



The icy beauty of Spitsbergen. Photo by Vitaly Novikov.

Source: <https://www.rgo.ru/en/file/vitaliy-novikov-ledenyashchaya-krasota-shpicbergena-427093jpg>

## Dynamics of Total Petroleum Hydrocarbon Content in the Surface Waters of Green Fjord (Greenland Sea)

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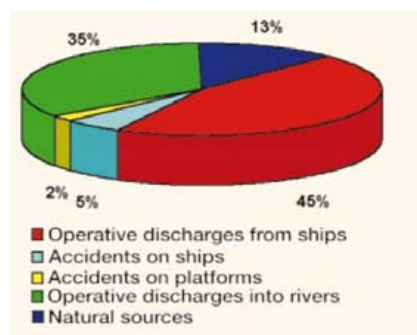
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### 1. Introduction

Oil pollution is one among the most dangerous factors of anthropogenic impact on aquatic ecosystems, the amount of oil spilled annually worldwide has been estimated at more than 4.5 million tons [1].



Estimate of the sources of oil spills at sea. Source: ESA (Prepared by: Remote Sensing Exploitation Division ESRIN) [1].

Wastewater discharge and local economic activities, namely, wastewater containing various hydrocarbons, makes a source of pollution not related to oil production. Leakage of oil products' components also takes place due to migration and dispersion processes during operations of oilfield facilities. In this article in purpose to investigate spatial and temporal variability of petroleum hydrocarbon concentrations an overview is performed based on the data from the areas of high economic activity. Local sources may also contribute to some elevated PAH and THC levels in the sediments of the Green Fjord (Grøn fjorden), the Greenland Sea). Waste disposals containing oil products bring about 10% of HC pollution recorded in coastal economic activities, which include oil storage and oil processing wastes as well. Some notable features of oil distribution in seawaters are the heterogeneity of its content in aquatic ecosystems, localization at the interface between water and atmosphere, in bottom sediments and along the coastline [2].

How different can be the features of distribution of petroleum hydrocarbons in different parts of the Green Fjord? Can the

existing concentrations affect badly on the conditions of the marine environment and sedimentation?

As noted, the identification of environmental factors of a cyclic nature is an important scientific task in oceanology and accounting to the cyclical nature of changes in the environment makes it possible to conduct a comparative analysis of transformations and substantiate the effect of polluting factor.

At present, there are sufficient long-term series of reliable observations of physical characteristics of seawaters and only some fragmentary data on hydrochemical parameters of the aquatic environment (in regards to the content of oil hydrocarbons in seawater/bottom sediments). It is very important that the specialized hydrochemical data banks should be created for the purpose of environmental monitoring and assessment of pollution levels. The results of this study are supposed to be used in a comprehensive assessment of anthropogenic impact, accounting to oil pollution and can possibly help to identify the processes between ongoing changes and influencing factors. All samples have been processed and analyzed for levels of organic contaminants and the values of total hydrocarbon content (THC).

## 2. Study Area

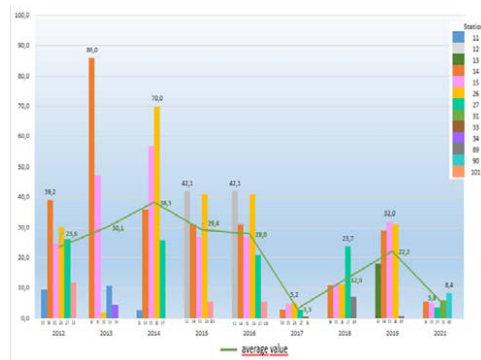
The Green Fjord, located in the Western Svalbard, is a part of the East Fjord (Spitsbergen archipelago, Greenland Sea). Herein in purpose to determine the levels of pollutants, including petroleum hydrocarbons (THC) the North-Western Branch of the FSBI RPA «Typhoon» took samples in the surface and in the near-bottom horizons. The fjords of southwestern Spitsbergen (European Arctic) are a climatically sensitive area neighboring the mixing zone of warm Atlantic water-masses and cold Arctic Water. Owing to reasonably high accumulation rates, these settings are especially suitable for providing high-resolution sedimentary records of regional hydrological and environmental changes. There is also a considerable number of watercourses in the area, which contribute to the accelerated rate of sedimentation in the basin. The consequences of accidental spills and natural hydrocarbon discharges can have a negative impact on basin ecosystems and sedimentation. Sedimentation undergoes spatial and temporal changes associated with the dynamics of the aquatic environment. The Svalbard archipelago is located in the high Arctic (76°-80°N) within the northernmost reach of the West Spitsbergen Current (WSC), which is the continuation of the North Atlantic Current. In this specific setting close to the Polar Front, even small variations in the system of flows are expected to provide large and distinct signals in palaeoceanographic parameters [3]. The Greenland Sea is the deepest sea of the Arctic Ocean: its average depth is 1450m, maximum depth is about 4800 – 5527 m. In the central part of the sea WSC forms powerful cyclonic eddies. The Green Fjord gulf is located between 77°07' and 77°58' N. latitude and 13°56' and 14°20' E. longitude in the western part of the archipelago and extends meridionally to the South-South-East. It constitutes the Southwestern branch of the East Fjord, goes far into the land, its southern coast borders on relatively large glaciers while the water area of the gulf is open to the Arctic basin. It extends southward for 17 km with the maximum depth – 155 m. Besides,

the North European Basin (NEB) including the Norwegian Sea and the Greenland Sea plays a key role in exchange between the Arctic Basin (AB) and the North Atlantic (NA). The total area is more than 193 km<sup>2</sup> and 60 km<sup>2</sup> of it – a subject to glaciation [4].

At present, the region of the Norwegian and the Greenland Seas remains the object of intensive field research. The concentrations of most of the pollutants in the waters of the Green Fjord showed values typical for the coastal waters of the Norwegian Sea and the North Sea. Monitoring of the seawaters is maintained according to water quality requirements for fishery reservoirs. The results make it possible to classify the waters of the gulf in summer periods of 2019, 2020 as «moderately polluted» and classify them as quality class III with an average or insignificant level of impact of coastal sources of pollution on the sea, which is consistent with the Norwegian classification (moderat, klasse III) [5-8]. This study is performed to continue the previous studies.

## 3. Results and Discussion

Generally, samples of local monitoring were taken at stations adjacent to the territory of Barentsburg in the eastern part of the Green Fjord. The results of the work during the expeditions highlight the transition from the summer warming phase with the maximum influence river runoff to the autumn cooling phase with reduced river runoff. The location of the stations is chosen accounting to geomorphological characteristics of the bottom and the configuration features of the gulf. The results of THC study (μg/dm<sup>3</sup>) in the surface horizon (0.5 m) showed average concentrations in seaward direction differentiating from 5 to 22 μg/dm<sup>3</sup> with a local maximum of 86 μg/dm<sup>3</sup> (at station 14) at the confluence of the stream flowing through Barentsburg. An increase in the concentration of hydrocarbons in the surface horizon is taking place in the range of 33 - 70 μg/dm<sup>3</sup> (stations 28, 26) in the coastal areas of the Green Fjord. An overview of THC levels in surface waters is shown in Figure 1. The maximum values declined in the later period and reached 3 μg/dm<sup>3</sup> (in 2021). In 2016 average concentrations were approximately at the level of 2015, but lower than those of the previous years, where their values in 2014, 2015 averaged 38-29 μg/dm<sup>3</sup> and at the western margin of the Green Fjord gulf reaching up to 42 μg/dm<sup>3</sup>.



**Figure 1:** Long-Term Changes in the Maximum and Average Concentrations of TPH (μg/dm<sup>3</sup>) in the Surface Water Layer in Different Parts of the Green Fjord

In this part of the basin, the content of hydrocarbons in the surface water layer varies on average from 5 to 22  $\mu\text{g}/\text{dm}^3$ , with a local maximum of up to 86  $\mu\text{g}/\text{dm}^3$ . In 2012 THC ranged from 9 to 39  $\mu\text{g}/\text{dm}^3$ , with an average value of 19  $\mu\text{g}/\text{dm}^3$ . In 2013 in the waters of the eastern part of the Green Fjord THC was in the range 2 - 86 ((in the water intake area and in the area of the confluence of the stream flowing through Barentsburg accordingly), with an average value of 10  $\mu\text{g}/\text{dm}^3$ . In 2014 THC varied within 2 - 70  $\mu\text{g}/\text{dm}^3$  (in the northern part of the Green Fjord and in the area of the confluence of the stream flowing through Barentsburg accordingly), with an average value of 26  $\mu\text{g}/\text{dm}^3$ . In 2015 it varied within 5 - 70  $\mu\text{g}/\text{dm}^3$ , with an average value of 25  $\mu\text{g}/\text{dm}^3$ . In 2016, THC concentrations ranged within 5 – 42  $\mu\text{g}/\text{dm}^3$ , with an average value of 25  $\mu\text{g}/\text{dm}^3$ . In 2017 the range of THC – from 0.6 to 5  $\mu\text{g}/\text{dm}^3$  with an average value of 2  $\mu\text{g}/\text{dm}^3$ . In 2018 THC varied from 7 to 23  $\mu\text{g}/\text{dm}^3$  ((in the adjacent water area of the Billefjorden to the North of Barentsburg), with an average value of 12  $\mu\text{g}/\text{dm}^3$ . In 2019, THC in the waters varied from 1 (in the water area of the Bill fjord Bay) to 32  $\mu\text{g}/\text{dm}^3$  (in the water area of the Green Fjord in the area where the stream flows north of Barentsburg), with an average value of 15  $\mu\text{g}/\text{dm}^3$ .

THC concentrations ranged from 3 - 5  $\mu\text{g}/\text{dm}^3$  with an average value of 4  $\mu\text{g}/\text{dm}^3$  in 2021. The average THC in the study area decreased for different areas in the sequence: waters of the Green Fjord at the confluence of a stream flowing through Barentsburg, station 14 (22  $\mu\text{g}/\text{dm}^3$ ), to the water area of the gulf to the north of Barentsburg (9  $\mu\text{g}/\text{dm}^3$ ) and to the gulf outlet (5  $\mu\text{g}/\text{dm}^3$ ) (Western part < Central part). The highest values of THC (70-86  $\mu\text{g}/\text{dm}^3$ ) are observed in 2019 in the surface waters. Maximum values of total hydrocarbons content, ( $\mu\text{g}/\text{dm}^3$ ) in surface waters for the period from 2012 to 2021 in different areas of the Green Fjord varied from 19 (in the open part) to 86  $\mu\text{g}/\text{dm}^3$  in the area of the confluence of the stream flowing through Barentsburg.

#### 4. Conclusions

The maximum content of THC was recorded at station 14 in the surface layer of seawaters at a depth of 87 m in the Greenland Sea in the area north of Barentsburg. There was a tendency to reduce the degree of pollution in the following five years since 2017. In 2021 lower concentrations of hydrocarbons in the gulf compared to previous years may occur due to a decrease in oil pollution and increased protection measures and supervisory activities. Local high concentrations for THC in the surface

horizon may be an evidence of the fact that economic activity has a marked anthropogenic impact on the water area along the coastline. The results of the work can be applied further in the development of measures for rehabilitation of water resources. Besides, the research works confirm that the Green Fjord is a rather representative area for conducting comprehensive observations in order to obtain estimates of the impact of economic activity on coastal environment, the state of sea hydrochemical balance and the level of pollution of seawater bodies.

#### Author Contributions

Authors all contributed to this work, took part in data processing. A.A. conducted the research and wrote the paper; A.D. collected samples and participated in data analysis; N.A. participated in data analysis and visualized the results; all authors had approved the final version.

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