



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

Annual report for 2021

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Sammendrag (norsk):

This report summarises the monitoring data collected in 2021 on the status of illegal substances, pharmaceuticals and contaminants in Norwegian farmed fish. In 2021, a total of 14135 fish were sampled. Samples examined for illegal compounds were collected at all stages of farming and are representative of farmed fish under production. The samples were analysed for substances with anabolic effects or unauthorized substances. Residues of the dye crystal violet were detected in two samples of salmon. A follow-up investigation conducted by the Norwegian Food Safety Authority (NSFA) concluded with the cause likely being a contamination of the samples during sample taking. No other residues of illegal compounds were found. Samples tested for approved veterinary drugs and contaminants were collected at processing plants and are representative of Norwegian farmed fish ready for human consumption. Residues of the anti-seallice agents cypermethrin, emamectin and lufenuron were found, with concentrations below the respective Maximum Residue Limits (MRLs). Other veterinary drugs, like antibiotics or drugs used against internal parasites were not found. No environmental contaminants were found above the EU maximum level (ML).

Sammendrag (engelsk):

Denne rapporten oppsummerer overvåkingsresultatene fra 2021 for ulovlige stoffer, legemidler og miljøgifter i norsk oppdrettsfisk. I 2021, ble det tatt ut prøver av totalt 14135 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 fargestoffet krystallfiolett ble påvist i to prøver av laks. Etterforskning iverksatt av Mattilsynet konkluderte med sannsynlig forurensing 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 inn på slakterier, og er representativt for norsk oppdrettsfisk som er klar for markedet. Rester av lusemidlene cypermethrin, emamectin, lufenuron ble funnet. Prøvene viste nivåer under de respektive grenseverdiene (MRL). Andre veterinære legemidler, som antibiotika eller legemidler brukt mot interne parasitter ble ikke funnet. Ingen miljøgifter ble funnet over EUs maksimumsgrenser.

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1 - Introduction

1.1 - Background

According to EU legislation (EU 2017/625, replacing Directive 96/23/EC), all food producing animals should be monitored for certain substances and residues thereof. The following residues or substance groups are monitored in Norwegian farmed fish:

Group A Substances with anabolic effects and unauthorized substances:

A1: Stilbenes, derivatives and their salts and esters

A3: Steroids

A6: Prohibited substances

Group B Veterinary drugs and contaminants:

B1: Antibacterial agents

B2a: Anthelmintics

B2c: Carbamates and pyrethroids

B2d: Sedatives

B3a: Organochlorine compounds

B3b: Organophosphorus compounds

B3c: Chemical elements

B3d: Mycotoxins

B3e: Dyes

B3f: Others

1.2 - Group A, Substances with anabolic effects and unauthorized substances

Fish tested for illegal compounds 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 and stilbenes, and unauthorized drugs. Unauthorized drugs considered most relevant for aquaculture are chloramphenicol, nitrofurans, metronidazole and dyes. Since the use of the dyes malachite green, crystal violet and brilliant green is not allowed for food producing species (EU 37/2010), they are considered Group A substances and hence monitored in samples throughout the production chain. However, according to Regulation (EU) 2017/625, these dyes belong to the group B3e. Thus, in order to fulfill criteria for group B sampling, some of the samples assigned to analysis of dyes were also collected at the slaughterhouse.

To ensure harmonized levels for the control of unauthorized substances, the analytical methods should meet a minimum required performance limits (MRPLs) set by the European Union (EU 2003/1881, EU 2004/25, CRL 2007), and European reference laboratories (EU-RLs), (EU 2003/1881, EU 2004/25, CRL 2007). Table 1 gives an overview of MRPLs of relevant compounds.

1.3 - Group B, veterinary drugs

In order to protect public health, current EU legislation (EU 37/2010) provisions the assignment of Maximum Residue Limits (MRLs) 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 for each substance and each food product individually. 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 - Group B, contaminants

Samples examined for contaminants were collected from fish at processing plants and are representative of fish ready for human consumption. The EU (EU 1881/2006) has set a Maximum limit (ML) for some of the contaminants in fish, while for others, such as pesticides, polycyclic aromatic hydrocarbons (PAH), perfluorocarbons (PFC) and brominated flame retardants (BFR), maximum limits have not been established.

2 - Material 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 randomised according to season and region. In 2021, the monitoring program included Atlantic salmon (*Salmo salar*), rainbow trout (*Oncorhynchus mykiss*), brown trout (*Salmo trutta*), turbot (*Scophthalmus maximus*), Atlantic halibut (*Hippoglossus hippoglossus*), Arctic char (*Salvelinus alpinus*), Atlantic cod (*Gadus morhua*) and spotted wolffish (*Anarhichas minor*).

Samples were transported to the Institute of Marine Research (IMR) in a frozen state. For most analyses, the Norwegian quality cut (NQC) was used (Johnsen, Hagen et al. 2011). 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, and in these cases, the whole fish except head, tail and gut were homogenised. The samples were analysed as pooled samples comprising five fish from the same cage/farm.

2.2 - Pre-treatment

Upon arrival at IMR the sample identification was anonymised for the analysts. A back-up sample was stored for all samples. Pooled samples of muscle from five fish from the same cage/farm were homogenised before analyses. 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, if residues were detected, the back-up sample of muscle was analysed by chemical methods. The maximum residue limits for veterinary drugs are set for muscle and skin in natural proportions (EU 37/2010). Therefore, according to the analytical protocol, any detection of drug residues in the muscle or liver was followed by a re-analysis of the back-up sample, consisting of muscle and skin in natural proportions, in duplicate.

2.3 - Analytical methods

The laboratory routines and most of the analytical methods are accredited in accordance with the standard ISO 17025 (Table 1). 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, or by analysing certified reference material (CRM), where such exist.

Table 1. Summary of analytical methods¹.

Group of substances	Analyte	Method	LOD (µg/kg w.w.)	LOQ (µg/kg w.w.)	Level of action (µg/kg w.w.)	Laboratory
A1 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			
A3 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					
A6 Annex IV substances	Chloramphenicol	LC-MS/MS	0.25		Presence (MRPL = 0.3)	IMR
	Metronidazole	LC-MS/MS	0.3		Presence (MRPL = 3.0)	
	Hydroxy-metronidazole		2.0			
	Nitrofurantoin AOZ	LC-MS/MS	0.5		Presence (MRPL = 1.0)	
	Nitrofurantoin AHD		0.6		Presence (MRPL = 1.0)	
	Nitrofurantoin AMOZ		0.4		Presence (MRPL = 1.0)	
	Nitrofurantoin SEM		0.5		Presence (MRPL = 1.0)	

Group of substances	Analyte	Method	LOD (µg/kg w.w.)	LOQ (µg/kg w.w.)	Level of action (µg/kg w.w.)	Laboratory	
B1 Antibacterial Substances Micro-biological method	Quinolones	3-plate Screening Method ²	200		100-600	IMR	
	Tetracyclines		200		100		
	Amphenicols		200		1000		
	Sulfonamides		400		100		
B1 Antibacterial substances Chemical method	Oxolinic acid	LC-MS/MS		40	100	IMR	
	Flumequine			40	600		
	Enrofloxacin			10	100		
	Ciprofloxacin			10	100		
	Trimethoprim			2	50		
	Oxytetracycline	LC-MS/MS		30	100	Eurofins	
	Florfenicol	LC-MS/MS		0.5	1000	IMR	
B2a Anthelmintics	Praziquantel	LC-MS/MS		1	-	IMR/ Eurofins	
	Fenbendazole	LC-MS/MS		1	-		
	Emamectin	LC-MS/MS		2-10	100		
	Diflubenzuron	LC-MS/MS		1-10	10		
	Teflubenzuron			1-50	500		
	Hexaflumuron			1-50	500		
	Lufenuron			1-50	1350		
	Ivermectin	LC-MS/MS		2	-		Eurofins
	Isoeugenol ³	GC-FID		50	6000		
B2c Carbamates and pyrethroids	Bifenthrin	GC-MS/MS		0.99-1	-	IMR	
	Cyfluthrin			0.99-1	-		
	Cypermethrin			0.99-1	50		
	Deltamethrin			0.99-1	10		
	Fenvalerate			0.99-1	-		
	Lambda-Cyhalothrin			0.99-1	-		
	Permethrin			2	-		
	Cypermethrin	GC-MS		5	50	Eurofins	
	Deltamethrin			10	10		
B3a Organo-chlorine compounds	Dioxins and dl-PCBs	HRGC-HRMS		0.0001- 0.1 ng TEQ/kg	6.5 ng TEQ/kg	IMR	
	PCB-6	GC-MS GC- MS/MS		0.004 – 0.5	75		
	Organochlorine pesticides	GC-MS/MS		0.04-0.4	-		
B3b Organo-phosphorus compounds	Azametiphos	LC-MS/MS		10	-	IMR	
	Dichlorvos						
	Chlorpyrifos Chlorpyrifos-methyl	GC-MS/MS		0.04 0.2	-		
	Pirimiphos-methyl			0.2	-		

Group of substances	Analyte	Method	LOD (µg/kg w.w.)	LOQ (µg/kg w.w.)	Level of action (µg/kg w.w.)	Laboratory
B3c Chemical elements	Lead	ICP-MS		0.005- 0.01 mg/kg	0.3 mg/kg	IMR
	Cadmium			0.001- 0.002 mg/kg	0.05 mg/kg	
	Arsenic			0.003 mg/kg	-	
	Mercury			0.002 mg/kg	0.5 mg/kg	
	Inorganic arsenic	LC-ICP-MS		4-6	-	
	Methylmercury	GC-ICP-MS		1	-	
	Tributyltin	GC-ICP-MS		0.3-0.5	-	
B3d Mycotoxins	Beauvericin, Enniatin A, A1, B and B1	LC-MS/MS		10	-	Eurofins
B3e, Dyes	Malachite green	LC-MS/MS	0.15		Presence (MRPL=2)	IMR
	Leuco malachite green		0.15			
	Crystal violet		0.30		Presence	
	Leuco crystal violet		0.15		Presence	
	Brilliant green		0.15		Presence	
B3f, Others	PBDE	GC-MS		0.002-0.01	-	IMR
	HBCD	LC-MS/MS		0.006-0.01	-	Eurofins
	TBBPA	GC-MS		0.03-0.2	-	Eurofins
	PAH	GC-MS/MS		0.5-1.0	-	IMR
	PFC	LC-MS/MS		0.5-13	-	IMR
	Ethoxyquin	HPLC-FLD		0.001	-	IMR
	Ethoxyquin dimer			0.005	-	

¹ All methods used muscle as sample matrix except for microbiological methods for antibacterial substances (B1), where liver was used. ² Only screening method, positive results must be confirmed by a chemical method. ³ Not accredited.

3 - Results

3.1 - Substances with anabolic effects and unauthorized substances

In 2021, a total of 1085 pooled fillet samples (5 fish/sample) were tested for residues of illegal substances, including stilbenes (164 pooled samples; Table 2), steroids (166 pooled samples; Table 3), and unauthorized veterinary drugs (754 pooled samples; Table 4). The samples were mainly taken from Atlantic salmon, but also samples from rainbow trout, Atlantic cod, brown trout and Atlantic halibut were analysed. With regards to illegal substances, the samples are monitored for and evaluated towards presence. No residues of stilbenes, steroids, chloramphenicol, nitrofurans or metronidazole were detected in any of the samples.

Dyes were measured in 167 pooled samples from fish taken at aquaculture farms. Crystal violet was detected in two of the samples (0.32 and 0.50 ng crystal violet/g ww, respectively). The analysis results were reported to the NFSA, who executed follow-up investigation of these samples. Crystal violet was not detected in other samples coming from the same batch. The absence of leucocrystal violet, the metabolite of crystal violet, indicated a contamination during sampling rather than a direct application of the dye during farming.

In addition to 168 samples analysed for residues of dyes as group A (illegal drugs) samples, dyes were measured in 88 pooled group B samples (contaminants; Group B3e, dyes). No residues of malachite green, crystal violet and brilliant green were detected in any of the group B samples.

Table 2. Stilbenes in fillets of farmed fish.

Stilbenes		Atlantic salmon	Rainbow trout	Atlantic cod	Brown trout	Atlantic halibut	LOQ (µg/kg w.w.)
	<i>n</i>	148	12	2	1	1	
17alpha-Estradiol	#Values	0	0	0	0	0	1
17alpha-Ethinyl estradiol	#Values	0	0	0	0	0	1
17beta-Estradiol	#Values	0	0	0	0	0	1
beta-Zearalanol	#Values	0	0	0	0	0	1
Dienestrol	#Values	0	0	0	0	0	1
Diethylstilbestrol	#Values	0	0	0	0	0	1
Estriol	#Values	0	0	0	0	0	1
Estrone	#Values	0	0	0	0	0	1
Hexestrol	#Values	0	0	0	0	0	1
Zeranol	#Values	0	0	0	0	0	1

Table 3. Steroids in fillets of farmed fish.

Steroids		Atlantic salmon	Rainbow trout	Brown trout	Atlantic cod	Atlantic halibut	LOQ (µg/kg w.w.)
	<i>n</i>	146	17	1	1	1	
16-Hydroxystanozolol/ 16-OH-Stanozolol	#Values	0	0	0	0	0	1
17alpha-Boldenone	#Values	0	0	0	0	0	1
17alpha-Trenbolone	#Values	0	0	0	0	0	1

Steroids		Atlantic salmon	Rainbow trout	Brown trout	Atlantic cod	Atlantic halibut	LOQ (µg/kg w.w.)
alpha-Nandrolone	#Values	0	0	0	0	0	1
Boldenone	#Values	0	0	0	0	0	1
Chlor-Testosterone (Clostebol)	#Values	0	0	0	0	0	1
Epitestosterone	#Values	0	0	0	0	0	1
Methyl-Boldenone (Dianabol)	#Values	0	0	0	0	0	1
Methyltestosterone	#Values	0	0	0	0	0	1
Nortestosterone/Nandrolone	#Values	0	0	0	0	0	1
Stanozolol	#Values	0	0	0	0	0	1
Testosterone	#Values	0	0	0	0	0	1
Testosterone propionate	#Values	0	0	0	0	0	2
Trenbolone	#Values	0	0	0	0	0	1
Trenbolone-acetate	#Values	0	0	0	0	0	2

Table 4. Unauthorized veterinary drugs in fillets of farmed fish.

Unauthorized veterinary drugs		Atlantic salmon	Rainbow trout	Atlantic cod	Brown trout	Atlantic halibut	LOQ (µg/kg w.w.)
	<i>n</i>	233	19	2	1	1	
Malachite Green	#Values	0	0	0	0	0	0.15
Leucomalachite Green	#Values	0	0	0	0	0	0.15
Brilliant Green	#Values	0	0	0	0	0	0.15
Crystal Violet	#Values	2	0	0	0	0	0.30
Leucocrystal Violet	#Values	0	0	0	0	0	0.15
	<i>n</i>	148	12	2	1	2	
Chloramfenicol	#Values	0	0	0	0	0	0.25
	<i>n</i>	149	13	2	1	1	
Metronidazole	#Values	0	0	0	0	0	0.30
Metronidazole hydroxide	#Values	0	0	0	0	0	2.0
	<i>n</i>	150	14	1	1	1	
AHD	#Values	0	0	0	0	0	0.6
AOZ	#Values	0	0	0	0	0	0.5
AMOZ	#Values	0	0	0	0	0	0.4
SEM	#Values	0	0	0	0	0	0.5

3.2 - Veterinary drugs

Samples analysed 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 (EU 37/2010). 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.

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) sulphonamides were screened in livers of 1665 fish (Table 5). A total of 119 pooled fillet samples, representing 595 fish were analysed by chemical methods (Table 6). No residues were detected in any of the samples analysed.

Table 5. Antibacterial agents in liver of farmed fish.

Antibiotics		Atlantic salmon	Rainbow trout	Arctic char	Atlantic cod	Atlantic halibut	Turbot	LOQ (µg/kg w.w.)
	<i>n</i>	301	22	5	2	2	1	
Quinolones	#Values	0	0	0	0	0	0	100
Sulfonamides	#Values	0	0	0	0	0	0	400
Tetracyclines	#Values	0	0	0	0	0	0	200
Amphenicols	#Values	0	0	0	0	0	0	200

Table 6. Antibacterial agents in fillets of farmed fish.

Antibacterial agents		Atlantic salmon	Rainbow trout	Arctic char	Atlantic cod	Atlantic halibut	LOQ (µg/kg w.w.)	MRL fin fish (µg/kg w.w.)
	<i>n</i>	89	6	1	1	1		
Ciprofloxacin	#Values	0	0	0	0	0	10	100
Enrofloxacin	#Values	0	0	0	0	0	10	100
Florfenicol	#Values	0	0	0	0	0	4	1000
Flumequine	#Values	0	0	0	0	0	40	600
Oxolinic acid	#Values	0	0	0	0	0	40	100
Trimethoprim	#Values	0	0	0	0	0	2	50
	<i>n</i>	16	3			1		
Tetracycline	#Values	0	0			0	30	100
Doxycycline	#Values	0	0			0	30	100
Chlortetracycline	#Values	0	0			0	30	100
Oxytetracycline	#Values	0	0			0	30	100

3.2.1 - Group B2a, Anthelmintics

The residues of anthelmintics, such as anti-sea-lice agents (Table 7) and agents for treatment of endoparasites (Table 8) were monitored in a total of 388 pooled fillet samples, representing 1940 fish.

Residues of the anti-sea-lice agent emamectin was detected in one out of 114 analysed samples, at a concentration of

10 µg/kg. This concentration is below the MRL of 100 µg/kg (EU 37/2010). Also residues of lufenuron were found in one out of 110 analysed samples. The concentration measured was 58 µg lufenuron/kg and was below the MRL of 1350 µg/kg. Residues of other agents in this group were not detected in any of the samples. LOQs for the substances are specified in Table 1.

Table 7. Anti-seallice agents (µg/kg w.w.) in fillet of farmed fish.

Anti-seallice agents		Atlantic salmon	Rainbow trout	Arctic char	Atlantic cod	Atlantic halibut	Turbot	LOQ	MRL fin fish
	<i>n</i>	98	15				2		
Emamectin	#Values	1	0				0		
	Max	10	-				-	2	100
	<i>n</i>	10	4				1		
Ivermectin	#Values	0	0				0		
	Max	-	-				-	2	-
Abamectin	#Values	0	0				0		
	Max	-	-				-	2	-
Doramectin	#Values	0	0				0		
	Max	-	-				-	2	-
Eprinomectin	#Values	0	0				0		
	Max	-	-				-	2	50
Moxidectin	#Values	0	0				0		
	Max	-	-				-	2	-
	<i>n</i>	98	9	1	1	1			
Diflubenzuron	#Values	0	0	0	0	0			
	Max	-	-	-	-	-		1	10 ¹
Teflubenzuron	#Values	0	0	0	0	0			
	Max	-	-	-	-	-		1	500 ¹
Lufenuron	#Values	1	0	0	0	0			
	Max	58	-	-	-	-		1	1350
Hexaflumeron	#Values	0	0	0	0	0			
	Max	-	-	-	-	-		1	500
Fluazuron	#Values	0	0	0	0	0			
	Max	-	-	-	-	-		1	200
	<i>n</i>	47	2						
Azamethiphos	#Values	0	0					10	-
Dichlorvos	#Values	0	0					10	-

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

Table 8. Agents against endoparasites ($\mu\text{g}/\text{kg}$ w.w.) in fillet of farmed fish.

		Atlantic salmon	Rainbow trout	Atlantic halibut	LOQ	MRL fin fish
	<i>n</i>	90	9	1		
Praziquantel	#Values	0	0	0	1	-
Fenbendazole	#Values	0	0	0	1	-

3.2.2 - Group B2c, Carbamates and pyrethroids

In addition to measurement of cypermethrin and deltamethrin with a method using GC-MS, in 2021, several carbamates and pyrethroid substances, including cypermethrin and deltamethrin were measured using GC-MS/MS (Table 9).

A total of 120 pooled fillet samples of Atlantic salmon, rainbow trout and turbot were analysed for cypermethrin and deltamethrin using GC-MS. All samples were below the LOQ of 5 $\mu\text{g}/\text{kg}$ for cypermethrin and 10 $\mu\text{g}/\text{kg}$ for deltamethrin.

With an LOQ of 0.99-1 $\mu\text{g}/\text{kg}$ for all of the measured substances on the GC-MS/MS, cypermethrin was detected in 24 out of 92 pooled fillet samples of Atlantic salmon, and one of 6 samples of rainbow trout. Cypermethrin is a pyrethroid insecticide, used both as anti-seallice agent in aquaculture, but also in commercial agricultural applications. Therefore, residues of cypermethrin in fish may also originate from transfer via plant-based ingredients in fish feed. The maximum level measured in salmon was 3.0 $\mu\text{g}/\text{kg}$, and 1.2 $\mu\text{g}/\text{kg}$ in rainbow trout, which is below the MRL of 50 $\mu\text{g}/\text{kg}$ (EU 37/2010). None of the other substances included in the monitoring, were detected in any of the samples.

Table 9. Carbamates and pyrethroid substances ($\mu\text{g}/\text{kg}$ w.w.) in fillet of farmed fish.

		Atlantic salmon	Rainbow trout	Arctic char	Turbot	LOQ	MRL fin fish
	<i>n</i>	202	15	1	1		
Cypermethrin	#Values	24	1	0	0		
	Median	LOQ	-	-	-		
	Max	3.0	1.2	LOQ	LOQ	0.99-5	50 ¹
Deltamethrin	#Values	0	0	0	0		
	Median	-	-	-	-		
	Max	LOQ	LOQ	LOQ	LOQ	0.99-10	10
	<i>n</i>	92	6	1			
Bifenthrin	#Values	0	0	0			
	Median	-	-	-			
	Max	LOQ	LOQ	LOQ		0.99-1	-
Cyfluthrin	#Values	0	0	0			
	Median	-	-	-			
	Max	LOQ	LOQ	LOQ		0.99-1	-
Fenvalerat	#Values	0	0	0			
	Median	-	-	-			
	Max	LOQ	LOQ	LOQ		0.99-1	-

Lambda-Cyhalothrin	#Values	0	0	0		
	Median	-	-	-		
	Max	LOQ	LOQ	LOQ	0.99-1	-
Permethrin	#Values	0	0	0		
	Median	-	-	-		
	Max	LOQ	LOQ	LOQ	2	-

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

3.2.3 - Group B2d, Sedatives

No residues of isoeugenol or eugenol were found in any of the 39 samples analysed for these sedatives (Table 10).

Table 10. Sedatives ($\mu\text{g}/\text{kg}$ w.w.) in fillet of farmed fish.

Sedatives		Atlantic salmon	Rainbow trout	Arctic char	Atlantic cod	LOQ	MRL fin fish
	<i>n</i>	34	3	1	1		
Isoeugenol	#Values	0	0	0	0	50	6000
Eugenol	#Values	0	0	0	0	50	-

3.3 - Contaminants

Samples analysed for contaminants were collected from fish at processing plants and are representative of fish ready for human consumption.

3.3.1 - Group B3a, Organochlorine compounds

The levels of organochlorine compounds were determined in 186 pooled samples. The results are summarised in Tables 11 to 13.

3.3.1.1 - Organochlorine pesticides

For several of the pesticides, the amount present is calculated as a sum including metabolites or transformation products (EU GD SANTE 2017). The results for these groups of pesticides are presented in Table 11. To calculate the sum of the components, conversion factors (Table A1, Appendix) are used to adjust for different molecular weights (EU GD SANTE 2017). The sums in Table 11 were calculated according to the upper bound (UB) formula. When using UB calculations, the numerical value of LOQ is substituted for analytes with levels below LOQ. UB 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. There are currently no MRLs established in fish fillet for any of the listed pesticides (EU 2014).

Table 11. The sum of groups of pesticides ($\mu\text{g}/\text{kg}$ w.w.) in fillet of farmed fish.

Pesticide		Atlantic salmon	Rainbow trout	Arctic char
Sum	<i>n</i>	92	6	1
DDT	Median (UB)	3.5 ¹ (3.3) ²	3.6 ¹ (3.4) ²	-
	Max (UB)	9.8 ¹ (9.6) ²	5.0 ¹ (4.9) ²	3.4 ¹ (3.3) ²
Endosulfan	Median (UB)	2.2	2.2	-
	Max (UB)	2.2	2.2	2.2

Pesticide		Atlantic salmon	Rainbow trout	Arctic char
Aldrin and dieldrin	Median (UB)	1.3	1.5	-
	Max (UB)	3.2	1.6	1.2
Chlordane	Median (UB)	0.59 ³ (0.40) ⁴	0.60 ³ (0.41) ⁴	-
	Max (UB)	1.7 ³ (1.4) ⁴	0.67 ³ (0.48) ⁴	0.52 ³ (0.32) ⁴
Heptachlor	Median (UB)	1.2	1.2	-
	Max (UB)	1.4	1.2	1.2
Toxaphene	Median (UB)	1.9	1.8	-
	Max (UB)	5.0	2.0	1.8

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).

The levels of pesticides calculated from a sum of several components were comparable to the previous years. The highest values of organochlorine pesticides in Atlantic salmon fillet were 9.8 µg/kg w.w. of DDT, and 5 µg/kg w.w. Toxaphene. The highest values for organochlorine pesticides in rainbow trout were DDT and endosulfan, with 5 and 2.2 µg/kg w.w, respectively.

The results for the other organochlorine pesticides are summarised in Table 12.

Table 12. Pesticides (µg/kg w.w.) in fillets of farmed fish.

Pesticide		Atlantic salmon	Rainbow trout	Arctic char	LOQ
	<i>n</i>	92	6	1	
α-Hexachlorocyclo- hexane	#Values	90	6	0	
	Median	0.10	0.085	-	
	Max	0.17	0.098	LOQ	0.04
β-Hexachlorocyclo- hexane	#Values	92	6	0	
	Median	0.10	0.095	-	
	Max	0.35	0.12	LOQ	0.04
γ-Hexachlorocyclo- hexane (Lindane)	#Values	64	4	0	
	Median	0.047	0.053	-	
	Max	0.082	0.061	LOQ	0.04
Hexachlorobenzene	#Values	92	6	1	
	Median	0.62	0.50	-	
	Max	2.0	0.58	0.49	0.06-1.0
Pentachlorobenzene	#Values	0	0	0	
	Median	-	-	-	
	Max	LOQ	LOQ	LOQ	0.99-0.10
Toxaphene Parlar 32	#Values	0	0	0	
	Median	-	-	-	
	Max	LOQ	LOQ	LOQ	0.99-1.0

Pesticide		Atlantic salmon	Rainbow trout	Arctic char	LOQ
Toxaphene Parlar 40+41	#Values	0	0	0	
	Median	-	-	-	
	Max	LOQ	LOQ	LOQ	2.0
Trans-Nonachlor	#Values	92	6	1	
	Median	0.42	0.41	-	
	Max	2.0	0.50	0.37	0.13-0.60
Endrin	#Values	0	0	0	
	Median	-	-	-	
	Max	LOQ	LOQ	LOQ	0.99-0.10
Endrin-ketone	#Values	0	0	0	
	Median	-	-	-	
	Max	LOQ	LOQ	LOQ	0.99-0.10
Mirex	#Values	25	2	0	
	Median	-	-	-	
	Max	0.13	0.04	LOQ	0.04
Isodrin	#Values	0	0	0	
	Median	-	-	-	
	Max	LOQ	LOQ	LOQ	0.99-0.10

3.3.1.2 - Dioxin, dl-PCBs and PCB-6

The levels of dioxins (PCDD+PCDF), dl-PCBs and PCB-6 in farmed fish are shown in Table 13. The data is mainly represented by Atlantic salmon, but also samples from rainbow trout were examined. The sums of dioxins, dioxins + dl-PCBs and PCB-6 are calculated as upper bound (EU 1259/2011). 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 dioxins 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 (EU 1259/2011, Van den Berg, Birnbaum et al. 2006).

In 2021, dioxin levels found in fish fillet were somewhat lower than in the previous year. For salmon, the median of the sum of dioxins was 0.16 ng TEQ/kg w.w. The maximum value found in salmon (0.45 ng TEQ/kg w.w.) was below the EU maximum level of 3.5 ng TEQ/kg w.w.

The median of the sum of all 29 dioxins and dl-PCBs was 0.36 ng TEQ/kg w.w for salmon (0.1 ng TEQ/kg w.w. lower than in 2020) and 0.37 ng TEQ/kg w.w for rainbow trout (0.41 ng TEQ/kg w.w in 2020). The highest result for sum dioxin and dl-like PCBs was 0.90 ng TEQ/kg w.w., measured in salmon. All measured values were below the EU maximum level of 6.5 ng TEQ/kg w.w.

Compared to 2020, in 2021 decreased fillet levels were also noted for PCB-6 measurements. The median of PCB-6 for salmon was 2.9 µg/kg w.w and 2.7 in rainbow trout, with maximum concentrations of 7.7 and 4.1 µg/kg w.w, respectively. For PCB-6, a maximum level is set at 75 µg/kg w.w. in the EU.

Table 13. Dioxins, dl-PCBs and PCB-6 in fillets of farmed fish.

		Atlantic salmon	Rainbow trout	EU Maximum Level
	<i>n</i>	97	3	
Sum dioxins (ng TEQ/kg w.w.)	Median	0.16	0.25	
	Max	0.45	0.26	3.5
Sum dioxin + dl-PCBs (ng TEQ/kg w.w.)	Median	0.36	0.37	
	Max	0.90	0.40	6.5
PCB-6 (µg/kg w.w.)	Median	2.9	2.7	
	Max	7.7	4.1	75

3.3.2 - Group B3b, Organophosphorous compounds

Organophosphorous pesticide residues, chlorpyrifos, chlorpyrifos-methyl and pirimiphos-methyl, were determined in 99 pooled fillet samples (Table 14). No residues of chlorpyrifos or chlorpyrifos-methyl were detected in any of the samples. Pirimiphos-methyl was detected in 8 of 92 samples of Atlantic salmon. The maximum concentration was 0.39 µg pirimiphos-methyl/kg w.w.. There is currently no MRL established for pirimiphos-methyl in fish fillet (EU 2014).

Table 14. Residues of organophosphorous compounds (µg/kg w.w.) in fillets of farmed fish.

Compound		Atlantic salmon	Rainbow trout	Arctic char	LOQ
	<i>n</i>	92	6	1	
Chlorpyrifos	#Values	0	0	0	
	Median	-	-	-	
	Max	LOQ	LOQ	LOQ	0.04
Chlorpyrifos-methyl	#Values	0	0	0	
	Median	-	-	-	
	Max	LOQ	LOQ	LOQ	0.2
Pirimiphos-methyl	#Values	8	0	0	
	Median	-	-	-	
	Max	0.39	LOQ	LOQ	0.2

3.3.3 - Group B3c, Chemical elements

In 2021, monitoring of the levels of chemical elements, such as arsenic (and inorganic arsenic), total mercury in addition to methylmercury, cadmium, lead included 73 samples of Atlantic salmon, 7 samples of rainbow trout, and one sample of Atlantic cod (Table 15). Mono-, di- and tributyltin were analysed in 52 samples of Atlantic salmon, 7 samples of rainbow trout and one sample of Atlantic cod.

The concentrations of total mercury were found below the EU maximum level, which is set at 0.50 mg/kg w.w. for these species. The highest concentrations of total mercury were 0.057 mg/kg w.w. in salmon, and 0.081 mg/kg w.w. in Atlantic cod, mainly present as methylmercury (Table 15).

Cadmium in all Atlantic salmon samples, Atlantic cod and 6 of 7 rainbow trout samples was below the LOQ. Only one sample of rainbow trout had cadmium at a level of 0.002 mg/kg w.w. in the fillet which is well below the EUs maximum

level of 0.05 mg/kg w.w. (EU 1881/2006).

Arsenic is determined as “total arsenic”, comprising the sum of all arsenic species. In addition, inorganic arsenic was determined in 20 of the samples. The median level of total arsenic in Atlantic salmon was 0.58 mg/kg w.w., and, same as in the previous year, the highest concentration measured was 1.4 mg/kg w.w. (Table 15). The median and maximum concentration of Arsenic in rainbow trout samples were 0.8 and 1 mg/kg w.w respectively. The concentrations of inorganic arsenic were below the LOQ in all samples measured (Table 15), indicating that arsenic in fish is present mainly as organo-arsenic compounds of low toxicity (Shiomi 1994). There is currently no EU upper limit for neither total arsenic nor inorganic arsenic in fish fillets.

In all 81 samples of Atlantic salmon, rainbow trout and Atlantic cod, the concentration of lead was below LOQ and well below the EU maximum level, which is currently set at 0.30 mg/kg w.w. in muscle meat of fish (EU 1881/2006).

Eleven additional chemical elements were analyzed in addition to the above-mentioned elements. There is currently no EU-limit established for any of these elements. Copper, iron, manganese, selenium and zinc were found at levels above LOQ in all samples analyzed (Table 15), with median values similar to the year before. The maximum concentrations among all 81 samples were 0.64 mg copper/kg, 4.5 mg iron/kg, 0.13 mg manganese/kg, 0.28 mg selenium/kg and 5.1 mg zinc/kg, respectively. Cobalt and nickel were not detected in any of the analysed samples. Chromium and vanadium were detected in 22 and 17 out of 81 samples, respectively. The highest concentrations were 0.035 mg chromium/kg and 0.006 mg vanadium/kg (both salmon) in 2021.

Mono-, di- and tributyltin were monitored in a total of 60 pooled fillet samples of Atlantic salmon, rainbow trout and Atlantic cod. There is currently no EU upper limit for tin in fish fillet. Monobutyltin was found at levels above LOQ in 7 samples, with the maximum concentrations of 1 µg/kg w.w. and 0.7 µg/kg w.w. in salmon and rainbow trout, respectively. Concentration of dibutyltin was below LOQ (0.2 µg/kg w.w.) in all samples. A total of 16 samples contained tributyltin above the LOQ, with the highest measured level of 1.8 µg/kg w.w. found in rainbow trout (median 0.2 µg/kg w.w.).

Table 15. Chemical elements in fillets of farmed fish.

Element		Atlantic salmon	Rainbow trout	Atlantic cod	LOQ	EU Maximum Level
	<i>n</i>	73	7	1		
Mercury (mg/kg w.w.)	#Values	73	7	1		
	Median	0.014	0.021	-		
	Max	0.057	0.030	0.081	0.002	0.50
Arsenic (mg/kg w.w.)	#Values	73	7	1		
	Median	0.58	0.80	-		
	Max	1.4	1.0	1.5	0.003	n.a.
Cadmium (mg/kg w.w.)	#Values	0	1	0		
	Median	-	-	-		
	Max	LOQ	0.002	LOQ	0.001-0.002	0.05
Lead (mg/kg w.w.)	#Values	0	0	0		
	Median	-	-	-		
	Max	LOQ	LOQ	LOQ	0.006-0.01	0.30
Cobalt (mg/kg w.w.)	#Values	0	0	0		
	Median	-	-	-		
	Max	LOQ	LOQ	LOQ	0.006-0.009	n.a.

Element		Atlantic salmon	Rainbow trout	Atlantic cod	LOQ	EU Maximum Level
Chromium (mg/kg w.w.)	#Values	17	5	0		
	Median	-	0.010	-		
	Max	0.035	0.015	LOQ	0.006-0.01	n.a.
Copper (mg/kg w.w.)	#Values	73	7	1		
	Median	0.39	0.35	-		
	Max	0.64	0.44	0.16	0.1	n.a.
Iron (mg/kg w.w.)	#Values	73	7	1		
	Median	2.6	2.8	-		
	Max	4.5	3.2	0.69	0.10	n.a.
Manganese (mg/kg w.w.)	#Values	73	7	1		
	Median	0.074	0.068	-		
	Max	0.13	0.072	0.16	0.030	n.a.
Molybdenum (mg/kg w.w.)	#Values	0	0	0		
	Median	-	-	-		
	Max	LOQ	LOQ	LOQ	0.01-0.40	n.a.
Nickel (mg/kg w.w.)	#Values	0	0	0		
	Median	-	-	-		
	Max	LOQ	LOQ	LOQ	0.07-0.1	n.a.
Selenium (mg/kg w.w.)	#Values	73	7	1		
	Median	0.16	0.26	-		
	Max	0.26	0.28	0.23	0.01	n.a.
Silver (mg/kg w.w.)	#Values	1	1	0		
	Median	-	-	-		
	Max	0.003	0.004	LOQ	0.002-0.004	n.a.
Vanadium (mg/kg w.w.)	#Values	16	1	0		
	Median	-	-	-		
	Max	0.006	0.003	LOQ	0.001-0.002	n.a.
Zinc (mg/kg w.w.)	#Values	73	7	1		
	Median	3.8	3.8	-		
	Max	5.1	4.1	4.4	0.5	n.a.
	<i>n</i>	20				
Methyl-mercury (mgHg/kg w.w.)	#Values	20				
	Median	0.016				
	Max	0.059			0.001	
Inorganic arsenic (µg/kg w.w.)	#Values	0				
	Median	-				
	Max	LOQ			2-3	
	<i>n</i>	52	7	1		
	#Values	6	1	0		

Element		Atlantic salmon	Rainbow trout	Atlantic cod	LOQ	EU Maximum Level
Monobutyltin ($\mu\text{g Sn/kg w.w.}$)	Median	-	-	-		
	Max	1.0	0.7	LOQ	0.4-0.5	n.a.
Dibutyltin ($\mu\text{g Sn/kg w.w.}$)	#Values	0	0	0		
	Median	-	-	-		
	Max	LOQ	LOQ	LOQ	0.2-0.5	n.a.
Tributyltin ($\mu\text{g Sn/kg w.w.}$)	#Values	9	6	1		
	Median	-	0.2	-		
	Max	0.1	1.8	0.3	0.06-0.09	n.a.

Calculated as upper bound, using the numerical LOQ values for measurements below LOQ. Median for elements with more than 50% of values below LOQ is not presented.

3.3.4 - Group B3d, Mycotoxins

The mycotoxins enniatin A, enniatin A1, enniatin B, enniatin B1 and beauvericin were measured in 95 pooled samples of Atlantic salmon and four 4 pooled samples of rainbow trout. No residues of these mycotoxins were detected in any of the samples (Table 16).

Table 16. Mycotoxins in fillets of farmed fish.

Mycotoxins		Atlantic salmon	Rainbow trout	LOQ ($\mu\text{g/kg w.w.}$)
	<i>n</i>	95	4	
Beauvericin	#Values	0	0	10
Enniatin A	#Values	0	0	10
Enniatin A1	#Values	0	0	10
Enniatin B	#Values	0	0	10
Enniatin B1	#Values	0	0	10

3.3.5 - Group B3f, others

The group B3f, others is a group not required for finfish products by Regulation (EU) 2017/625, but are deemed relevant for analyses in Norwegian aquaculture by the NFSA and IMR, because these undesirable compounds are present in the environment and may affect food safety. This group currently consists of brominated flame retardants (BFR), perfluorinated compounds (PFC), polyaromatic hydrocarbons (PAHs), and since 2018 also the technological feed additive ethoxyquin (EQ) and its main transformation product ethoxyquin dimer (EQDM).

3.3.5.1 - Brominated flame retardants

In addition to the PBDEs included in PBDE-7 (PBDE 28, 47, 99, 100, 153, 154, 183), 10 other tri-hepta PBDEs (PBDE 35, 49, 66, 71, 75, 77, 85, 118, 119, 138) and five octa-deca PBDEs (PBDE 196, 197, 206, 207 and 209) were measured in 97 pooled fillet samples from Atlantic salmon and 3 pooled fillet samples of rainbow trout (Table 17). Median values of PBDE-7 were $0.27 \mu\text{g/kg w.w.}$ and $0.28 \mu\text{g/kg w.w.}$ for salmon and rainbow trout, respectively.

Table 17. Polybrominated diphenyl ethers (PBDEs) ($\mu\text{g}/\text{kg}$ w.w) in fillets of farmed fish.

		Atlantic salmon	Rainbow trout	LOQ
PBDE	n	97*	3	
PBDE ₇ (UB)	Median	0.27	0.28	
	Max	0.71	0.29	
PBDE 28	#Values			
	Median	0.0087	0.0073	
	Max	0.025	0.011	0.0016-0.0027
PBDE 35	#Values	0	0	
	Median	-	-	
	Max	-	-	0.0033-0.0054
PBDE 47	#Values	97	3	
	Median	0.15	0.082	
	Max	0.38	0.16	0.013-0.022
PBDE 49	#Values	97	3	
	Median	0.043	0.023	
	Max	0.12	0.054	0.0033-0.0054
PBDE 66	#Values	80	1	
	Median	0.0058	-	
	Max	0.020	0.0061	0.0033-0.0054
PBDE 71	#Values	1	0	
	Median	-	-	
	Max	0.0049	-	0.0016-0.0027
PBDE 75	#Values	96	3	
	Median	0.0075	0.0047	
	Max	0.021	0.0077	0.0016-0.0027
PBDE 77	#Values	2	0	
	Median	-	-	
	Max	0.014	-	0.0065-0.011
PBDE 85	#Values	0	0	
	Median	-	-	
	Max	-	-	0.0033-0.0054
PBDE 99	#Values	96	3	
	Median	0.023	0.014	
	Max	0.068	0.026	0.0065-0.011
PBDE 100	#Values	97	3	
	Median (UB)	0.039	0.019	
	Max	0.12	0.043	0.0065-0.011
PBDE 110	#Values	0	0	
	Median	-	-	

PBDE 118		Atlantic salmon	Rainbow trout	LOQ
PBDE	n	97*	3	
	Max	-	-	0.0065-0.011
PBDE 119	#Values	1	0	
	Median	-	-	
	Max	0.0097	-	0.0033-0.0054
PBDE 138	#Values	0	0	
	Median	-	-	
	Max	-	-	0.0065-0.011
PBDE 153	#Values	9	0	
	Median	-	-	
	Max	0.023	-	0.0065-0.011
PBDE 154	#Values	97	3	
	Median	0.025	0.012	
	Max	0.085	0.031	0.0065-0.011
PBDE 183	#Values	4	0	
	Median	-	-	
	Max	0.012	-	0.0065-0.011
PBDE 196	#Values	0	0	
	Median	-	-	
	Max	-	-	0.0017-0.0027
PBDE 197	#Values	0	0	
	Median	-	-	
	Max	-	-	0.010-0.016
PBDE 206	#Values	0	0	
	Median	-	-	
	Max	-	-	0.010-0.016
PBDE 207	#Values	0	0	
	Median	-	-	
	Max	-	-	0.010-0.016
PBDE 209	#Values	5	0	
	Median	-	-	
	Max	0.092	-	0.010-0.016

*For PBDE 196, 197, 206, 207 and 209, the number of samples analysed were 93.

TBBPA was not found in any of the 55 pooled fillet samples from Atlantic salmon samples, three pooled rainbow trout samples and one Atlantic cod sample (Table 18). Alpha-HBCD was found in 41 of the 55 salmon fillet samples and two of three rainbow trout fillet samples, while beta- and gamma- HBCD were only found in salmon samples (Table 18). The median HBCD concentration (Sum alpha-, beta-, gamma-HBCD; UB) for salmon was 0.055 µ g/kg w.w., with a maximum concentration of 0.30 µ g/kg w.w.. There is currently no EU maximum limit for BFRs in food.

Table 18. Tetrabromobisphenol A (TBBPA) and hexabromocyclododecane (HBCD) ($\mu\text{g}/\text{kg w.w.}$) in fillets of farmed fish.

		Atlantic salmon	Rainbow trout	Atlantic cod	LOQ
	<i>n</i>	55	3	1	
TBBPA	#Values	0	0	0	
	Median	-	-	-	
	Max	LOQ	LOQ	LOQ	0.04- 0.3
Sum HBCD (alpha-, beta-, gamma-), UB	#Values	55	3	1	
	Median	0.055	0.037	-	
	Max	0.30	0.043	0.018	
alpha-HBCD	#Values	41	2	0	
	Median	0.043	0.023	-	
	Max	0.24	0.031	LOQ	0.04- 0.3
beta-HBCD	#Values	5	0	0	
	Median	-	-	-	
	Max	0.031	LOQ	LOQ	0.006- 0.01
gamma-HBCD	#Values	12	0	0	
	Median	-	-	-	
	Max	0.042	LOQ	LOQ	0.006- 0.01

3.3.5.2 - Perfluorinated compounds

The results for the analysis of perfluorinated compounds are presented in Table 19.

Table 19. Perfluorinated compounds ($\mu\text{g}/\text{kg w.w.}$) in fillets of farmed fish.

		Atlantic salmon	Rainbow trout	Atlantic cod	Arctic char	LOQ
	<i>n</i>	87	8	1	1	
PFBA	#Values	0	0	0	0	
	Max	-	-	-	-	1
PFBS	#Values	0	0	0	0	
	Max	-	-	-	-	1
PFDA	#Values	0	0	0	0	
	Max	-	-	-	-	0.2
PFDoDA	#Values	0	0	0	0	
	Max	-	-	-	-	0.2
PFDS	#Values	0	0	0	0	
	Max	-	-	-	-	0.2
PFHpA	#Values	0	0	0	0	
	Max	-	-	-	-	0.2
	#Values	0	0	0	0	

PFHxA		Atlantic salmon	Rainbow trout	Atlantic cod	Arctic char	LOQ
	Max	-	-	-	-	0.5
PFHxS	#Values	0	0	0	0	
	Max	-	-	-	-	1
PFNA	#Values	0	0	0	0	
	Max	-	-	-	-	0.2
PFOA	#Values	0	0	0	0	
	Max	-	-	-	-	0.6
PFOS	#Values	0	0	0	0	
	Max	-	-	-	-	0.2
PFOSA	#Values	0	0	0	0	
	Max	-	-	-	-	0.5
PFTeDA	#Values	1	0	0	0	
	Max	0.2	-	-	-	0.2
PFTTrDA	#Values	0	0	0	0	
	Max	-	-	-	-	0.2
PFUdA	#Values	0	0	0	0	
	Max	-	-	-	-	0.2
N-EtFOSA	#Values	0	0	0	0	
	Max	-	-	-	-	1.5
N-EtFOSE	#Values	0	0	0	0	
	Max	-	-	-	-	1
N-MeFOSA	#Values	0	0	0	0	
	Max	-	-	-	-	1
N-MeFOSE	#Values	0	0	0	0	
	Max	-	-	-	-	0.5

3.3.5.3 - Polycyclic aromatic hydrocarbons

The results for PAH are summarised in Table 20. There is no maximum limit for PAH in fresh fish (EU 835/2011).

Table 20. PAH ($\mu\text{g}/\text{kg}$ w.w.) in fillets of farmed fish.

PAH		Atlantic salmon	Rainbow trout	Arctic char	Atlantic cod	Spotted wolffish	LOQ
	<i>n</i>	87	7	2	1	1	
5-methylchrysene	#Values	0	0	0	0	0	
	Max	-	-	-	-	-	0.017 - 0.12
Benz(a)anthracene	#Values	20	1	1	1	0	
	Max	0.7	0.2	0.5	0.02	-	0.041 - 0.12
Benzo(a)pyrene	#Values	2	0	0	0	0	
	Max	0.4	-	-	-	-	0.017 - 0.12

PAH		Atlantic salmon	Rainbow trout	Arctic char	Atlantic cod	Spotted wolffish	LOQ
Benzo(b)fluoranthene	#Values	3	0	0	1	0	
	Max	0.3	-	-	0.03	-	0.041 - 0.12
Benzo(c)fluorine	#Values	8	1	1	0	0	
	Max	0.3	0.2	0.2	-	-	0.017 - 0.12
Benzo(ghi)perylene	#Values	1	0	0	0	0	
	Max	0.1	-	-	-	-	0.017 - 0.12
Benzo(j)fluoranthene	#Values	2	0	0	0	0	
	Max	0.1	-	-	-	-	0.017 - 0.12
Benzo(k)fluoranthene	#Values	1	0	0	0	0	
	Max	0.1	-	-	-	-	0.017 - 0.12
Chrysene	#Values	24	1	1	1	0	
	Max	1.1	0.2	0.8	0.04	-	0.041 - 0.12
Cyclopenta(cd)pyrene	#Values	2	0	0	0	0	
	Max	0.2	-	-	-	-	0.017 - 0.12
Dibenz(ah)anthracene	#Values	0	0	0	0	0	
	Max	-	-	-	-	-	0.017 - 0.12
Dibenzo(a,e)pyrene	#Values	0	0	0	0	0	
	Max	-	-	-	-	-	0.083-0.58
Dibenzo(a,h)pyrene	#Values	0	0	0	0	0	
	Max	-	-	-	-	-	0.083-0.58
Dibenzo(a,i)pyrene	#Values	0	0	0	0	0	
	Max	-	-	-	-	-	0.083-0.58
Dibenzo(a,l)pyrene	#Values	0	0	0	0	0	
	Max	-	-	-	-	-	0.083-0.58
Indeno(1,2,3,-cd)pyrene	#Values	1	0	0	0	0	
	Max	0.1	-	-	-	-	0.017 - 0.12

3.3.5.4 - Ethoxyquin

EQ and EQDM levels were measured in a total of 66 samples, mostly taken from Atlantic salmon (61 samples; 5 fish/sample), but also five samples of rainbow trout were analysed (Table 21). Following the suspension of authorization for use of ethoxyquin as a technological feed additive in 2020, a decline in samples showing measurement values above LOQ was noted. In 2021, none of the samples contained ethoxyquin or its dimer at levels above LOQ.

Table 21. Ethoxyquin and ethoxyquin dimer (mg/kg w.w.) in fillets of farmed fish.

	Atlantic salmon	Rainbow trout	LOQ
Samples	61	5	
Ethoxyquin	LOQ	LOQ	0.001
Ethoxyquin dimer	LOQ	LOQ	0.005

4 - Conclusions

Residues of the dye crystal violet were detected in two samples of salmon, likely caused by contamination of the samples during sample taking. No residues of other unauthorized substances were detected in any of the samples analysed.

Residues of the authorized anti-seallice agents cypermethrin, emamectin and lufenuron were detected. However, the concentrations were well below the respective MRLs for the compounds.

Consistent with the data gathered in the recent 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 MLs, where such levels have been established (sum dioxins, sum dioxins and dl-PCBs, PCB-6, mercury, lead and cadmium).

5 - References

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6 - Appendix

Table A 1. Calculations of sums for certain pesticides according to EU GD SANTE (2017).

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 26, 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; Camphechlor (Toxaphene).



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