Residue Findings of QuPPe-Compounds in Samples of Plant Origin from the German Market in 2023

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The aim of this compilation is to give an overview as to which highly polar (QuPPe-) compounds are currently encountered in food products of plant origin. This should help other institutions when it comes to taking decisions on how to expand the scope of targeted SRM analytes, on how to plan sampling and on which QuPPe compounds are worthwhile targeting in the various types of samples. With the knowledge communicated here we ultimately aim at contributing to a more targeted and efficient use of lab resources within the EU-OfLs.

At CVUA Stuttgart, 47 QuPPe-compounds were routinely monitored in 2023 (see Table 1). Some of these compounds are not legally relevant, as they are not part of the legal residue definition, yet still of interest for potential exposure and risk-assessment evaluations.

Despite not being a QuPPe compound, a very brief overview of the residue findings of 2-chloroethanol (2-CE; formed from the reaction of the fumigant ethylene oxide with chloride ions naturally contained in food products) in 2023 is given at the end of this document. 2-CE findings in various products have been causing severe turbulences in the EU-food market in 2020-2022, but the situations has improved from 2023 onwards.

Table 1: Scope of QuPPe-compounds that were routinely monitored by the CVUA Stuttgart in 2023

Compound	Notes on legal aspects	General notes
4-Methylimidazoline	Non regulated metabolite	Marker of propylene-bis-dithiocarbamates (propineb). Limited specificity at very low concentrations (<0.005 mg/kg).
Ammelide	Non-regulated metabolite and contaminant	Ammelide can originate from various sources, similar to ammeline. Ammelide (and ammeline) are formed as intermediates during the gradual transformation of melamine (a compound with multiple sources, see below) to cyanuric acid. Ammelide is reported as a metabolite of various triazine pesticides incl.: cyromazine (insecticide), anilazine (fungicide) and the herbicides terbuthylazine, prometryn, simazine, atrazine, ametryne and cyanazine. Among those, only terbuthylazine is currently approved within the EU.
Ammeline	Non-regulated metabolite and contaminant	Intermediate in the conversion of melamine to cyanuric acid. For more info, see ammelide
Amitrole	MRLs are set at the LOQ in all products	Non-approved herbicide, the most important of the very few triazole pesticides with herbicidal properties. Approval expired in mid-2016.
Bromide	MRLs refer to bromide ion. Background levels are generally considered in MRLs for food of plant origin, but rather not considered in MRLs for food of animal origin. Collection of data on background levels in the latter would be useful.	Reaction product of the fumigant methylbromide. Mostly originating from soil and irrigation water. Counter ion of certain quarternary ammonium cations such as benzalkonium, didecyldimethylammonium (DDA-), diquat and paraquat
Chlorate	New MRLs set in 2020	Formerly used as herbicide, but nowadays mainly originating from chlorinated water, that is often used to irrigate fields or for washing harvested products or the equipment that is used for processing or storage of agricultural products.
Chloridazon-desphenyl	Regulated metabolite	Metabolite of chloridazon (approval expired on 31/12/2018). Chloridazon-desphenyl is quite persistent in the environment, thus residues in succeeding crops, and in water, have been reported.
Chlormequat	MRLs refer to chlormequat chloride	EU-Approved growth regulator with a wide range of applications. It has also been reported as a processing contaminant formed during the thermal degradation of choline (and its natural derivates) in presence of chloride ions. Formation has been for example reported during thermal treatment of egg powder, wheat flour, barley and coffee.

Compound	Notes on legal aspects	General notes
Cyanuric acid	Non-regulated metabolite	Compound originating from multiple sources, e.g.: **Triazine pesticides** (incl. the herbicides terbuthylazine, atrazine, cyanazine, the fungicide; anilazine and the insecticide cyromazine). From the above only terbuthylazine is currently in use within the EU. Cyromazine has lost EU-approval in Dec. 2019. **Cyanamide-based fertilizers.** Cyanamide contained in fertilizers may convert to melamine through trimerization, which can further hydrolyze to cyanuric acid. **Urea-based fertilizers or feed:** especially at high temperatures urea loses ammonia converting to isocyanic acid (HNCO), which trimerises to cyanuric acid. **Mono-, Di- and Trichloroisocyanurates:** Used as disinfectants, algaecides and bactericides, e.g. in sanitation liquids, bleaching agents as well as in swimming pools (pool-tabs) to retard the loss of chlorine in chlorinated water. In water, they gradually convert to cyanuric acid. **Natural formation** of cyanuric acid has also been reported (e.g. in humus).
Cyromazine	Since August 2023 all MRLs in food of plant origin are set at the LOQ. MRLs for food of animal origin are also set at the LOQ with exception of sheep tissues (The MRL for sheep milk is set at LOQ)	Non-approved fungicide (EU-approval expired in Dec. 2019). Also used as an ectoparasiticide (e.g. on sheep, but not on lactating sheep) and as a biocide on manure against fly larvae
Daminozide	MRLs are set at the LOQ in all products	Approved growth regulator
Difenzoquat	No specific MRLs established (0.01 mg/kg applies)	Non-approved herbicide
Dimethoate-O-desmethyl	Non-regulated metabolite	Also known as Metabolite X of dimethoate
Diquat	Specific MRLs set for products where desiccation takes place prior to harvest (e.g. potatoes, pulses, oilseeds) and for some other products, (e.g. citrus, stone fruit, tree nuts, oats, strawberries, eggs)	Non-approved herbicide, formerly used for desiccation in potatoes (EU-approval expired in Dec. 2019)
Diquat dipyridone	Non-regulated metabolite	Metabolite of diquat
Diquat monopyridone	Non-regulated metabolite	Metabolite of diquat
Diquat Met. TOPPS	Non-regulated metabolite	Metabolite of diquat
Ethephon		Approved growth regulator with multiple applications
HEPA	Non-regulated metabolite	Metabolite of ethephon. Likelihood of a natural formation by bacteria in the intestines of cattle under anaerobic conditions was reported by the EURL-SRM in 2019. Detected by the EURL-SRM in all analyzed samples of bovine liver (levels around 0.5 mg/kg). These levels are considered natural artefacts. Manure from cows, sheep and horse (collected from organic farms) and analysed by the EURL-SRM contained in all cases HEPA (highest level in cow manure at 1.3 mg/kg). Whether manure application in fields can explain the HEPA findings in some organic products is currently being investigated.
ETU (ethylene thiourea)	Non-regulated degradant	Degradant of ethylen-bis-dithiocarbamates. Reported as impurity in formulations based on EBTCs. Also formed during food processing. Marker compound for the screening of DTC-residues of products with EBTC-application history. Where EU and ETU are detected simultaneously the likelihood of relevant CS2 levels increases. Note: Most EBDTCs lost approval within the EU (Mancozeb expired on Jan 2021 with the period of grace ending in Jan 2022; Maneb expired in Jan 2017, Zineb and Nabam didn't receive EU-approval). Metiram is still approved (current approval period ends Jan 24).
EU (2-Imidazolidinone)	Non regulated metabolite	Degradant of ethylen-bis-dithiocarbamates. Degradant of ETU (see above). Marker compound for the screening of DTC-residues of products with EBTC-application history. Where EU and ETU are detected simultaneously the likelihood of relevant CS2 levels increases. See also ETU.
Fosetyl		Approved fungicide (converts to phosphonic acid, which is the active component)
Phosphonic acid	Regulated with parent fosetyl	Approved fungicide, used as such and also formed as a metabolite of fosetyl Phosphonate-based water-softening agents (e.g. ATMP. HEDP, DTPMP), that are used in cleansing agents contain some residual phosphonic acid, which may lead to small (rather insignificant) contamination of food, e.g. when in contact with surfaces that were not sufficiently rinsed after washing. Formation of phosphonic acid and derivatives thereof, such as HEPA, through the reduction of phosphates within the anaeropic environment in intestines of ruminants and other animals is likely. To which extend phosphonates formed here will lead to relevant residue levels in organic products needs to be investigated.
Glufosinate	Specific MRLs apply for many crops	Non-approved herbicide, also used in the cultivation of glufosinate-resistant transgenic crops. EU-approval expired in mid-2018 and not renewed
MPP (MPPA)	Included in residue definition of glufosinate	Metabolite of glufosinate

Compound	Notes on legal aspects	General notes
N-Acetyl Glufosinate	Included in residue definition of glufosinate	Metabolite of glufosinate
Glyphosate	Specific MRLs apply for many crops	Approved herbicide, also used in the cultivation of glyphosate-resistant transgenic crops. Current approval periods end in Dec 2022.
AMPA	Non-regulated metabolite.	Metabolite of glyphosate. Planned inclusion in RD of glyphosate.
N-Acetyl-Glyphosate	Non-regulated metabolite.	Metabolite of glyphosate. Planned inclusion in RD of glyphosate.
Maleic hydrazide	Plant product MRLs set at 0.2* / 0.5* except for Potatoes, Carrots, Parsnips, Onions, Garlic, Shallots, Chicory	Approved sprouting inhibitor.
Matrine	MRL of 0.01 mg/kg applies (listed in EU-pesticide database)	Natural quinolizidine alkaloid, that is considered (together with oxymatrine) as the active ingredient of biopesticides based on extracts of certain plants of the *Sophora* family. Not approved within the EU as PPP, neither in conventional nor in organic production. Registered in various countries in Asia, Africa and South America. There were cases of illegal addition of *Sophora* root extracts in fertilizers in Italy. Together with oxymatrine, often found in so-called "acacia honey" from China, which mostly originated from flowers of *Sophora* plants. *Sophora* extracts are also used in traditional Asian medicine and cosmetics. Co-harvesting of licorice and *Sophora* roots results in a considerable contamination of licorice and licorice products with matrine (and oxymatrine).
Oxymatrine	MRL of 0.01 mg/kg applies (listed in EU-pesticide database)	Quinolizidine alkaloid present in *Sophora* extracts, remarks on matrine apply
Melamine	Regulated by Reg. 1881/2006/EC as a contaminant	Metabolite of cyromazine (pesticide and vet. drug). May also originate from cyanamide fertilizers (trimerization of cyanamide) and from urea fertilizers, where it is formed through trimerisation of urea to triuret and subsequent elimination of ammonia and carbon dioxide (Note: biuret and triuret are related non-cyclic products formed from the di-and trimerisation of urea respectively). Melamine hydrolyses to cyanuric acid via ammeline and ammelide. Melamine is widely used for the synthesis of melamine-formaldehyde resins that are employed in synthetic surfaces of furniture, textiles, kitchenware as well as in moulding and packaging materials. Also used as a fire-retardant.
Mepiquat	MRLs refer to mepiquat chloride	Approved growth regulator. Similar to chlormequat, mepiquat has been reported to be formed as a natural processing contaminant through maillard-like reactions, e.g. during roasting of coffee and barley grain with the latter being use for the production of brewery malt, which is a main ingredient of beer.
Mepiquat, 4-Hydroxy	Non-regulated metabolite	Metabolite of mepiquat, mainly relevant for food of animal origin
Morpholine	Not regulated as a pesticide	Additive of waxes. Typically used together with oleic acid to assist emulsification of wax and facilitate wax handling. In the EU, the use of morpholine in fruit coating is not permitted, but it is widely used in other parts of the world.
Nereistoxin	Non-regulated metabolite	Transformation product of various members of the nereistoxin pesticides (e.g. bensultap, sultap, cartap, thiocyclam). There are rumors that it is illegally used as such in agriculture.
Nicotine	Specific MRLs set for rose hips, herbs, edible flowers, wild fungi, teas, herbal infusions and spices. MRLs will be revised when information on origin of background levels become available.	Non-approved insecticide. Nicotine originating from tobacco may contaminate food at all stages of food production, through air, soil and human contact. Crops experiencing intensive human contact during harvest or processing are particularly affected
Paraquat	MRL at LOQ 0.02 to 0.05 mg/kg	Non-approved herbicide, EU-approval expired in Dec. 2007
Perchlorate	Regulated as a contaminant, see Reg. (EC) 1881/2006/EC	Persistent and ubiquitous environmental contaminant. Mainly originating from fertilizers, may be also formed as a byproduct of disinfection of drinking water. Temporarily inhibits the intake of iodine in the thyroid gland.
Propamocarb	Current approval end on 15/06/2025	Approved fungicide, mainly relevant for vegetables, e.g. root-, bulb-, fruiting-, and leafy vegetables
Propamocarb N-desmethyl	Non regulated metabolite	Metabolite of propamocarb
Propamocarb-N-oxide	Non regulated metabolite	Metabolite of propamocarb
PTU (propylene thiourea = 4-Methyl-2-imidazolidinethione)	**Formerly** regulated in infant- and baby food Reg. EC 125/2006 and 141/2006 . Nowadays not regulated	Degradant of propylen-bis-DTCs (i.e. propineb). Also impurity in propineb-based PPPs. Also formed from propineb during food processing (heating). Useful marker for propineb-application history. Note: Propineb is not any more approved within the EU (approval expired in March 2018)
Thiocyanate	No specific MRLs set. Formally, the default MRL of 0.01 mg/kg applies. Collection of data on background levels would help introduce reasonable MRLs that consider background levels.	Non-approved fungicide. Also naturally formed in various cultivated plants of the brassica and allium family. Temporarily inhibits the intake of iodine in the thyroid gland. Eggs and milk may contain higher levels if the animals are fed with brassica crops. Also naturally formed in animals (e.g. in saliva).
Thiram metabolite M1	Non regulated metabolite	Marker of dimethyldithiocarbamates. Specificity questionable at low levels.

Compound	Notes on legal aspects	General notes
Trimesium	MRLs of dry commodities do not always take into account the amounts formed during the drying process.	Counter-ion of glyphosate, also naturally formed as an artefact during the drying process of food. Also known as trimethylsulfonium cation.

Residue Findings:

In 2023, a total of 2385 samples, mainly fruit and vegetables, but also cereals, pulses, processed goods, tea and others, were analyzed for QuPPe-amenable compounds at the CVUA Stuttgart. 1631 samples (68 %) contained quantifiable residues of one or more of the tested QuPPe compounds.

Table 2 sorts the compounds based on the frequency of finding above the reporting limit. Table 3 shows a compilation of all the results concerning the above-listed highly polar compounds.

Table 2: Residue findings of QuPPe-compounds (CVUA Stuttgart 2023) by detection frequency

Frequency of findings > respective RL	Compounds (pesticides and legally relevant metabolites shown in bold)
> 10 % of samples.	*Cyanuric acid,* ***Phosphonic acid***, ***Chlorate*** *and Perchlorate*
> 1 - 10 % of samples.	*Melamine,* ***Thiocyanate***[2)]*,* ***Propamocarb****, Propamocarb-N-oxide,* ***2-Chloroethanol***[1)]***,*** ***Paraquat***[4)]***,*** *Propamocarb-N-desmethyl,* ***Nicotine***, ***Ethephon,*** *Ammelide,* ***Trimesium***, ***Chlormequat-chloride, Bromide***[3)]*, and* ***Chloridazon-desphenyl***
0.1 -1% of samples	*Ethephon metabolite HEPA,* ***Maleic hydrazide,*** *Thiram metabolite M1,* ***Diquat***[4)]***, Glyphosate, Mepiquat-chloride,*** *Dimethoate-O-desmethyl,* ***Glufosinate met. MPPA****, EU, 4-Methylimidazoline,* ***Fosetyl****, Morpholine, ETU, Mepiquat- 4-hydroxy and* ***Matrine***
<0.1 - LOQ	***Cyromazine****, Oxymatrine, Nereistoxin,* ***N-Acetyl-glufosinate***, ***Daminozide***
Not detected above LOQ	***Amitrole,*** *Ammeline,* ***Difenzoquat****, Diquat-dipyridone, Diquat met. TOPPS, Diquat-*monopyridone*,* ***Ethylene oxide*** [1)]***,*** ***Glufosinate****, and Glyphosate met. N-Acetylglyphosate, Glyphosate met. AMPA and PTU*

[1)] ***EO/2-CE are technically not QuPPe compounds but still shown here (see towards the end of this document), note EO/2-CE analysis was semi-targeted with dry commodities being the main focus.***
[2)] ***No MRLs were deemed necessary for potassium thiocyanate.***
[3)] ***Bromide is ubiquitous and virtually every sample is positive. The RL of 5 mg/kg represents the lowest MRL is food of plant origin.***
[4)] ***Paraquat and Diquat analysis was semit-tageted. Main focus were dry commodities such as pulses, oily seeds and cereals as well as potatoes***

Table 3: Residue findings of QuPPe-compounds (CVUA Stuttgart 2023) by compound

Compound	# samples	# pos. [1)]	% pos.	Max (mg/kg)	Mean[2)] (mg/kg)	Median[2)] (mg/kg)	# >MRL[3)]	% >MRL	RL[4)]
Cyanuric acid	2381	706	**30**	4,9	0,0558	0,0135	Not part of RD		0.005
Fosetyl, sum (Phosphonic acid)	2381	454	**19**	106	4,9	1,4	11	0.5	0.05
Chlorate	2381	370	**16**	3	0,0458	0,012	7	0,3	0.005
Perchlorate	2381	349	**15**	15,7	0,108	0,012	6[5)]	0,3	0.005
Melamine	2382	229	**9,6**	6,5	0,104	0,031	0[4)]	0	0.01
Thiocyanate	2381	173	**7,3**	51,1	10,8	6,2	0	0	0.1
Propamocarb	2382	102	**4,3**	3,5	0,182	0,028	2	0,08	0.005
Propamocarb-N-oxide	2382	82	**3,4**	0,34	0,0479	0,017	0	0	0.005
Paraquat	245	7	**2,9**	0,2	0,0626	0,032	2	0,8	0.01
Propamocarb-N-desmethyl	2382	55	**2,3**	0,11	0,0207	0,009	Not part of RD		0.005
Ammelide	2381	39	**1,6**	0,59	0,0845	0,029	Not part of RD		0.005
Ethephon	2381	37	**1,6**	1	0,245	0,16	0	0	0.01
Nicotine	2382	38	**1,6**	0,58	0,0693	0,0215	13	0,5	0.01
Bromide	2381	31	**1,3**	159	34	23	0	0	5[7)]
Chlormequat-chloride	2382	30	**1,3**	0,81	0,108	0,044	3	0,1	0.005
Trimesium	2382	32	**1,3**	0,52	0,0632	0,023	9[6)]	0,4	0.005
Chloridazon-desphenyl	2382	27	**1,1**	0,027	0,0117	0,009	0	0	0.005
Ethephon metabolite HEPA	2381	25	**1,0**	0,54	0,095	0,042	Not part of RD	0	0.01
Maleic hydrazide	2381	22	**0,9**	27,7	5,6	4,1	0	0	0.01
Diquat	245	2	**0,8**	0,041	0,0295	0,030	0	0	0.01
Thiram M1[8)]	2382	20	**0,8**	0,049	0,0123	0,006	Not part of RD	0	0.002
Glyphosate	2381	16	**0,7**	0,99	0,225	0,093	2	0,08	0.02

Compound	# samples	# pos. [1]	% pos.	Max (mg/kg)	Mean[2] (mg/kg)	Median[2] (mg/kg)	# >MRL[3]	% >MRL	RL[4]
Dimethoate-O-desmethyl	2381	13	**0,5**	0,2	0,0646	0,033	0	0	0.005
Mepiquat chloride	2382	11	**0,5**	0,17	0,0377	0,021	1	0,04	0.005
4-Methylimidazoline[8]	2382	9	**0,4**	0,022	0,0117	0,011	Not part of RD	0	0.004
EU[7]	2382	10	**0,4**	0,52	0,135	0,098	Not part of RD	0	0.02
Glufosinate met. MPPA	2381	9	**0,4**	0,13	0,0329	0,02	0	0	0.01
Fosetyl	2381	6	**0,3**	0,65	0,261	0,19	0	0	0.01
Morpholine	2382	6	**0,3**	3,6	0,75	0,092	additive	0	0.02
ETU[8]	2382	5	**0,2**	0,35	0,201	0,21	Not part of RD	0	0.02
Matrine	2385	3	**0,1**	0,21	0,159	0,185	0	0	0.01
Mepiquat, 4-hydroxy	2382	3	**0,1**	0,095	0,0658	0,095	Not part of RD	0	0.005
Cyromazine	2382	2	**0,08**	0,015	0,0135	0,0135	1	0,04	0.005
Daminozide	2382	1	**0,04**	0,006	0,00637		0	0	0.005
N-Acetyl-glufosinate	2381	1	**0,04**	0,13	0,13		0	0	0.02
Nereistoxin	2382	1	**0,04**	0,035	0,035		Not part of RD	0	0.005

[1] The number of positive samples refers to samples exceeding the RL.
[2] Mean and median of positives
[3] Numerical MRL-exceedances
[4] RL= Reporting Limit (exemplary for fruits and vegetables)
[5] Perchlorate and melamine are legally contaminants. In six cases the ML of perchlorate, as defined in Reg.(EC) No. 1881/2006, was exceeded
[6] MRL-exceedances of trimesium are in most cases most likely due to the formation of trimesium during processing
[7] Bromide is ubiquitous and virtually every sample is positive. The RL of 5 mg/kg represents the lowest MRL in food of plant origin. Analytically much lower levels can be quantified.
[8] Additional findings below LOQ were used for dithiocarbamate screening purposes. The reporting limits given are semi-quantitative

MRL exceedances

In 58 samples (thereof 9 organic) MRLs of different compounds were numerically exceeded. In 28 of these samples (thereof 4 organic) the MRLs were exceeded even after deducting 50% measurement uncertainty. Table 4 gives an overview of these exceedances. In 9 samples (thereof 3 organic) the MRL-exceedance concerned trimesium, which is known to be generated naturally during the drying process of plants.

Table 4: Samples with residues of QuPPe-compounds exceeding existing MRLs* (CVUA Stuttgart 2023)

Compound	Commodity	Country of Origin	Conc. (mg/kg)	>2x MRL**	Note
Chlorate *(herbicide. but chlorinated water used in irrigation or sanitation is mostly responsible for levels found in food)*	Baby and infant foods	Unknown	0.017		organic
	Sesame	Nigeria	3	x	
	Sesame	Unknown	0.074		
	Grapes	Chile	0.605	x	
	Lime	Mexico	0.077		
	Leafy vegetables, dried	Germany	0.21	x	
	Moringa oleifera	Spain	0.21	x	organic
Chlormequat chloride	Peanut, roasted with shell	Turkey	0.812	x	Might have been formed as a processing contaminant during roasting
	Potato	Germany	0.012		
	Garlic	China	0.025	x	
Cyromazine	Bell peppers	Turkey	0.015		
Fosetyl, sum *(phosphonic acid was the only detected compound in most cases)*	Chick pea	Unknown	12.1	X	
	Peanut, roasted with shell	Egypt	6.2	x	
	Peanut, roasted with shell	Turkey	11.3	x	
	Peanut, roasted with shell	Unknown	12.2	x	
	White bean	Argentina	7.9	X	
	White bean	Brazil	6.7	X	
	Cherry	Germany	3.9		
	Sour Cherry, frozen	Unknown	11.3	x	
	Green beans	Morocco	3.1		
	Onion	New Zealand	56.3		
	Spring onion	Germany	39.9		
Glyphosate	Kaki	Spain	0.17		
	Kaki	Spain	0.23	x	
Mepiquat chloride	Sweet potato	Egypt	0.04		organic

Compound	Commodity	Country of Origin	Conc. (mg/kg)	>2x MRL**	Note
Nicotine *(insecticide, but tobacco-related contamination mostly responsible for levels found in food)*	Chick peas	India	0.021		
	Pumpkin seeds	China	0.039		
	Triphala powder	Germany	0.33	x	organic
	Clementine	Croatia	0.018		
	Medlar	Italy	0.013		
	Cumin seeds	Turkey	0.0785		
	Ginger	Peru	0.0405	x	
	Lamb's lettuce	Germany	0.015		organic
	Lamb's lettuce	Germany	0.022	x	
	Leek	The Netherlands	0.015		
	Rucola	Germany	0.03	x	
	Spinach	Germany	0.013		
	Spinach	Italy	0.012		
Oxymatrine	Fennel tea	Unknown	0.022	x	
Paraquat	Brown lentil	Unknown	0.11	x	
	Mung bean	Argentina	0.2	x	
Perchlorate *(contaminant in fertilizers)*	Prickly pear	Turkey	0.061		
	Basil dried	Unknown	15.7	x	
	Moringa oleifera	Germany	5.2	x	
	Bell peppers	Germany	0.25	x	
	Moringa oleifera	Spain	4.2	x	organic
	Pak choi	Belgium	0.074		
Propamocarb	Peanut, roasted with shell	Egypt	0.029	x	
	Pepper	Iraq	0.054		
Trimesium *(Counter ion of glyphosate but also natural formation during drying process of crops)*	Moringa oleifera	Germany	0.061		organic
	Moringa oleifera	Germany	0.051		
	Parsley, dried	Unknown	0.52		
	Black tea	Sri Lanka	0.088		
	Black tea	Unknown	0.39	x	organic
	Black tea	Unknown	0.067		
	Black tea	Unknown	0.09		
	Moringa oleifera	Germany	0.12	x	
	Moringa oleifera	Spain	0.094		organic

* >1xMLR

** >2xMRL means that the sample exceeded MRL even after deducting measurement uncertainty of 50%

Table 5: Top 15 residue levels of the most-frequently found QuPPe-compounds (with > 50 findings in total)

Compound	Commodity	Country of origin	Residue level (mg/kg)
Cyanuric acid *(non-regulated pesticide metabolite and contaminant in fertilizers)*	Algae, dried	Germany	4.9
	Shiitake, dried	China	1.5
	Potato	Germany	0.95
	Cultivated mushroom , dried	China	0.78
	Mandarine	Israel	0.76
	Pineapple	Costa Rica	0.74
	Cordyceps capsules	Germany	0.71
	Orange juice	Unknown	0.68
	Apple juice	Germany	0.66
	Chili powder	Unknown	0.63
	Paprika spice	Unknown	0.62
	Paprika spice	Germany	0.61
	Pineapple	Costa Rica	0.60
	Chili powder	Unknown	0.46
	Pineapple	Costa Rica	0.44
Phosphonic acid *(Metabolite of Fosetyl but also used as such. Shows high persistence in plants. and residues in crops of perennial plants may originate from previous seasons)*	Almond	USA	79.2
	Hops	Germany	56.1
	Onion	New Zealand	41.9
	Raisin and Sultana	South Africa	41.8
	Hops pellets	Germany	38.4
	Avocado	Brazil	38.2
	Spring onion	Germany	29.7
	Strawberry	Germany	29.3
	Hops pellets	Germany	25.9
	Strawberry	Italy	22.6

Compound	Commodity	Country of origin	Residue level (mg/kg)
	Strawberry	Germany	22.1
	Bell peppers	Turkey	20.4
	Grapes	Italy	16.3
	Potato	France	16.1
	Strawberry	Germany	15.9
Chlorate *(herbicide, but chlorinated water used in irrigation or sanitation mostly responsible for levels found in food)*	Sesame	Nigeria	3.0
	Paprika spice	Unknown	1.1
	Parsley, dried	Unknown	0.68
	Chili powder	Unknown	0.68
	Grapes	Chile	0.61
	Parsley	Spain	0.54
	Algae, dried	Germany	0.41
	Paprika spice	Germany	0.34
	Chili powder	Unknown	0.29
	Bell peppers	Belgium	0.22
	Moringa oleifera	Germany	0.21
	Moringa oleifera	Spain	0.21
	Dill leaves	Unknown	0.21
	Chives, frozen	Unknown	0.19
	Chives, frozen	The Netherlands	0.17
Perchlorate *(Regulated as contaminant)*	Basil dried	Unknown	15.7
	Moringa oleifera	Germany	5.2
	Moringa oleifera	Spain	4.2
	Parsley, dried	Unknown	0.62
	Moringa oleifera	Germany	0.42
	Cumin seeds	Turkey	0.42
	Moringa oleifera	Tanzania	0.41
	Moringa oleifera	Germany	0.37
	Oregano dried	Unknown	0.33
	Cumin seeds	Unknown	0.31
	Cumin seeds	Unknown	0.27
	Oregano dried	Unknown	0.27
	Bell peppers	Germany	0.25
	Cumin seeds	Unknown	0.25
	Cumin seeds	Germany	0.24
Melamine *(Metabolite of cyromazine, but also contaminant originating from multiple sources; regulated as contaminant)*	Cultivated mushroom , dried	China	6.5
	Potato	Germany	1.30
	Parsley	Italy	1.18
	Chives	Germany	0.68
	Leek	Germany	0.52
	Parsley	Germany	0.52
	Hops pellets	Germany	0.45
	Celeriac	Germany	0.42
	Carrot	Germany	0.41
	Hops pellets	Germany	0.39
	Potato	Germany	0.38
	Hops	Germany	0.36
	Cucumber	Spain	0.33
	Coriander leaves	Germany	0.27
	Lambs lettuce	Italy	0.25
Thiocyanate *(mostly of natural origin, especially in brassica crops)*	Red cabbage	Germany	51.1
	Brussels sprout	The Netherlands	47.2
	Brussels sprout	The Netherlands	44.4
	Red cabbage	Germany	43.9
	Broccoli	Spain	42.1
	White cabbage	Germany	41.8
	Brussels sprout	The Netherlands	37.0
	Brussels sprout	The Netherlands	34.3
	Brussels sprout	The Netherlands	34.3
	Brussels sprout	The Netherlands	34.0
	Brussels sprout	The Netherlands	33.0
	Red cabbage	Germany	31.7
	Red cabbage	Germany	31.0

Compound	Commodity	Country of origin	Residue level (mg/kg)
	Red cabbage	Germany	30.0
	White cabbage	Germany	29.7
Propamocarb	Head lettuce	Belgium	3.5
	Cucumber	Germany	1.3
	Cucumber	Spain	1.2
	Cucumber	Spain	1.2
	Cucumber	Spain	1.1
	Cucumber	Spain	1.0
	Cucumber	Unknown	0.98
	Cucumber	Spain	0.81
	Cucumber	Spain	0.73
	Cucumber	Greece	0.49
	Tomato	Spain	0.48
	Melon	Costa Rica	0.41
	Cucumber	Spain	0.39
	Iceberg lettuce	Germany	0.39
	Cucumber	Spain	0.37
Propamocarb-N-oxide	Cucumber	Spain	0.34
	Cucumber	Spain	0.32
	Cucumber	Germany	0.31
	Cucumber	Spain	0.29
	Cucumber	Spain	0.26
	Cucumber	Spain	0.18
	Cucumber	Spain	0.17
	Cucumber	Spain	0.17
	Head lettuce	Belgium	0.15
	Cucumber	Spain	0.14
	Cucumber	Unknown	0.14
	Cucumber	Greece	0.13
	Cucumber	Spain	0.11
	Cucumber	Germany	0.09
	Cucumber	Spain	0.04
Propamocarb-N-desmethyl	Tomato	Spain	0.11
	Cucumber	Spain	0.10
	Head lettuce	Belgium	0.07
	Cucumber	Spain	0.06
	Cucumber	Spain	0.06
	Cucumber	Spain	0.06
	Cucumber	Spain	0.05
	Cucumber	Greece	0.05
	Iceberg lettuce	Germany	0.05
	Cucumber	Germany	0.04
	Tomato	Spain	0.03
	Cucumber	Spain	0.03
	Melon	Costa Rica	0.03
	Pickled cucumbers, preserved	Germany	0.02
	Cucumber	Unknown	0.02

Table 6: Top 10 residue levels of less frequently found QuPPe-compounds (with < 50 findings in total)

Compound	Commodity	Country of origin	Residue level (mg/kg)
Ammelide *(Metabolite of some triazine herbicides as well as of melamine, see above)*	Cultivated mushroom, dried	China	0.59
	Pepper	Unknown	0.57
	Shiitake, dried	China	0.36
	Algae, dried	Germany	0.30
	Shiitake mushroom	Germany	0.22
	Pumpkin seed	China	0.15
	Pineapple, dried	Ghana	0.13
	Shiitake mushroom	Germany	0.12
	Shiitake mushroom	The Netherlands	0.11
	King oyster mushroom	Germany	0.10

Compound	Commodity	Country of origin	Residue level (mg/kg)
Ethephon	Tomato	Turkey	1.03
	Figs	Turkey	0.99
	Pineapple	Costa Rica	0.91
	Tomato	The Netherlands	0.55
	Figs	Turkey	0.52
	Figs	Turkey	0.45
	Grapes	Spain	0.42
	Grapes	South Africa	0.36
	Sour Cherry, frozen	Unknown	0.34
	Pineapple	Costa Rica	0.33
Nicotine	Wild mushroom, dried	Turkey	0.58
	Wild mushroom, dried	Unknown	0.38
	Triphala capsule	Germany	0.33
	Wild mushroom, dried	Unknown	0.19
	Black tea	Unknown	0.12
	Black tea	Unknown	0.10
	Black tea	Unknown	0.09
	Cumin seeds	Turkey	0.08
	Chili powder	Unknown	0.08
	Cumin seeds	Unknown	0.07
Bromide	Turmeric	Unknown	159
	Cumin seeds	Unknown	131
	Moringa oleifera	Spain	85
	Cumin seeds	Germany	43
	Pepper	Unknown	39
	Pepper	Unknown	37
	Moringa oleifera	Germany	35
	Walnut	Germany	34
	Pepper	Unknown	30
	Moringa oleifera	Germany	29
Chlormequat chloride	Peanut, roasted with shell	Turkey	0.81
	Cordyceps capsules	Germany	0.39
	Rye flour	Unknown	0.32
	Rye flour	Germany	0.30
	Rye flour	Germany	0.23
	Rye flour	Germany	0.19
	Pasta	Unknown	0.11
	Coarse grains	Germany	0.11
	Vegan/vegetarian food, no milk	Unknown	0.10
	Rye flour	Germany	0.09
Trimesium *(Counter ion of glyphosate but also natural formation during drying process of crops)* *(Non-regulated metabolite of Ethephon)*	Parsley, dried	Unknown	0.52
	Black tea	Unknown	0.39
	Moringa oleifera	Germany	0.12
	Majoram dried	Unknown	0.11
	Moringa oleifera	Spain	0.09
	Black tea	Unknown	0.09
	Black tea	Sri Lanka	0.09
	Black tea	Unknown	0.07
	Moringa oleifera	Germany	0.06
	Moringa oleifera	Germany	0.05
Chloridazon-desphenyl	Dill, frozen	Germany	0.03
	Chives, frozen	Unknown	0.02
	Parsley, frozen	Unknown	0.02
	Dill leaves	Germany	0.02
	Dill, frozen	Germany	0.02
	Parsley	Unknown	0.02
	Chives, frozen	Germany	0.02

Compound	Commodity	Country of origin	Residue level (mg/kg)
	Green beans, frozen	Unknown	0.01
	Cimarapa	Italy	0.01
	Green beans	Unknown	0.01
HEPA	Pineapple	Costa Rica	0.54
	White button mushroom	Germany	0.39
	White button mushroom	Germany	0.31
	Artichoke	Italy	0.30
	Grapes	South Africa	0.10
	Pineapple	Costa Rica	0.10
	Grapes	Italy	0.07
	Grapes	South Africa	0.07
	Grapes	Spain	0.07
	Tomato	Turkey	0.06
Maleic hydrazide	Potato	Germany	27.7
	Potato	France	12
	Potato products	Unknown	7.7
	Onion	Spain	7.6
	Shallots	Germany	7.5
	Potato	France	6.6
	Potato	Israel	6.4
	Potato products	Unknown	6.2
	Onion	Germany	6.2
	Potato products	Unknown	5.3
Thiram M1	Bell peppers	Turkey	0.05
	Green beans	Senegal	0.04
	Green beans	Morocco	0.04
	Zucchini	Turkey	0.02
	Apricot	Turkey	0.02
	Strawberry	Spain	0.01
	Pear	Turkey	0.01
	Plum	Portugal	0.01
	Pear	Italy	0.01
	Mint	Unknown	0.01
Glyphosate	White beans	Brazil	0.99
	Black tea	Sri Lanka	0.52
	Brown lentil	Unknown	0.49
	White beans	Argentina	0.34
	Paprika	Unknown	0.29
	Kaki	Spain	0.23
	Kaki	Spain	0.17
	Pepper	Unknown	0.10
	Pomegranate	Turkey	0.09
	Carrot	Germany	0.08
Dimethoate-O-desmethyl	Onion	Germany	0.20
	Leek	Germany	0.14
	Orange	Italy	0.13
	Black-eyed pea	Madagascar	0.10
	Wine leaves, prepared in brine	Egypt	0.09
	Melon	Costa Rica	0.05
	Sweet potato	Egypt	0.03
	Raspberry, frozen	Unknown	0.03
	Avocado	Colombia	0.02
	Sweet potato	Egypt	0.02
Mepiquat chloride	Cordyceps capsules	Germany	0.17
	Rye flour	Unknown	0.06
	Sweet potato	Egypt	0.04

Compound	Commodity	Country of origin	Residue level (mg/kg)
	Sunflower seed	Unknown	0.02
	White button mushroom	Poland	0.02
	White button mushroom	Germany	0.02
	White button mushroom	Germany	0.02
	White button mushroom	Poland	0.02
	Rye flour	Germany	0.02
	Mango	Dom. Republic	0.01
4-Methylimidazoline	Lime	Colombia	0.02
	Grapes	India	0.02
	Grapes	India	0.02
	Melon	Costa Rica	0.01
	Grapes	India	0.01
	Mango	Dom. Republic	0.01
	Grapes	India	0.01
	Lime	Colombia	0.01
	Grapes	India	0.01
EU	Cumin seeds	Turkey	0.52
	Basil dried	Unknown	0.18
	Wine leaves, prepared in brine	Turkey	0.12
	Parsley	Germany	0.11
	Papaya	Ghana	0.11
	Wine leaves, prepared in brine	Turkey	0.08
	Wine leaves, prepared in brine	Turkey	0.08
	Head lettuce	Germany	0.06
	Wine grapes	Germany	0.04
	Head lettuce	Germany	0.04
Glufosinate MPPA	Shiitake, dried	China	0.13
	Lemon	South Africa	0.03
	Grapes	South Africa	0.03
	Grapes	South Africa	0.02
	Plum	South Africa	0.02
	Raspberry, frozen	Unknown	0.02
	Raspberry, frozen	Spain	0.02
	Plum	South Africa	0.02
	Raspberry, frozen	Unknown	0.01
Fosetyl	Melon	Honduras	0.65
	Hops	Germany	0.47
	Cucumber	Germany	0.30
	Grapes	South Africa	0.08
	Grapes	Italy	0.04
	Grapes	India	0.02

Findings in organic samples

A look at the residues encountered in organic products gives an insight on compounds that potentially end up in food products from natural sources and on the matrices affected by such background contamination.

In 2023 the vast majority of the findings in organic products concerned compounds known to contaminate food products either naturally, or from applications other than the use of pesticides. Thiocyanate is naturally occurring in various crops of the brassica and allium family. Bromide is ubiquitous and is always contained in living organisms. Chlorate is often a result of using chlorinated water for irrigation or for sanitation purposes in packing and processing facilities (e.g. for washing surfaces or the products themselves). The contaminant perchlorate is often contained in fertilizers, including guano, which is used in organic agriculture. Melamine, ammelide and cyanuric acid may also originate from fertilizers. Trimesium is naturally formed when certain products are dried, and can be thus considered a processing contaminant. Phosphonic acid may originate from past applications as it is quite

persistent both in perennial plants and the soil. Still some findings raise the suspicion of a recent misuse and require further investigation. Chloridazon-desphenyl is a metabolite of chloridazon, which is quite persistent in the environment, thus residues in succeeding crops, and in water, are encountered.

Table 7: Overview of findings in 356 organic samples (no. of findings ≥5); (CVUA in 2023)

Compound Name	No. of samples	RL (mg/kg)	No. of findings >RL	Percentage of positives	Mean (mg/kg)	Max (mg/kg)	Remarks
Ammelide	353	0.005	12	3,4	0,086	0,30	May originate from fertilizers (incl. urea fertilizers)
Bromide	353	5	5	1,4	29,2	85,3	Ubiquitous element
Chlorate	353	0.005	52	14,7	0,034	0,41	May end up in organic products through irrigation or sanitation procedures in the processing facilities
Chloridazon-desphenyl	353	0.01	13	3,7	0,013	0,027	Metabolite of chloridazon quite persistent in the environment, thus residues in succeeding crops, and in water, are encountered. Findings concerned in the following commodities: Green beans frozen 4x, parsley frozen 2x, dill 2x, chives frozen 2x, carrot, pumpkin, basil
Cyanuric acid	353	0.005	111	31,4	0,097	4,9	May originate from fertilizers (incl. urea fertilizers)
Melamine	353	0.005	24	6,8	0,050	0,182	May originate from fertilizers (incl. urea fertilizers)
Perchlorate	353	0.005	56	15,9	0,108	4,2	May originate from fertilizers inclusion guano
Phosphonic acid	353	0.05	8	2,3	10,4	79,2	Phosphonic acid used to be employed by organic farmers in the past as it was marketed as a "leaf fertilizer" suitable for organic farming. As the compound is quite persistent, residues are still found especially in crops of perennial plants such as berries. The findings >LOQ concerned the following matrices: Almond (2x), Wine grapes (2x), Lemon, Kiwi, Avocado, Zucchini. Contamination through manure is also conceivable source especially for in vege-tables.
Thiocyanate	353	0.1	22	6,2	9,6	43,9	Naturally occurring in various *allium* and *brassica* products, such as onions and kale
Trimesium	353	0.005	5	1,4	0,117	0,39	Trimesium was shown to be formed naturally during the drying process of various products of Black tea, Sweet potato, Moringa 3x.

Residues of Ethylene oxide / 2-Chloroethanol

In 2023 a total of 131 samples, mainly highly processed products from third countries or unknown origin, were analyzed for residues of a fumigation with ethylene oxide. Ethylene oxide fumigations are not approved within the EU but are not uncommon elsewhere. The main purpose is disinfestation and disinfection. Since ethylene oxide is carcinogenic, mutagenic and reprotoxic and since 2-chloroethanol, the main a reaction product of eth-ylene oxide, is a suspected mutagenic, EU-MRLs are set at the analytical limit of determination (practical zero tolerance).

2-chloroethanol was encountered in quantifiable levels in only four of the 131 samples (in food supplements (3x) and in sesame (1x)). The food supplements with positive findings were based on Triphala, Cordyceps and Moringa. Residues of the highly volatile and reactive ethylene oxide were not found in any of the tested samples.

Is seems as if the official border controls as well the controls of the food business operators themselves seem to be very successful in preventing the import of ethylene oxide fumigated food products into EU market.