 1992, nr. 2 31.

Greenhouses: closed space or not?

Table 6. *Estimation of the emission of glasshouses to the environment (RIZA 1992); percentage of the applied volume of pesticides.*

Environmental compartment	Open field crops	Glasshouses
Air	20-22	51-52
Water	1-2	0.2
Groundwater	1-2	pm
Surface water	1-3	3.5-4

Rainwater monitoring near greenhouse areas was also done in the nineties[19]. However, unfortunately, such sampling was terminated by the authorities. Therefore there is no current data covering greenhouse pesticide emissions into the air and their deposition in rainwater.

Box 3: Are greenhouses a closed space which prevents emissions of pesticides into the environment according to available scientific literature?

Historical data demonstrate unquestionably that pesticides are released from greenhouses.

In the case of surface water, the proof is obvious. Emissions through different routes into surface water near greenhouse fields have been recorded in several Member States, often going above the surface water thresholds (national or originating from the Water Framework Directive).

In terms of soil emissions, unfortunately, scientific data on the topic are still to be found. However, it is fair to assume that in the case of soil-bound crops, emissions through the soil happen in similar patterns to open fields.

Finally, in regard to air pollution, studies have demonstrated that air volatilisation happens outside of the greenhouse structures. It even has been illustrated that emissions are such that they often lead to high levels of aquatic contamination via rainwater and other types of atmospheric deposition. The pesticides used in greenhouses are not selected to prevent evaporation. Air pollution furthermore depends on the chemical properties of pesticides (vapour pressure mainly), temperature, ventilation rate and the way of application.

[19] Provincie Zuid-Holland (1994). Bestrijdingsmiddelen in neerslag in Zuid-Holland. Dienst Water en Milieu.

3.2. Surface and rainwater samples, how many pesticides are greenhouses releasing into the environment? A snapshot view

PAN Europe, its members and partners conducted, in springtime in 2023, a collection of surface water samples in four countries (Belgium, Germany, Spain and the Netherlands) and rainwater samples in three countries (Belgium, Germany and the Netherlands), in two sampling rounds between April and June. The intention was to check if pesticides applied in greenhouses were released into the environment as a 'snapshot' rather than carrying out a thorough investigation. Indeed, as previously demonstrated (see part 3.1), there is strong evidence from a plethora of studies that greenhouses emit pesticides into the environment.

This sampling procedure aimed to analyse pesticides present in water courses near greenhouse fields with very sensitive detection methods. Since most contract testing laboratories are focused on testing food residues, it was a difficult task to find an adequate, sensitive and specialised enough laboratory. Finally, we selected to contract a laboratory that had the capacity to analyse 160 pesticides simultaneously using the Gas chromatography–mass spectrometry (GC-MS) analytical method, which has low detection limits. It is important to note that this number of pesticide-active substances seriously underestimates the reality (for instance, other pesticides, identified by other methods (e.g. combined with LC-MS technique) are not included). Indeed, looking only at the authorised pesticide active substances, there are currently around 446 approved at the EU level and might, consequently, be present in the environment. Moreover, substances may be found during other months than during the months of our sampling. For this study, the focus was put on pesticides that are known from the literature to be detected around greenhouse fields. The samples were taken in areas where greenhouses were the only or predominant agricultural activity. In certain cases, it was not possible to exclude that other types of agricultural fields were not present in the areas (e.g. Germany).

a) General results overview

Overall, out of the 160 pesticide-active substances analysed, 65 were detected in total, across the 14 samples taken from Belgium, Germany, Spain and the Netherlands. About 53 different pesticides were detected in rainwater samples and 52 in surface water samples.

Pesticide Cocktails:

Worryingly, a broad number of pesticides were detected in individual samples, both from rainwater and surface waters. A total of 35 different pesticides were detected in the rainwater sample from the Netherlands in June and 23 in the surface water sample from Spain in May. Overall the number of pesticides detected in the individual surface water and rainwater samples was high across all countries examined (Figure 3 and 4). This is concerning because the risk assessment of pesticides, which determines safe exposure levels to pesticides, is based on the assumption that we are exposed to one pesticide at a time, which as our study shows is far from the truth.

In terms of emissions into the environment, the sum of pesticides released was highest in Belgium, with a total of 90.12 μg/L of pesticides detected in surface water in May (round 1) and 34.7 μg/L in April (round 2). Thereafter, the highest levels were detected in Spain in round 2, in May (5.9 μg/L), followed by Germany (0.54μg/L; round 1) and the Netherlands (0.53 μg/L; round 1) both in April. High levels of pesticides were also detected in the rainwater sample collected from Belgium in May (21.3 μg/L; round 1), followed by Germany in April (1.25 μg/L; round 2) and the Netherlands in June (1.2 μg/L; round 2).

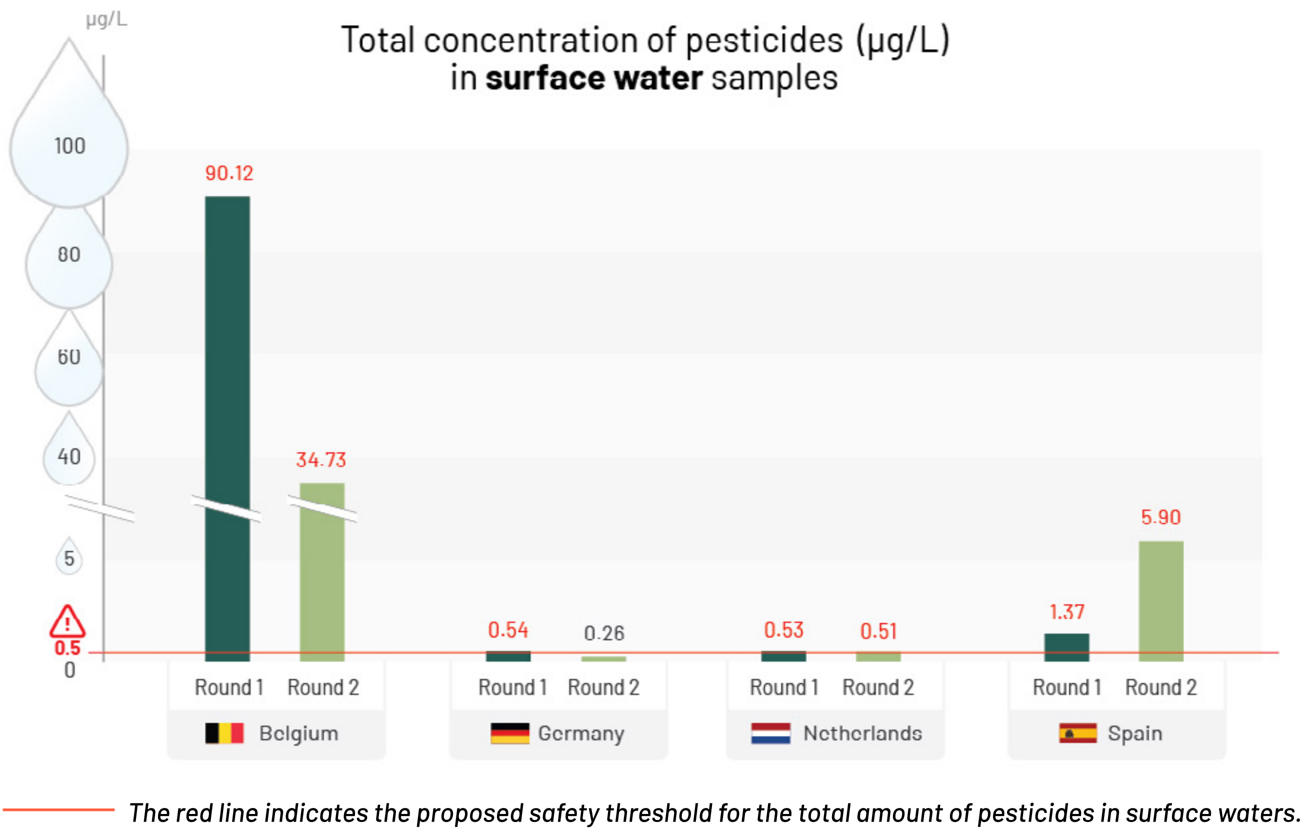


Figure 1. *Total concentrations of pesticides (μg/L) in surface water samples from Belgium, Germany, the Netherlands and Spain*

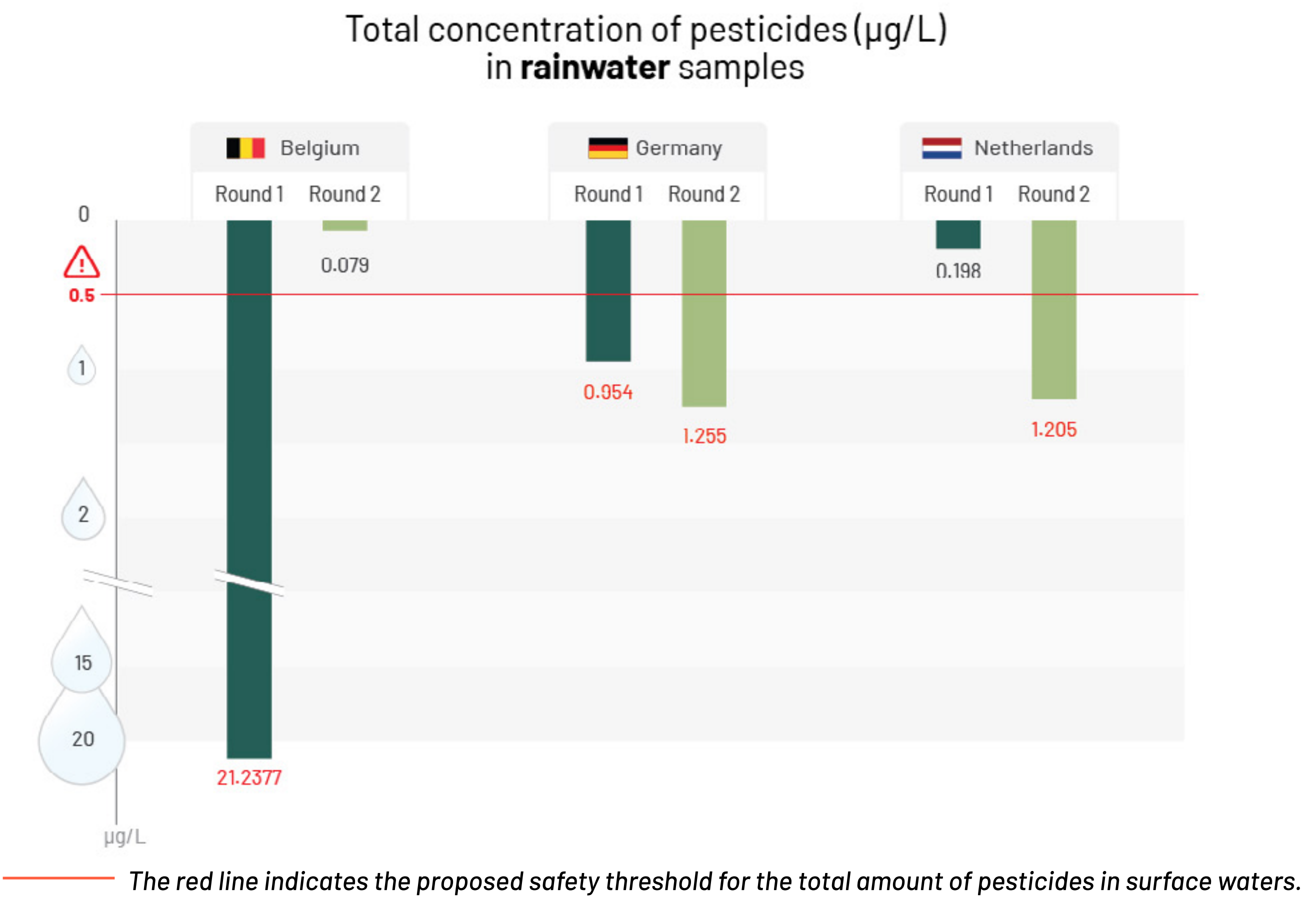


Figure 2. *Total concentrations of pesticides (µg/L) in rainwater samples from Belgium, Germany and the Netherlands*

In terms of frequency, the pesticides detected across all countries and all surface water samples were the PFAS active substance fluopyram[20], together with 2,6-dichlorobenzamid (a metabolite of dichlobenil, banned since 2008) and boscalid (endocrine disruptor), the latter authorised for use mainly in greenhouses. Dimethomorph, which is known to damage fertility and is an endocrine disruptor, the PFAS substance fluopicolide[21], and fluxapyroxad were detected in all countries (but not all samples). Metalaxyl-M, which has been associated with thyroid cancer, was detected in all countries but Germany. Boscalid and the two greenhouse PFAS pesticides fluopyram and flupicolide were also detected in rainwater samples across all countries, revealing contamination from the air too. Table 7, provides a shortlist of eight of the pesticides detected most frequently together with their toxicity profile.

[20] PAN Europe, 'Europe's Toxic Harvest: Unmasking PFAS Pesticides Authorities in Europe', 2023 <https://www.pan-europe.info/sites/pan-europe.info/files/public/resources/reports/PFAS%20Pesticides%20report%20November%202023.pdf>

[21] Metabolite M15, which has to be considered relevant since fluopicolide is classified as reprotoxic category 2, is expected in groundwater at concentrations above the legal limit for relevant metabolite, according to EFSA. The Commission did not follow the opinion of EFSA on this issue. See PAN Europe, PFAS Report, 2023. p31.

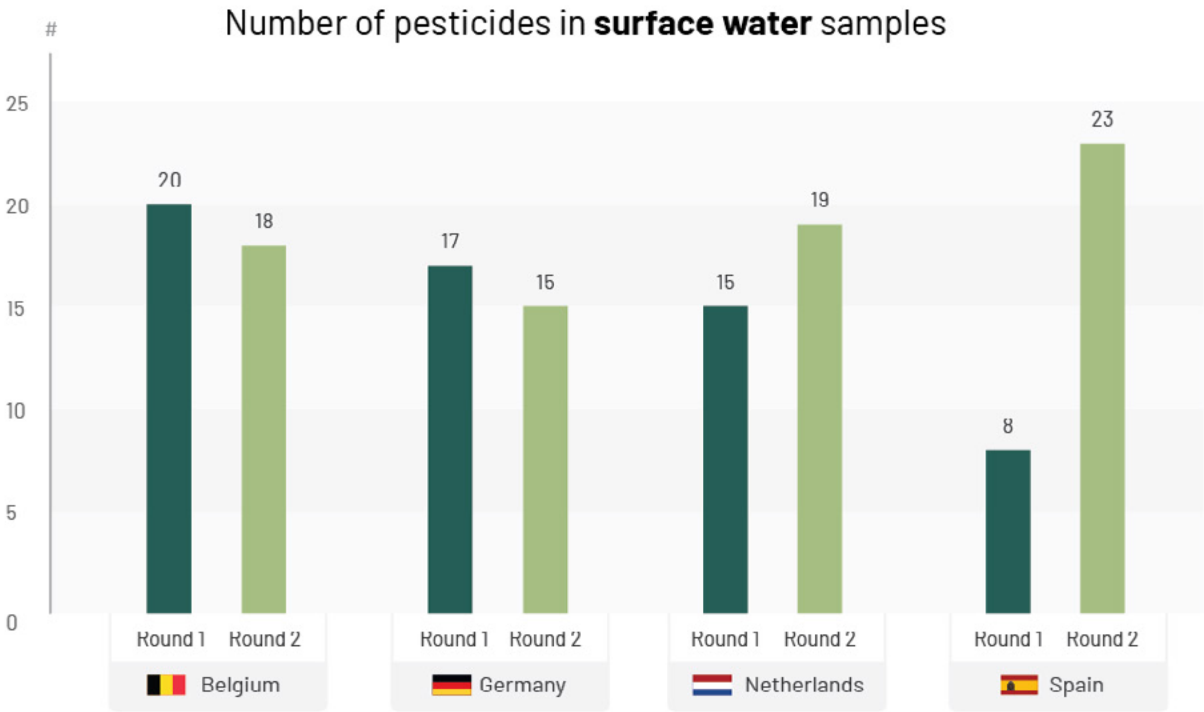


Figure 3. *Total number of pesticides in surface water samples from Belgium, Germany, the Netherlands and Spain*

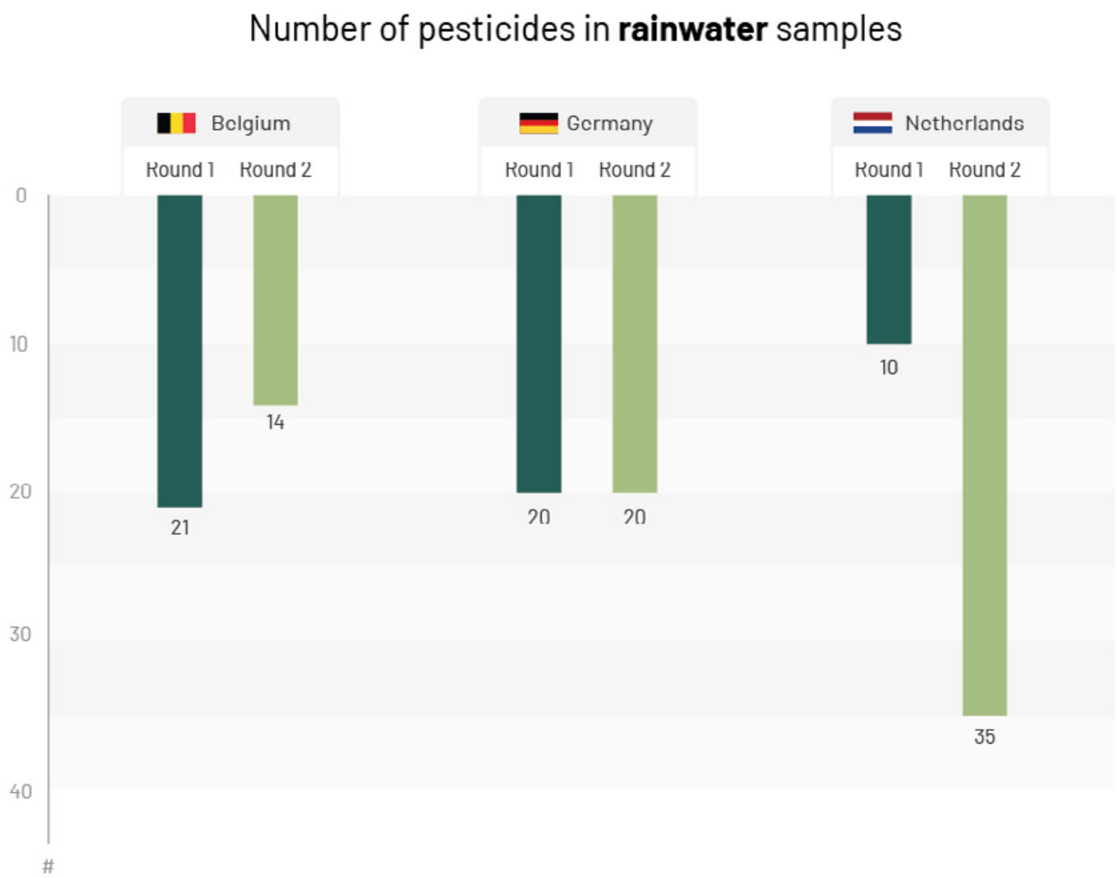


Figure 4. *Total number of pesticides in rainwater samples from Belgium, Germany and the Netherlands*

Such a high number of substances being detected in rainwater, near greenhouse fields, is a high concern from a human health perspective. Residents are indeed exposed to such rainwater, which will contaminate their (vegetable) gardens, and contribute to the total exposure of pesticides of residents of greenhouse areas by air and dust.

Taking a closer look at the other active substances detected, typical greenhouse pesticides like pendimethalin, kresoxim-methyl, bupirimate and dodemorph were found, whereas pesticides applied in open fields like esfenvalerate, methyl pirimiphos and pirimicarb were not detected at all. Here, it should be noted that only 2 rounds of samples were collected therefore the application of other pesticides during other times of the year cannot be excluded.

It is also important to note that a number of the detected pesticides are already banned under Regulation 1107/2009. For instance, dichlobenil's metabolite 2,6-dichlorobenzamid (banned since 2008), atrazine (banned in 2004), diazinon (banned in 2007), chlorpropham (banned in 2019), chlorpyrifos (banned in 2019), dichlorbenil (banned in 2008), propazine (banned in 2002), and simazine (banned in 2004) were detected. The presence of these substances indicates illegal use in the area or very high persistence.

It is finally important to mention that a group of pesticides known to be volatile and causing a blanket of pesticides across Europe, as a publication in Germany and the Netherlands indicates, were also analysed. Indeed, prosulfocarb, flufenacet and terbuthylazine, which are known to be volatile were also detected in these rainwater samples. While the origin of these pesticides can be attributed to long-range transport, greenhouses, with their high temperature, are by excellence the suspects of volatilisation contamination.

Are the levels of detected pesticides considered safe?

Unfortunately in the EU, the Water Framework Directive sets safety EU water standards for a very small number of pesticides. Occasionally national water standards include some additional pesticides. However, for most of the detected active substances, no legal safety standards are available. Therefore, the results of this study can only be compared to acute toxicity standards – also known as maximum allowable concentration (MAC EQS) – for a very limited number of substances (either from the Water Framework Directive, from national standards or the regulatory standard for pesticide authorisation delivered by national authorities when authorising a

[20] PAN Europe, 'Europe's Toxic Harvest: Unmasking PFAS Pesticides Authorities in Europe', 2023 <https://www.pan-europe.info/sites/pan-europe.info/files/public/resources/reports/PFAS%20Pesticides%20report%20November%202023.pdf>

[21] Metabolite M15, which has to be considered relevant since fluopicolide is classified as reprotoxic category 2, is expected in groundwater at concentrations above the legal limit for relevant metabolite, according to EFSA. The Commission did not follow the opinion of EFSA on this issue. See PAN Europe, PFAS Report, 2023. p31.

pesticide product). When compared to national standards for surface water, most of the found active substances are within the safety limits, as far as they are available. Some, however, are close to the upper limits of the standards. For instance, Fluopyram 16 µg/L in surface water in Belgium, with the Dutch MAC EQS of 32 µg/L. On some occasions, these acute standards are even exceeded. For example, Fluopicolide in Belgium was found at 47 µg/L, which is 60 times higher than the Dutch water standard of 0.71 µg/L. Similarly, dimethomorph in Belgium was found at 25 µg/L, which is 2.5 times higher than the Dutch standard of 10 µg/L. The EU drinking water standard of 0.1 µg/L for individual pesticides was exceeded on several occasions in Belgium, Spain and to a lesser extent in the Netherlands and Germany, which makes the water samples collected unsuitable for human consumption. However, to the best of our knowledge, the water sources from which the samples were collected are not (and should not be) intended for drinking water.

While it appears that very few of the substances detected in the samples exceeded surface water safety standards at the EU or national level, the number of substances found in individual samples is alarmingly high, resulting in high accumulated concentrations. This, thus, raises the concern of toxicity in terms of mixture effects, which are not properly assessed under the EU law on pesticides, despite the legal requirement to take cumulative (additive) and synergistic (magnifying) effects into account. Although pesticide risk assessment does not take the effects of mixtures into account, the Drinking Water Directive and the European Commission's proposal updating the Water Framework Directive, Ground Water Directive and Environment Quality Standards Directive set a threshold concentration for all pesticides detected (total), which is 0.5 µg/L[22]. As we can see from Figures 1 and 2, all surface water samples but one (Germany, round 1) exceeded this threshold. Likewise all rainwater samples but one (Belgium, round 2) exceeded this threshold.

Such mixtures of pesticides in such high concentrations in surface waters and rainwater are extremely concerning, posing a clear threat to the aquatic environment and ecosystems, and potentially to human health. Our study shows that the current risk assessment procedure, which focuses on single substances, is a significant underestimation of real life where people and the environment are exposed to mixtures of pesticides often exceeding safety thresholds.

[22] A recent EC proposal (21/10/2022) updating the WFD, GWD and EQSD introduced a total threshold of 0,5 ug/L for surface waters (the proposal was strengthened and supported by the European Parliament and is now going through discussion with the European Council) <https://environment.ec.europa.eu/publications/proposal-amending-water-directives_en>

***Table 7.** Active substances and health hazards*

Active Substance	Type	CHL status (adopted)	Health hazards
Boscalid *(herbicide)*		Aquatic Chronic 2, H411	Boscalid is part of the group of pesticides that induce mitochondrial dysfunction and animal studies show that there is a risk of developmental damage, such as incomplete ossification of the thoracic centrum in foetuses and abortion It causes thyroid histopathology alterations such as follicular cell hypertrophy and hyperplasia, and decreased thyroid hormone levels. It causes inhibition of the synthesis of prostaglandin, which could point to endocrine disruption. It is frequently detected in human biomarkers (urine). Several other pesticides often used in greenhouses, such as Fluxapyroxad which has the same mechanism of action as Boscalid, could contribute to causing cumulative effects on human health and non-target species.
Fluopyram *(fungicide)*	PFAS	Aquatic Chronic 2, H411	Fluopyram shows a risk for foetal development, (visceral and skeletal minor variations, and decreased foetal weight. Effects on thyroid weight and histopathology have been observed in animal studies, as well as thyroid tumours and liver cell adenoma and carcinoma (in mice).
Difenoconazole *(fungicide)*	Candidate for sub-stitution (CfS)	Acute Tox. 4, H302 Acute Tox. 4, H332 Aquatic Acute 1, H400 Aquatic Chronic 1, H410	Difenoconazole is an endocrine disruptor that alters sex hormones and causes reproductive effects, such as poor semen quality. No safe dose can be derived for endocrine disruptors and the exposure to this type of pesticide should be zero. Countries like the Netherlands have asked the Commission to ban Difenoconazole.
Fluxapyroxad *(fungicide)*		Lact., H362 Aquatic Acute 1, H400 Aquatic Chronic 1, H410	Fluxapyroxad is known for its reproductive effects, with the risk of causing increased post-implantation loss. The main target organs in rats were the liver and the thyroid, whereas liver tumours were recorded in test animals.
Propyzamide *(herbicide)*	CfS	Carc. 2, H351 Aquatic Acute 1, H400 Aquatic Chronic 1, H410	Linked to causing cancer ("C2" classified carcinogen). Connected to thyroid tumours, adenomas and carcinomas; many histopathological findings. Causes alterations in hormonal levels and endocrine glands. It was found to be an endocrine disruptor according to the EU Joint Research Centre (JRC). Concern for neurotoxicity: reduced motor activity in acute toxicity study; no chronic studies available.
Metalaxyl-M *(fungicide approved exclusively in greenhouses at the EU level for seed treat-ments)*		Acute Tox. 4, H302 Eye Dam. 1, H318	Metalaxyl-M demonstrated negative uterus histopathology findings. Showed thyroid effects and even thyroid cancer in one independent study. Absolute liver weights and relative liver weights were increased. Also developmental effects, and increased incidence of skeletal variations. An impurity is potentially clastogenic.
Dimethomorph *(fungicide)*	Toxic to Reproduc-tion 1B	Aquatic Chronic 2, H411 Repr. 1B, H360F	Dimethomorph was found to be an endocrine disruptor to humans and wild mammals in May 2023. It has also been classified since September 2019 as damaging fertility (toxic for reproduction 1B) but its approval period has been repeatedly prolonged (initial end of approval in 2017).
Fluopicolide *(fungicide)*	CfS, PFAS	Repr. 2; H361	Fluopicolide has effects on the liver and kidneys; increased incidence of hepatocellular adenomas (not rel acc. to EFSA); Impaired foetal development (decreased crown-rump length), It is a PFAS substance. Both fluopicolide and its metabolite M-01 are very persistent in the environment. It has been linked with decreased foetal weight and premature delivery (not rel acc. to EFSA);

b) Member States results overview

i) Results in Belgium

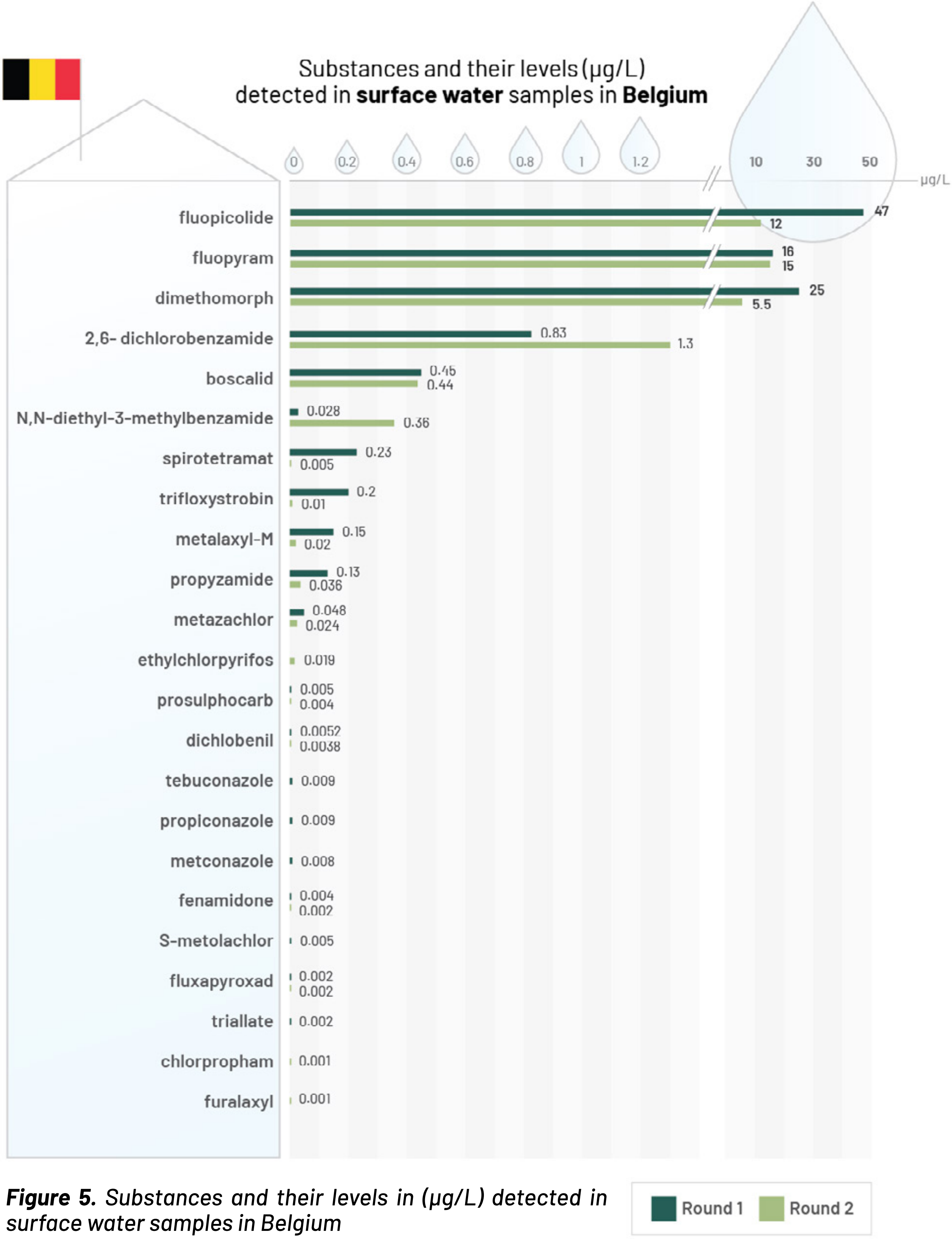


***Figure 5.** Substances and their levels in (μg/L) detected in surface water samples in Belgium*

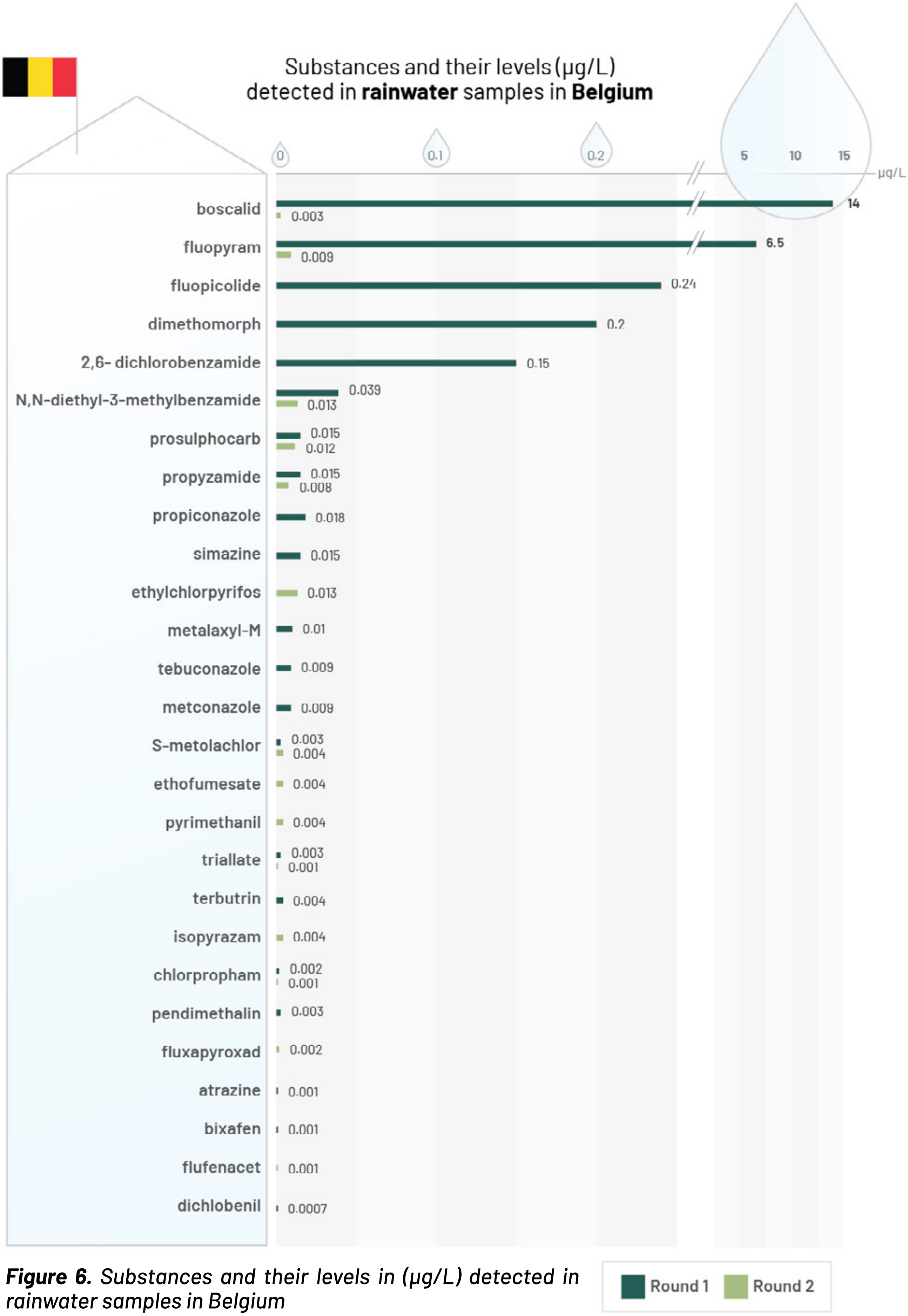


Figure 6. *Substances and their levels in (µg/L) detected in rainwater samples in Belgium*

In Belgium, overall 33 pesticides were detected in all samples. A total of 21 and 12 substances were found in the rainwater samples, while 20 and 18 were found in the surface water, in rounds 1 and 2, respectively. The sum of all pesticides in surface water samples in rounds 1 and 2, was 90.12 µg/L and 34.73 µg/L, and in rainwater samples, it was 21.24 µg/L and 0.079 µg/L, respectively. Therefore samples collected from Belgium contained a high number of pesticides and in most cases, a high level of residues.

For comparison, the threshold proposed in the recent proposal updating the list of priority substances in surface and groundwater, for the total concentration of pesticides is 0.5 µg/L. This threshold was exceeded in surface water samples from Belgium about 180 times in round 1 and 70 times in round 2.

Belgium was the country with the highest level of pesticides found, with fluopicolide reaching 47 µg/L, followed by dimethomorph (25 µg/L) and fluopyram (16 µg/L) in surface water from round 1, whereas levels of those pesticides remained high in round 2 as well. Boscalid and 2,6-dichlorobenzamide were also at the top of the list. Worryingly, those pesticides were detected at high levels in rainwater samples too (graphs SW BE + RW BE). Considering that these substances have been identified to cause toxicity to reproduction (dimethomorph) or suspected (fluopicolide), are endocrine disruptors (boscalid, dimethomorph) or PFAS (fluopyram and fluopicolide) or banned (2,6-dichlorobenzamide), their combined presence is an issue of concern both for the environment and human health.

Several substances that were banned because of their high risk to the environment and human health, among them due to their endocrine-disrupting properties and risks for groundwater contamination, were found in rainwater and/or surface water samples, such as atrazine (banned in 2004), simazine (banned in 2004), and fenamidone (2018), chlorpropham (banned in 2020) ethyl-chlorpyrifos (banned in 2020) and isopyrazam (banned in 2022).

ii) Results in the Netherlands

In the Netherlands, overall 42 pesticides were detected in all samples. Out of them, 5 (12%) come from insecticides, 11 (26%) are herbicides and 26 (62%) are fungicides. A total of 10 and 35 pesticides were found in rainwater samples, while 15 and 19 were found in surface water samples, in rounds 1 and 2, respectively. The Netherlands was the country with the highest number of pesticides in a single rainwater sample showing a dramatic atmospheric pollution from diverse pesticides in greenhouses fields. Across all samples, 4 detected active substances are nationally and/ or at the European level approved for use in greenhouses (metalaxyl-M, fluopyram, prosulphocarb and pyrimethanil).

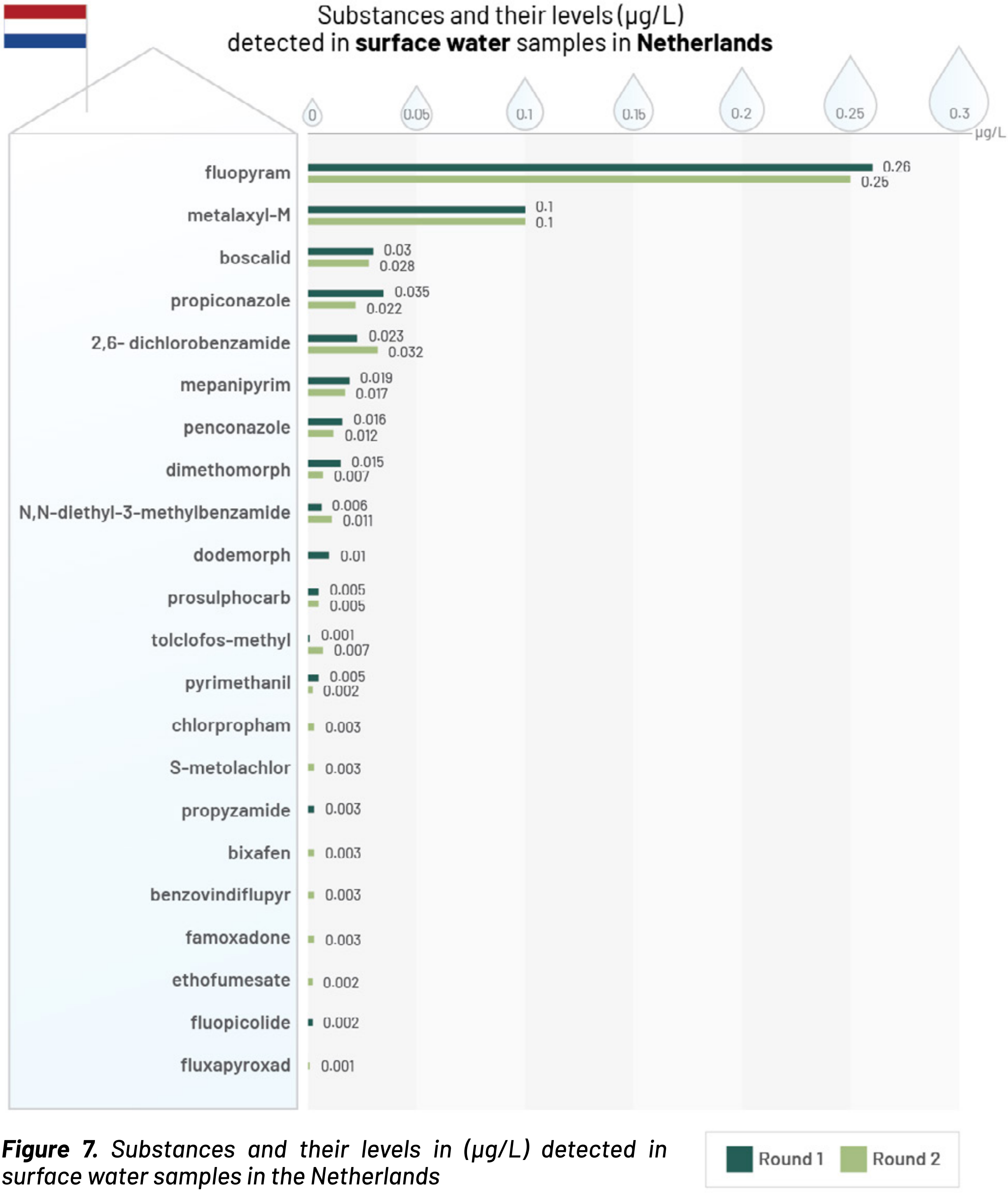


***Figure 7.** Substances and their levels in (µg/L) detected in surface water samples in the Netherlands*

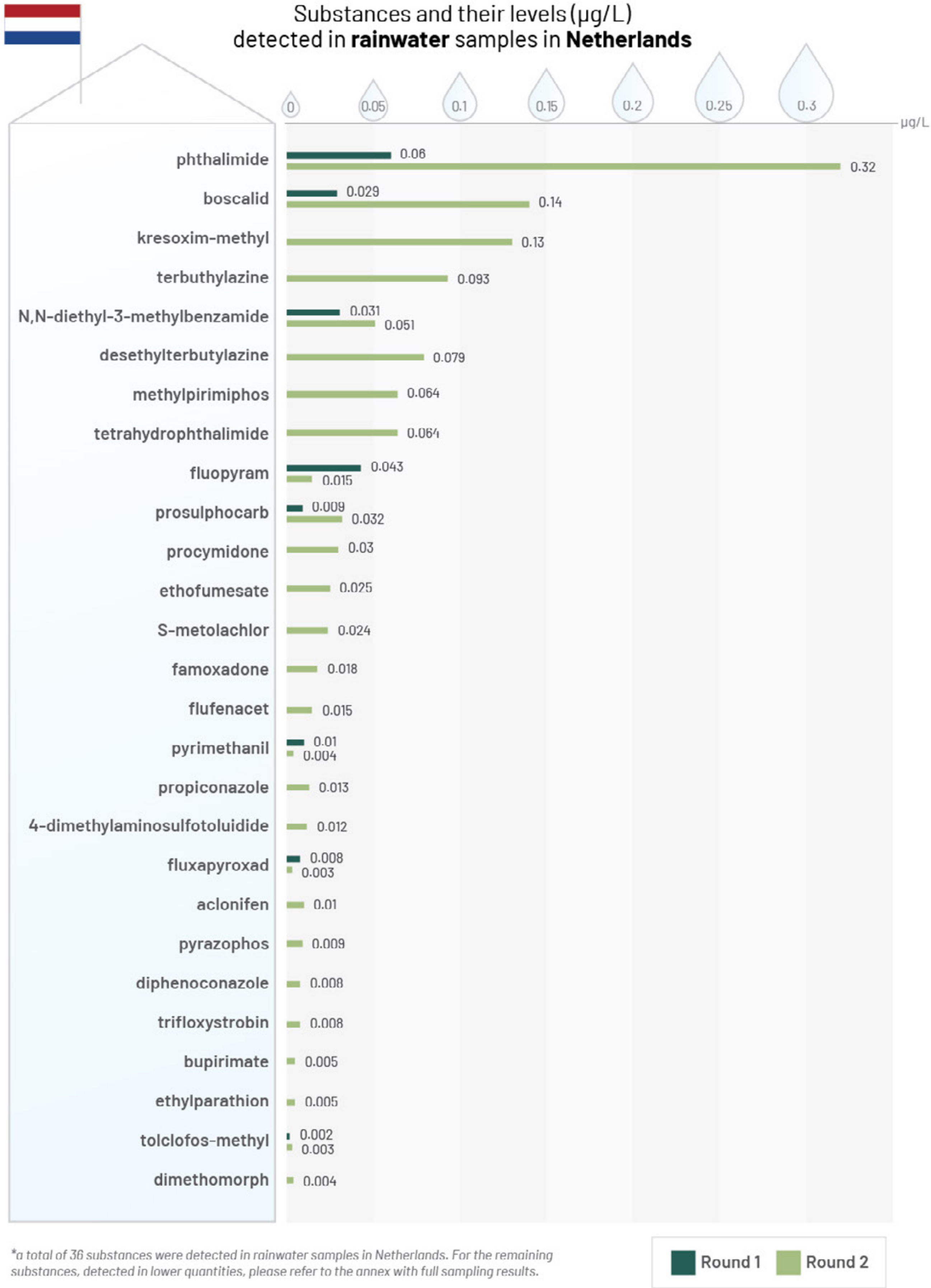


***Figure 8.** Substances and their levels in (µg/L) detected in rainwater samples in the Netherlands*

Indeed, based on information from the Dutch Pesticide Atlas, of the 42 substances found in our study, 13 substances (boscalid, cyflufenamide, dodemorph, diphenoconazole, dimethomorph, fluopyram, kresoxim-methyl, mepanipyrim, metalaxyl (group), metconazole, metrafenone, penconazole, propiconazole) are highly up to strongly correlated to greenhouses and 3 (fluxapyroxad, propyzamide, pyrimethanil) are simply correlated.

The samples were taken at the end of April (round 1) and the end of June (round 2) with an interval of almost 9 weeks. In the surface water sample taken in April out of the 15 substances detected, 2 were banned substances (propiconazole and the metabolite 2,6- dichlorobenzamide of the banned parent substance dichlobenil). These substances are still detected even though they have been used in agriculture for a long time. In the surface sample taken in June, out of the 19 substances detected, 4 were banned substances (chlorpropham, famoxadone, propiconazole and the metabolite 2,6- dichlorobenzamide). Furthermore, the substances fluopyram, prosulfocarb, pyrimethanil, toclofos-methyl, tetrahydrophthalimide (a metabolite of folpet) and N,N-diethyl-chlorpropham, famoxadone,3-methylbenzamide (DEET) were found in all surface and rainwater samples. The PFAS substance fluopyram (0.26 µg/l and 0.25 µg/l) exceeded the limit for drinking water in both surface water samples, while metalaxyl-M (0.1 µg/l) just reached the limit for drinking water.

In the rainwater sample of June, the concentration of one found pesticide (ethylparathion) is equal to the AA-EQS of 0.005 µg/L. The banned pesticide famoxadone exceeds the AA-EQS, 2 times and methylpirimiphos 128 times. The substance boscalid (0.14 µg/L) exceeded the limit for drinking water in the sample taken in June.

Finally, it is important to consider that this study was not able to investigate the air ambient and the seasonal fluctuation of pesticides in rainwater and surface water for one year. Nevertheless, based on the sampled location with only greenhouses and within 5 km of open fields with crop production, the results of our limited study indicate an unacceptable pollution of the environment linked to pesticide use in greenhouse farming.

iii) Results in Germany

In Germany, a total of 36 pesticides were detected across all samples. In rainwater, 23 different pesticides were detected, with 20 active substances per sample on each of the sampling rounds, indicating atmospheric pollution from pesticides used in the area. This high number alone is problematic due to possible cocktail effects and indicates intensive use of pesticides. The total level of pesticides was overall lower in Germany. Nevertheless, the levels still exceeded the proposed EU threshold of 0.5 µg/L for surface water in all samples but one (surface water, round 2).

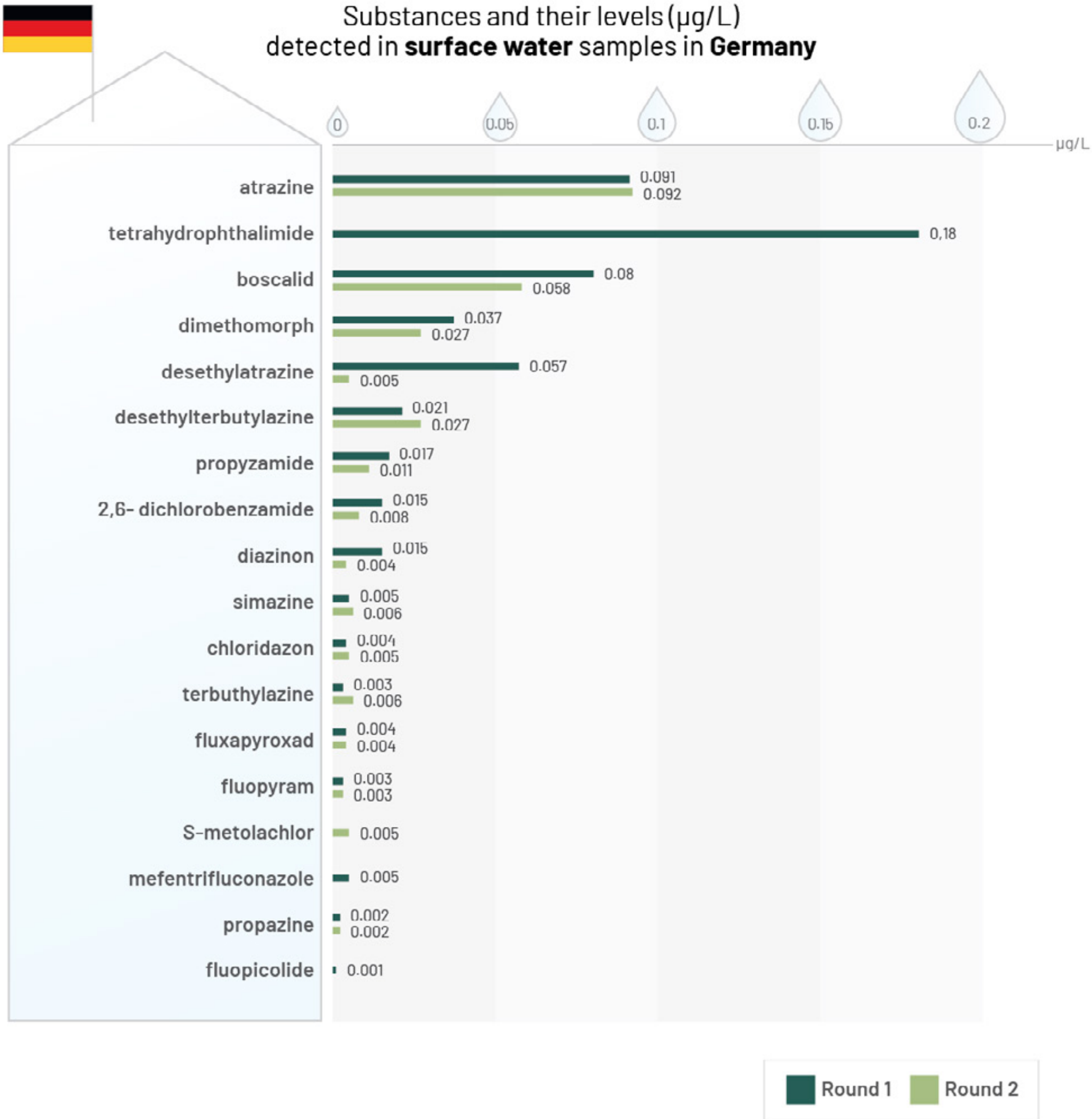


Figure 9. *Substances and their levels in (µg/L) detected in surface water samples in Germany*

Greenhouses: closed space or not?

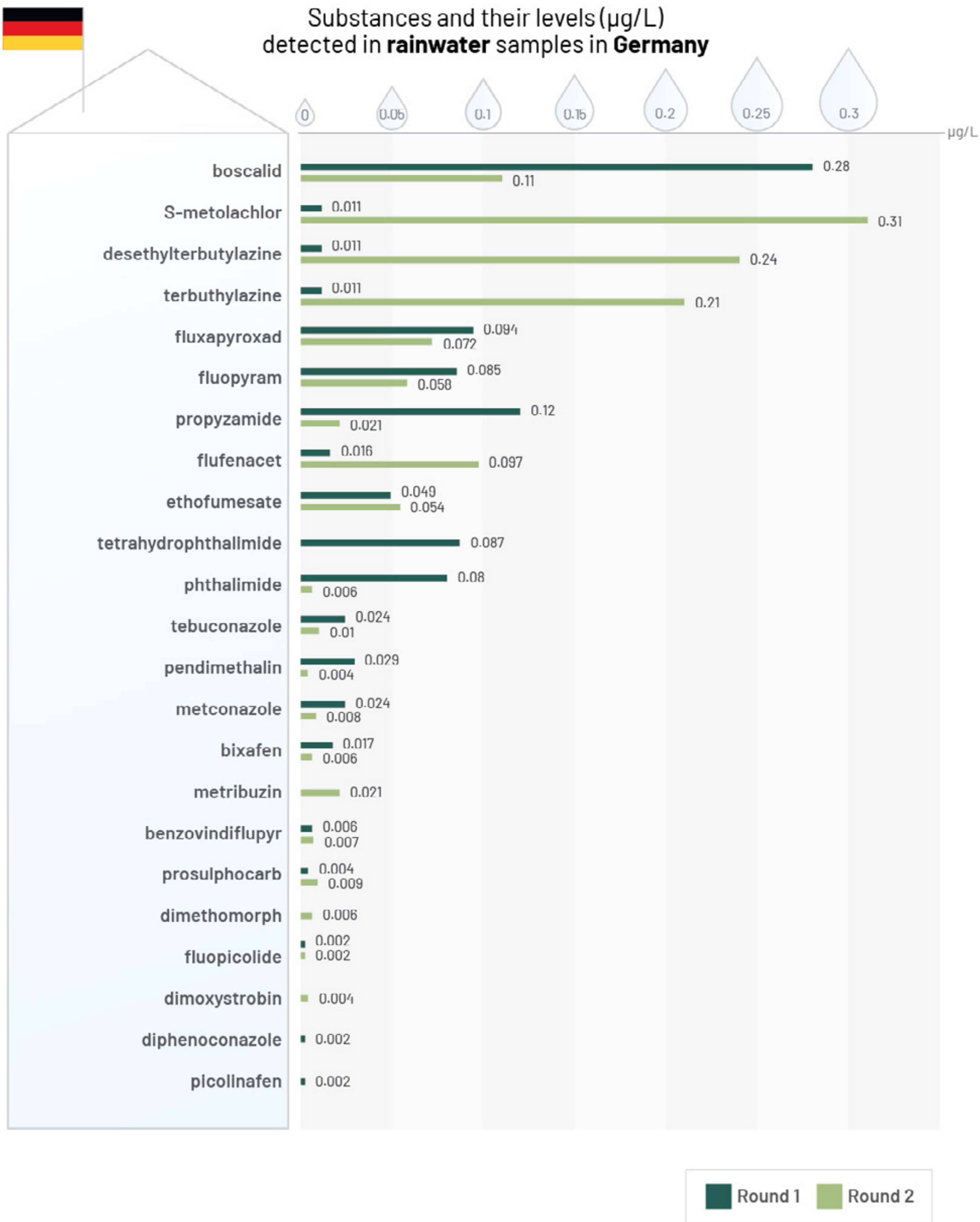


Figure 10. *Substances and their levels in (µg/L) detected in rainwater samples in Germany*

Boscalid was detected in relatively high levels in both rainwater and surface water samples. In rainwater samples, levels reached 0.28 and 0.11 µg/L in rounds 1 and 2 respectively. Other pesticides with high concentrations in rainwater were S-metolachlor (0.31 µg/L round 2), desethylterbutylazine (0.24 µg/L round 2) and terbuthylazine (0.21 µg/L round 2). All these exceeded the drinking water EU limit for pesticides of 0.1 µg/L. Comparatively high concentrations were found for the fungicides fluopyram (0.085 µg/l), which is a PFAS substance and fluxapyroxad (0.094 µg/l). Both active ingredients are approved in products for growing eggplants in greenhouses, fluxapyroxad is also approved for strawberry cultivation under glass. It is therefore at least conceivable that the findings in the water samples originate from such uses. One result of the herbicide flufenacet at 0.098 µg/l clearly exceeded the national annual average environmental quality standard (AA-EQS) of 0.04 µg/l (OGewV, annex 6). At the time of the evaluation, 35 different products containing this active ingredient were approved for cereal cultivation in Germany.

In surface water samples, a total of 17 different pesticides were detected, 17 were found in the first sample in March (round 1), and 15 pesticides in May (round 2). In March, a comparatively high value of 0.18 µg/l was detected for tetrahydrophthalimide, which exceeds the drinking water limit of 0.1 µg/L. Tetrahydrophthalimide is a metabolite of the fungicide captan, which is classified as a Highly Hazardous Pesticide (HHP) in the PAN International List of HHPs. Captan, which causes chronic toxicity to a wide range of non-target species, is among others that are approved in Germany for the cultivation of strawberries and ornamental plants in greenhouses. It also can be noted that boscalid residues were found in concentrations of 0.08 and 0.058 µg/l in the surface water. This fungicide is often used in glasshouses and is still approved in Germany for glasshouse application in strawberries, lettuce, herbs, beans and ornamentals. Dimethomorph – a fungicide classified as a reproductive toxicant pesticide 9R1b) and identified by EFSA as an endocrine disruptor to humans and wild animals – was detected in surface water at concentrations of 0.027 and 0.037 µg/L. Finally, it is remarkable that even more than 30 years after the ban in Germany, the herbicide atrazine could still be measured in the small stream in both samples in concentrations of around 0.09 µg/l.

iii) Results in Spain

In Spain only surface water samples were collected in April and May 2023. In the first water sample, eight pesticide active substances were detected out of the 160 tested, while in the second sample, 23 pesticides were found. The total level of pesticides was 1.37 µg/L in sampling round 1 and 5.9 µg/L in round 2. Therefore, Spain's samples exceeded the proposed threshold for total levels of pesticides of 0.5 µg/L approximately 2.7 times and 12 times, respectively.

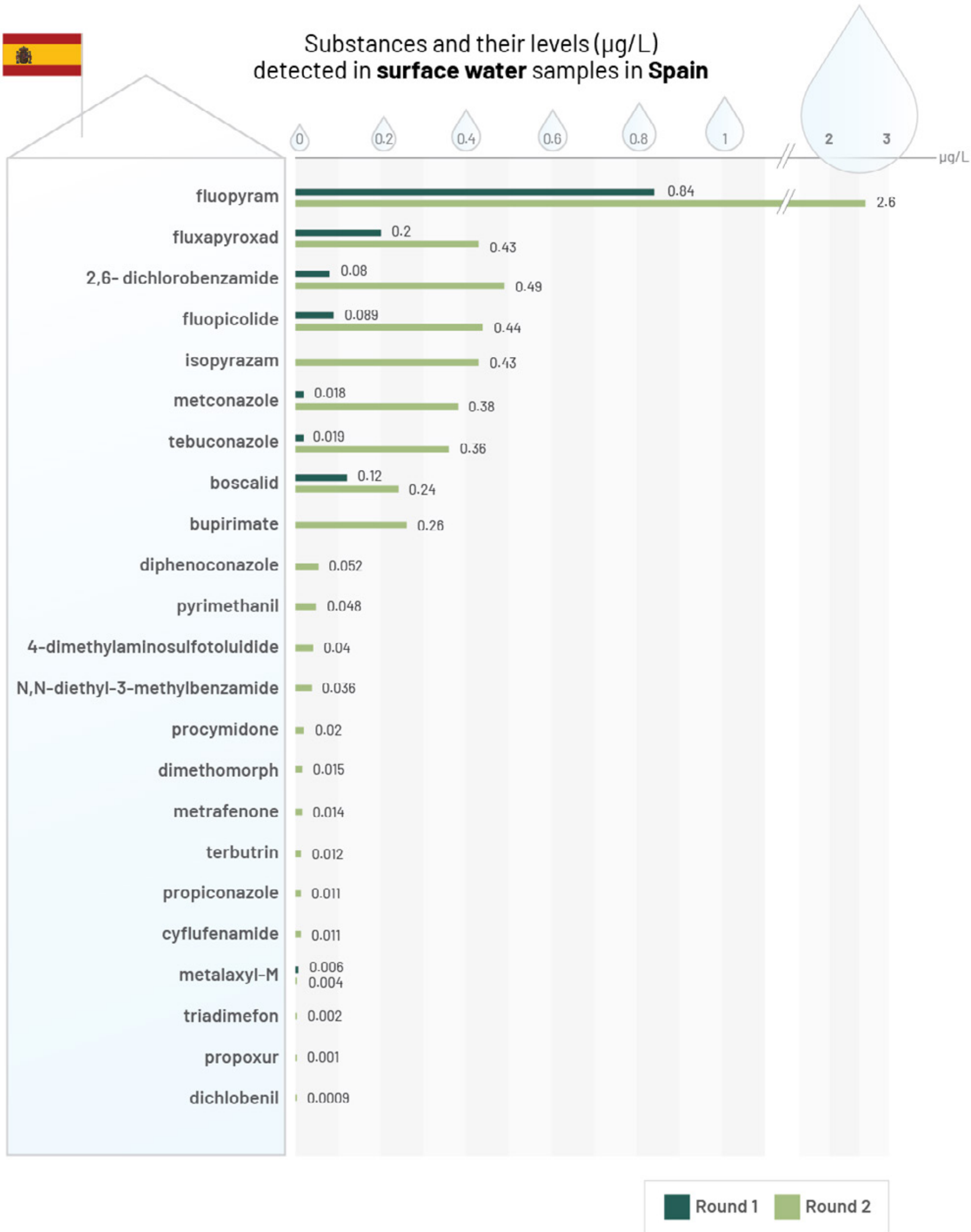


Figure 11. *Substances and their levels in (µg/L) detected in surface water samples in Spain*

The PFAS pesticide fluopyram was on the top of the list of pesticides detected, followed by fluxapyroxad, 2,5- dichlorobenzamide (of the banned parent substance dichlobenil) and PFAS substance fluopicolide. The azole pesticides metconazole and tebuconazole, classified as suspected to be toxic to reproduction and boscalid, which is an endocrine disruptor, were also detected in both samples. Finally, it is important to note that some of the other pesticides detected, such as the banned isopyrazam, have a toxicological profile of high concern, being classified by ECHA (European Chemicals Agency) as carcinogenic category 2 and toxic for reproduction 1B.

If the number of pesticides found is high enough to answer the raised question of the theory of emission-free greenhouses and the EU legal standards applicable to them, it is even more worrying that banned pesticides were detected across both rounds of sampling. The origin of these unauthorised pesticides cannot be determined from the limited information available, as even the Spanish competent authority, the Ministry of Agriculture, Fisheries and Food, seems to be unaware of the type of pesticides and their quantities used annually in this region (Almeria). However, the presence of banned pesticides could be explained by historical contamination, which must be remedied, or by the illegal use of banned substances, which must be prosecuted and eradicated.

3.3. The differences in the greenhouses' legal definition: which should apply?

Based on the greenhouse definition of Article 3(27) and Article 6, which allows the application of restrictions and conditions, the Commission has been authorising the use of substances which would be too toxic to be used in open fields to be re-approved under a restriction of use to (permanent) greenhouses. However, the definition of greenhouses in Article 3(27) does not reflect the reality of the situation, as pesticides used in greenhouses are emitted outside of these covered structures into the environment.

Countless studies and reports highlight substantial pieces of evidence establishing that, in practice, emissions from greenhouses occur (see part 3.1). More importantly, the 2014 EFSA guidance document on greenhouses explicitly studies how pesticide emissions from greenhouse structures should be assessed. The EFSA even concludes that *"extensive efforts shall be put towards understanding the routes of exposure from greenhouses to the outside environment within a holistic context (e.g.,* *including indirect transport via air and water, considering the specific infrastructure, practices, etc), in order to develop efficient mitigation strategies specific to greenhouse production and pesticide use"*[23].

Additionally, EFSA's 2012 scientific opinion precisely notes that, in the case of air emissions, *"the emitted amounts from covered crops are of the same order of magnitude as emissions from open field cultivations"*. It further emphasises that *"as emissions to air are expected to occur after the application of plant protection products to covered crops, the Panel then recommends assessing the potential for long-range transport, via estimation and evaluation of the half-life of the substance in air, as is required for open field applications"*. In the case of surface water, it recommends *"collecting information on the disposal of condensation and to include this emission route in the risk assessment methodology when this route is not excluded by law"*. Finally, the document concludes that *"emissions from covered crops to the environmental receptors air, groundwater, and surface water do occur and that these cannot be ignored when evaluating the authorisation of PPPs"*.

These developments directly oppose the definition of Article 3(27), raising questions and creating legal uncertainty.

- Does that mean that in practice no greenhouses fulfil the conditions established by law?
- Are approvals of active substances based on such a definition unlawful?
- Which definition should prevail?

To these questions, the EFSA partially answers, *"These systems do not fulfil the condition of preventing the release of PPPs into the environment and therefore do not fall under what would be defined as a -greenhouse according to the definition of Regulation (EC) 1107/2009. Therefore, it is necessary to clarify under which scenarios the different protected crops fall under the definition of greenhouse according to EU regulation"*[24].

On the conflict of law, even though soft law (such as EFSA's guidance documents) is by definition not legally binding, the Court of Justice of the European Union (CJEU) distinguishes between binding legal force and the legal effect of a soft law instrument (CJEU, Case 22/70 (1971), para.42). The Court follows a substantive approach in this respect, focusing on the wording, context,

[23] EFSA Guidance Document on clustering and ranking of emissions of active substances of plant protection products and transformation products of these active substances from protected crops (greenhouses and crops grown under cover) to relevant environmental compartments, 20 March 2014 <https://www.efsa.europa.eu/en/efsajournal/pub/3615>

[24] Ibid, supra 23.

substance, and intention of the author of an EU act (Case T-721/1 (2015), para. 18) rather than on its form and nature (CJEU, Case 22/70 (1971), para.42) to determine whether it produces legal effects. In such a context, although non-binding by nature a guidance document should not be ignored as it provides interpretation to the main legal act. Moreover, should also be taken into account the implementation of the precautionary principle. According to the precautionary principle[25], the most protective norm should prevail, especially when risks (critical areas of concern) have been identified. EFSA Guidance document on greenhouses provides further details and explanations as well as recommends further investigation should not be ignored. Consequently, the (re) approval procedure of active substances with a restriction to (permanent) greenhouses, should acknowledge pesticide emissions into the environment.

3.4. Is the reapproval of otherwise banned pesticides in greenhouses legally valid? The case of bifenazate

Bifenazate is an insecticide that was reapproved in May 2022 (Regulation 2022/698) with a restriction to non-edible plants, and greenhouses. As per the re-approval procedure, EFSA published its first Peer review on the assessment of the active substance bifenazate in 2017. In its conclusions, EFSA identified multiple data gaps and issues that could not be finalised as well as critical areas of concern, among them: 1) A high risk to birds and mammals via long-term exposure was found for all the representative uses, 2) A high risk to non-target arthropods was found for all the representative uses. Instead of a non-renewal, the Commission requested an updated peer review by EFSA concerning the exposure and risk assessments for bifenazate, which EFSA published in 2021. In the meantime, the approval of bifenazate was extended by the European Commission and Member States 6 times, for one year each time, until 2022, keeping this hazardous substance in the market. EFSA 2021's peer review also identified several data gaps and issues that could not be finalised, as well as one critical area of concern related to a high risk to birds via long-term exposure for all the representative uses, which include uses in greenhouses.

[25] The precautionary principle is an approach to risk management, where if it is possible that a given policy or action might cause harm to the public or the environment and if there is still no scientific agreement on the issue, the policy or action in question should not be carried out.

In Regulation 2022/698, re-approving the active substance bifenazate, the European Commission states that *"the restriction to use only in greenhouses will ensure that birds are not exposed to bifenazate (Critical area of concern) [...] and will also prevent exposure to those non-target organisms as well as in drinking water"*. However, as previously mentioned, greenhouses are not a closed space and the release of the active substances outside into the environment happens regularly.

In this case, by renewing the approval of the active substance bifenazate based on the concept that greenhouses will prevent the release of pesticides, the European Commission ignored the precautionary principle, the required high level of protection of human health and the environment, and Article 4 of Regulation 1107/2009. This is especially true since the EFSA had identified critical areas of concern in both its Peer reviews (2017 and 2021). The identification of critical areas of concern as well as unfinished risk assessment should lead to a non-approval of the substance, as the protection of the environment and its ecosystems cannot be guaranteed. Indeed, re-approving the active substance bifenazate, while areas of concern have been identified, is a breach of the environmental and health criteria laid down in Article 4, § 1 to 3 of Regulation 1107/2009. More precisely, the Commission appears to be breaching the following criteria: on the condition of using current scientific knowledge, on the point that no immediate or delayed harmful effects should occur to animals or humans, and no unacceptable effects to the environment.

Furthermore, it appears that the risk assessment methodology for greenhouses does not correctly allow the identification of one or more representative uses of at least one plant protection product as required by Regulation 1107/2009. For some parts of the risk assessment, the model used by EFSA was the Greenhouses Emissions Model - version 3.3.2. (hereinafter "GEM Model"). However, this model reflects only Dutch conditions for "high-technology greenhouses". Indeed according to EFSA *"It should be noted that the GEM model reflects Dutch conditions for high technology (permanent) greenhouses, and it may not be representative for the range of these types of structures present in all EU territories. For soil-bound uses, the assessment is still based on field uses also for the lowest application rate"*. It therefore appears that the GEM Model cannot be considered suitable for the assessment of substances to be re-approved under restriction in permanent greenhouses at the EU Level. By doing so, the re-approval of the active substance bifenazate, based on such a risk assessment, does not meet the environmental and health criteria laid down in Article 4, § 1 to 3 of Regulation 1107/2009. Additionally, this behaviour illustrates a lack of consideration for all scientific data, including peer-reviewed scientific literature, as reminded by the [EU Court of Justice judgement C-616/17][26]. Such incomplete risk assessment thus breaches

[26] §94: With that in mind, it is the duty of the competent authorities, in particular, to take account of the most reliable scientific data available and the most recent results of international research and not to give in all cases preponderant weight to the studies provided by the applicant.

the requirements of Article 191(2) of the TFEU, the precautionary principle (reflected in Article 1(4) Regulation 1107/2009). As specified by the CJEU in the same case *"a correct application of [the precautionary principle] in the area covered by Regulation No 1107/2009 presupposes, first, identification of the potentially negative consequences of the use of the active substances and plant protection products falling within its scope, and, second, a comprehensive assessment of the risk based on the most reliable scientific data available and the most recent results of international research"* (Case C-616/17, (2019), point 46).

Finally, Articles 1(3) and (4) Regulation 1107/2009 states that the Regulation *"aims to ensure a high level of protection of both human and animal health and the environment and to improve the functioning of the internal market through the harmonisation of the rules on the placing on the market of plant protection products while improving agricultural production. The provisions of this Regulation are underpinned by the precautionary principle in order to ensure that active substances or products placed on the market do not adversely affect human or animal health or the environment"*. By proceeding with renewing such an approval, the Commission empties Regulation 1107/2009 of its substance and legal value.

The wrongful reasoning of the Commission can be summarised by the following: in its final review report, the European Commission states that *"In its conclusion, EFSA identified the following point as a critical area of concern, but it does not prevent the renewal because [...] use in permanent greenhouses (as defined in Art 3.27 of the Regulation (EC) No 1107/200912) will not lead to exposure of these non-target species in the environment"*. From our perspective, the identification of critical areas of concern as well as unfinished risk assessment should lead to a non-approval of the substance according to Regulation 1107/2009. In the case of bifenazate and the identified critical areas of concern, limiting its use in permanent greenhouses fails to address the risk as greenhouses are never completely closed systems.

By proposing to re-approve the active substance Bifenazate despite the identified critical areas of concern, several unfinished risk assessment issues and data gaps as well as the knowledge that greenhouses release substances into the environment (see Chapter 2, 2.1.1), the Commission, therefore, breaches Regulation 1107/2009 as well as the precautionary principle.

Box 4: Why is Regulation 2022/698 on the approval of bifenazate to be used in greenhouses only unlawful?

Regulation 2022/698 (re)approving the active substance bifenazate is unlawful as per:

- EFSA 2014 Guidance Document's conclusion recommends further developing exposure scenarios for greenhouses and walking tunnels and acknowledging pesticide emissions from greenhouses. This is essential since no studies were carried out in the risk assessment of bifenazate to confirm that no leakage/ emissions into the environment will happen when its use is restricted in permanent greenhouses only;

- Article 4(1) to (3), Regulation 1107/2009
  - on the condition of using current scientific knowledge; as available and recent independent scientific studies such those presented in this report were not incorporated in the risk assessment.
  - on the point that no immediate or delayed harmful effects should happen to animals or humans, and on the point of no unacceptable effects to the environment, taking into consideration biodiversity and ecosystems; as greenhouses are not a closed space preventing the release of pesticides into the environment.

- Article 1(3) Regulation 1107/2009 states that the Regulation *"aims to ensure a high level of protection of both human and animal health and the environment and to improve the functioning of the internal market through the harmonisation of the rules on the placing on the market of plant protection products while improving agricultural production"*; since greenhouses are not a closed space preventing the release of pesticides into the environment, the high level of protection is not ensured.

- Article 1(4) Regulation 1107/2009 *"The provisions of this Regulation are underpinned by the precautionary principle in order to ensure that active substances or products placed on the market do not adversely affect human or animal health or the environment"* and TFEU Article 191(2); by proposing to re-approve the active substance bifenazate despite the identified critical areas of concern, several unfinished risk assessments and data gaps as well as the knowledge that greenhouses release substances into the environment.

4. Conclusions and Policy Recommendations

Pesticides used in greenhouses result in emissions into the environment, as reported in the scientific literature and confirmed in the report by the rain and surface water samples collected near greenhouse fields. Not only does this prove that further work is necessary to understand the emission pathways from greenhouses, but, more importantly, also that the nature of these pesticides as well as their concentrations pose a risk to various species and ecosystems, as well as to human health.

The practice of approving active substances that do not fulfil the conditions required by Regulation 1107/2009, with a restriction for use in greenhouses assuming that they will not be released into the environment without a proper risk assessment should stop. It is now time for the European Institutions to take action and thoroughly address the issue of pesticide emissions from greenhouses. Evidently, greenhouses are not closed spaces that truly prevent the release of PPPs into the environment. With the number of covered crop production bound to rise over the years, such active substances cannot continue to be used and approved.

In light of the findings from the report, and recognising the importance of protecting our European waters, human health, the environment and its ecosystems, we recommend the following:

- **Greenhouses should not be further considered closed spaces where emissions can be controlled and prevented**. Particularly it should be assumed that:
  - Bees and other arthropods are not protected and/or exposed;
  - birds are not protected;
  - surface waters and aquatic organisms are not protected (as illustrated by the conducted surface water samples);
  - groundwaters and soils are not protected;
  - air pollution is not prevented (as illustrated by the conducted rainwater samples);
  - humans may still be exposed via contaminated air, water and food.
- **Active substances that do not meet the conditions required by Regulation 1107/2009 should be banned for all uses**, and not (re)-approved for use in greenhouses, permanent or not.
- **Immediately withdraw the currently approved active substances** that are considered toxic in light of Regulation 1107/2009's criteria, and that have been restricted to greenhouses only.

Conclusions and Policy Recommendations

- **The European Commission and Member States need to develop a better understanding of pesticide emissions routes in greenhouses and should provide an adequate risk assessment on the use of pesticides in greenhouses**, taking into account their emissions into the environment and potential impacts on human health and environmental species.

- **A correct definition of greenhouses should be provided, to ensure adequate and harmonised risk assessment for this area of pesticide application in the context of active substance approval**, product authorisation and mutual recognition of product authorisations.

- **Acknowledge that humans and the environment are exposed to mixtures of pesticides and implement an additional safety factor** (mixtures assessment factor) of 10 or higher when considering safe thresholds of individual pesticides for the environment and human health.

Contact: Manon Rouby, Policy Officer/ Legal Adviser, Greenhouses - water pollution, manon@pan-europe.info
Hans Muilerman, Chemicals Coordinator, Pesticides & Alternatives, hans@pan-europe.info

The contents of this publication are the sole responsibility of PAN Europe and do not necessarily reflect the opinion of the European Union.

References

The Free Dictionary, "greenhouse" https://www.thefreedictionary.com/Greenhouse+technology (accessed, 1st December 2022).

NSW, Department of Primary Studies https://www.dpi.nsw.gov.au/agriculture/horticulture/greenhouse/structures-and-technology/types#:~:text=Shape,%2C%20Sawtooth%2C%20Skillion%2C%20Tunnel (accessed, 1st December 2022).

Regulation (EC) No 1107/2009 of the European Parliament and the Council of 21 October 2009 concerning the placing of plant protection products on the market and repealing Council Directives 79/117/EEC and 91/414/EEC https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:309:0001:0050:en:PDF

Pesticide Action Network Europe, (May 31, 2023), 'PAN Europe requests to end the use of very toxic pesticides in greenhouses' https://www.pan-europe.info/blog/pan-europe-requests-end-use-very-toxic-pesticides-greenhouses

Pesticide Action Network Europe, (April 8, 2022), 'European Commission bans bee-toxic Sulfoxaflor insecticide: One less bee-killing neonicotinoid in the EU' https://www.pan-europe.info/press-releases/2022/04/european-commission-bans-bee-toxic-sulfoxaflor-insecticide-one-less-bee

Schäffer A. et al (2018,Diskussion Nr. 16), 'Der stumme Frühling – Zur Notwendigkeit eines umweltverträglichen Pflanzenschutzes' https://www.leopoldina.org/uploads/tx_leopublication/2018_Diskussionspapier_Pflanzenschutzmittel.pdf

Commission Implementing Regulation (EU) 2022/698 of 3 May 2022 renewing the approval of the active substance bifenazate in accordance with Regulation (EC) No 1107/2009 of the European Parliament and of the Council concerning the placing of plant protection products on the market, and amending the Annex to Commission Implementing Regulation (EU) No 540/2011 https://eur-lex.europa.eu/eli/reg_impl/2022/698/oj

Roseth R., Haarstad K. (2010), Pesticide runoff from greenhouse production. Water Sci Technol. https://pubmed.ncbi.nlm.nih.gov/20351415/

Teunissen, R.J.M., Ministerie van Verkeer en Waterstaat, Rijkswaterstaat, Rijksinstituut voor Integraal Zoetwaterbeheer en Afvalwaterbehandeling (RWS RIZA); R.J.M. Teunissen (2005), 'Emissies van gewasbeschermingsmiddelen uit de glastuinbouw' https://open.rijkswaterstaat.nl/open-overheid/onderzoeksrapporten/@20145/emissies-gewasbeschermingsmiddelen/

Duyzer, J. et al., (2004), De blootstelling van omwonenden van kassen aan gewasbeschermingsmiddelen via de lucht . TNO MEP. Rapportnr. 2004/517. Apeldoorn.

Lieffijn H. et al., (2000), Schatting van de emissie van bestrijdingsmiddelen uit de glastuinbouw. Een nulmeting (1997) ten behoeve van het Milieuconvenant Glastuinbouw en Milieu. Expertisecentrum LNV, Onderdeel Landbouw. Expertisecentrum LNV (249) https://library.wur.nl/WebQuery/titel/984462

Bas van de Wal, Hoogheemraadschap van Delfland, in: 'Leve de sloot', H.Muilerman & E. Matser, Stichting Natuur en Milieu, 1994. https://www.bibliotheek.nl/catalogus/titel.12615676X.html/leve-de-sloot-/

Boye, K., Boström, G., Jonsson, O., Gönczi, M., Löfkvist, K., & Kreuger, J. (2022). Greenhouse production contributes to pesticide occurrences in Swedish streams. Science of The Total Environment, 809, 152215. https://www.sciencedirect.com/science/article/pii/S0048969721072910

Haarstad K., Bavor J. and Roseth R. (2012), Pesticides in Greenhouse Runoff, Soil and Plants: A Screening. The Open Environmental & Biological Monitoring Journal (5), 1-13. https://benthamopen.com/contents/pdf/TOEBMJ/TOEBMJ-5-1.pdf

References

Hoogheemraadschap van Delfland. (2023), Waterkwaliteitsrapportage 2022. https://www.hhdelfland.nl/ontdek-werk/schoon-gezond-water/waterkwaliteitskaart

Silva V., Mol HGJ., Zomer P., Tienstra M., Ritsema CJ., Geissen V. (2019). Pesticide residues in European agricultural soils - A hidden reality unfolded. Sci Total Environ. https://pubmed.ncbi.nlm.nih.gov/30759587/

Hofmann, F., Wosniok, W., Schlechtriemen, U., & Kohlschütter, N. (2021). Pesticides and pesticide-related products in ambient air in Germany. Environmental Sciences Europe, 33(1), 1-21. https://enveurope.springeropen.com/articles/10.1186/s12302-021-00553-4

Socorro, J., Durand, A., Gligorovski, S., Wortham, H., & Quivet, E. (2016). The persistence of pesticides in atmospheric particulate phase: An emerging air quality issue. Scientific Reports, 6(1), 1-7. https://www.nature.com/articles/srep33456#citeas

López A, Yusà V, Muñoz A, Vera T, Borràs E, Ródenas M, Coscollà C. (2017), Risk assessment of airborne pesticides in a Mediterranean region of Spain. Sci Total Environ. https://pubmed.ncbi.nlm.nih.gov/27664759/

Jenny Kreuger, Bodil Lindström (2019), Long-term monitoring of pesticides in air and atmospheric deposition in Sweden. Swedish University of Agricultural Sciences (SLU). https://www.slu.se/globalassets/ew/org/centrb/ckb/publikationer/presentationer/presentation-luft_kreuger-iupac-2019.pdf

Doan Ngoc, K., Van den Berg, F., Houbraken, M., & Spanoghe, P. (2015). Volatilisation of pesticides after application in vegetable greenhouses. Science of The Total Environment, 505, 670-679. https://www.sciencedirect.com/science/article/abs/pii/S0048969714014740

De Poorte, J. and C.J. Van Leeuwen., (1997). How toxic is rain? H2O 30, 168-171.

Faasen J., RIZA, (1992), Landbouwbestrijdingsmiddelen in oppervlaktewater, een situatieschets. H20 (25), nr. 2 31.

EFSA (2010). Scientific Opinion on emissions of plant protection products from greenhouses and crops grown under cover: Outline for a new guidance. EFSA Journal, 8(4), 1567. https://efsa.onlinelibrary.wiley.com/doi/abs/10.2903/j.efsa.2010.1567

EFSA (2012). Scientific Opinion on clustering and ranking of emissions of plant protection products from protected crops (greenhouses and crops grown under cover) to relevant environmental compartments. EFSA Journal, 10(3), 2611. https://efsa.onlinelibrary.wiley.com/doi/10.2903/j.efsa.2012.2611

EFSA (2014). EFSA Guidance Document on clustering and ranking of emissions of active substances of plant protection products and transformation products of these active substances from protected crops (greenhouses and crops grown under cover) to relevant environmental compartments. EFSA Journal, 12(3), 3615. https://efsa.onlinelibrary.wiley.com/doi/10.2903/j.efsa.2014.3615

European Commission, Summary Report of the Standing Committee on Plants, Animals, Food and Feed, (2015), (Section Phytopharmaceuticals - Plant Protection Products - Legislation). https://circabc.europa.eu/w/browse/2e04b70e-4392-49f3-91a9-0d99b25f0422

European Commission, Commission Guidance Document SANCO/12184/2014 – rev. 5.1 (2015), Guidance Document on clustering and ranking of emissions of plant protection products and transformation products of these active substances from protected crops (greenhouses and crops grown under cover) to relevant environmental compartments. https://food.ec.europa.eu/system/files/2016-10/pesticides_ppp_app-proc_guide_fate_efsa_protected-crops.pdf

References

European Commission, Commission Notice (2015), Technical guidance on the interpretation of points 3.6.3. to 3.6.5, and 3.8.2 of Annex II to Regulation (EC) No 1107/2009, in particular regarding the assessment of negligible exposure to an active substance in a plant protection product under realistic conditions of use. https://food.ec.europa.eu/system/files/2017-02/adv-grp_wg_20150625_tech-guidance.pdf

Wageningen University & Research, Areaal tuinbouw onder glas en aantal bedrijven, https://agrimatie.nl/SectorResultaat.aspx?subpubID=2232&sectorID=2240 (accessed January 2023).

Criado & Lopez, Soluciones Agrotextiles a tu Medina, (2022). 'Récord en superficie de invernaderos de Almería, 31.614 hectáreas, mayor concentración mundial'. https://criadoylopez.com/record-en-superficie-de-invernaderos-de-almeria-31-614-hectareas-mayor-concentracion-mundial/

Statistisches Bundesamt, 'Bush berry yields in 2021 up 27% on 2020', Press release No. 062 of 14 February 2022. https://www.destatis.de/EN/Press/2022/02/PE22_062_412.html

Statistisches Bundesamt, (2021), 'Land- und Forstwirtschaft, Fischerei Landwirtschaftliche Bodennutzung - Anbau von Zierpflanzen -', Fachserie 3 Reihe 3.1.6. https://www.destatis.de/DE/Themen/Branchen-Unternehmen/Landwirtschaft-Forstwirtschaft-Fischerei/Obst-Gemuese-Gartenbau/Publikationen/Downloads-Gartenbau/zierpflanzen-2030316219004.pdf;jsessionid=748A128C4E8AA20D5F3BA103A2B7717F.live731?__blob=publicationFile

Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz (BMELV), (2010), 'Gute fachliche Praxis im Pflanzenschutz'. https://www.nap-pflanzenschutz.de/fileadmin/SITE_MASTER/content/Service/GutePraxisPflanzenschutz2010.pdf

Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz (BMELV), Definition des Anwendungsbereichs "Gewächshaus". https://www.bvl.bund.de/DE/Arbeitsbereiche/04_Pflanzenschutzmittel/03_Antragsteller/04_Zulassungsverfahren/03_Wirksamkeit_Anwendung/psm_definition_gewaechshaus_basepage.html?nn=11010962 (accessed February 2023).

SPF Santé Publique, Sécurité de la Chaîne Alimentaire et Environnement (2017), 'Qu'est-ce qu'une culture sous protection ?'. V.1.0 (19/01/2017) https://fytoweb.be/sites/default/files/guide/attachments/quest-ce_quune_culture_sous_protection_1.pdf

EFSA (2017). Peer review of the pesticide risk assessment of the active substance bifenazate. EFSA Journal, 15(1), e04693. https://efsa.onlinelibrary.wiley.com/doi/full/10.2903/j.efsa.2017.4693

Alvarez, F. et al, (2021). Updated peer review of the pesticide risk assessment of the active substance bifenazate. EFSA Journal, 19(8), e06818. https://efsa.onlinelibrary.wiley.com/doi/10.2903/j.efsa.2021.6818

Judgment of the Court of 31 March 1971. - Commission of the European Communities v Council of the European Communities. - European Agreement on Road Transport. - Case 22-70. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A61970CJ0022

Order of the General Court (Second Chamber), 27 October 2015, Case T-721/14. https://curia.europa.eu/juris/document/document.jsf?text=&docid=171001&pageIndex=0&doclang=EN&mode=lst&dir=&occ=first&part=1&cid=376963

Judgement of the Court (Grand Chamber), 1 October 2019, Case C-616/17. https://curia.europa.eu/juris/document/document.jsf?text=&docid=218463&pageIndex=0&doclang=en&mode=lst&dir=&occ=first&part=1&cid=3776203

References

REGISTRATION REPORT Part B Section 8 Environmental Fate Detailed summary of the risk assessment, Product code: SHA 102000 B, Product name: BINDASS Chemical active substance: Bifenazate, 480 g/L, February 2022, Rapporteur Member State: Malta.

Directive (EU) 2020/2184 of the European Parliament and of the Council of 16 December 2020 on the quality of water intended for human consumption (recast) https://eur-lex.europa.eu/eli/dir/2020/2184/oj

Proposal for a Directive amending the Water Framework Directive, the Groundwater Directive and the Environmental Quality Standards Directive, 26 October 2023. https://environment.ec.europa.eu/publications/proposal-amending-water-directives_en

Maren Kruse-Plaß et al, (2021), Pesticides and pesticide-related products in ambient air in Germany. Environ Sci Eur 33:114. https://enkeltauglich.bio/wp-content/uploads/2021-Environmental_Sciences_Europe-3.pdf

Zaller,et al, (2022). Pesticides in ambient air, influenced by surrounding land use and weather, pose a potential threat to biodiversity and humans. Science of The Total Environment, 838. https://doi.org/10.1016/j.scitotenv.2022.156012

Atlas bestrijdingsmiddelen in oppervlaktewater, Samenvattingen, https://www.bestrijdingsmiddelenatlas.nl/samenvattingen (accessed August 2023).

Annexes

Annex 1. Partners in the water sampling

1. **Spain:** Ecologistas en Acción
2. **Germany:** Bündnis für eine enkeltaugliche Landwirtschaft e.V., Pesticide Action Network Germany
3. **Belgium:** Pesticide Action Network Europe
4. **The Netherlands:** Natuur en Milieufederatie Zuid-Holland, Pesticide Action Network Netherlands

Annex 2. Literature review and sampling methodology

1. Literature review methodology

In identifying sources for this literature review, multiple databases were used. Initially, Google Scholar was utilised to take a first sample of the type of articles to consider. Later, the main research was conducted using the database "PUBMED". The search terms selected for this literary analysis consisted of: "greenhouses, glasshouses, pesticides, emissions". Sources were analysed according to a number of criteria. First, the source had to be in line with the purpose of the literature review, to establish evidence of emissions of pesticides into the environment connected with greenhouse fields. Second, the source had to be a primary source of research. Third, the source had to be from a relevant scientific publication and, or peer-reviewed journal.

2. Sampling methodology

PAN Europe, together with its members and partners Ecologistas en Acción, PAN Germany, PAN Netherlands, Bündnis für eine enkeltaugliche Landwirtschaft e.V. and Natuur en Milieufederatie Zuid-Holland collected surface and rainwater samples across 4 countries in two rounds: one round of samples in April 2023 and another round of samples in May/ June 2023. Samples were taken by members and partners of PAN Europe (list of partners in Annex 1) from the Netherlands, Belgium Germany and Spain. Samples were then sent in cooling boxes with ice packs to the laboratory "Aqualysis" in Zwolle, the Netherlands, for analysis of a total of 159 active substances using the GCMS – bma approach as proposed by the laboratory.

Description of waterbodies and sampling locations

The samples collected and analysed for the purpose of this study originate from rivers and streams as well as puddles and rainwater collectors in proximity to greenhouses from 4 different European countries with relatively intense greenhouses production: the Netherlands, Germany, Belgium and Spain.

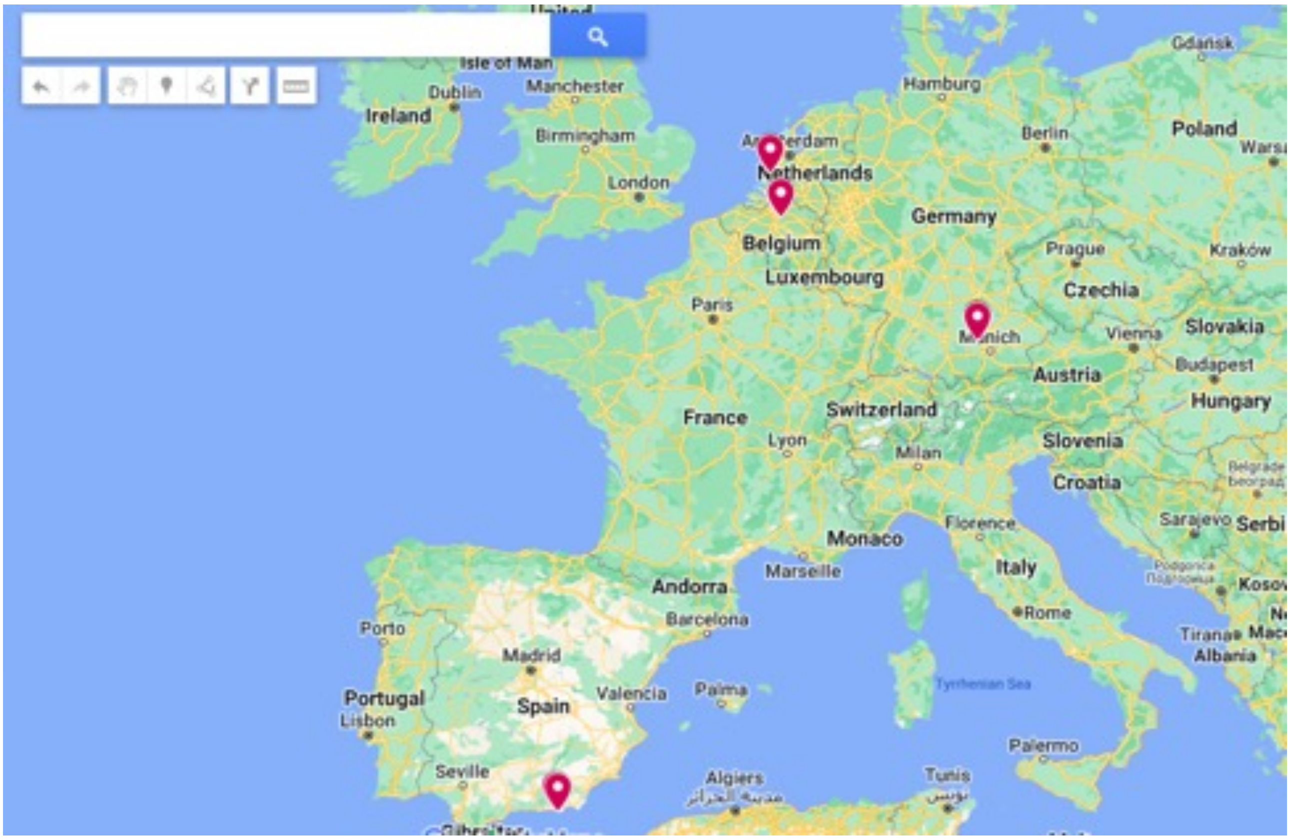
Table. *Collection sites of the water samples*

Surface water samples			
Country	**Water body**	**Size of river**	**GPS**
The Netherlands	Loopend Gat	Medium	Sampling 1 & 2 52.006712, 4.210837
Germany	Watercourse in the district of Aichach-Fried-berg, Bavaria	Small	District of Aichach-Friedberg, Bavaria[27]
Belgium	Dwersehagenloop	Small	Sampling 1 & 2 51.065161, 4.548317
Spain	Albufera Honda	Medium	36°45'19.9"N 2°56'47.1"W
Spain	No name	Small	36.714098, -2.840809

Rainwater samples			
Country	**Water body**	**Size of river**	**GPS**
The Netherlands	Rainwater collector	Medium	Sampling 1 & 2 Schepen 6, 2671 HN Naaldwijk, Netherlands
Germany	Puddle	Small	District of Aichach-Friedberg, Bavaria[28]
Belgium	Puddle	Small	51.063578, 4.548593
Belgium	Private Tank	Medium	51.061134, 4.550012

[27] In Germany, greenhouses are more dispersed in contrast to those in other countries. In order to ensure the anonymity of the farm, the exact location was not specified.

[28] Ibid, supra 25.



Location samples surface and rainwater. Map data

Surface and rainwater sampling location, Sint-Katelijne-Waver, Belgium

In the district of Aichach-Friedberg, Bavaria

Surface water sampling location, Boschpolder, the Netherlands

Surface water sampling location, round 2, Matagorda, Spain

Annex 3. Surface and rainwater sample results in µg/L, 2023

Round 1

Active Substance	BErw20230424	BEsw20230424	DErw20230424	DEsw20230424	NLrw20230428	NLsw20230428	SPsw20230425
atrazine	0.001			0.091			
chloridazon				0.004			
chlorpropham	0.002						
desethylatrazine				0.057			
diazinon				0.015			
2,6-dichlorobenzamide	0.15	0.83		0.015		0.023	0.08
dichlobenil	0.0007	0.0052					
N,N-diethyl-3 -methylbenzamide	0.039	0.028			0.031	0.006	
dimethomorph	0.2	25		0.037		0.015	
dodemorph					0.004	0.01	
ethofumesate			0.049				
metalaxyl-M	0.01	0.15				0.1	0.006
S-metolachlor	0.003	0.005	0.011				
pendimethalin	0.003		0.029				
propazine				0.002			
prosulfocarb	0.015	0.005	0.004		0.009	0.005	
pyrimethanil					0.01	0.005	
simazine	0.015			0.005			
terbuthylazine			0.011	0.003			
tetrahydrophthalimide			0.087	0.18			
tolclofos-methyl					0.002	0.001	
triallate	0.003	0.002					
tebuconazole	0.009	0.009	0.024				0.019
diphenoconazole			0.002				
metazachlor		0.048					
penconazole						0.016	
propiconazole	0.018	0.009				0.035	

Active Substance	BErw20230424	BEsw20230424	DErw20230424	DEsw20230424	NLrw20230428	NLsw20230428	SPsw20230425
propyzamide	0.015	0.13	0.12	0.017		0.003	
terbutrin	0.004						
desethylterbutylazine			0.011	0.021			
boscalid	14	0.45	0.28	0.08	0.029	0.03	0.12
trifloxystrobin		0.2					
metconazole	0.009	0.008	0.024				0.018
bixafen	0.001		0.017				
fluopicolide	0.24	47	0.002	0.001	0.002	0.002	0.089
fluxapyroxad	0.005	0.002	0.094	0.004	0.008		0.2
phthalimide			0.08		0.06		
benzovindiflupyr			0.006				
fenamidone		0.004					
flufenacet			0.016				
fluopyram	6.5	16	0.085	0.003	0.043	0.26	0.84
mepanipyrim						0.019	
picolinafen			0.002				
spirotetramat		0.23					
mefentrifluconazole				0.005			
TOTAL	**BE_rw: 21**	**BE_sw: 20**	**DE_rw: 20**	**DE_sw: 17**	**NL_rw: 10**	**NL_sw: 15**	**SP_sw: 8**
SUM	**21.2427**	**90.1152**	**0.954**	**0.54**	**0.198**	**0.53**	**1.372**

Annex 3. Surface and rainwater sample results, 2023

Round 2

Active Substance	BErw20230521	BEsw20230521	DErw20230523	DEsw20230523	NLrw20230620	NLsw2023052	SPsw20230522
atrazine				0.092			
bupirimate					0.005		0.26
chloridazon				0.005			
chlorpropham	0.001	0.001			0.003	0.003	
desethylatrazine				0.005			
diazinon				0.004			
2,6- dichlorobenzamide		1.3		0.008	0.002	0.032	0.49
dichlobenil		0.0038					0.0009
N,N-diethyl-3-methylben-zamide	0.013	0.36			0.051	0.011	0.036
dimethomorph		5.5	0.006	0.027	0.004	0.007	0.015
4-dimethylaminosulfo-toluidide					0.012		0.04
ethofumesate	0.004		0.054		0.025	0.002	
furalaxyl		0.001					
kresoxim-methyl					0.13		
metalaxyl-M		0.02				0.1	0.004
S-metolachlor	0.004		0.31	0.005	0.024	0.003	
metribuzin			0.021		0.004		
ethylparathion					0.005		
pendimethalin			0.004				
methylpirimiphos					0.064		
procymidone					0.03		0.02
propazine				0.002			
propoxur					0.001		0.001
prosulphocarb	0.012	0.004	0.009		0.032	0.005	
pyrimethanil	0.004				0.004	0.002	0.048
simazine				0.006			
terbuthylazine			0.21	0.006	0.093		
tetrahydrophthalimide					0.064		
tolclofos-methyl					0.003	0.007	
triallate	0.001						

Annexes

Active Substance	BErw20230424	BEsw20230424	DErw20230424	DEsw20230424	NLrw20230428	NLsw20230428	SPsw20230425
ethylchlorpyrifos	0.013	0.019					
tebuconazole			0.01				0.36
diphenoconazole					0.008		0.052
fenarimol					0.003		
metazachlor		0.024					
penconazole						0.012	
propiconazole					0.013	0.022	0.011
propyzamide	0.008	0.036	0.021	0.011			
pyrazophos					0.009		
terbutrin							0.012
triadimefon							0.002
vinclozolin					0.004		
desethylterbutylazine			0.24	0.027	0.079		
aclonifen					0.01		
boscalid	0.003	0.44	0.11	0.058	0.14	0.028	0.24
trifloxystrobin		0.01			0.008		
metconazole			0.008				0.38
metrafenone							0.014
bixafen			0.006			0.003	
fluopicolide		12	0.002		0.001		0.44
fluxapyroxad	0.002	0.002	0.072	0.004	0.003	0.001	0.43
isopyrazam	0.004						0.43
phthalimide			0.006		0.32		
benzovindiflupyr			0.007			0.003	
cyflufenamide							0.011
fenamidone		0.002					
flufenacet	0.001		0.097		0.015		
fluopyram	0.009	15	0.058	0.003	0.015	0.25	2.6
mepanipyrim						0.017	
spirotetramat		0.005			0.003		
dimoxystrobin			0.004				
famoxadone					0.018	0.003	
TOTAL	BE_rw: 14	BE_sw: 18	DE_rw: 20	DE_sw: 15	NL_rw: 35	NL_sw: 19	SP_sw: 23
SUM	0.079	34.7278	1.255	0.263	1.205	0.511	5.8969