MONITORING PROGRAM FOR PHARMACEUTICALS, ILLEGAL SUBSTANCES AND CONTAMINANTS IN FARMED FISH

Annual report for 2023

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Summary (English):

This report summarizes the results of the monitoring of illegal substances, pharmaceuticals, and contaminants in Norwegian farmed fish in 2023. In 2023, 2680 analyses were conducted on samples of 1815 fish. Samples examined for illegal substances were collected at all stages of farming and are representative of farmed fish under production. The samples were analyzed for substances with anabolic effect or unauthorized substances. Residues of testosterone were detected in one sample of rainbow trout. A follow-up investigation conducted by the Norwegian Food Safety Authority (Mattilsynet) concluded that contamination of the samples during sample taking was the cause of the positive result. Samples tested for approved veterinary drugs and contaminants were collected at slaughterhouses and are representative of Norwegian farmed fish ready for human consumption. Residues of the authorized anti-sealice agents emamectin, cypermethrin, and deltamethrin were found at concentrations below the respective Maximum Residue Limits (MRLs) in fish meat. Residues of other authorized veterinary drugs, such as antibiotics, drugs against internal parasites, or sedatives, were not detected. The concentrations of environmental contaminants were found below the EU Maximum Levels (MLs), where those are established for fish.

Summary (Norwegian):

Denne rapporten oppsummerer overvåkingsresultatene fra 2023 for ulovlige stoffer, legemidler og miljøgifter i norsk oppdrettsfisk. I 2023, ble det utført 2680 analyser på prøver av 1815 fisk. Prøver som ble analysert for ulovlige forbindelser, som stoffer med anabole effekter eller uautoriserte legemidler ble tatt ut under alle livsstadier, og er representative for oppdrettsfisk under produksjon. Rester av steroidhormonet testosteron ble funnet i én prøve regnbueørret. Etterforskning iverksatt av Mattilsynet konkluderte med sannsynlig av prøvene under prøvetakingen. Utover det ble det ikke detektert rester av ulovlige stoffer i noen av prøvene. Prøver som ble testet for godkjente veterinære legemidler og miljøgifter ble samlet in på slakterier, og er representative for norsk oppdrettsfisk som er klar for markedet. Rester av lusemidlene emamektin, cypermethrin og deltamethrin ble funnet på nivåer under de respektive grenseverdiene (MRLs). Andre veterinære legemidler, som antibiotika, legemidler brukt mot interne parasitter eller bedøvelsesmidler ble ikke funnet. Nivåene av miljøgifter ble målt under EUs maksimumsgrenser, der disse er blitt satt for fisk.

Content

1 - Introduction

1.1 - Background

Official control rules enable the enforcement of EU regulations and standards governing food safety and animal health. This ensures that businesses and operators comply with legal requirements, preventing fraudulent practices, and maintaining the integrity of food products. Moreover, the rules are designed to uphold standards of food safety and quality throughout the agri-food chain. By conducting official controls, authorities can identify, and address risks associated with food production, processing, and distribution, thereby increasing consumer safety and confidence in food products marketed in EU and EEA countries.

To introduce a more harmonized and coherent approach to official controls and to simplify the existing framework, the official control rules to verify compliance with food and feed law, animal health and welfare, plant health, and animal-by-products rules were integrated into a single regulation. With effect from 14 December 2017, the Official Controls Regulation (EU) 2017/625[1] (OCR) repealed Council Directive 96/23/EC. The OCR also included relevant transitional measures, which provided that, until 14 December 2022, competent authorities were obliged to continue the performance of necessary official controls in accordance with Directive 96/23/EC. In Norway, legislation on official controls (“kontrollforordningen”) was updated and aligned with the OCR, entering into force as of April 2020[2].

In 2022, supplementing regulations were adopted, laying down the specific requirements for the performance of official controls of *pharmacologically active substances authorised as veterinary medicinal products or as feed additives and of prohibited or unauthorised pharmacologically active substances and residues thereof* (Commission Delegated Regulation (EU) 2022/1644[3] and Commission Implementing Regulation (EU) 2022/1646[4]), and *contaminants in food* (Commission Delegated Regulation (EU) 2022/931[5] and Commission Implementing Regulation (EU) 2022/932[6]).

The requirements for the national risk-based control plan on illegal or authorized pharmacologically active substances and contaminants, in accordance with these specifications, were implemented in the monitoring program for farmed fish in 2023.

Considering relevance in aquaculture production, the following residues and substance groups were included into the national risk-based control plan for pharmacologically active substances in Norwegian farmed fish in line with Annexes I and II of Commission Delegated Regulation (EU) 2022/1644:

Group A – Prohibited or unauthorized pharmacologically active substances in food-producing animals

A1a Stilbenes;

A1c Steroids;

A1d Resorcylic acid lactones, including zeranol;

A1e Beta-agonists;

A2a Chloramphenicol;

A2b Nitrofurans;

A2c Metronidazole;

A2d Other substances;

A3a Dyes

Group B – Pharmacologically active substances authorized for use in food-producing animals

B1a Antimicrobial substances;

B1b Insecticides, fungicides, anthelmintics and other antiparasitic agents;

B1c Sedatives

Contaminant groups included in the national risk-based control plan according to Annex I of Commission Delegated Regulation (EU) 2022/931:

(1) Halogenated persistent organic pollutants;

(2) Metals;

(3) Other contaminants

1.2 - Group A, Prohibited or unauthorized pharmacologically active substances in food-producing animals

Fish tested for illegal compounds (Commission Regulation (EU) 37/2010[7]) were collected at the farm by official inspectors from the Norwegian Food Safety Authority (NSFA), without prior notification to the farmers. Samples were taken at all stages of farming in order to represent farmed fish during production. Substances monitored in Group A include growth promoters like steroids, stilbenes and beta-agonists, unauthorized pharmacologically active feed additives, such as resorcylic acid lactones and unauthorized drugs. Unauthorized drugs considered most relevant for aquaculture are chloramphenicol, nitrofurans, metronidazole and dyes.

To ensure harmonized levels for the control of unauthorized substances, the analytical methods should meet a minimum method performance requirements (MMPRs) set by the European Union[8], and European reference laboratories (EU-RLs)[9].

1.3 - Group B, Pharmacologically active substances authorized for use in food-producing animals

In order to protect public health, current EU legislation[7] provisions the assignment of Maximum Residue Limits (MRLs), where required, for all legally applied pharmacologically active substances in products intended for human consumption. An MRL denotes the highest permitted residual concentration of a legally applied veterinary drug and is evaluated individually for each substance and food product. Consumption of food with drug residues below the MRL should not pose a health risk to the consumer. For fish, the MRLs are set for muscle and skin in natural proportions. Samples examined for veterinary drugs were collected from fish at processing plants and the samples are representative of fish ready to be placed on the market for human consumption.

1.4 - Contaminants

Samples examined for contaminants were collected from fish at processing plants and are representative of fish ready for human consumption. In the EU, maximum levels (MLs) have been established for certain

contaminants in food[10]. For fish MLs are established for dioxins, dioxins and dioxin-like PCBs, PCB-6, per- and polyfluoroalkyl substances (PFAS) within the compound group of halogenated persistent organic pollutants, as well as the heavy metals mercury, cadmium, and lead, which are therefore mandated within the official control plan for contaminants. In addition, although no MLs have been established for fish, the levels of polybrominated diphenyl esters (PBDEs), chlorinated and organophosphorus pesticides, and other chemical elements were included in the monitoring in 2023.

2 - Materials and methods

2.1 - Sampling

Samples were taken on fish farms or slaughterhouses by official inspectors from the NFSA in all fish-producing regions in Norway. The sampling plan was randomized according to season and region. In 2023, the monitoring program included a total of 988 samples of Atlantic salmon (*Salmo salar*), rainbow trout (*Oncorhynchus mykiss*), turbot (*Scophthalmus maximus*), Atlantic halibut (*Hippoglossus hippoglossus*), Atlantic cod (*Gadus morhua*) and spotted wolffish (*Anarhichas minor*).

Samples were transported to the Institute of Marine Research (IMR) in a frozen state. Analyses of substances with anabolic effects or unauthorized substances were performed on individual fish samples, whereas authorized pharmacologically active substances and contaminants were analyzed as pooled samples comprising three fish from the same cage/farm. For most analyses, the Norwegian quality cut (NQC) was used[11,12]. However, both NQC and individual liver samples were collected for analysis of antibiotics. Samples to be used for analyses of substances with anabolic effects or unauthorized substances also included small fish from early life stages. In these cases, the whole fish except head, tail and gut were used.

2.2 - Pre-treatment

Upon arrival at the IMR the sample identification was anonymised for the analysts. A backup sample was stored for all samples. The muscle samples were homogenized before analyses. For analyses of group B substances and contaminants, pooled samples of muscle from three fish from the same cage/farm were homogenized. Samples of liver were excised from the fish to be screened for residues of antimicrobial agents by the microbiological inhibition zone assay. Liver samples were examined individually and if residues were detected, the backup sample of muscle was analyzed by chemical methods. The maximum residue limits for veterinary drugs are set for muscle and skin in natural proportions[7]. Therefore, according to the analytical protocol, any detection of drug residues in the muscle or liver was followed by a duplicate re-analysis of the backup sample, consisting of muscle and skin in natural proportions.

2.3 - Analytical methods

The laboratory routines and most of the analytical methods are accredited in accordance with the standard ISO 17025. A summary of the analytical methods and their limit of detection (LOD) or limit of quantification (LOQ) is shown in Table 1. The LOD is the lowest level at which the method is able to detect the substance, while the LOQ is the lowest level for a reliable quantitative measurement. For all methods, a sample blank and a quality control sample (QC) with a known composition and concentration of target analyte are included in each series. The methods are regularly verified by participation in inter laboratory proficiency tests, and by analysing certified reference material (CRM), where such exist.

*Table 1 . Summary of analytical methods * .*

Group of substances	Analyte	Method	LOD (µg/kg w.w.)	LOQ (µg/kg w.w.)	Reference limit for assessment (µg/kg w.w.)	Laboratory
A1a Stilbenes	Diethylstilbestrol	LC-MS/MS	1		Presence	Eurofins
	Dienestrol		1			
	Hexestrol		1			
	B-Estradiol		1			
	α-Estradiol		1			
	Estriol		1			
	Estrone		1			
	Ethinyl estradiol		1			
A1c Steroids	α-nandrolon	LC-MS/MS	1		Presence	Eurofins
	β-nandrolon		1			
	α-trenbolon		1			
	β-trenbolon		1			
	Trenbolone-acetate		2			
	16-Hydroxy stanozolol		1			
	α -Boldenone		1			
	Boldenone		1			
	Chlor-Testosterone (Clostebol)		1			
	Epitestosterone		1			
	Methyl-Boldenone (Dianabol)		1			
	Methyltestosterone		1			
	Nortestosterone/ Nandrolone		1			
	Stanozolol		1			
	Testosterone		1			
	Testosterone-propionate		2			
A1d Resorcylic acid lactones, incl. Zeranol	Zeranol	LC -MS/MS	1		Presence	Eurofins
	Beta-Zearalanol		1			
	Brombuterol		0.10			
	Cimaterol		0.50			
	Cimbuterol		0.50			
	Clenbuterol		0.10			
	Clencyclohexerol		1.0			
	Clenpenterol		0.50			

Group of substances	Analyte	Method	LOD (µg/kg w.w.)	LOQ (µg/kg w.w.)	Reference limit for assessment (µg/kg w.w.)	Laboratory
A1e Beta-agonists	Clenproperol	LC-MS/MS	0.50		Presence	Eurofins
	Fenoterol		5.0			
	Hydroxymethyl-clenbuterol		0.10			
	Isoxsuprine		0.50			
	Chlorbrombuterol		0.10			
	Mabuterol		0.10			
	Mapenterol		0.10			
	Metaproterenol (Orciprenalin)		10			
	Ractopamine		1.0			
	Ritodrine		0.50			
	Salbutamol		5.0			
	Salmeterol		5.0			
	Terbutaline		10			
	Tulobuterol		0.10			
	Zilpaterol		5.0			
A2a Chloramphenicol	Chloramphenicol	LC-MS/MS	0.25		Presence	IMR
A2b Nitrofurans	Nitrofuran AOZ	LC-MS/MS	0.5		Presence	IMR
	Nitrofuran AHD		0.6			
	Nitrofuran AMOZ		0.4			
	Nitrofuran SEM		0.5			
A2c Metronidazole	Metronidazole	LC-MS/MS	0.3		Presence	IMR
	Hydroxy-metronidazole		2.0			
A2d Other substances	Dapsone	LC-MS/MS	30		Presence	Eurofins
A3a Dyes	Malachite green	LC-MS/MS	0.15		Presence	IMR
	Leuco malachite green		0.15			
	Crystal violet		0.30		Presence	
	Leuco crystal violet		0.15		Presence	
	Brilliant green		0.15		Presence	
B1a Antibacterial Substances Micro-biological method	Quinolones	3-plate Screening Method**	200		100-600	IMR
	Tetracyclines		200		100	
	Amphenicols		200		1000	
	Sulfonamides		400		100	
	Oxolinic acid			40	100	
	Flumequine			40	600	

Group of substances	Analyte	Method	LOD (µg/kg w.w.)	LOQ (µg/kg w.w.)	Reference limit for assessment (µg/kg w.w.)	Laboratory
		LC-MS/MS				IMR
B1a Antibacterial substances Chemical methods	Enrofloxacin			10	100	
	Ciprofloxacin			10	100	
	Trimethoprim			2.0	50	
	Florfenicol			4.0	1000	
	Oxytetracycline	LC-MS/MS		30	100	Eurofins
	Ormethoprim†	LC-MS/MS		30	100 (Sum sulfonamides)	Eurofins
	Trimethoprim†			30		
	Sulfabenzamide†			30		
	Sulfacetamide†			30		
	Sulfachloropyridazine†			30		
	Sulfaclozine†			30		
	Sulfadiazine†			30		
	Sulfadimethoxine†			30		
	Sulfadimidine†			30		
	Sulfadoxine†			30		
	Sulfaguanidine†			30		
	Sulfamerazine†			30		
	Sulfameter†			30		
	Sulfamethizole†			30		
	Sulfamethoxazole†			30		
	Sulfamethoxypyridazine†			30		
	Sulfamonomethoxine†			30		
	Sulfanilamide†			30		
	Sulfaphenazole†			30		
	Sulfapyridine†			30		
	Sulfaquinoxaline†			30		
	Sulfathiazole†			30		
	Sulfisomidine†			30		
	Sulfisoxazole†			30		
	Praziquantel	LC-MS/MS		2	20	IMR
	Fenbendazole	LC-MS/MS		3	-	IMR
	Emamectin	LC-MS/MS		2.0	100	IMR
	Diflubenzuron	LC-MS/MS		1.0	10	IMR
	Teflubenzuron			1.0	500	
	Hexaflumuron			1.0	500	

Group of substances	Analyte	Method	LOD (µg/kg w.w.)	LOQ (µg/kg w.w.)	Reference limit for assessment (µg/kg w.w.)	Laboratory
B1b Insecticides, fungicides, anthelmintics and other antiparasitic drugs	Lufenuron			1.0	1350	
	Abamectin	LC-MS/MS		2	-	Eurofins
	Doramectin			2	-	
	Emamectin B1a			2	100	
	Eprinomectin			2	50	
	Ivermectin			2	-	
	Moxidectin			2	-	
	Imidacloprid***	LC-MS/MS		4	600	Eurofins
	Bifenthrin	GC-MS/MS		0.51-1.0	-	IMR
	Cyfluthrin			0.51-1.0	-	
	Cypermethrin			0.51-1.0	50	
	Deltamethrin			0.51-1.0	10	
	Fenvalerate			0.51-1.0	-	
	Lambda-Cyhalothrin			0.51-1.0	-	
	Permethrin			1.0-2.1	-	
B1c Sedatives	Isoeugenol***	GC-FID		50	6000	Eurofins
Halogenated persistent organic pollutants	Dioxins and dl-PCBs	HRGC-HRMS		0.0000010-0.11 ng TEQ/kg	6.5 ng TEQ/kg	IMR
	PCB-6	GC-MS GC-MS/MS		0.0052 – 0.040	75	IMR
	PBDEs	GC-MS		0.00052-0.052	-	IMR
	Organochlorine pesticides	GC-MS/MS		0.020-2.1	-	IMR
	Chlorpyriphos	GC-MS/MS		0.020-0.041	-	IMR
	Chlorpyrifos-methyl			0.10-0.21	-	
	Pirimiphos-methyl			0.10-0.21	-	
	PFAS	LC-MS/MS		0.1-1	-	IMR
	PFOS			0.1	2	
	PFOA			0.2	0.2	
	PFNA			0.5	0.5	
	PFHxS			0.1	0.2	
	Sum PFAS-4				2	
	Other PFAS			0.1-1		
	PFOS			0.01	2	
	PFOA			0.01	0.2	

Group of substances	Analyte	Method LC-MS/MS	LOD (µg/kg w.w.)	LOQ (µg/kg w.w.)	Reference limit for assessment (µg/kg w.w.)	Laboratory Eurofins
	PFNA			0.01	0.5	
	PFHxS			0.01	0.2	
	Sum PFAS-4				2	
	Other PFAS			0.01-0.3		
Metals/ Chemical elements	Lead	ICP-MS		0.005-0.010 mg/kg	0.3 mg/kg	IMR
	Cadmium			0.001-0.002 mg/kg	0.05 mg/kg‡	
	Arsenic			0.002-0.003 mg/kg	-	
	Mercury			0.001-0.002 mg/kg	0.3/ 0.5/ 1 mg/kg‡	
	Cobalt			0.005-0.010 mg/kg	-	
	Chromium			0.006-0.010 mg/kg	-	
	Copper			0.1 mg/kg	-	
	Iron			0.1 mg/kg	-	
	Manganese			0.03 mg/kg	-	
	Molybdenum			0.02-0.04 mg/kg	-	
	Nickel			0.06-0.10 mg/kg	-	
	Selenium			0.01 mg/kg	-	
	Silver			0.002-0.004 mg/kg	-	
	Vanadium			0.001-0.002 mg/kg	-	
	Zinc			0.5 mg/kg	-	

* All methods used muscle as sample matrix except for microbiological methods for antibacterial substances (B1), where liver was used. ** Only screening method, positive results must be confirmed by a chemical method. *** Not accredited. †All chemical analyses included for B1a Antibacterial substances used muscle from fish sampled at slaughterhouses, except for chemical analysis of sulfonamides, which was performed on muscle samples from fish sampled at fish farms. ‡Maximum levels for cadmium and mercury are dependent on the fish species. The ML for cadmium is 0.05 mg/kg for all included species, while the MLs for mercury are 0.3 mg/kg for Atlantic cod, Atlantic salmon and rainbow trout, 0.5 mg/kg for spotted wolffish, and 1 mg/kg for Atlantic halibut, respectively[10].

3 - Results

3.1 - Substances with anabolic effects and unauthorized substances

In 2023, a total of 384 individual fillet samples were tested for residues of illegal substances, including stilbenes (191 samples), steroids (95 samples), resorcylic acid lactones (Zeranol & beta-Zearalanol; 191 samples), beta agonists (98 samples), and unauthorized veterinary drugs including Chloramphenicol (96 samples), Nitrofurans (98 samples), Metronidazole (95 samples), Dapsone (95 samples) and Dyes (191 samples). The samples were mainly taken from Atlantic salmon, but also samples from rainbow trout, Atlantic cod, spotted wolffish and Atlantic halibut were analysed. The evaluation criterion for samples for official controls of illegal substances is presence.

In 2023, testosterone was detected (3.7 ug/kg) in one sample rainbow trout. The confirmed (re-analysis) laboratory-analysed finding was reported to the Norwegian Food Safety Authority (Mattilsynet). The subsequent investigation concluded with compliance for the sample, identifying a source of cross-contamination at the sampling site as the cause for the positive result. The analysis result, handling, processing and conclusion on the positive sample were further reported to the European Authorities through the annual data reporting.

No residues of any other unauthorized compounds were detected in any of the samples. The individual substances included in the monitoring of these substance groups, analytical methods, and reference limits are listed in Table 1, Materials and Methods.

Table 2. Substances with anabolic effect and unauthorized substances in fillets of farmed fish. The table shows the total number of samples analysed in 2023, number of samples per fish species and number of positive samples for residues of illegal substances included in the monitoring.

	Total number of samples[1]	Species				
		Atlantic salmon	Rainbow trout	Atlantic cod	Spotted wolffish	Atlantic halibut
A1a Stilbenes[2]	191	176	11	2	-	2
A1c Steroids[2]	95	83	7	3	1	1
A1d Resorcylic acid lactones, incl. Zeranol[2]	191	176	11	2	-	2
A1e Beta-agonists[2]	98	92	3	2	-	1
A2a Chloramphenicol	96	88	6	1	-	1
A2b Nitrofurans (AHD, AOZ, AMOZ, SEM)	98	92	3	2	-	1
A2c Metronidazole, Metronidazole hydroxide	95	83	7	3	1	1
A2d Dapsone	95	88	5	1	-	1
A3a Dyes[2]	191	171	13	4	1	2

[1] Fillet from individual fish per sample taken at the production site.

[2] A list over all individual substances included in the monitoring, analytical methods, and reference limits can be found in Chapter 2, Materials and Methods, Table 1.

3.2 - Residues of authorized veterinary drugs

Samples analyzed for veterinary drugs were collected from fish at processing plants, representing fish ready for human consumption. The maximum residue limit (MRL) for veterinary drugs is defined for muscle and skin in natural proportions[7]. Therefore, according to the analytical protocol, any detection of drug residues in a sample of muscle or liver would be followed by a re-analysis of the backup sample, consisting of muscle and skin in natural proportions, in duplicate.

3.2.1 - Group B1a, Antimicrobial substances

Antibacterial agents were monitored through a combination of a three-plate bioassay and chemical methods. The broad groups a) quinolones, b) amphenicols and tetracyclines and c) sulfonamides were screened in 127 pooled liver samples, representing livers from 381 fish (Table 3). In addition, a total of 108 pooled fillet samples, representing 324 fish taken at processing sites (Group B samples), were tested for residues of antibacterial substances using chemical analysis methods (Table 4). No residues were detected in any of the samples analyzed. Furthermore, sulfonamides, ormethoprim and trimethoprim were measured in muscle samples of 95 individual fish samples taken at the farm (Group A samples), using a chemical analysis method (Table 4). None of the substances included in the measurement were detected above LOQ.

Table 3 . Antibacterial agents in liver of farmed fish. The table shows total number of pooled samples analysed in 2023, number of samples analysed per fish species, number of samples above LOQ (n >LOQ), and method LOQs for the screening for residues of four groups of broad-spectrum antibiotics in liver tissue (µg/kg w.w.).

Antibiotics[1]	Total number of pooled samples	Atlantic salmon	Rainbow trout	Atlantic halibut	Turbot	LOQ (µg/kg w.w.)
n	**127**	116	9	1	1	
Quinolones	*n >LOQ*	0				100
Sulfonamides	*n >LOQ*	0				400
Tetracyclines	*n >LOQ*	0				200
Amphenicols	*n >LOQ*	0				200

[1] No MRL established for liver

Table 4 . Antibacterial agents in fillets of farmed fish. The table shows the total number of pooled samples analyzed in 2023, the number of samples analyzed per fish species, the number of samples above the LOQ (n >LOQ), method LOQs (µg/kg w.w.), and legal maximum residue limits (MRLs) for residues of different antibacterial substances included in the monitoring.

Antibacterial agents	Total number of pooled samples	*Species*				LOQ (µg/kg w.w.)	MRL (µg/kg w.w.)
		Atlantic salmon	Rainbow trout	Atlantic cod	Atlantic halibut		
n	**88**	77	10	1	**-**		
Ciprofloxacin	*n >LOQ*	0				10	100
Enrofloxacin	*n >LOQ*	0				10	100
Florfenicol	*n >LOQ*	0				4	1000
Flumequine	*n >LOQ*	0				40	600
Oxolinic acid	*n >LOQ*	0				40	100
Trimethoprim	*n >LOQ*	0				2	50
n	**20**	18	1	1	-		
Tetracycline	*n >LOQ*	0				30	100

Doxycycline	*n >LOQ*	0				30	100
Chlortetracycline	*n >LOQ*	0				30	100
Oxytetracycline	*n >LOQ*	0				30	100
n	**95**	88	5	1	1		
Sulfonamides[1]	*n >LOQ*	0				30	100
Ormethoprim[1]	*n >LOQ*	0				30	-
Trimethoprim[1]	*n >LOQ*	0				30	50

[1] Analysed in 95 individual fillet samples taken at the farm.

3.2.2 - Group B1b, Insecticides, fungicides, anthelmintics and other antiparasitic agents

3.2.2.1 - Carbamates and pyrethroids

In 2023, carbamates and pyrethroid substances were monitored in 111 samples (Table 5). Cypermethrin was detected in 22 out of 99 pooled fillet samples of Atlantic salmon and one out of seven samples of rainbow trout. Residues of deltamethrin were found in one samples of salmon.

Table 5. Carbamates and pyrethroid substances in fillet of farmed fish. The table shows the total number of pooled samples analyzed in 2023, the number of samples analyzed per farmed fish species, the number of samples above LOQ (n >LOQ), and the median and maximum values for measured residues of carbamate and pyrethroid substances (µg/kg w.w.). The median was calculated when more 50% of the samples had values above LOQ. Where none of the samples had values above LOQ, the maximum value was set at LOQ. Method LOQs and legal maximum residue limits (MRL) for the different substances (µg/kg w.w.) are given in the last two columns.

	Total number of pooled samples	Atlantic salmon	Rainbow trout	Atlantic cod	Spotted wolffish	LOQ	MRL fin fish
n	111	99	7	4	1		
Cypermethrin	*n >LOQ*	22	1	0	0	0.50-1.0	50[1]
	Median	LOQ	LOQ	-	-		
	Max value	2.9	1.2	LOQ	LOQ		
Deltamethrin	*n >LOQ*	1	0	0	0	0.50-1.0	10
	Median	-	-		-		
	Max value	1.6	LOQ	LOQ	LOQ		
Bifenthrin	*n >LOQ*	0	0	0	0	0.50-1.0	-
	Median	-	-	-	-		
	Max value	LOQ	LOQ	LOQ	LOQ		
Cyfluthrin	*n >LOQ*	0	0	0	0	0.50-1.0	-
	Median	-	-	-	-		
	Max value	LOQ	LOQ	LOQ	LOQ		
Fenvalerat	*n >LOQ*	0	0	0	0	0.50-1.0	-
	Median	-	-	-	-		
	Max value	LOQ	LOQ	LOQ	LOQ		
Lambda-Cyhalothrin	*n >LOQ*	0	0	0	0	0.50-1.0	-
	Median	-	-	-	-		
	Max value	LOQ	LOQ	LOQ	LOQ		

	Total number of pooled samples	Atlantic salmon	Rainbow trout	Atlantic cod	Spotted wolffish	LOQ	MRL fin fish
Permethrin	*n >LOQ*	0	0	0	0	1.0-2.0	-
	Median	-	-	-	-		
	Max value	LOQ	LOQ	LOQ	LOQ		

[1] MRL established for *Salmonidae* only (muscle and skin in natural proportions).

Both cypermethrin and deltamethrin are synthetic pyrethroid substances used as pharmaceutical delousing agents applied as bath treatment in aquaculture farm cages, but also as insecticides in large-scale commercial agricultural applications. Residues of cypermethrin and deltamethrin in fish may therefore also originate from transfer via plant-based ingredients in fish feed.

There are no pesticide MRLs established for cypermethrin or deltamethrin in fish muscle[13,14]. The maximum values of cypermethrin measured were 2.9 µg/kg in salmon, and 1.2 µg/kg in rainbow trout, which are both below the MRL of 50 µg/kg[7] established for cypermethrin residues from use as veterinary drugs. The MRL for deltamethrin used as veterinary drug is established at 10 µg/kg for fin fish[7]. The maximum value of deltamethrin detected (1.6 µg/kg in Atlantic salmon) was found below this MRL.

None of the other carbamate or pyrethroid substances included in the monitoring, were detected in any of the samples.

3.2.2.2 - Anthelmintics

The residues of anthelmintics, such as anti-sea-lice agents (Table 6) and agents for treatment of endoparasites (Table 7), were monitored in a total of 490 pooled fillet samples, representing 1470 fish.

Residues of the anti-sea lice agent emamectin (6.2 µg/kg) were detected in one out of 142 analyzed samples; the level was below the MRL of 100 µg/kg[7]. Residues of imidacloprid (5.6 µg/kg) were detected in one sample of Atlantic salmon and were below the MRL established at 600 µg imidacloprid/kg for fish fillet[7]. No residues of other anti-sea lice agents or antiparasitic agents were detected in any of the samples in 2023.

Table 6. Anti-sea lice agents in fillet of farmed fish. The table shows the total number of pooled samples analysed in 2023, number of samples analysed per fish species, number of samples with residues above LOQ (n >LOQ), method LOQs, and legal maximum residue limits (MRL). Where residues above LOQ were detected, the maximum value measured (µg/kg w.w.) is given in the row underneath.

Anti-sealice agents	Total number of pooled samples	Atlantic salmon	Rainbow trout	Atlantic cod	Turbot	Atlantic halibut	LOQ (µg/kg w.w.)	MRL (µg/kg w.w.)
n	**142**	123	12	5	1	1		
Emamectin	*n >LOQ*	1	0	0	0	0		
	Max value (µg/kg w.w.)	6.2	-	-	-	-	2	100
n	**10**	7	3	-	-	-		
Ivermectin	*n >LOQ*	0	0				2	-
Abamectin	*n >LOQ*	0	0				2	-
Doramectin	*n >LOQ*	0	0				2	-
Eprinomectin	*n >LOQ*	0	0				2	50
Moxidectin	*n >LOQ*	0	0				2	-
n	**114**	101	11	2	-	-		
Diflubenzuron	*n >LOQ*	0	0	0			1	10
Teflubenzuron	*n >LOQ*	0	0	0			1	500
Lufenuron	*n >LOQ*	0	0	0			1	1350
Hexaflumeron	*n >LOQ*	0	0	0			1	500
Fluazuron	*n >LOQ*	0	0	0			1	200
n	**110**	93	9	4	2	2		
Imidacloprid	*n >LOQ*	1	0	0	0	0		
	Max value (µg/kg w.w.)	5.6	-	-	-	-	4	600

Table 7. Agents against endoparasites in fillet of farmed fish. The table shows the total number of pooled samples analyzed in 2023, the number of samples analyzed per fish species, the number of samples above LOQ (n >LOQ), method LOQs, and legal maximum limits (MRLs) for praziquantel and fenbendazole measured in fish fillets (µg/kg w.w.).

	Total number of pooled samples	***Species***			LOQ (µg/kg w.w.)	MRL (µg/kg w.w.)
		Atlantic salmon	Rainbow trout	Atlantic cod		
n	**114**	101	11	2		
Praziquantel	*n >LOQ*	0			2	20
Fenbendazole	*n >LOQ*	0			3	-

3.2.3 - Group B1c, Sedatives

No residues of isoeugenol or eugenol were found in any of the 113 samples analyzed (Table 8).

Table 8 . Sedatives in fillet of farmed fish. The table shows the total number of pooled samples analyzed in 2023, the number of samples analyzed per farmed fish species, and the number of samples above LOQ (n >LOQ), method LOQs, and legal maximum limits (MRLs) for isoeugenol and eugenol measured in fish fillets (µg/kg w.w.).

Sedatives	Total number of pooled samples	Species					LOQ (µg/kg w.w.)	MRL (µg/kg w.w.)
		Atlantic salmon	Rainbow trout	Turbot	Atlantic cod	Atlantic halibut		
n	**113**	104	5	1	2	1		
Isoeugenol	*n >LOQ*	0					50	6000
Eugenol[1]	*n >LOQ*	0					50	-

[1] Eugenol *n* (total)=103; *n* (*Atlantic salmon*)= 94

3.3 - Contaminants

3.3.1 - Halogenated persistent organic pollutants

3.3.1.1 - Dioxin, dl-PCBs and PCB-6

The levels of dioxin (PCDD+PCDF), dl-PCBs and PCB-6 in farmed fish are shown in Table 9. Most of the samples were taken from Atlantic salmon, but also samples from rainbow trout, Atlantic cod, turbot and Atlantic halibut were examined. The sums of dioxins, dioxins + dl-PCBs and PCB-6 are calculated as upper bound[10]. Accordingly, the numerical LOQ values were used for congeners with levels below LOQ.

The levels of dioxins and dl-PCBs are reported as ng toxic equivalents 2005 (TEQ05)/kg and represent the sum of 17 different PCDD/F and 12 dl-PCBs where each congener was multiplied by a Toxic Equivalency Factor (TEF). TEF values are determined by the World Health Organization (WHO), and the toxicity of each congener is expressed relative to the most toxic form of dioxin, which has a TEF value of 1[10,15]. TEF values have recently been reevaluated and updated[16]. However, the new values have not yet been incorporated into the legal framework, and the 2005 TEF is still applied for the calculation of the TEQ.

Dioxin levels measured in different farmed fish species in 2023 were similar to those found in the previous year. For salmon, the median of the sum of dioxins was 0.11 ng TEQ/kg w.w. The maximum value found in salmon (0.28 ng TEQ/kg w.w.) was below the EU maximum level of 3.5 ng TEQ/kg w.w.[10] The median of the sum of all 29 PCDD/F and dl-PCBs was 0.32 ng TEQ/kg w.w for salmon (same as in 2022) and 0.50 ng TEQ/kg w.w for rainbow trout. The highest result for sum dioxin and dl-like PCBs was 0.76 ng TEQ/kg w.w., measured in tubot. All measured values were below the EU maximum level of 6.5 ng TEQ/kg w.w.[10]. The median of PCB-6 for salmon was 2.7 µg/kg w.w and 3.9 µg/kg in rainbow trout, with maximum concentrations of 5.7 and 4.7 µg/kg w.w, respectively. For PCB-6, a maximum level is set at 75 µg/kg w.w. in the EU[10].

Table 9. Median and maximum (Max value) concentrations of the sum of dioxins (ng TEQ/kg w.w.), the sum of dioxin and dioxin-like PCBs (dl-PCBs; ng TEQ/kg w.w.) and PCB-6 (µg/kg w.w.) in fillets of different farmed fish species in 2023. All concentrations are calculated as upper bound (UB). The EU maximum levels established for fish muscle (ng TEQ/kg w.w.) are given in the last column.

		Atlantic salmon	Rainbow trout	Atlantic cod	Turbot	Atlantic halibut	EU Maximum Level
	n	**100**	**5**	**2**	**1**	**1**	
Sum dioxins (ng TEQ/kg w.w.)	*Median*	0.11	0.14	-	-	-	
	Max value	0.28	0.22	0.01	0.22	0.21	3.5
Sum dioxin + dl-PCBs (ng TEQ/kg w.w.)	*Median*	0.32	0.50	-	-	-	
	Max value	0.74	0.57	0.02	0.76	0.73	6.5
PCB-6 (µg/kg w.w.)	*Median*	2.7	3.9	-	-	-	
	Max value	5.7	4.7	0.091	5.6	5.6	75

3.3.1.2 - Organochlorine pesticides

For several of the pesticides, the amount present is calculated as a sum, including metabolites or transformation products[17]. The results for these groups of pesticides are presented in Table 10. To calculate the sum of the components, conversion factors (Table A1, Appendix) are used to adjust for different molecular weights[17]. The sums in Table 10 were calculated according to the upper bound (UB) formula. DDT and Chlordane levels were calculated as both the sum of all measured metabolites, as well as the sums of metabolites according to the legal residue definitions established through Regulation (EC) No 149/2008[18]. When using UB calculations, the numerical value of LOQ is used as a concentration value for each non-quantified analyte. UB thus represents a "worst-case scenario". As an example, all measurements of endosulfan are below LOQ, however, a sum is generated based on the LOQ-values. The results for the organochlorine pesticides are summarised in Table 11.

There are currently no MRLs established in fish fillet for any of the listed pesticides[19].

Table 10. Median and maximum (Max) concentrations of the sum of certain organochlorine pesticides and their metabolites in fillet of farmed fish (µg/kg w.w.). The values are calculated as upper bound and adjusted for molecular weights.

Pesticide		Atlantic salmon	Rainbow trout	Atlantic cod	Spotted wolffish
Sum	*n*	99	7	4	1
DDT	*Median (UB)*	4.0[1] (3.9)[2]	4.0[1] (3.9)[2]	0.32[1] (0.27)[2]	-
	Max (UB)	9.1[1] (8.9) [2]	6.0[1] (5.9)[2]	0.34[1] (0.28)[2]	5.6[1] (5.5)[2]
Endosulfane	*Median (UB)*	2.2	2.2	-	-
	Max (UB)	2.2	2.2	1.1	2.2
Dieldrin	*Median (UB)*	1.5	1.4	0.41	-
	Max (UB)	3.6	2.0	0.41	2.1
Chlordane	*Median (UB)*	0.69[3] (0.49)[4]	0.64[3] (0.44)[4]	0.25[3] (0.15)[4]	-
	Max (UB)	1.9[3] (1.6)[4]	0.73[3] (0.54)[4]	0.25[3] (0.15)[4]	0.79[3] (0.60)[4]
Heptachlor	*Median (UB)*	1.2	1.2	0.6	-
	Max (UB)	1.4	1.2	0.6	1.2

Pesticide		Atlantic salmon	Rainbow trout	Atlantic cod	Spotted wolffish
Toxaphene	*Median (UB)*	1.9	1.9	0.9	-
	Max (UB)	4.8	2.0	0.9	2.7

[1] DDT (sum of p,p-DDT, o,p-DDT, p,p-DDD, o,p-DDD, p,p-DDE,and o,p-DDE expressed as DDT)

[2] Legal residue definition according to Reg. (EC) No 149/2008: DDT (sum of p,p´-DDT, o,p´-DDT, p-p´-DDE and p,p´-TDE (DDD) expressed as DDT).

[3] Chlordane (sum of cis- and trans-isomers and oxychlordane expressed as chlordane).

[4] Legal residue definition according to Reg. (EC) No 149/2008: Chlordane (sum of cis- and trans-chlordane).

Table 11. Pesticides in fillets of farmed fish (µg/kg w.w.). The table shows the number of samples analysed in 2023 per species, number of samples above LOQ (n >LOQ), median, and maximum measured value (Max value). The median was calculated when more 50% of the samples had values above LOQ. Where none of the samples had values above LOQ, the maximum value was set at LOQ. Method LOQs for the different compounds are given in the last column.

Pesticide		Atlantic salmon	Rainbow trout	Atlantic cod	Spotted wolffish	LOQ
	n	99	7	4	1	
α-Hexachlorocyclo- hexane	*n >LOQ*	99	7	0	1	
	Median	0,089	0.081	-	-	
	Max value	0.14	0.1	LOQ	0.051	0.020-0.040
β-Hexachlorocyclo- hexane	*n >LOQ*	99	7	0	1	
	Median	0.098	0.093	-	-	
	Max value	0.16	0.11	LOQ	0.068	0.020-0.040
γ-Hexachlorocyclo- hexane (Lindane)	*n >LOQ*	40	5	0	0	
	Median	-	0.043	-	-	
	Max value	0.072	0.054	LOQ	LOQ	0.020-0.040
Hexachlorobenzene	*n >LOQ*	99	7	0	1	
	Median	0.85	1	-	-	
	Max value	2.5	1.2	LOQ	1.3	0.10-0.20
Pentachlorobenzene	*n >LOQ*	0	0	0	0	
	Median	-	-	-	-	
	Max value	LOQ	LOQ	LOQ	LOQ	0.50- 1.0
Toxaphene Parlar 32	*n >LOQ*	0	0	0	0	
	Median	-	-	-	-	
	Max value	LOQ	LOQ	LOQ	LOQ	0.50- 1.0

Pesticide		Atlantic salmon	Rainbow trout	Atlantic cod	Spotted wolffish	LOQ
Toxaphene Parlar 40+41	*n >LOQ*	0	0	0	0	
	Median	-	-	-	-	
	Max value	LOQ	LOQ	LOQ	LOQ	1.0-2.0
Trans-Nonachlor	*n >LOQ*	99	7	0	1	
	Median	0.55	0.59	-	-	
	Max value	1.6	0.72	LOQ	0.9	0.50- 1.0
Endrin	*n >LOQ*	0	0	0	0	
	Median	-	-	-	-	
	Max value	LOQ	LOQ	LOQ	LOQ	0.50- 1.0
Endrin-ketone	*n >LOQ*	0	0	0	0	
	Median	-	-	-	-	
	Max value	LOQ	LOQ	LOQ	LOQ	0.50- 1.0
Mirex	*n >LOQ*	16	1	0	1	
	Median	-	-	-	-	
	Max value	0.076	0.041	LOQ	0.046	0.020-0.40
Isodrin	*n >LOQ*	0	0	0	0	
	Median	-	-	-	-	
	Max value	LOQ	LOQ	LOQ	LOQ	0.5- 1.0

3.3.1.3 - Perfluorinated compounds

Per- and polyfluoroalkyl substances (PFAS) are a large class of synthetic chemicals. They have a wide range of physical and chemical properties and have been used in various applications for over 50 years. PFAS are increasingly detected as environmental pollutants, and some of the substances have been linked to negative health effects. From the 1st January 2023, MLs have been established for fish fillet for four PFAS (PFOS, PFOA, PFNA, PFHxS) individually and their sum (PFAS-4). PFAS are thus included into the control plan for farmed fish and have been analyzed in a total of 296 fillet samples in 2023. To survey the potential presence of additional PFAS compounds, 40 samples (36 samples of Atlantic salmon, two samples of rainbow trout, one sample of cod, and one sample of turbot) were sent for analysis with an extended method covering an additional 29 compounds (listed in Table A2, Appendix). The combined results of the PFAS measurements are presented in Table 12.

Table 12. Perfluorinated compounds in fillets of different farmed fish species (µg/kg w.w.). The table shows the number of samples analyzed per species, the number of samples with values above LOQ (n > LOQ), and the maximum concentration measured (Max value) of different perfluorinated compounds. Method LOQs and maximum levels (ML) for the different compounds are given in the last column (µg/kg w.w.).

		Atlantic salmon	Rainbow trout	Atlantic cod	Turbot	Atlantic halibut	LOQ†	ML
	n	**260**	**22**	**10**	**2**	**2**		
PFBA	n >LOQ	0	0	0	0	0	1 (0.3)	
	Max value	-	-	-	-	-		
PFBS	n >LOQ	0	0	0	0	0	0.1 (0.01)	
	Max value	-	-	-	-	-		
PFDA	n >LOQ	0	0	0	1	0	0.1 (0.01)	
	Max value	-	-	-	0.027	-		
PFDS	n >LOQ	0	0	0	0	0	0.1 (0.1)	
	Max value	-	-	-	-	-		
PFDoDA	n >LOQ	0	0	0	0	0	0.5 (0.01)	
	Max value	-	-	-	-	-		
PFDoDS	n >LOQ	0	0	0	0	0	0.5 (0.1)	
	Max value	-	-	-	-	-		
PFDS	n >LOQ	0	0	0	0	0	0.1 (0.1)	
	Max value	-	-	-	-	-		
PFHpA	n >LOQ	0	0	0	0	0	0.2 (0.01)	
	Max value	-	-	-	-	-		
PFHpS	n >LOQ	0	0	0	0	0	0.1 (0.01)	
	Max value	-	-	-	-	-		
PFHxA	n >LOQ	0	0	0	0	0	0.5 (0.1)	
	Max value	-	-	-	-	-		
PFHxDA	n >LOQ	0	0	0	0	0	1 (0.01)	
	Max value	-	-	-	-	-		
PFHxS	n >LOQ	0	0	0	0	0	0.1 (0.01)	0.2
	Max value	-	-	-	-	-		

		Atlantic salmon	Rainbow trout	Atlantic cod	Turbot	Atlantic halibut	LOQ	ML
PFNA	n >LOQ	0	0	0	1	0	0.5 (0.01)	0.5
	Max value	-	-	-	0.081	-		
PFNS	n >LOQ	0	0	0	0	0	0.1 (0.1)	
	Max value	-	-	-	-	-		
PFOA	n >LOQ	0	0	0	0	0	0.2 (0.01)	0.2
	Max value	-	-	-	-	-		
PFOS	n >LOQ	5	1	3	2	2	0.1 (0.01)	2
	Max value	0.12	0.012	0.13	0.32	0.13		
FOSA	n >LOQ	35	2	1	1	0	0.5 (0.01)	
	Max value	0.061	0.043	0.041	0.097	-		
PFPeA	n >LOQ	0	0	0	0	0	0.5 (0.1)	
	Max value	-	-	-	-	-		
PFPeS	n >LOQ	0	0	0	0	0	0.1 (0.01)	
	Max value	-	-	-	-	-		
PFTeDA	n >LOQ	0	0	0	0	0	0.5 (0.01)	
	Max value	-	-	-	-	-		
PFTrDA	n >LOQ	0	0	0	0	0	0.5 (0.01)	
	Max value	-	-	-	-	-		
PFUnDA	n >LOQ	0	0	1	1	0	0.2 (0.01)	
	Max value	-	-	0.017	0.055	-		
PFUnDS	n >LOQ	0	0	0	0	0	0.2 (0.1)	
	Max value	-	-	-	-	-		
*Perfluorbutansulfonamid**	n >LOQ	33	2	0	1	0	0.01	
	Max value	0.051	0.016	-	0.080	-		
*PFHxSA**	n >LOQ	1	0	0	1	0	0.01	
	Max value	0.01	-	-	0.014	-		

		Atlantic salmon	Rainbow trout	Atlantic cod	Turbot	Atlantic halibut	LOQ	ML
Sum PFOS, PFOA, PFNA, PFHxS	Mean	0.00068	0.00055	0.026	0.32	0.13		2
	Median	0	0	0	0.32	0.13		
(PFAS-4; LB)	Max value	0.12	0.012	0.13	0.32	0.13		

*Measured in 40 samples in total; n(Atlantic salmon)= 36, n(rainbow trout)= 2, n(cod)= 1, n(turbot)= 1.

† The LOQ of the extended method is given in brackets.

While most of the analyzed PFAS compounds were not found at levels above the respective LOQs, perfluorbutansulfonamid, FOSA, and PFOS were detected in samples of (almost) all species analyzed.

In addition, PFDA, PFNA, PFUnDA and PFHxSA were detected in individual samples of mainly turbot, but also cod and salmon. However, the measured levels did not exceed the MLs established for PFOS and PFNA individually, nor their sum (Sum PFAS-4).

In 2023, two turbot samples were included in the control plan. These samples consistently showed the highest levels, albeit not always significantly higher than the other species.

3.3.1.4 - Brominated flame retardants

PBDEs were measured in 109 pooled fillet samples (Table 13). The EU currently has no maximum limit for BFRs in food.

Table 13. Polybrominated diphenyl ethers (PBDEs) (µg/kg w.w) in fillets of different farmed fish species. The table shows the number of samples analyzed per species, the number of samples with values above LOQ (n > LOQ), the median, and the maximum concentration measured (Max value). The median was calculated as upper bound, when more 50% of the samples had values above LOQ. Where none of the samples had values above LOQ, the maximum value was set at LOQ. Method LOQs (µg/kg w.w) are given in the last column.

		Atlantic salmon	Rainbow trout	Atlantic cod	Turbot	Atlantic halibut	LOQ
PBDE	***n***	**100**	**5**	**2**	**1**	**1**	
PBDE 28	*n >LOQ*	100	5	2	1	1	
	Median	0.0086	0.0085	0.0006	-	-	
	Max value	0.02	0.012	0.00061	0.013	0.013	0.00054-0.086
PBDE 35	*n >LOQ*	0	0	0	0	0	
	Median	-	-	-	-	-	
	Max value	LOQ	LOQ	LOQ	LOQ	LOQ	0.00079-0.0054
PBDE 47	*n >LOQ*	100	5	2	1	1	
	Median	0.13	0.17	0.0058	-	-	
	Max value	0.34	0.18	0.0063	0.24	0.26	0.0032-0.021
PBDE 49	*n >LOQ*	100	5	2	1	1	
	Median	0.041	0.058	0.0018	-	-	
	Max value	0.14	0.08	0.002	0.066	0.07	0.00079-0.0054
PBDE 66	*n >LOQ*	89	5	0	1	1	
	Median	0.0061	0.0064	-	-	-	

		Atlantic salmon	Rainbow trout	Atlantic cod	Turbot	Atlantic halibut	LOQ
	Max value	0.019	0.01	LOQ	0.01	0.012	0.00079-0.0054
PBDE 71	*n >LOQ*	0	0	0	0	0	
	Median	-	-	-	-	-	
	Max value	LOQ	LOQ	LOQ	LOQ	LOQ	0.00054-0.0027
PBDE 75	*n >LOQ*	82	3	0	1	1	
	Median	0.0043	0.0025	-	-	-	
	Max value	0.023	0.009	LOQ	0,01	0.0082	0.00054-0.0027
PBDE 77	*n >LOQ*	3	0	0	0	0	
	Median	-	-	-	-	-	
	Max value	0.0095	LOQ	LOQ	LOQ	LOQ	0.00079-0.011
PBDE 85	*n >LOQ*	0	0	0	0	0	
	Median	-	-	-	-	-	
	Max value	LOQ	LOQ	LOQ	LOQ	LOQ	0.00079-0.0054
PBDE 99	*n >LOQ*	100	5	0	1	1	
	Median	0.022	0.031	-	-	-	
	Max value	0.065	0.037	LOQ	0.029	0.053	0.0022-0.011
PBDE 100	*n >LOQ*	100	5	0	1	1	
	Median	0.034	0.045	-	-	-	
	Max value	0.12	0.055	LOQ	0.064	0.067	0.00079-0.011
PBDE 118	*n >LOQ*	25	2	0	0	0	
	Median	-	-	-	-	-	
	Max value	0.0018	0.0021	LOQ	LOQ	LOQ	0.00079-0.011
PBDE 119	*n >LOQ*	46	3	0	1	1	
	Median	-	0.0084	-	-	-	
	Max value	0.012	0.013	LOQ	0.0037	0.0053	0.00079-0.0054
PBDE 138	*n >LOQ*	0	0	0	0	0	
	Median	-	-	-	-	-	
	Max value	LOQ	LOQ	LOQ	LOQ	LOQ	0.0022-0.011
PBDE 153	*n >LOQ*	50	3	0	1	1	
	Median	0.0085	0.0088	-	-	-	
	Max value	0.016	0.0088	LOQ	0.0096	0.017	0.00079-0.011
PBDE 154	*n >LOQ*	100	5	0	1	1	
	Median	0.025	0.037	-	-	-	
	Max value	0.073	0.055	LOQ	0.047	0.054	0.00079-0.011
PBDE 183	*n >LOQ*	24	2	0	0	0	
	Median	-	-	-	-	-	

		Atlantic salmon	Rainbow trout	Atlantic cod	Turbot	Atlantic halibut	LOQ
	Max value	0.032	0.0014	LOQ	LOQ	LOQ	0.00079-0.011
PBDE 196	*n >LOQ*	1	0	0	0	0	
	Median	-	-	-	-	-	
	Max value	0.0013	LOQ	LOQ	LOQ	LOQ	0.00079-0.027
PBDE 197	*n >LOQ*	0	0	0	0	0	
	Median	-	-	-	-	-	
	Max value	LOQ	LOQ	LOQ	LOQ	LOQ	0.00079-0.016
PBDE 206	*n >LOQ*	2	0	0	0	0	
	Median	-	-	-	-	-	
	Max value	0.0058	LOQ	LOQ	LOQ	LOQ	0.0024-0.016
PBDE 207	*n >LOQ*	2	0	0	0	0	
	Median	-	-	-	-	-	
	Max value	0.0047	LOQ	LOQ	LOQ	LOQ	0.0024-0.016
PBDE 209	*n >LOQ*	1	0	0	0	0	
	Median	-	-	-	-	-	
	Max value	0.020	LOQ	LOQ	LOQ	LOQ	0.0044-0.086

3.3.2 - Metals and chemical elements

In 2023, monitoring of the levels of chemical elements, such as arsenic, total mercury, cadmium, and lead, included 341 samples of Atlantic salmon, 22 samples of rainbow trout, 10 samples of Atlantic cod, two samples of turbot and two samples of Atlantic halibut (Table 14).

The concentrations for total mercury were below the EU MLs for fish fillet, for all samples. The highest concentrations of total mercury were 0.06 mg/kg w.w. in salmon and rainbow trout (ML: 0.3 mg/kg), and 0.07 mg/kg w.w. in Atlantic cod (ML: 0.3 mg/kg), turbot (ML: 0.5 mg/kg) and halibut (ML: 1 mg/kg; Table 13).

Cadmium was found in one sample of Atlantic salmon (0.001 mg/kg w.w.) and one sample of Atlantic halibut (0.001 mg/kg w.w.), and both samples of turbot. The maximum concentration was 0.003 mg/kg w.w. in turbot, and was below the EUs maximum level of 0.05 mg/kg w.w.[10]. None of the samples of rainbow trout and Atlantic cod contained cadmium above the LOQ.

Lead was found in two samples of Atlantic salmon (0.01 mg/kg w.w.). In all remaining samples of Atlantic salmon, and all samples of rainbow trout, Atlantic cod, turbot and Atlantic halibut the concentration of lead was below the LOQ. The EU maximum level is currently set at 0.30 mg/kg w.w. in muscle meat of fish[10].

Table 14. Chemical elements (mg/kg w.w.) in fillets of different farmed fish species. The table shows the number of samples analysed, number of samples with values above LOQ (n>LOQ), the median, and the maximum concentration measured (Max value). The median was calculated as upper bound, when more 50% of the samples had values above LOQ. Where none of the samples had values above LOQ, the maximum value was set at LOQ.

Element		Atlantic salmon	Rainbow trout	Atlantic cod	Turbot	Atlantic halibut	LOQ	EU ML
	n	**341**	**22**	**10**	**2**	**2**		
Total Mercury	*n >LOQ*	341	22	10	2	2		
	Median	0.013	0.023	0.061	0.056	0.066		

Element		Atlantic salmon	Rainbow trout	Atlantic cod	Turbot	Atlantic halibut	LOQ	EU ML
Total Mercury	*Max value*	0.057	0.063	0.070	0.065	0.066	0.001-0.002	0.3/ 0.5/ 1[†]
Total Arsenic	*n >LOQ*	341	22	10	2	2		
	Median	0.51	0.8	1.4	1.6	1.3		
	Max value	1.5	1.7	1.9	1.9	1.4	0.002-0.003	n.a.
Cadmium	*n >LOQ*	1	0	0	2	1		
	Median	-	-	-	0.003	-		
	Max value	0.001	LOQ	LOQ	0.003	0.001	0.0009-0.002	0.05[†]
Lead	*n >LOQ*	2	0	0	0	0		
	Median	LOQ	-	-	-	-		
	Max value	0.01	LOQ	LOQ	LOQ	LOQ	0.005-0.01	0.3
Cobalt	*n >LOQ*	1	0	0	0	0		
	Median	-	-	-	-	-		
	Max value	0.022	LOQ	LOQ	LOQ	LOQ	0.005-0.01	n.a.
Chromium	*n >LOQ*	58	6	7	1	1		
	Median	LOQ	LOQ	0.0065	-			
	Max value	0.17	0.098	0.077	0.011	0.030	0.005-0.01	n.a.
Copper	*n >LOQ*	341	22	10	2	2		
	Median	0.40	0.40	0.22	0.19	0.21		
	Max value	0.76	0.5	0.3	0.19	0.23	0.1	n.a.
Iron	*n >LOQ*	341	22	10	2	2		
	Median	2.6	2.7	1.1	0.61	0.94		
	Max value	6.9	3.5	1.5	0.62	1	0.1	n.a.
Manganese	*n >LOQ*	341	22	10	2	2		
	Median	0.078	0.072	0.12	0.58	0.11		
	Max value	1.3	0.13	0.16	0.6	0.12	0.03	n.a.
Molybdenum	*n >LOQ*	0	0	0	0	0		
	Median	-	-	-	-	-		
	Max value	LOQ	LOQ	LOQ	LOQ	LOQ	0.02-0.04	n.a.
Nickel	*n >LOQ*	0	0	0	0	0		
	Median	-	-	-	-	-		
	Max value	LOQ	LOQ	LOQ	LOQ	LOQ	0.06-0.1	n.a.
Selenium	*n >LOQ*	341	22	10	2	2		
	Median	0.18	0.23	0.24	0.22	0.28		
	Max value	0.43	0.37	0.33	0.23	0.28	0.01	n.a.
Silver	*n >LOQ*	0	0	0	0	0		
	Median	-	-	-	-	-		

Element		Atlantic salmon	Rainbow trout	Atlantic cod	Turbot	Atlantic halibut	LOQ	EU ML
	Max value	LOQ	LOQ	LOQ	LOQ	LOQ	0.002-0.004	n.a.
Vanadium	*n >LOQ*	44	0	0	0	0		
	Median	LOQ	-	-	-	-		
	Max value	0.018	LOQ	LOQ	LOQ	LOQ	0.0009-0.002	n.a.
Zinc	*n >LOQ*	341	22	10	2	2		
	Median	4	4	4.6	8.4	4.2		
	Max value	15	4.5	5.4	8.6	4.3	0.5	n.a.

† Maximum levels for cadmium and mercury are dependent on the fish species. The ML for cadmium is 0.05 mg/kg for all included species, while the MLs for mercury are 0.3 mg/kg for Atlantic cod, Atlantic salmon and rainbow trout, 0.5 mg/kg for spotted wolffish, and 1 mg/kg for Atlantic halibut, respectively[10].

Arsenic is determined as “total arsenic”, comprising the sum of all arsenic species. The highest concentration measured was 1.9 mg/kg w.w. in cod and turbot (Table 14). The median and maximum concentrations of total arsenic in Atlantic salmon were 0.51 and 1.5 mg/kg w.w., respectively. The median and maximum concentrations of Arsenic in rainbow trout samples were 0.8 and 1.7 mg/kg w.w., respectively. There is currently no EU upper limit for arsenic in fish fillets.

Eleven additional chemical elements were analyzed in 2023. There is currently no EU limit established for any of these elements. Molybdenum, nickel and silver were not detected in any of the analyzed samples. Cobalt and vanadium were only found in salmon (one and 44 samples, respectively), with maximum concentrations of 0.022 and 0.018 mg/kg w.w., respectively. Chromium was found in all fish species, with maximum concentrations ranging from 0.011 mg/kg w.w. in turbot to 0.17 mg/kg w.w. in Atlantic salmon.

Iron, manganese, selenium and zinc are essential nutrients for humans. The levels of iron, manganese and selenium were found to be similar to the previous years. Moreover, zinc and copper concentrations in fish fillet were found at similar levels to previous years[20].

3.3.3 - Others

The compound group “others” is a group not required for finfish products by Regulation (EU) 2017/625 but includes substances deemed relevant for analyses in Norwegian aquaculture fish by the NFSA and IMR, because these undesirable compounds are present in the environment and may affect food safety. In 2023, organophosphorous pesticides were included in this group.

3.3.3.1 - Organophosphorous compounds

Organophosphorus pesticide residues, chlorpyriphos, chlorpyriphos-methyl, and pirimiphos-methyl, were determined in 111 pooled fillet samples, representing fillet of 333 fish (Table 15). No residues of chlorpyriphos or chlorpyriphos-methyl were detected in any of the samples. Pirimiphos-methyl was detected in seven of 99 samples of Atlantic salmon. The maximum concentration was 0.31 µg pirimiphos-methyl/kg fillet w.w.. There is currently no MRL established for pirimiphos-methyl in fish fillet[19]. No residues were detected in samples of rainbow trout, Atlantic cod or spotted wolffish.

Table 15. Residues of organophosphorous compounds (µg/kg w.w.) in fillets of different species of farmed fish. The table shows the number of samples analyzed in 2023 per species, the number of samples above LOQ (n >LOQ) and the maximum measured value (Max value). Where none of the samples had values above LOQ, the maximum value was set at LOQ. Method LOQs for the different compounds (µg/kg w.w.) are given in the last column.

Compound		Atlantic salmon	Rainbow trout	Atlantic cod	Spotted wolffish	LOQ
	n	99	7	4	1	
Chlorpyriphos	n >LOQ	0	0	0	0	
	Max value	LOQ	LOQ	LOQ	LOQ	0.02-0.04
Chlorpyriphos-methyl	n >LOQ	0	0	0	0	
	Max value	LOQ	LOQ	LOQ	LOQ	0.1-0.2
Pirimiphos-methyl	n >LOQ	7	0	0	0	
	Max value	0.31	LOQ	LOQ	LOQ	0.1-0.2

4 - Conclusions

In 2023, presence of steroids (testosterone) was confirmed in one sample of rainbow trout. However, the sample was found compliant following investigation by the NFSA. Apart from that, no residues of substances with anabolic effect or unauthorized substances were detected in any of the samples analysed.

Residues of the authorized anti-sea-lice agents emamectin and imidacloprid were detected in one sample of salmon each. In addition, cypermethrin and deltamethrin, which can be used both as anti-sealice agents and plant protection agents, was found. However, the concentrations for all of the residues were well below the respective MRLs for the compounds.

As for the previous years, no residues of antibiotics, endoparasitic agents or sedatives were detected in any of the samples.

For contaminants, none of the samples exceeded the EUs maximum levels, where such levels have been established.

5 - References

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5. Commission Delegated Regulation (EU) 2022/931 of 23 March 2022 supplementing Regulation (EU) 2017/625 of the European Parliament and of the Council by laying down rules for the performance of official controls as regards contaminants in food (Text with EEA relevance). (OJ L 162, 17.6.2022, p. 7–12).

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7. Commission Regulation (EU) No 37/2010 of 22 December 2009 on pharmacologically active substances and their classification regarding maximum residue limits in foodstuffs of animal origin (Text with EEA relevance). (OJ L 15, 20.1.2010, p. 1–72).

8. Commission Implementing Regulation (EU) 2021/808 of 22 March 2021 on the performance of analytical methods for residues of pharmacologically active substances used in food-producing animals and on the interpretation of results as well as on the methods to be used for sampling and repealing

Decisions 2002/657/EC and 98/179/EC (Text with EEA relevance). (OJ L 180, 21/05/2021, p. 84–109).

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10. Commission Regulation (EU) 2023/915 of 25 April 2023 on maximum levels for certain contaminants in food and repealing Regulation (EC) No 1881/2006 (Text with EEA relevance). (OJ L 119, 05/05/2023, p. 103–157).

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6 - Appendix

Table A 1 . Calculations of sums for certain pesticides based on molecular weights according to EU DG SANTE (2022)[16].

Sum	Substances included in the sum	Conversion factor
DDT (sum of p,p´-DDT, o,p´-DDT, p,p´-DDD, o,p´-DDD, p,p´-DDE and o,p-DDE expressed as DDT)	op-DDT	1
	pp-DDT	1
	op-DDD	1.108
	pp-DDD	1.108
	op-DDE	1.115
	pp-DDE	1.115
DDT (sum of p,p´-DDT, o,p´-DDT, p-p´-DDE and p,p´-DDD expressed as DDT) [1]	op-DDT	1
	pp-DDT	1
	pp-DDD	1.108
	pp-DDE	1.115
Endosulfan (sum of alpha- and beta-isomers and endosulfan-sulphate expressed as endosulfan) [2]	alpha-endosulfan	1
	beta-endosulfan	1
	endosulfan sulphate	0.962
Aldrin and dieldrin (Aldrin and dieldrin combined expressed as dieldrin) [3]	dieldrin	1
	aldrin	1.044
Chlordane (sum of cis- and trans-isomers and oxychlordane expressed as chlordane)	trans-chlordane	1
	cis-chlordane	1
	oxychlordane	0.967
Chlordane (sum of cis- and trans-chlordane) [1]	trans-chlordane	1
	cis-chlordane	1
Heptachlor (sum of heptachlor and heptachlor epoxide expressed as heptachlor) [1]	heptachlor	1
	trans-heptachlor epoxide	0.959
	cis-heptachlor epoxide	0.959
Toxaphene (sum of Parlar No 2, Parlar No 50 and Parlar No 62) [4]	Toxaphene 26	1
	Toxaphene 50	1
	Toxaphene 62	1

[1] Legal residue definition according to Reg. (EC) No 149/2008.

[2] Legal residue definition according to Reg. (EU) No 310/2011.

[3] Legal residue definition according to Reg. (EC) No 839/2008.

[4] Legal residue definition according to Reg. (EU) 2015/868; Campechlor (Toxaphene).

Table A 2. Additional PFAS compounds included into the monitoring in 2023, and limits of quantification (LOQ; µg/kg ww) of the analytical method. The analytes were measured in 40 samples of farmed fish. None of the analytes were found at levels above the LOQ.

Analyte	LOQ (µg/kg ww)
10:2 Fluortelomersulfonat (10:2 FTS)	< .01
3:3 Fluortelomerkarboksylat (3:3 FTCA)	< .1
4:2 Fluortelomersulfonat (FTS)	< .01
5:3 Fluortelomerkarboksylat (5:3 FTCA)	< .1
6:2 Cl-PFAES	< .01
6:2 Fluortelomer sulfonat (FTS) (H4PFOS)	< .01
7:3-Fluortelomerkarboksylat (7:3 FTCA)	< .1
7H-Dodekafluorheptansyre (HPFHpA)	< .1
8:2 Cl-PFAES	< .01
8:2 Fluortelomersulfonat (FTS)	< .01
DONA (Dodekafluor-3H-4,8-dioxanonanoat)	< .1
HFPO-DA (GenX)	< .1
N-etylperfluoroktansulfonamidetanol (EtFOSE)	< .05
N-etylperfluoroktansulfonamid-HAc (EtFOSAA)	< .1
N-metylperfluoroktansulfonamid (MeFOSA)	< .05
N-metylperfluoroktansulfonamidetanol (MeFOSE)	< .05
N-metylperfluoroktansulfonamid-HAc (MeFOSAA)	< .1
Perfluor(2-etoksyetan)sulfonat (PFEESA)	< .01
Perfluor-1-propansulfonat	< .1
Perfluor-3,6-dioksoheptansyre (NFDHA/3,6-OPFHpA)	< .01
Perfluor-3-metoksypropansyre (PFMPA/PF4OPeA)	< .01
Perfluor-4-metoksybutansyre (PFMBA/PF5OHxA)	< .01
Perfluorheksansyre (PFHxA)	< .1
Perfluoro-4-(perfluoroethyl)cyclohexylsulfonic aci	< .01
Perfluoroktadekansyre (PFODA)	< .01
perfluoro-n-tridecane sulfonic acid (PFTriDS)	< .1
Perfluortetradekansyre (PFTA)	< .01

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