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Research Article

Presence of some commonly used pharmaceutical residues in seawater and net plankton: A case study of Spitsbergen, Svalbard Archipelago

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Abstract

The occurrence of eleven pharmaceutical compounds in the surface seawater and plankton samples from Spitsbergen, Svalbard Archipelago, were investigated. The target compounds included diclofenac, fenoprofen, ketoprofen, ibuprofen, naproxen, carbamazepine, clofibric acid, gemfibrozil, estrone, 17β-estradiol, and 17α-ethynylestradiol, which are among the most widely used pharmaceuticals in the world. The water samples were extracted by liquid-liquid extractions, which were followed by solid-phase extractions (SPE). Ultrasonic extractions were used for the plankton samples, and a clean-up process was then carried out using the SPE method. The quantifications of the pharmaceutical compounds were obtained by using high-performance liquid chromatography (HPLC–DAD). The highest concentrations (2.17 µg L^{-1}) that were measured in seawater were for gemfibrozil. 17α-ethynylestradiol and fenoprofen were the most abundant pharmaceuticals that were detected in the seawater samples. All of the studied compounds were detected in the plankton samples. The concentrations of ibuprofen (4543 ng g^{-1}), 17β-estradiol (3338 ng g^{-1}), 17α-ethynylestradiol (3262 ng g^{-1}), and gemfibrozil (6940 ng g^{-1}) were high in the plankton samples. Pharmaceutical compounds have been identified in the Arctic region due to the inadequate or incomplete wastewater treatment facilities in this region, which exhibit reduced biodegradation levels at low temperatures and prolonged half-life for the compounds in the receiving environments at low temperatures.

Keywords: Pharmaceutical residues, seawater, plankton, Arctic

Introduction

The presence of pharmaceutical compounds and their residues in water bodies have received much attention in recent years, as these compounds can produce adverse effects on aquatic organisms and ecosystems (Brausch and Rand, 2011; Claessens, et al., 2013; Fent et al., 2006; Kümmerer, 2009; Lonappan, et al., 2016). Pharmaceuticals are emerging contaminants that enter aquatic environments from many different sources. The main source of this type of pollution is attributed to the effluents from wastewater treatment plants (WWTPs), in which pharmaceuticals cannot be completely treated et al., 2014). For example, the maximum removal rates of diclofenac and ibuprofen from WWTPs were reported to be 75% and >70%, respectively (Almeida, et al., 2020; Bueno et al., 2012). Additionally, the removal rate of carbamazepine (<45%) on WWTPs is very low (Clara, et al., 004). Other pollution sources also include domestic wastes, industrial effluents, landfills, livestock and agricultural activities (Archer, et al., 2017; Gaw, et al., 2014). The pharmaceutical compounds that reach aquatic environments can undergo various processes, such as photodegradation, biodegradation, diffusion, dilution, evaporation and adsorption in sediments (Anekwe, et al., 2017; Baena-Nogueras, et al., 2017; Liu and Wong, 2013). These processes are mostly dependent on the pH, temperature, solar radiation intensity, eutrophic conditions in water and the organic matter structure in sediments (Anekwe et al., 2017; Baena-Nogueras et al., 2017; Emídio, Calisto, et al., 2017; Jin et al., 2017; Koumaki et al., 2015).

Pharmaceutical compounds are present in surface water, freshwater, groundwater, drinking water, wastewater, and marine water bodies with concentrations that range from ng L^{-1} to mg L^{-1} (Brausch, et al., 2018; Runnalls, et al., 2010). Although pharmaceutical compounds have been detected in seawater (marine and coastal areas) with a broad range of concentrations that is similar to that detected in freshwater systems, there are fewer studies on the presence of pharmaceutical compounds in marine ecosystems (Álvarez-Muñoz et al., 2015; Alygizakis et al., 2016; Arpin-Pont, et al., 2016; Ebele, Abou-Elwafa Abdallah, and Harrad, 2017; Gaw et al., 2014; Mezzelani et al., 2018). The detection of pharmaceuticals in water bodies has great importance for determining the effects of these compounds on both aquatic organisms and ecosystems.

Table 1. Therapeutic groups, compound names, log K_{ow} values and solubilities for all studied pharmaceutical compounds (Aydin and Talinli, 2013; Kim and Tanaka, 2009; NCBI, 2020; Patel et al., 2013; Scheytt et al., 2005; Westerhoff et al., 2005)

Therapeutic groups	Compounds	Molecular formula	Log K_{ow}	Solubility (mg/L)
Nonsteroidal anti-inflammatory drugs (NSAIDs)	Diclofenac	$C_{14}H_{11}Cl_2NO_2$	4.51	2.37
	Fenoprofen	$C_{15}H_{14}O_3$	3.1	slightly
	Ibuprofen	$C_{13}H_{18}O_2$	4	21
	Ketoprofen	$C_{16}H_{14}O_3$	3.12	51
	Naproxen	$C_{14}H_{14}O_3$	3.18	15.9
Hormones (natural and synthetic)	Estrone	$C_{16}H_{22}O_2$	3.13	12.42
	17β-estradiol	$C_{18}H_{24}O_2$	4.01	3.9
	17α-ethynylestradiol	$C_{20}H_{24}O_2$	3.67	11.3
Antilipidemic agent	Clofibric acid	$C_{10}H_{11}ClO_3$	2.84	582.5
	Gemfibrozil	$C_{15}H_{22}O_3$	4.77	11
Antiepileptic	Carbamazepine	$C_{15}H_{12}N_2O$	2.77	17.66

The Arctic is considering to be a pollution-free zone, as it is located in the northernmost region of the world. However, several studies have verified the presence of anthropogenic pollutants (e.g., polyaromatic hydrocarbons and pharmaceuticals) in this remote environment (Butt, et al., 2010; Wang et al., 2015; Zhu et al., 2015). Several recent studies have shown that the occurrence of these organic pollutants in this region occurs especially due to sea currents or due to pollutant transport via the atmosphere (Choi, et al., 2020). However, the source of the pharmaceutical contaminants that are detected in Arctic environments has been shown to be directly related to human activities in this area. Little is known about the presence of pharmaceutical compounds in the Arctic region (Kallenborn, et al., 2018). Therefore, this study will provide data on the levels of pharmaceutical compounds in the seawater of Spitsbergen, Svalbard.

The aims of this study were:

i. to determine the levels of different types of pharmaceuticals, including antiepileptic drugs, nonsteroidal anti-inflammatory drugs, hormones, and antilipidemic agents, in surface seawater at several stations in the Spitsbergen, Svalbard,
ii. to identify the presence of the selected pharmaceuticals in plankton samples (net plankton suspended solids). Eleven types of pharmaceuticals (e.g., carbamazepine, naproxen, fenoprofen, ibuprofen, ketoprofen, diclofenac, 17α-ethynylestradiol, estrone, 17β-estradiol, gemfibrozil, and clofibric acid) were analyzed in this study. These compounds were selected based on their common use worldwide, their frequent detection in water bodies (wastewater, freshwater, groundwater, and seawater), and their toxicological effects on marine organisms. Furthermore, the hormones were chosen according to their existence on the European Union's watch list (EC, 2018). The physicochemical characteristics of the target compounds are presented in Table 1.

Materials and Methods

Chemicals

HPLC-grade acetonitrile (≥99.9%), methanol (99.5%), dichloromethane (99.8%), chloroform (99.4%) and sulfuric acid (98%) were purchased from Merck (Darmstadt, Germany). Potassium dihydrogen phosphate was purchased from Fluka (Steinheim, Germany). The SPE cartridges [Cleanert PEP (500 mg/6 mL)] were supplied by Agela Technologies (Torrance, USA). The standards for diclofenac, fenoprofen, ibuprofen, naproxen, ketoprofen, clofibric acid, gemfibrozil, carbamazepine, estrone, 17β-estradiol and 17α-ethynylestradiol were purchased from Sigma-Aldrich (purity >95% or higher) (Athens, Greece).

Study Area and sampling

The Arctic Ocean is undergoing rapid change because of the effects of oceanic and atmospheric warming, sea ice losses, and rises in freshwater inputs (Wassmann, and Reigstad, 2011; Onarheim et al., 2014, Polyakov et al., 2017). Svalbard archipelago is located in the Atlantic Arctic that the Arctic Ocean connects to the North Atlantic Ocean via the Barents Sea and the Fram Strait Jones et al., 2021). The Svalbard archipelago has become a very important center for polar scientific research in recent years (Çetin and Büyüksağnak, 2021). Spitsbergen Island is the only permanently populated island in the Svalbard archipelago and is also the largest. Many fjords surround this island, such as Isfjorden, Hornsund and Bellsund. Arctic fjords can be considered to be critical aquatic areas, as they host terrestrial, oceanic, atmospheric, and cryospheric interactions that are especially susceptible to human-induced factors and climate change (Bianchi et al., 2020; Zaborska, et al., 2020). Isfjorden is Svalbard's second longest fjord and is located in the western part of Spitsbergen. The three largest settlements on Svalbard are located around the Isfjorden fjord: Longyearbyen, Barentsburg, and Pyramiden. Another fjord is Hornsund, which is located on the southern side of Spitsbergen Island. Hornsund is affected by warm waters of Atlantic origin that are carried along the shelf by the western Spitsbergen Current (Walczowski and Piechura, 2006). Additionally, cold Arctic water enters the fjord along with the eastern Spitsbergen current. The melting of

glaciers, inputs from rivers, and precipitation are the sources of Hornsund's freshwater (Błaszczyk et al., 2019). Additionally, although it is categorized as a fjord, Bellsund is actually a sound, which is wider than a fjord, and is located on the west coast of Spitsbergen.

Svalbard's climate is mainly a conclusion of its latitude (74° and 81° north). The North Atlantic Current causes the temperatures of Spitsbergen to be moderate, especially during the winter months (Jónsdóttir, 2005). Average temperatures in Svalbard in 2019 were -9.1 ºC in winter and 6.5 ºC in summer (MOSJ, 2022). Generally, precipitation is low on the west coast of Spitsbergen (200-400 mm/year). However, the precipitation rates have increased by 20-30% in this region in recent years (Johansen, et al., 2021). In general, the area around Svalbard is covered with glaciers and has sparse vegetation. Therefore, seasonal erosion occurs in the area, and large amounts of sediment are transported to the receiving coastal zones from June to September (Bogen and Bønsnes, 2003; Forwick et al., 2010).

The seawater and plankton samples were collected from different parts of Spitsbergen in July 2019. Sampling stations are shown on the map in Fig. 1. The sampling stations, sample types, locations, sampling dates, and water temperatures are shown in Table 2. Station 1 was located close to Isfjorden fjord, and station 2 was located in Hornsund fjord. Station 3, which was the sea ice boundary, and also station 4 were located offshore to the north of the Nordvest-Spitsbergen National park. Station 5 was located at Bellsund sound, and station 6 was located offshore to the west of Spitsbergen. Surface water samples were collected from stations 1, 2, 3, and 4 using amber glass bottles. Plankton samples were collected from stations 1, 3, 4, 5 and 6 by using a conical plankton net (mouth opening: 55 cm, mesh size: 60 µm). Each net plankton sampled an area that extended for approximately 2 km during superficial horizontal hauls that lasted for approximately 30 minutes. The plankton sampling process was unaffected by ship oscillations. After the sample collection, 10M HCl was added as a preservative. The water and plankton samples were brought to the laboratory and were filtered through glass fiber filter papers (GF/F, 0.7 µm). After filtration, the suspended solids of the net plankton samples (Pss) were used to analyze the studied pharmaceutical compounds.

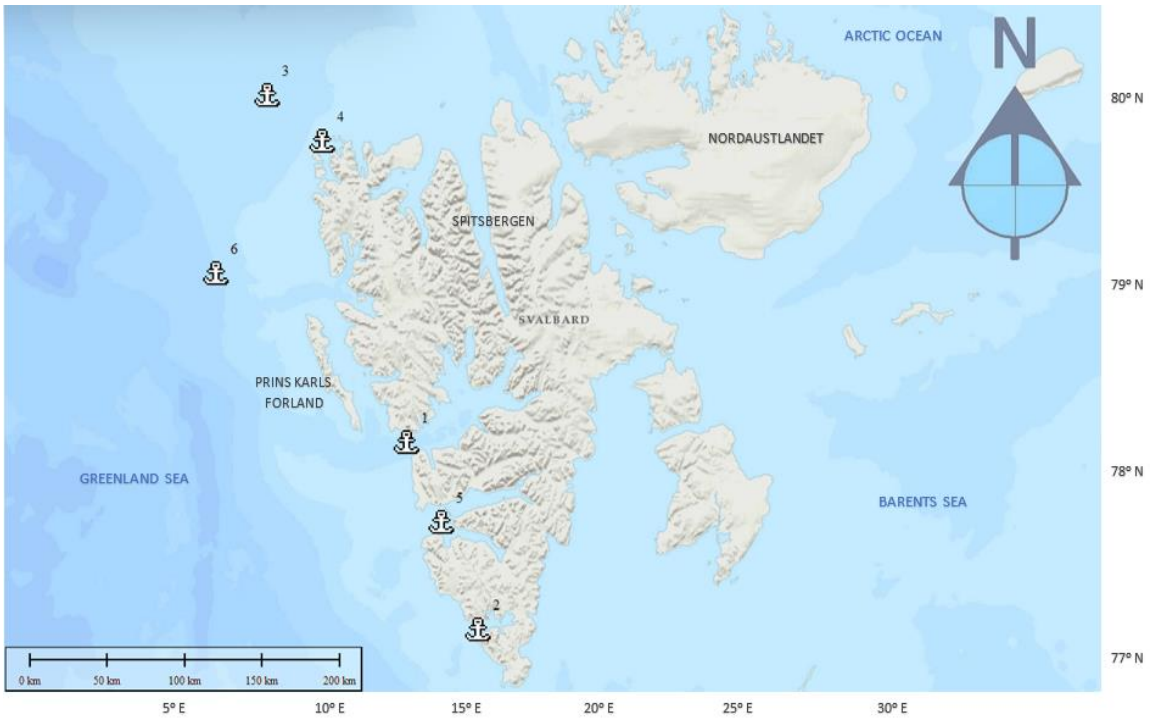

Fig. 1. Locations of sample collection from Svalbard, the Arctic Ocean.

Extraction and purification methods

The seawater samples were extracted using liquid-liquid extractions (100 mL CH_2Cl_2/$CHCl_3$ (1/1, v/v)). Aliquots of the extracts were evaporated to dryness. Before the solid-phase extractions (SPE), the samples were dissolved by adding 2 mL of ultrapure water. SPE was conducted with Cleanert-PEP (500 mg, 6 mL) cartridges that were conditioned with 4 mL of methanol and 4 mL of distilled water. Next, the samples (2 mL) were loaded into the cartridges. The cartridges were washed with 10 mL of deionized water and eluted with 10 mL of methanol and 10 mL of acidic methanol. The final samples were evaporated to dryness, and the volumes were then adjusted to 5 mL with acetonitrile: water (1/1, v/v). The samples were filtered using syringe filters (0.22 µm). The enrichment factor that was obtained for the water samples was 1000.

The Pss samples were lyophilized and homogenized. The ultrasonic extraction method proposed by Xie et al. was modified and used (Xie et al., 2019). Acetonitrile (10 mL) was added to the samples (average weights were 2.27 g), and ultrasonic extraction was applied for 30 min. The samples were then kept in the dark for 24

hours and then decanted. Then, 10 mL of acetonitrile: water (8/2, v/v) was added to the solid part of the decanted samples, and ultrasonic extraction was applied for 30 min. Next, the samples were kept in the dark for 24 hours, decanted and mixed with the first decanted solution. The final volumes were adjusted to 10 mL with acetonitrile: water (8/2, v/v) after the solutions were evaporated using a rotary evaporator. SPE was applied for clean-up, and the applied SPE method was the same as that applied for the water samples.

Table 2. Sampling stations, sample types, locations, sampling dates, and water temperatures.

Station	Sample Type	Latitude (N)	Longitude (E)	Date	Water temperature (°C)
1	Surface water (S1) Net plankton suspended solids (Pss1)	78.108392°	13.71174°	14/07/2019	6
2	Surface water (S2)	76.998966°	15.571538°	15/07/2019	6
3	Surface water (S3) Net plankton suspended solids (Pss3)	80.173637°	9.701489°	20/07/2019	2
4	Surface water (S4) Net plankton suspended solids (Pss4)	79.849206°	10.954807°	20/07/2019	8
5	Net plankton suspended solids (Pss5)	77.632017°	14.48217°	15/07/2019	6
6	Net plankton suspended solids (Pss6)	79.091125°	7.752208°	23/07/2019	2

Instrumental analysis of the target compounds

Ten microliters of each sample were analyzed using HPLC (DAD detector). The separations were performed with a C18 column (250 × 4.6 mm, 5 µm). Acetonitrile and 25 mM potassium dihydrogen phosphate were used as the mobile phases. The flow rate was set to 1.2 mL min^{-1}. The gradient elution that was used by Camacho-Muñoz et al. was also used in this study (Camacho-Muñoz, et al., 2009). The wavelengths ranged from 220 to 300 nm (Camacho-Muñoz et al., 2009; Debska, et al., 2005). Pharmaceutical compounds analyzes were performed within 65 min. The recoveries of the pharmaceutical compounds in the seawater and Pss samples varied between 65.7 – 100% and 67.8 – 93.2%, respectively. The detection limits of these compounds in seawater and Pss were 0.009 – 0.156 µg L^{-1} and 20.7 – 235 ng g^{-1}, respectively. Average recoveries, MDL, and MQL of pharmaceutical compounds are shown in Table 3.

Table 3. Average recoveries (R, n=3), MDL, and MQL of the target compounds in water and net plankton samples in the Spitsbergen, Svalbard.

Pharmaceutical compounds	Seawater			Net plankton		
	R±RSD (%)	MDL (µg L^{-1})	MQL (µg L^{-1})	R±RSD (%)	MDL (ng g^{-1})	MQL (ng g^{-1})
Diclofenac	82.2 ± 5.7	0.023	0.077	82.3 ± 3.9	29.2	97.2
Ketoprofen	66.5 ± 5.1	0.031	0.103	70.5 ± 8.7	39.8	133
Fenoprofen	91.3 ± 4.2	0.015	0.050	89.7 ± 7.2	59.1	197
Ibuprofen	97.4 ± 7.1	0.012	0.040	81.2 ± 4.4	20.7	69
Naproxen	66.1 ± 5.9	0.019	0.063	67.8 ± 2.9	21.1	71
17α-ethynylestradiol	100 ± 6.7	0.009	0.030	91.3 ± 4.2	70.5	235
17β-estradiol	98.7 ± 8.6	0.029	0.096	85.1 ± 6.7	40.7	136
Estrone	95.2 ± 8.8	0.043	0.140	93.2 ± 3.7	69.2	230
Clofibric acid	65.7 ± 3.4	0.047	0.156	69.8 ± 3.7	45.5	152
Gemfibrozil	69.5 ± 8.3	0.013	0.043	71.2 ± 8.7	30.1	101
Carbamazepine	90.3 ± 6.8	0.035	0.117	91.4 ± 5.9	25.5	84.9

Results and Discussion

The presence of the selected pharmaceutical compounds in the surface seawater and Pss samples of the Spitsbergen, Svalbard archipelago were investigated in July 2019.

Presence of the target pharmaceutical compounds in seawater

The spatial distributions of the target pharmaceuticals in the seawater of Spitsbergen are shown in Fig. 2.

The concentrations of diclofenac, ketoprofen, naproxen, fenoprofen and ibuprofen in the seawater of Spitsbergen ranged between (<0.023 - 0.44 µg L^{-1}), (<0.031 µg L^{-1}),

(<0.019 - 0.23 μg L^{-1}), (0.23 - 0.60 μg L^{-1}) and (<0.012 - 1.24 μg L^{-1}), respectively. Diclofenac was detected at two of the four stations in the study area. Diclofenac is quickly degraded by photodegradation and biodegradation (Andreozzi, et al., 2003; Baena-Nogueras et al., 2017; Benotti and Brownawell, 2009; Koumaki et al., 2015; Yamamoto et al., 2009). However, this compound was detected at two stations because the low-temperature environmental conditions in the Arctic environment caused reduced microbiological degradation (Green et al., 2008; Gunnarsdóttir, et al., 2013; Huber et al., 2013; Kallenborn et al., 2008; Vasskog, et al., 2008; Vasskog, et al., 2006; S. Weigel et al., 2004; Weigel, et al., 2004). Among the NSAIDs, fenoprofen was detected at all stations in the seawater of Spitsbergen. Fenoprofen can be removed in only low amounts after traditional treatments and is therefore one of the highest persistence pharmaceutical compounds found in wastewater and sediments (Kramer, et al., 2018). As a result, given that wastewater treatments are insufficient or incomplete in most Arctic regions (Gunnarsdóttir et al., 2013), it was a predictable result that fenoprofen was commonly detected in the seawater of the study area. Ibuprofen was detected at high concentrations (1.04 - 1.24 μg L^{-1}) at some stations when compared to other NSAID pharmaceuticals. The half-life of ibuprofen in aquatic environments is 50 days (Buser, et al., 1999). However, due to the low temperatures in the northern environments, the half-life of the compounds in the receiving seawaters were found to be longer than those in middle-latitude regions. In addition, high ibuprofen levels in the receiving environments are expected to result as the biodegradation rate of ibuprofen is decreased due to the low temperatures in northern environments (Kallenborn et al., 2008). The ketoprofen concentrations were below the method detection limit (MDL) at all stations (Fig. 2).

The carbamazepine concentrations in the Spitsbergen seawater ranged between <0.035 and 1.57 μg L^{-1}. Carbamazepine was detected at station 1 (1.57 μg L^{-1}) and station 3 (1.19 μg L^{-1}) (Fig. 2). The detection of high carbamazepine concentrations suggested that this pharmaceutical compound was used by the people living in the area. Carbamazepine is a persistent ($t_{1/2}$ 82 days) pharmaceutical compound in aquatic environments (Lam et al., 2004). Additionally, its detection in offshore areas, such as station 3, proved the persistence of this compound. The clofibric acid and gemfibrozil concentrations in the seawater were in the ranges of <0.047 and 0.94 - 2.17 μg L^{-1}, respectively. The clofibric acid levels were below the method detection limit (MDL) at all stations. Accordingly, clofibric acid was not consumed by humans in this region. Gemfibrozil was detected at all stations, and the highest concentration of this compound was 2.17 μg L^{-1} at station 4 (Fig. 2). Gemfibrozil is a permanent contaminant in aquatic environments due to its long half-life (200 days) in surface water (Araujo et al., 2011; Fang, et al., 2019). In addition, gemfibrozil undergoes less photodegradation at low temperatures (Daneshvar, et al., 2010; Loraine and Pettigrove, 2006). In addition, the large amounts of fresh water input in the summer months (July-September) (Zaborska et al., 2020) caused increases in the amounts of organic pollutants (e.g., pharmaceutical) in the receiving environment. For this reason, gemfibrozil was detected at all stations in the study area.

The concentrations of estrone, 17β-estradiol and 17α-ethynylestradiol in seawater ranged from (<0.043 - 0.42 μg L^{-1}), (<0.029 - 0.14 μg L^{-1}) and (0.34 - 0.85 μg L^{-1}), respectively. The highest estrone and 17β-estradiol concentrations were observed at station 1. 17α-ethynylestradiol was detected at all stations (Fig. 2). The half-life of 17β-estradiol and 17α-ethynylestradiol in water systems are 2 and 81 days, respectively. Therefore, the synthetic hormone, 17α-ethynylestradiol, is more persistent in aquatic environments than the natural hormone 17β-estradiol (Adeel, et al., 2017). As a result, it was an expected result that synthetic hormones were detected at higher concentrations than natural hormones. Many studies have shown that 17β-estradiol easily degrades to estrone (Adeel et al., 2017; Xuan, et al., 2008). The fact that the estrone concentrations were higher than the 17β-estradiol concentrations at the three stations in this study suggests that estrone may be the main degradation product of 17β-estradiol.

There are very few studies on the presence of these selected pharmaceuticals in Arctic sea waters. The diclofenac, ibuprofen, and naproxen concentrations that were determined in this study were higher than those found in other studies of the Arctic region (Choi et al., 2020; Kallenborn et al., 2018; S. Weigel et al., 2004). Diclofenac and naproxen were not detected in the seawater of Kongsfjorden in Spitsbergen in the study by Choi et al. (2020). Weigel et al. detected ibuprofen with maximum concentration of 0.7 ng L^{-1} in the seawater of Tromsø/Norway (S. Weigel et al., 2004). In a different study, Kallenborn et al. indicated that the maximum concentrations of diclofenac and ibuprofen in the seawater of Oslo were 48 ng L^{-1} and 52 ng L^{-1}, respectively. Additionally, the maximum diclofenac and ibuprofen concentrations in the Longyearbyen, Svalbard seawater, were determined to be 4 ng L^{-1} and 1 ng L^{-1}, respectively (Kallenborn et al., 2018).

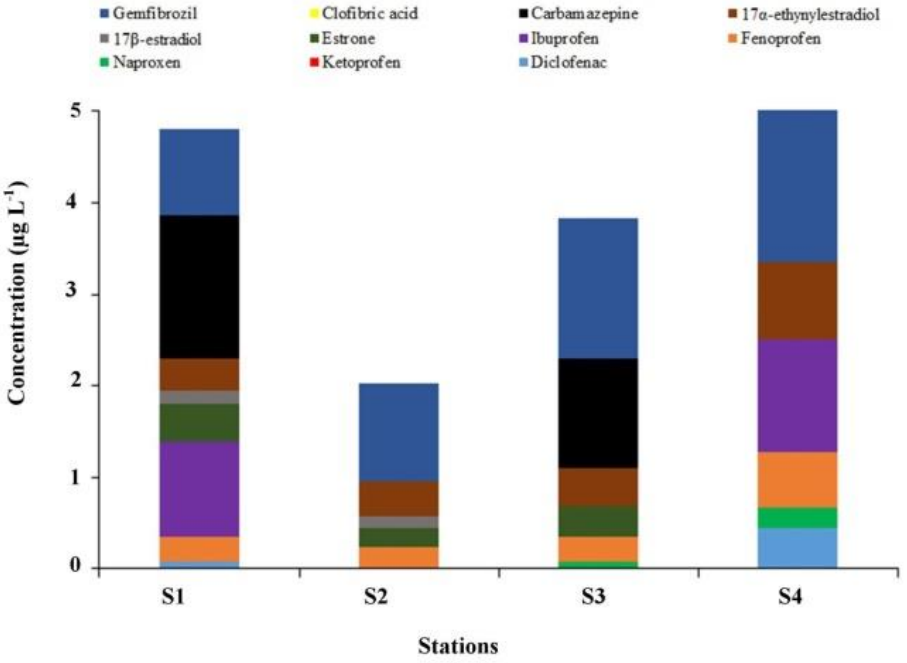

Fig. 2. Cumulative levels of pharmaceutical compounds in the seawater of Spitsbergen, Svalbard.

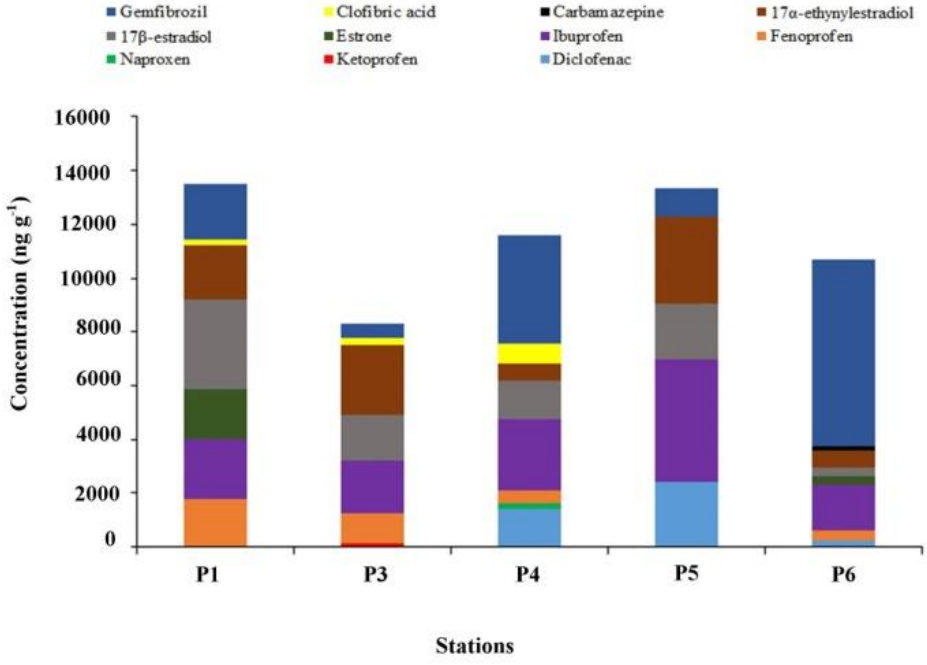

Fig. 3. Cumulative levels of pharmaceutical compounds in the net plankton of Spitsbergen, Svalbard.

Presence of the target pharmaceutical compounds in the net plankton suspended solids (Pss)

The concentrations of the selected compounds in the Pss samples from Spitsbergen are shown in Fig. 3. The compounds that had the highest concentrations in the Pss samples were ibuprofen (4543 ng g^{-1}), 17β-estradiol (3338 ng g^{-1}), 17α-ethynylestradiol (3262 ng g^{-1}) and gemfibrozil (6940 ng g^{-1}). Complexation, ion exchange, hydrogen bonding and hydrophobic partitioning processes are sorption processes of organic pollutants into solids (e.g., suspended solids and sediment). The sorption of polar and ionic pharmaceutical compounds to solids cannot be evaluated from their log K_{ow} values (Kwon and Armbrust, 2008). Since the log K_{ow} values of the studied pharmaceuticals are in the range of 3 - 4.8, they can be found in both water and solids. Another factor that affects the sorption of organic pollutants into solids is the pK_a values of these compounds. Compounds with pK_a>7 have higher sorption to solids (Silva et al., 2011). In this work, it was determined that 17β-estradiol (pK_a 10.6) and 17α-ethynylestradiol (pKa 10.4), with their basic properties, had strong tendencies to bind to suspended solids. However, acidic pharmaceuticals (pKa 4.1-4.9) (Fent et al., 2006) such as diclofenac, naproxen, ketoprofen, ibuprofen, fenoprofen, clofibric acid and gemfibrozil, for which the sorption of these compounds into solids is very weak, were thought to be absorbed in suspended solids by

forming ternary surface complexation (Fein, 2002). In addition, ibuprofen and gemfibrozil were detected at high levels in both water and suspended solids, which confirms their high consumption levels by humans near the study area. As a result, it was determined that the amounts of the pharmaceutical compounds in the Pss samples were too high to be neglected. To our knowledge, there is no study on the concentrations in the plankton of these selected pharmaceutical compounds around Svalbard. Therefore, this work will provide valuable information for the literature.

Conclusion

Eleven selected pharmaceutical compounds that were analyzed using HPLC-DAD were investigated in the surface seawater and plankton samples of Spitsbergen, Svalbard. The results showed that the highest concentration of these compounds (2.17 μg L^{-1}) in the seawater occurred for gemfibrozil. Additionally, 17α-ethynylestradiol and fenoprofen were detected in the seawater at all sampling stations. Also, gemfibrozil, ibuprofen, 17β-estradiol, and 17α-ethynylestradiol were detected at high concentrations in the plankton samples. Gemfibrozil was a dominant component of the investigated seawater and plankton samples. There are several reasons why pharmaceutical compounds are detected in the Arctic environment. The main reasons were thought to be that these compounds could not be treated in the Arctic region due to the lack of wastewater treatment facilities and because of their prolonged half-life in the receiving environment due to the low temperatures. One of the reasons was thought to be that in the summer melting season, during which our sampling was conducted, freshwater, which transported micropollutants from the terrestrial to marine waters, extensively entered the Arctic Ocean. Another reason was the increased tourism activities in Spitsbergen during the summer season, which was when we conducted sampling. In addition, the detection of these micropollutants in offshore areas can be explained by the fact that they are transported over long distances in marine areas by binding to suspended solids.

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