Assessment of the contamination of the harbor beds with PCBs and mercury, and its risks assessment at Tivat Bay and Risan Harbour in Montenegro

Final report covers the activities, as stipulated in the SSFA
Approved for payment

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Introduction

Every country has its regions that it calls a national treasure, and Montenegro is no exception. One of the most beautiful and southernmost bays in Europe is Boka Bay. The bay is uniquely divided into four smaller bays: Herceg Novi, Risan, Kotor, and Tivat. Surrounded by high mountains Orjen and Lovćen, Boka Bay is the only fjord in the Mediterranean. The bay is home to several small fishing villages and three larger cities - Herceg Novi, Tivat, and Kotor - and also has seven islands and two peninsulas. The Kotor area is part of the UNESCO World Heritage List, which includes cultural and natural assets that have exceptional universal value for humanity. Established in 1978 based on the Convention on the Protection of World Cultural and Natural Heritage adopted by UNESCO in 1972, the list currently comprises over 1,100 sites from around the world. The Kotor area was one of the first 60 sites to be inscribed on the World Heritage List in 1979 due to its exceptional universal value.

Although the bay has undergone significant development over the years, certain areas have faced challenges due to their historical use for industrial and port activities. Indications of challenges were obtained through the implementation of the National Program for Monitoring Marine Ecosystems. The research results of the monitoring program showed that the localities near the port in the Bay of Kotor have a concentration of certain chemical elements as well as organic substances (PAH, PCB) that exceed the effects range low (ERL). The ERL indicates the concentration below which toxic effects are scarcely observed or predicted. Concentrations equal to and above the ERL, but, below the effects range median (ERM) represent a "Possible-effects" range within which effects would occasionally occur.

The results of the aforementioned research were the basis for the Center for Ecotoxicological Research (CETI) to sign a Small-Scale Funding Agreement (SSFA) with UNEP regarding the realization of one part of the project entitled "Reducing Pollution from Harmful Chemicals and Wastes in Mediterranean Hot Spots and Measuring Progress to Impacts -Child Project 1.1 "

The objective of the SSFA is to contribute to the implementation of the UNEP/MAP Programme of Work (PoW) and Budget for the biennium 2022-2023 and the GEF MedProgramme-Child Project 1.1 entitled Reducing Pollution from Harmful Chemicals and Wastes in Mediterranean Hot Spots and Measuring Progress to Impacts (hereinafter referred to as Child Project 1.1 or CP 1.1). The MedProgramme is being implemented in several GEF-eligible countries, including Montenegro. For this SSFA, Component 1, Output 1.1. on the management of persistent organic pollutants (POPs) will be addressed by assessing the contamination of the harbor beds with PCBs and mercury, and its risks assessment at Tivat Bay and Risan Harbour in Montenegro.

The main expected output of this assessment is to identify possible contamination of the harbor beds and based on the results carry out a risk assessment of the port area.

The process of carrying out the contracted activities began with a comprehensive review of all available technical documentation related to the current state and challenges at the locations of the research subjects. After visiting the locations and working alongside the UNEP expert, the areas that will be investigated were agreed upon, a conceptual site model

was developed, and a sampling plan was put in place. A substantial amount of sediments samples were tested, and a thorough evaluation of the results was conducted.

Background information on the site and surrounding environmental media and area Risan Bay – Port of Risan

Risan, in the Kotor municipality, is officially recognized as a port of local importance by the Decision on port designation (published in the "Official Gazette of Montenegro" 020/11, 041/12, 014/14, 070/18). Managed by a designated legal entity, it holds historical significance as the oldest settlement in Boka Kotorska, with a millennia-old history as a vital port. Founded by the Illyrians, Risan features famous Roman mosaics from the 2nd century BC. Located 15 km from Kotor and 20 km from Herceg Novi, the port is easily accessible by the Adriatic highway. Situated at the bay's northernmost point, it has adjacent roads, a city park to the northeast, a residential area to the northwest, and private beaches on the southwestern side. Coordinates: 42°30'47.21"N 18°41'41.39"E.

Montenegro's Government approved the 2022 Plan for port concessions, including the Port of Risan, designated for nautical tourism. The Special Purpose Spatial Plan for the Coastal Area categorizes it as a marina. Despite strong boater interest, careful construction planning is crucial due to environmental restrictions.

The concession encompasses construction, reconstruction, maintenance, management, and infrastructure provision for the Port of Risan. It allows a maximum of 150 commercial berths and 30 communal berths. The concession area covers 5,039 m^2 of land and corresponding aquatic spaces—17,100 m^2 for commercial berths and 4,495 m^2 for communal berths.

Geomorphological and geological characteristics

The Municipality of Kotor boasts a complex geological structure and tectonic arrangement, particularly evident in the intricate topography of the Boka Bay along the Montenegrin coast. The bay's unique shape is attributed to denudation and fluvial erosion on flysch rocks during the Miocene and Pliocene epochs. Steep bay shores are limestone-based, while gently sloping areas like Škaljari, Risan, Morinj, Grbalj, and Mrčevo field consist mainly of flysch rocks.

Grbalj and Mrčevo fields, Trojica, Risan, and Strp feature flysch sediments from the middle and upper Eocene, comprising clays, sandstones, marls, and occasionally breccia and conglomerate. The mountainous hinterland of Morinj, Risan, and Kotor Bay is shaped by shallow-water carbonate deposits from the Jurassic and Cretaceous periods, along with carbonate breccias from the Cretaceous-Eocene and middle Eocene flysch sediments.

Senonian sediments, primarily limestone, are present in Risan Bay, Krivošija, and Ledenice areas, lacking a transition between dolomite and limestone found elsewhere. Above these layers lies transgressive flysch from the middle Eocene.

The terrain near Risan is diverse, featuring flat, gently sloping, and steep areas with significant elevation variations. The bay's shores consist of limestone and flysch rocks, with springs emerging at their intersections, some exhibiting vrulja spring characteristics. The complex formation of Boka Bay occurred during the Miocene and Pliocene when the sea level was lower. This process involved erosion of flysch rocks through denudation and fluvial erosion, and corrosion at limestone-flysch contact points.

In the inner parts of Boka Bay, like Morinj, Risan, and Kotor bay, smaller expansions developed on flysch layers, often covered with shale and breccia layers, contributing to the picturesque geological diversity of the region.

Hydrography

The Boka area experiences an ongoing erosive process, impacting all watercourses. Kotor and Risan bays are distinctive for frequent underwater springs, often called 'vrulje', with the Sopot spring near Risan being notable. These springs serve as outlets for the karst hinterland, both along the coastline and beneath the sea surface. Sopot, a typical spring, has an open exit above the sea surface and significant water flow, especially in heavy rainfall.

In Risan, Veliki Potok and Spila are key surface watercourses. In the Municipality of Kotor, numerous sources and torrential streams play a crucial role in hydrography due to intense precipitation, terrain configuration, and geological composition.

Most water ultimately reaches the sea through karst beds, navigating complex underground paths. A substantial portion flows beneath the sea surface through 'vrulje,' contributing to a scarcity of surface water bodies, both flowing and stagnant, along the coastline.

Marine aquatorium

Risan Bay, with a 39-meter depth at the entrance and 13 meters near Risan, exhibits an average Adriatic Sea salinity of 2.8‰ due to freshwater sources, reducing the regional 38.22‰ average. Surrounded by high coastal mountains, the hinterland receives 5000-5500mm annual precipitation, following a Mediterranean pattern peaking in winter.

The bay's calm waters and rich marine life result from springs, underwater springs, and rivers, creating dynamic water masses up to 5 meters deep. These dynamics peak in winter and spring with maximum freshwater inflow, particularly in the enclosed Bay of Kotor. Local hydrometeorological conditions cause significant fluctuations in seawater properties.

Temperature extremes occur in July (28.3°C in Risan Bay) and February (7.4°C in the Bay of Kotor, 6.85°C in Risan Bay). Kotor and Risan Bay sections have steep, rocky slopes extending from the sea surface to the bay's depths, with a seabed covered by fine silt and sandy clay near Risan, influencing benthic marine life distribution.

Various winds, like the cold Bura from the northeast and humid Jugo from the southeast in winter, and the mistral from the west-southwest in warmer months, influence the area. Winds, notably Bura and Jugo, create southeast-northwest currents along the coast, impacting sea visibility. Maximum water transparency, up to 25 meters, occurs in the summer.

Municipal water

Risan's sewage system, initially designed for a few older buildings, a hospital, and a nursing home, faces challenges. Older structures often discharge sewage into the immediate land surroundings, and many houses rely on septic tanks. The 'Teuta' hotel manages sewage through three overflowing septic tanks, with a north-south pipeline directing fecal matter and wastewater to a submarine outlet extending 30 meters into the sea. A nearby residential building has a similar system extending 50 meters into the sea, while older houses by the sea have outlets only 2 meters from the shore.

In addition to the fecal water outlet, a rainwater collection system along the western sea-facing side channels water from the pool through a concrete pipe to the pebble beach, causing occasional issues with sand and gravel entering the pipe due to wind and waves.

Climatic conditions

Risan experiences a mild Mediterranean climate with notable differences between the coastal zone and the karst hinterland. The average annual air temperature is 15.8°C, with January being the coldest and August the warmest. There are only 4.3 days with temperatures below 0°C, and over 40 days exceed 30°C. Summer temperatures result from limestone rocks heating up, while the hinterland shields from cold air intrusion.

The average monthly and annual cloud cover is 5.3/10, the highest in the Bay of Kotor, with November being the cloudiest and August the clearest.

Risan has 117 cloudy days annually (32.05% of the year) and 76.9 clear days (21.06%). Annual precipitation is 3429 mm/m2, with a peak in November and a minimum in July. Prevailing winds are the cold north wind and humid south-south wind in colder months, while the mistral-northwest wind brings refreshment in warmer months. Windless days account for 36% of the year.

Sea level changes have a mean amplitude of 23 cm, reaching 29 cm between higher high waters and lower low waters. The total amplitude is 64.1 cm, with extremes at 87 cm above and 42 cm below the hydrographic level. Maximum sea level changes occur in October, November, and December.

The knee dock in Risan Bay protects the harbor from southerly winds, preventing significant waves. Only westerly winds have the potential to generate stronger waves, while storms with strong gusts typically don't result in significant waves. The northwest wind creates a southerly current when the river north of the port swells.

Mooring and anchoring in the port of Risan

Smaller vessels can moor along the inner side of the 70-meter-long jetty or within the protected area behind it. However, sediment accumulation in one section, due to rainwater runoff, occasionally reduces the depth to 0.2 meters, requiring special attention.

Larger vessels can safely moor outside the 88-meter-long jetty, equipped with rubber bumpers to prevent collisions during adverse weather. The port offers 19 cleats and numerous shackles for mooring.

For larger vessels, anchoring in front of Risan is an option, with depths ranging from 13 to 20 meters. The hard silt seabed provides reliable anchorage during southward winds. During strong bura winds, using two anchors is recommended for added stability and vessel safety.

Tivat bay

Tivat Bay is the central basin of Boka Bay and the second largest after Herceg Novi Bay. The average depth of the bay is 25.5 m. It is deepest in the central and western parts, and shallowest in the southeastern part. With the Kumbor Strait (730 m wide) it is connected to the outer Herceg Novi Bay, and with the Verige Strait (340 m wide) it is connected to the inner part of the Bay of Kotor (Kotor and Risan Bay). Unlike the Kotor and Risan bays, this bay is much less influenced by fresh waters. The influence of fresh waters is primarily seasonal, mainly through the rivers Široka Rijeka and Gradiošnica and several seasonal

streams that collect water from Tivatsko and Grbaljsko polje. The hydrographic characteristics of the bay are dominantly influenced by the two neighboring bays with which it exchanges water masses via the two straits mentioned earlier. The flow of water masses in the bay is of weak intensity, especially in the warmer part of the year. In the colder part of the year, in the central part of the bay in the surface layer, the outflow current with an average speed of 5-23 cm/s prevails. The current intensity is the weakest in the eastern part of the bay and the highest in the western part at the junction of Verige-Kumbor. The Montenegrin coast is protected from the action of winds from the mainland. Tivat bay is specially protected. In the bay area, the estimate of the frequency of silence is extremely high, the annual average is 49%, while in summer and autumn it is 52%.

Geological-seismic characteristics

The area of Tivat is mainly formed by geologically youngest rocks. The wide coastal belt and lower slopes along the Tivat Plain are built of Quaternary and Paleogene sediments. Alluvial (Holocene) alluvium prevails there, over which a thick layer of silt has been deposited in places. The data indicate very pronounced seismic activity in the area of the Montenegrin coast. This activity is genetically linked not only to the evolution of different structures, but also to the physical properties of geological environments, i.e. the positions of deep faults. The reinterpretation of geophysical data, geomagnetic, gravimetric, as well as the results of deep seismic sounding, resulted in the Seismotectonic Map of Montenegro, with the location of seismogenic zones, on which five deep regional faults stand out. From a macro seismic point of view, the territory of Tivat is located within the area with very pronounced seismic activity. The last devastating earthquake (1979), as well as the earlier ones, show that earthquakes with a strength of around 9 degrees MCS scale can occur right in the area of the city in medium ground conditions. The fact that the area is largely built of flysch, predominantly clastic sediments and quaternary formations, represents a major disadvantage from the aspect of seismic risk.

Climatic characteristics

Tivat has a typical Mediterranean climate, with mild, rainy winters and bright and warm summers. The average annual air temperature is 15°C, and the average summer temperature is 27°C. During the summer period, tropical air temperatures of over 30°C are possible during the day. Tivat is considered the sunniest city of Boka Bay, with an average of 240 sunny days a year, with the swimming season lasting 180 days.

This area is under the influence of strong cyclonic activity in which, for days, there can be very unstable weather with heavy rain and strong stormy southerly winds. There are very frequent situations when this area is hit by strong, stormy winds from the north or storms at sea.

The most common winds are bura (northeast wind) in winter and mistral (northwest wind) in summer. Jugo, a warm wind that brings a lot of rain, is common in autumn and winter.

Relative air humidity shows a stable annual trend. The maximum of average monthly values occurs during the transitional months (April-June and July-August), and the minimum during the summer period, and in some cases also during the winter (January - February).

This area has a maritime type of precipitation with a minimum during the summer period and a maximum during the cold period of the year. The cold period November-December-January provides over 30% of the annual precipitation. The average annual amount of

precipitation in Tivat is 1,755 mm. As for dry periods, they are very common during the summer period.

Municipality of Tivat

The city and municipality of Tivat is located in the central part of the Boka Bay, on the southwestern slopes of the Vrmac hill (765m). Tivat covers an area of 46 km2, of which about 5 km2 overlooks the open sea. It is located at 42°26´ north latitude and 18º42´ east longitude. According to the last population census from 2011, Tivat has 14,031 inhabitants.

Hydrological characteristics

The Montenegrin coast belongs to the Adriatic Basin and is one of the most water-rich areas in the world. It is characterized by a high amount of precipitation and unfavorable seasonal oscillations. Due to the rapid runoff of water through the soil, the water balance is not favorable, so a water deficit occurs in key periods (tourist season, vegetation period). The water flows through the karst bed into the sea, and a large part of it flows under the surface of the sea in the form of springs. In a wider area3, torrential watercourses that cause floods are very common. They are characterized by the sudden rise and fall of the water level and the transfer of a large amount of crushed material - sediment. They cause the greatest damage in the lower reaches, at the mouth of the sea. The Municipality of Tivat has a total of about 50 watercourses and canals that are maintained by the Municipal Corporation. The rainwater drainage system consists of natural watercourses and rain channels (Source: Elaborate: Basic characteristics of small watercourses of the Montenegrin coast, Institute of Hydrometeorology and seismology in cooperation with UNDP, Podgorica 2013). The Adriatic water area is about 200 km wide and forms part of the southern Adriatic basin, where the greatest depths of the Adriatic (1340 m) have been measured. It is characterized by the largest mass of water and a stronger exchange of water with the Mediterranean. The length of the coastal line with the islands is about 311 km, with a slope coefficient of about 2.9. The salinity value of seawater varies greatly throughout the year, especially vertically. The structure of the seabed consists of rocky, sandy and muddy bottom, whose particles are of terrigenous and pelagic marine origin. Waves are more frequent in winter from the north (January - March) or south (November), and are mostly 0.5 to 1.5 m high. Waves larger than 1.5 m are rare and occur from the south, and those over 4.5 m are the rarest. Sea currents are under the direct influence of the southern Adriatic currents, with the highest speeds from 42cm/s (input) to 88cm/s (output). The main surface current moves from SE to NW at a speed of 42 cm/s, following the coast. Due to the large volume of water, the temperature does not fall below 12°C in winter. In summer, surface coastal waters warm up to 27°C and above, and in winter it settles down isotherm, which spreads towards the open sea. Spring warming in a layer of 10-30m establishes a thermos climate, especially pronounced at the end of summer. The salinity of seawater varies, so it was 38.30 - 38.48% at the researched sites (Institute for Marine Biology-Kotor), and up to 39% in the open sea.

Climate conditions

The climatic conditions in this area play a crucial role in its development, particularly when considering the available tourist resources. However, there is no hydrometeorological station located in or near the area. As a result, some data on the climatic characteristics of the object in question were presented for a wider region. There is limited weather data available for the

object in question. However, data from the Tivat airport weather station, located in the nearby region, can be used to understand the climatic characteristics. Tivat has a typical Mediterranean climate, with mild and rainy winters, and warm and sunny summers. The average annual air temperature is 15°C, with an average summer temperature of 27°C. Tivat is known for being the sunniest city in Kotor Bay, with an average of 240 sunny days a year. The bathing season lasts for 180 days. The annual precipitation in Tivat is 1,755 mm. The city is also known for its various winds, with the bura (north wind) blowing mostly in winter, and mistral (west wind) in summer. During autumn and winter, the southerly warm wind that usually brings rain often blows.

The wind data for the period of 1981-1995 shows different values of frequency distribution of directions and speed, as well as the occurrence of silences. The most frequent winds for Tivat station are from the southeast (8.7%), west-southwest (7.9%), east-southeast and south (6.4% each), and the silence share is 31%. The maximum speeds for winds from the northern and southern quadrants are not exceeding 5m/s on average. The highest average wind speed by direction is from north-northeast (with a frequency of 3.8%, average speed 5.5m/s and maximum speed 19m/s). The relative air humidity shows a stable annual trend. The maximum average monthly values occur during the transitional months (April-June and July-August), and the minimum during the summer period, and in some cases also during the winter (January-February). The mean daily relative humidity values show oscillations that are of reduced intensity in the summer period (about 10%-20%), and significantly more pronounced during the winter (about 20%-30%). The average annual relative humidity for the Tivat station is 70.8% (min. 62% in July, max. 75.6% in October). On average, 42% of the sky is covered by clouds in the Montenegrin coast throughout the year. During summer, the cloudiness is about 40% less than the annual average. The Tivat station has an average annual cloudiness of 3.84, with the minimum of 1.8 in July and the maximum of 5.0 in February and March. The monthly average values indicate that over 50% of the sky is covered by clouds from November to April, except for Tivat where this occurs in February and March. Also, 18 - 22% of cloud cover at all stations occurs in July and August.

Sunbathing refers to the duration of sunshine in hours, and the annual average for the entire sea area is about 2455 hours, with 931 hours (40%) in summer (June, July, August). During winter, sunbathing is significantly reduced, with January having only about 125 hours, which is 5% of the annual value. There is an average of about 7 hours of sunshine per day throughout the year, with daily oscillations of ±3.5 hours. The precipitation in this area is maritime type, with minimum during the summer and maximum during the cold season of the year. Two precipitation events occur per batch. The total precipitation series shows that 29% of rainfall happens during October, 24% during January, and so on. Dry periods are quite frequent during the summer season. Specifically, there are 2,808 dry periods that last for 10 days, 41% of which occur during June, July, and August. Meanwhile, 18% of the 10-day dry periods occur in December, January, and February. There are 1,441 dry periods that last for 15 days, with 47% occurring during the summer and 17% during the winter season. Lastly, there are 747 dry periods that last for 20 days, with 54% happening in the summer and 14% in the winter.

Atmospheric Water

An essential aspect of the infrastructure in the Municipality of Tivat is the drainage and processing of atmospheric water. This system includes facilities like channels and watercourses that are functionally connected with the goal of collecting, removing, purifying, and ultimately discharging atmospheric water into the sea.

Municipal water

Municipal wastewater in the municipality of Tivat is collected and treated at a shared wastewater treatment plant, which serves both the municipalities of Tivat and Kotor. It is important to note that there might still be some households that are not connected to the city's sewage network. The wastewater treatment plant became operational in 2018 and was designed to handle the wastewater equivalent to 72,500 inhabitants (ES - equivalent inhabitants)

Locations under investigation

To determine the locality for research, a thorough review was conducted on possible sources of pollution, both historical and potential pollution from the operational plant. The parameters for analysis were carefully selected to accurately present the quality status of the bay.

Three localities have been determined in the Tivat Bay:

- Marina “Porto Montenegro”
- “Navar” Nautical Center
- Location near Tivat airport

Marina “Porto Montenegro”

Porto Montenegro is a luxurious marina for yachts and a nautical resort located in Tivat. It represents one of the most luxurious marinas on the Adriatic. The complex has a marina (450 moorings for yachts from 12 to 250 meters long), residences, business premises, 5-star Hotel "Regent Porto Montenegro", Collection of maritime heritage with valuable museum exhibits, located in the reconstructed building of the former Austro-Hungarian sawmill, Yacht club, International School "Knightsbridge School International Montenegro".

Marina Porto Montenegro is located in the Boka Bay, the largest bay of the Adriatic Sea (87 km^2). After the last expansion, the marina can accommodate yachts up to 250m in length. The current capacity of the marina is 450 berths, with a total of 850 planned by the end of the project, of which 311 will be specifically for superyachts.

Porto Montenegro was built on the site where the naval-technical overhaul institute "Sava Kovačević" was previously located. Naval-technical overhaul institute "Sava Kovačević" was a military institution intended for overhauling ships and other naval-technical funds, development and production of spare works and funds for war techniques which was in the arsenal Wartime navy army of Yugoslavia.

In the frame overhaul ships docking was being done ships as and small medium and general overhaul the same. Except overhaul of ships, was carried out in the institute as and overhaul of underwater weapons, which included navy and diversionary mines, and overhaul funds coastal artillery, shooting weapons, and of the ship artillery weapons.

The institute provided overhaul services and civilian boats (fishing, tourist, tug boats...), as well as other services by expressed needs and available capacities. The naval-technical overhaul institute was created at the end of the 19th century, by the decision Austro-Hungarian of navy in Tivat to establish a naval arsenal. After the First World War II, and Yugoslavia war the Navy took over the institution when it started its modernization and it

was founded the Naval-artisan School. By the end of the second after the World War, reconstruction began, and the development of the Naval-technical Overhaul Institute up to the level and roles that he had until the middle of 2000.
In October 2006, the Government of Montenegro concluded a contract with a foreign partner on buying, selling, and investing in the military property Naval-technical Overhaul Institute "Sava Kovačević" in Tivat with the aim that the former military complex and overhaul shipyards do it elite destination nautical of tourism: touristic settlement high categories and nautical marina most categories with following contents, what Porto Montenegro today and makes. In the Porto Montenegro complex, today there is a marina for yachts from 12 to 250 meters in length, a residential part with fairies and hotels and business spaces.

Geological and geomorphological characteristics- Porto Montenegro

In terms of geological and geomorphological characteristics, the area around Porto Montenegro can be divided into two main units:
1. The land coastal zone located between the sea and the main road is primarily constructed of flysch sediments, with elevations ranging from 1.0 to 5.7 meters above sea level.
2. The sea coastal belt, which encompasses sea depths ranging from 2 to 12 meters, is primarily built from Quaternary sediments. These sediments overlay the base terrain constructed of flysch. A portion of the sea coastal zone is filled with different materials.

The former naval-technical overhaul institute, "Sava Kovačević," is largely built on land that was previously sea surface. As such, a portion of it, including parts of the docks is constructed using an embankment composed of limestone blocks, backfill material, construction fill, and other materials of anthropogenic origin. In general, the embankment is thicker near the coast and gradually slopes toward the landward side.
Within the former shipyard area, there are various layers of materials, including sand, gravel, and crushed stone, as well as layers of silty-sandy clays, soft organic clays, silt, and soft lacustrine-marine clays. Finer-grained materials, like loose or soft silt and soft clays, are more prevalent in the western part of the site, beneath the existing docks. Below the layers of sand, clay, and silt, there is a substrate made up of flysch, which comprises limestone, marl, and sandstone rocks with varying strength. These rocks are often degraded, fractured, disturbed, and predominantly highly stratified.

The broader Tivat area is fundamentally constructed of flysch sediments from the Eocene age (E3). These sediments include marl, clay, and sandstone. Over the flysch sediments, Quaternary proluvial and marine sediments have been deposited. The thickness of these Quaternary sediments varies, ranging from 3.0 to over 20.0 meters.
In the land part of the location, there are poorly permeable to practically impermeable sediments in which there is no underground water. In the coastal and sea areas, the locations are silty clay with silt, sand, gravel, and crushed stone. It is a hydrogeological complex of permeable and impermeable sediments within which the compacted type is represented with a free or sub-arterial water level (the sub-arterial water level is if the gravelly-sandy sediments are limited by impermeable clays or flysch and subbed and foundations). The flysch in the base of the terrain belongs to waterproof rocks, they are podin insulators.

Hydrogeological Characteristics -Porto Montenegro

The hydrogeological characteristics of the area are strongly influenced by the geological composition, structural porosity types, and the rock masses' hydrogeological properties.

Based on the hydrogeological properties and functions of the rock masses in the wider area, the following can be distinguished:
-impermeable rocks (flysch sediments): flysch sediments act as underground barriers for groundwater flow. They are known for their low permeability and serve as confining layers preventing the easy movement of water.
-complex of permeable, poorly permeable, and impermeable rocks: This includes a variety of sediments with different degrees of permeability, from highly permeable materials like gravelly-sandy clays to less permeable sediments. Groundwater conditions in these formations depend on their specific characteristics.
Part of the coastal zone's terrain is composed of Quaternary sediments, which exhibit highly complex hydrogeological characteristics. In areas where sandy-gravelly sediments are present, directly below the fill material, a compacted type is observed. This type maintains a free water level, which, at the hydrological peak, is practically at the surface of the terrain. In other words, the depth to the groundwater level falls within the range of 0.0 to 0.5 meters.
When pebbly sandy sediments are confined by impermeable clays in the bed and impermeable flysch sediments at the base, they exhibit a compact type under pressure with a sub-artesian water level. From a hydrogeological perspective, these sediments are primarily poorly permeable and impermeable.

"NAVAR" Nautical Center

The Nautical Center "Navar" is situated in the village of Bonići, which comes under the municipality of Tivat. Its GPS coordinates are 42°25.104'N, 18°42.531'E. The company was established in 1992 and offers repair and shipbuilding services for yachts and smaller vessels. Additionally, it provides wintering services for yachts. The Nautical Center Navar covers an area of 10,681 square meters, which includes civil engineering facilities, wharves, docks, a marina, and an auxiliary shipbuilding building. The harbor water area, which is situated on the south, southwest, and east sides, covers 14,500 square meters. A marina is a specialized tourist port that is naturally or artificially protected and equipped to cater to tourists and crew. It provides maintenance and equipment services for nautical tourism vessels. Within the marina, there are three different areas for mooring boats:
1. Dock "A", the length of Dock "A" is 77m. There are 11 moorings for vessels of 15-40m on the dock.
2. Dock "B", the length of dock "B" is 112m. There are 13 moorings for vessels of 20-50 m on the dock.
3. Dock "C", the length of dock "C" is 54 m. There are 12 moorings for vessels of 7-15 m on the dock.
The dry berth on land at "Navar" can accommodate over 200 yachts and smaller vessels. This marina is the only one in Montenegro that provides a boat storage service in a specially built hall covering an area of more than 1,700 square meters. The service center at "Navar" offers repair services for yachts and smaller vessels. It has two basins for pulling ships out of the sea onto dry land. The smaller basin measures 14 by 5.5 meters and has a travel lift with a capacity of 60 tons. The larger basin measures 33 by 10 meters and has a travel lift with a capacity of 200 tons. The marina has two remote-controlled diesel-electric-hydraulic special trolleys for yachts that can transport ships on land. The smaller trolley has a capacity of 20 tons and can transport ships up to 15 meters long. The larger trolley has a capacity of 100 tons. The complex at "Navar" has workshops for mechanical, electrical, motor, carpentry, plastic and locksmith services.

Tivat airport

The Tivat Airport is situated in close proximity to the coastal and beach region. Due to the potential release of harmful pollutants, mainly new POPs chemicals, from the airport, it is crucial to consider the impact of the location near the airport. Therefore, extensive research has been conducted on this matter. Otherwise, Tivat International Airport is located in the south of Montenegro in the Boka Bay, in the municipality of Tivat. It covers an area of 545.32 thousand square meters and is situated 4 km southeast of Tivat, 8 km south of Kotor and 20 km north of Budva. The airport was established after the Second World War and was initially intended for military and civilian parachuting training as well as competitions. It was officially opened on May 1, 1957. Tivat Airport includes a control tower, a runway that measures 2500m x 45m, a dock platform with 7 parking spaces, a passenger building, and facilities for supporting services. Over 80% of the airport's traffic takes place during the summer tourist season. Aviation Service Jugopetrol AD – Hellenic Petroleum Group, which provides fuel supply and collection services, is located very close to Tivat Airport.

Geological and geomorphological characteristics – Nautical Center "Navar" and Airport Tivat

In terms of geomorphology, the terrain on which are located Navar and Tivat Airport is flat and belongs to Grbalj field.

Based on data on the geological structure of the wider area of Tivat, it was built from carbonate sediments of the Cretaceous and partly Triassic, flysch sediments of Triassic and Eocene age, as well as alluvial sediments of Quaternary age.

Mesozoic

Triassic (T)-These rocks are mainly flysch sediments from the middle Triassic, along with limestones from the middle and upper Triassic. The flysch series includes conglomerates, graywackes, and marls.

Jurassic (J)-Found in the northeast part of the area, these sediments consist of calcarenites, micrites, dolomitic limestones, cherts, breccias, and dolomites. This sediment series is part of the Budva tectonic zone.

Chalk (K)-Chalk formations include para-autochthonous limestones and constitute the majority of the Lustica Peninsula. In the northeast part of the area, upper chalk introduces a series of limestone and limestone breccia, also belonging to the Budva zone. Transitional series from the Late Cretaceous to Eocene age, featuring marly limestone, marl, and calcarenites, have been identified in some parts.

Eocene (E)-Eocene grade sediments are developed in facies flash. These sediments start with marls and marl limestones and transition into nummulitic limestone. Flysch sediments follow, along with the reappearance of marls. Above this, there are sequences with sandstone and conglomerate layers.

Quaternary

These sediments are predominantly in the form of alluvial deposits and slope debris. Alluvial material, such as sand, gravel, and clay, can be found in the broader Tivat and Radanović areas. The Crvenica region, characterized by karst soils and carbonate substrate, is developed on upper Cretaceous limestones and covers a significant surface area, especially in Krtola settlement.

Hydrogeological Characteristics – Nautical Center "Navar" and Airport Tivat

The area in question, defined as a topographical watershed, is characterized by the dominant presence of Eocene flysch sediments. This basin is overlaid with Mesozoic carbonate

sediments. A hydrogeological analysis of the area makes it clear that the hydrogeological conditions are primarily influenced by the Eocene flysch and alluvial sediments in this region.

According to the structural porosity of the rocks, they can be categorized into various types:

- Rocks with karst-fissure porosity, exhibiting a range from poor to good water permeability.
- Rocks with intergranular porosity, also have a water permeability range from poor to good.
- Waterproof rocks.

Rocks karst-cracked porosity

Complex rock formations with karst-fissure porosity, which belong to the Mesozoic carbonate sediments, have been identified in the area. While their hydrogeological function has not been extensively studied, the existing findings suggest that underground water within this complex rock formation generally flows in a southeast-to-northwest direction. These formations may not have significant overall hydrogeological importance.

Rocks intergranular porosity

The rocks with intergranular porosity, exhibiting water permeability ranging from poor to good, are primarily composed of alluvial sediments within the lower-lying areas. These sediments are identified on geological maps and encompass both alluvial (al) and deluvial (d) materials, mainly concentrated in the eastern and southeastern parts of the region. It's important to note that the deluvial material holds limited hydrogeological significance.

Based on our prior knowledge regarding the lithological composition of alluvial sediments in this area, we can assert that they are primarily composed of clay, sandy clay, sand, and gravel. The underground water formed within these alluvial sediments constitutes an aquifer with intergranular porosity.

Waterproof rocks

The conditionally waterproof rocks, which encompass a significant portion of the geological maps, primarily consist of flysch sediments from the middle and upper Eocene (E2, E3), along with a narrow zone of flysch sediments from the middle Triassic. All the flysch sediments, from a hydrogeological perspective, can be considered as a unified complex composed of clay, marl, sandstone, and conglomerate. These waterproof rocks serve as hydrogeological barriers, impeding the movement of underground water within the region.

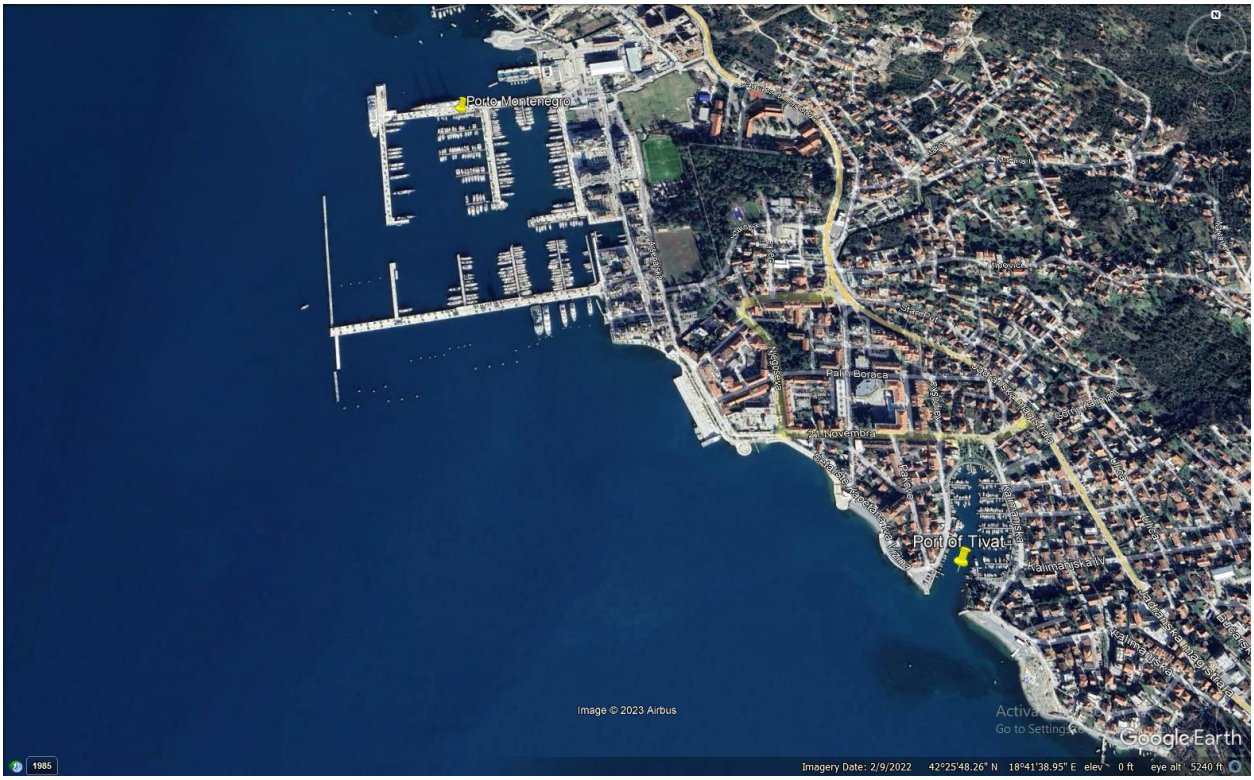
Summary of previous technical studies and site investigations, including gap analysis

Chemical pollution studies in the areas of the Port of Risan and the Tivat Bay have been conducted as part of the national marine ecosystem monitoring program from 2009 to the present, with intermittent breaks. The results from this program were utilized in the preparation of the Initial Assessment of the state of the marine environment for the coastal area of Montenegro and in the assessment of Good Environmental Status (GES).

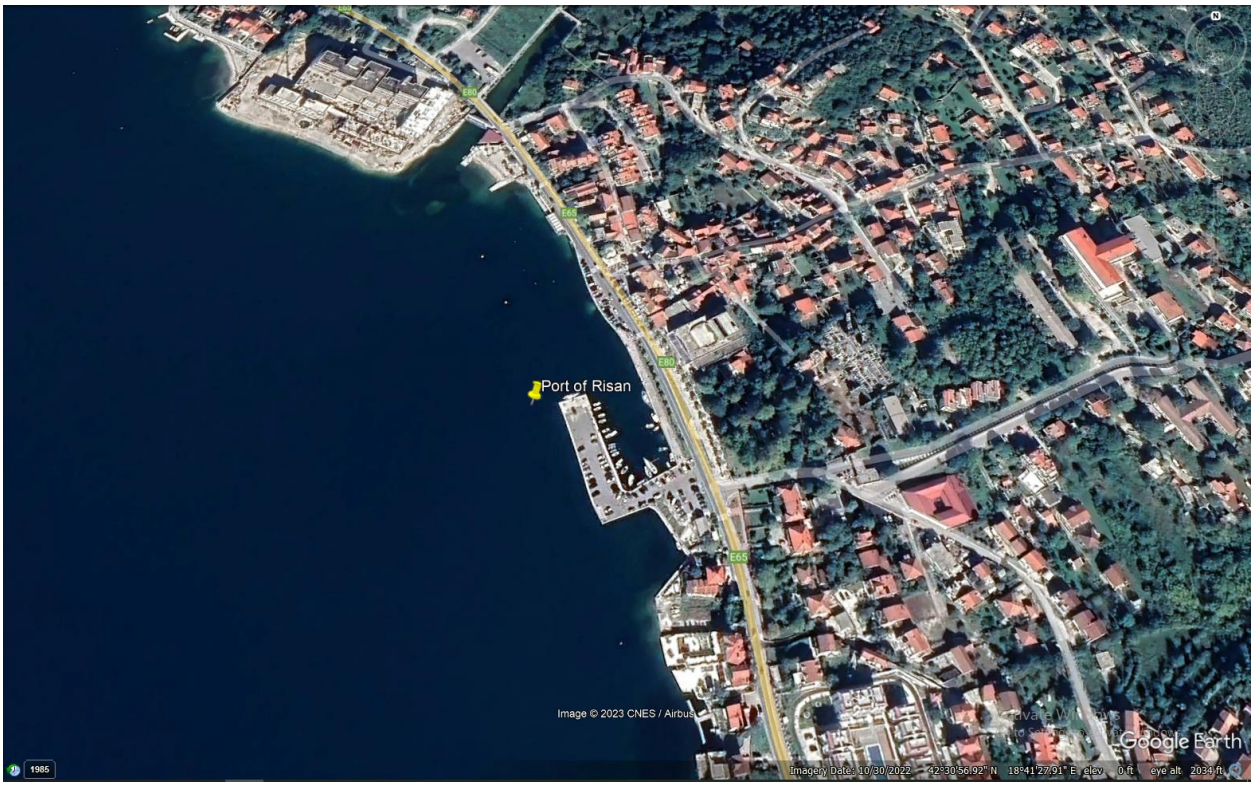
In 2021, as part of the “Support to Implementation and Monitoring of Water Management, Montenegro” project, a chemical analysis of sediments in the Adriatic Sea was carried out, including sampling in these locations. Additionally, in 2009, the Center for Ecotoxicological Research in Podgorica conducted sediment analyses for the needs of Adriatic Marinas in the area of the former Arsenal shipyard in Tivat.

The Program for monitoring the state of the coastal ecosystem in Montenegro's coastal sea has been conducted since 2009, with intermittent breaks (2012-2013). Until the end of 2016, the "Program for monitoring the state of the coastal ecosystem in Montenegro" consisted of seven complementary subprograms, and the research of contaminants was included in the program for monitoring the quality of water and sediment in HOT SPOT areas.

In July 2016, the Government of Montenegro adopted the Environmental Approximation Strategy, which includes the implementation of provisions of the Marine Strategy as one of the measures. In this regard, the "Program for monitoring the marine ecosystem" has been carried out since 2017, with one of the subprograms focusing on contaminants. These programs primarily covered locations burdened with polluting materials such as ports, former repair facilities, shipyards, and areas influenced by effluents. Among the locations included in this program, Luka Risan, Porto Montenegro, and Luka Tivat were examined (Map. 1 and 2).



Map 1. Monitoring locations in Tivat Bay



Map 2. Monitoring location Port of Risan

The Initial Assessment of the marine ecosystem, which includes all available data since 2009, reveals that the arsenic content at all locations has been below MedBAC values, except at the Porto Montenegro location.

The average mass concentration values of most metals in the shells, calculated based on all available data (Av conc), exceed the Background Assessment Criteria (BAC) values. However, for cadmium, the average value is at the BAC level. The report also notes a correlation in trends for certain metals (Ni, Zn, Cd) between sediments and shells, but no such correlation exists for lead and mercury.

When analyzing the results for lead, cadmium, and mercury in relation to the maximum allowable concentrations stipulated by the Regulation on the Maximum Permitted Levels of Contaminants in Food ("Sl. list CG," No. 48/16, 066/19), it is found that the clams sampled at the location in Tivat Bay - Luka Tivat exceed the allowable lead content, rendering them unsafe for consumption. On the other hand, clams from other locations can be considered safe for consumption.

The average values of mass concentrations of phenanthrene, anthracene, fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, and benzo(g,h,i)perylene, calculated based on all available data, exceed the ERL value in location Porto Montenegro, indicating the potential for adverse effects on marine organisms. The ratio of concentrations of phenanthrene and anthracene, fluoranthene and pyrene, as well as benzo(a)anthracene and chrysene, provides information that PAH contamination on locations Port of Risan and Porto Montenegro originates from pyrogenic origin, primarily stemming from the combustion of exhaust gases in traffic, transportation and logistics activities, industrial activities, waste incineration, as well as forest fires, etc. Concerning shellfish, the PAH (Polycyclic Aromatic Hydrocarbon) content at locations in Risan Bay and Tivat Bay exceeds values considered close to natural levels. However, during the study period, except for naphthalene, the content of all analyzed PAHs decreases. When compared to the Regulation on Maximum Permitted Levels of Contaminants in Food (Official Gazette of Montenegro, No. 48/16, 066/19), which sets the maximum allowable contaminant content in shellfish, the analysis results show that the content of ΣPAH (benzo(a)pyrene, benzo(a)anthracene, chrysene, and benzo(b)fluoranthene) is below 30 μg/kg, the maximum permitted concentration for ΣPAH in shellfish. The benzo(a)pyrene content is also below 5 μg/kg, the maximum permitted concentration for this PAH in shellfish.

During the initial assessment of the marine ecosystem, it was found, based on all available data, that the average values of all tested PCB congeners in the sediment at the Porto Montenegro location exceed the ERL (Effects Range Low) values. This suggests that PCB contamination and the potential harmful effects of Polychlorinated Biphenyls are apparent at harbor sites and repair facilities. Research further indicates the possibility of a significant correlation between the source of PAH emissions (molecular markers) and PCBs, which can help identify the likely source of PCB emissions. The average content of all analyzed PCB congeners in shellfish during the examined period at the Porto Montenegro location was higher than the average value measured at all locations covered by the monitoring. The PCB 118 content in some samples from the Luka Risan and Luka Tivat locations exceeded the ERL

(Effects Range Low) values, while at the Porto Montenegro location, this was also the case with PCB 101 and PCB 138 congeners.

The average content of SUM OTC (including monobutyltin, dibutyltin, tributyltin, tetrabutyltin, monooctyltin, dioctyltin, triphenyltin, and tricyclohexyltin) in shellfish at locations in Tivat Bay exceeds the average value of mass concentrations of SUM OTC calculated from all available data used for the initial assessment. The average content of TBT (tributyltin) in shellfish sampled at locations in Tivat Bay and Risan Harbor is significantly above both the BAC (Background Assessment Concentration) and EAC (Effect Assessment Concentration) values.

The initial assessment also covered the Program for the Control of Contaminants in Marine Organisms for Human Consumption in Montenegro, which was implemented through a monitoring program for the control of biotoxins and chemical contaminants in mussels (Mytilus galloprovincialis) in shellfish farming areas.

Based on the obtained results for cadmium, mercury, lead, benzo(a)pyrene, and the sum of four PAHs, and by comparing them with the maximum permitted concentrations specified in the Regulation on Maximum Permitted Levels of Contaminants in Food (Official Gazette of Montenegro, No. 48/16, 066/19), it can be concluded that the consumption of shellfish was safe throughout the entire study period. No significant seasonal variations were observed. The concentrations of the analyzed PAHs in mussels from all tested locations are very low compared to literature data for this type of mussel in the Mediterranean Sea. These investigations covered three locations in Tivat Bay and one in Risan Bay (Lipci, Kalardovo, Solila and Sveta Nedelja, Map. 3).

Map 3. Location of samplinf shellfish from farming

During the assessment of GES, the initial assessment of Ecological Objective 9 (EO9) was conducted, with a specific focus on Common Indicator 17 (CI17), which relates to chemical contaminants in the marine ecosystem. This assessment encompassed the period from 2016 to 2020 and adhered to IMAP assessment criteria.

The state of affairs at the locations Luka Risan and Porto Montenegro is presented in table 1, which illustrates the results of the quantitative assessment for CI17. These findings are categorized by chemical groups and compared against established thresholds, including Background Concentrations (BC), Med BAC, and EACs/ERLs as outlined in the IMAP Guidance Factsheets for EO9.

The report emphasizes that a noteworthy percentage of sediment samples, particularly those from Boka Kotorska Bay, exceeded the thresholds, which roughly correspond to the ERL (Effects Range Low) assessment criteria, for mercury (Hg) and lead (Pb) during the period from 2016 to 2020.

Table 1 indicates that all datasets for HCB, Lindane, and DDTs are below Background Assessment Criteria (BACs), signifying no concerns. However, there's a significant issue with PCBs (ICES 7 sum), with nearly samples exceeding ERLs thresholds, indicating probable toxicological risks. This concern is particularly notable in Boka Kotorska Bay, including Port of Risan i Porto Montenegro.

Table 1. Assessment of contaminants monitoring datasets (averaged 2016–2020 by location) against IMAP EO9 assessment criteria for CI17 multiparametric indicator (units µg/Kg dry weight). As defined by IMAP CI17 assessment criteria, red color cells indicate „concern" (concentrations are at levels where probable toxicological effects to organisms can occur), blue and green/orange indicate „no concern", despite the later indicate concentrations above the background levels for the area.

	Cd		Hg		Pb		PCBs sum 7 ICES congeners		HCB, Lindane, DDTs		PAHs (BaP as reference)	
	Biota	Sediment	Biota	Sediment	Biota	Sediment	Biota	Sediment	Biota	Sediment	Biota	Sediment
Port of Risan	824	180	112	497	993	31500	11	37	<0.5	<0.1	2.2	400
Porto Montenegro	696	240	131	8046	1713	77800	12	288	<0.5	<0.1	2.1	1640
Port of Tivat	1070	134	128	650	18811	33500	19	55	<0.5	<0.1	<0.5	287

In the assessment of Good Environmental Status, it is worth noting that the origin of hydrocarbon contamination, as determined by the PAH congener ratios P/A, F/Py, and BaA/C (although not displayed), indicates both petrogenic and pyrolytic sources for biota and

sediments. This suggests that the contamination is linked to various inputs of oil-related hydrocarbons in these areas, some of which may be widespread, while others may be localized.

Regarding CI18 data, a significant cause for concern was observed specifically at these locations within Boka Kotorska Bay. In this area, the Acetylcholinesterase (AchE) activity and the frequency of micronuclei in all mussel samples were inhibited to toxic levels, surpassing the Mediterranean Background Assessment Criteria (Med BAC) values.

Within the sampling conducted in 2020 and 2021 as part of the project "Support to the implementation and monitoring of water management, Montenegro-EuropeAid/139429/IH/SER/ME," the Center for Ecotoxicological Studies in Podgorica collected sediment samples at 21 locations, including the locations of Risan Bay and Tivat Bay. On the Risan Bay site, sampling was conducted for both shells and seawater. An overview of the obtained results at these two locations in the sediment samples is provided in Table 2.

Table 2. Assessment of data obtained during the 2021 sampling for contaminants using IMAP EO9 assessment criteria for the CI17 multiparametric indicator (units: µg/kg dry weight). As defined by IMAP CI17 assessment criteria, red cells indicate 'concern' (concentrations at levels where probable toxicological effects on organisms can occur), while blue and green/orange cells indicate 'no concern,' even though the latter indicate concentrations above the background levels for the area.

		Location	Hg	Cd	Pb
Sediment June 2021		Tivat Bay	51	119	43063
		Port of Risan	422	202	36031
Biota Sep 2020		Port of Risan	81	1200	1100
Biota June 2021			64	717	659

	Location	Naph	Phen	Anth	Fluo	Pyr	B(a)anth	Chry	B(a)pyr	I(123-cd)py	B(g,h,i)per
Sediment June 2021	Tivat Bay	18.1	67.4	16.2	101.6	87.8	73.1	65.2	90.6	83.2	70.5
	Port of Risan	<0.5	11.4	3.5	38.3	35.2	19.4	21.9	21.1	16.3	15.3
Biota Sep 2020	Port of Risan	<0.5	7	<0.5	3	4.6	3.1	4.3	3.5	<0.5	<0.5
Biota June 2021		<0.5	2.6	1.1	6.1	8.4	1.6	3	3.1	1.1	<0.5

	Location	PCB 28	PCB 52	PCB 101	PCB 118	PCB 153	PCB 138	PCB 180
Sediment	Tivat Bay	0.06	0.32	0.84	0.48	2.5	1.6	1.0

June 2021	Port of Risan	1.2	0.32	0.46	0.42	2.0	1.0	0.85
Biota Sep 2020	Port of Risan	0.2	0.8	2.7	2.1	5.8	12.3	1.1
Biota June 2021		<0.2	0.5	2.6	1.4	2.8	8.5	<0.2

The assessment aimed to evaluate the chemical status of organic and inorganic contaminants in sediment, biota (Mitilus galloprovincialis), and seawater samples, comparing their concentrations to standards set by UNEP/MAP, OSPAR, and Montenegro's Rulebook.

Results revealed that at the Port of Risan location, the mercury content in sediment exceeded the ERL threshold. PCB118 congeners at this site were at levels where probable toxicological effects on organisms could occur. Some components were found above observed background concentrations but below levels associated with toxic effects.

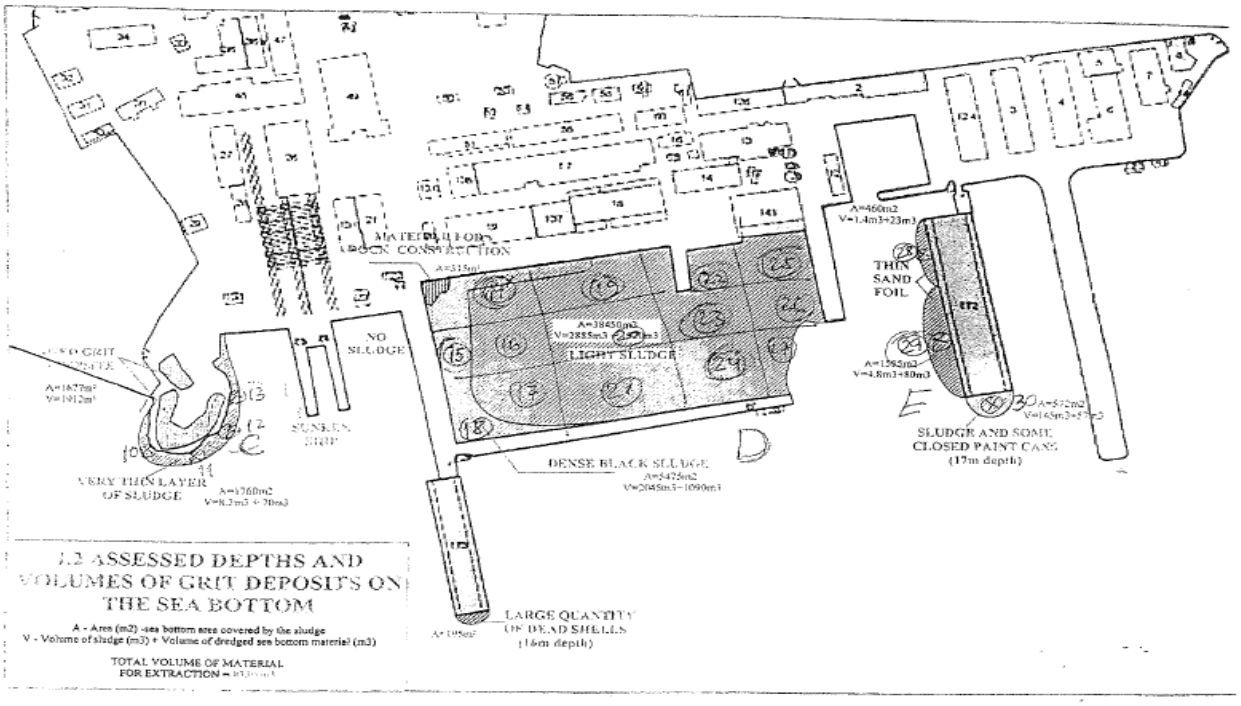
In 2009, a study conducted at the request of the company Adriatic Marinas involved the analysis of three zones C, D, and E, with a total of 22 samples (Map 4). During that period, Montenegro did not have regulations regarding the maximum allowable concentrations of pollutants in sediment. Therefore, the results were compared to the recommendations of UK and Dutch standards.

During the mentioned study, it was found that the mercury content in almost all the samples exceeded intervention levels. The lowest recorded mercury content in the examined samples was 1.5 mg/kg, while the highest measured value reached 43 mg/kg.

The conclusion of this study, conducted by the Center for Ecotoxicological Research, indicated the necessity of dredging polluted sediment. In most of the samples, the detected levels of one or more components exceeded some of the reference levels, highlighting the need for remediation due to elevated pollutant levels.

In this study, sediment samples were considered as waste material, which would become waste when removed from the sea. From each zone, a specific portion of the samples exhibited hazardous waste characteristics, primarily due to the presence of polycyclic aromatic hydrocarbons (PAHs), and in one instance, due to the mercury content.

Although there were enough indications about the loading of the sediment of the bay with both heavy metals and organic pollutants, no detailed research was carried out to determine the degree of pollution and the level of risk to the ecosystem.



Map 4 The sediment sampling locations in 2009, Adriatic Marinas

Scope of research

An analysis of chemical elements was conducted, including Mercury (as well as Methyl mercury), Cadmium, Lead, Arsenic, Copper, Nickel, Chromium, and Zinc. Additionally, a comprehensive analysis of organic pollutants was performed (Table 3).

Table 3. Overview of organic pollutants that were analyzed in the test region

Polycyclic Aromatic Hydrocarbons	**Polychlorinated biphenyls**	**Organotin compounds**	**Perfluorinated Compounds**	
Naphtalene	PCB 18	Monobuthyl-tin	Perfluorobutanoic acid (PFBA)	Perfluorooctane sulfonamide(FOSA)
2-methylnaphtalene	PCB 31	Dibuthyl- tin	Perfluoropentanoic acid (PFPeA)	N-Methyl perfluorooctane sulfonamide (MeFOSA)
1-methylnaphtalene	PCB 28	Tributhyl-tin	Perfluorohexanoic acid (PFHxA)	N-Ethyl perfluorooctane sulfonamidoacetic acid (EtFOSAA
Acenaphtylene	PCB 52	Monooctyl-tin	Perfluoroheptanoic acid (PFHpA)	N-Methyl perfluorooctane

				sulfonamidoethanol (MeFOSE)
Acenaphtene	PCB 44	Tetrabuthyl-tin	Perfluorooctanoic acid (PFOA)	N-Ethyl perfluorooctane sulfonamidoethanol (EtFOSE)
Fluorene	PCB 101	Dioctyl-tin	Perfluorononanoic acid (PFNA)	Perfluoropentane sulfonic acid(PFPeS)
Phenanthrene	PCB 149	Triphenyl-tin	Perfluorodecanoic acid (PFDA)	Perfluorooctane sulfonamidoacetic acid (FOSAA)
Anthracene	PCB 118	Tricyclohexyl-tin	Perfluoroundecanoic acid(PFUnDA)	Perfluorooctadecanoic acid(PFOcDA)
Fluoranthene	PCB 153	**Organochlorine pesticides**	Perfluorododecanoic acid(PFDoDA)	Perfluorononane sulfonic acid(PFNS)
Pyrene	PCB 138	Alpha endosulfan	Perfluorotridecanoic acid(PFTrDA)	Perfluorohexadecanoic acid(PFHxDA)
Benzo(a)anthracene	PCB 180	Beta endosulfan	Perfluorotetradecanoic acid(PFTeDA)	Perfluorododecane sulfonic acid (PFDoDS)
Chrysene	PCB 194	α-HCH	Perfluorobutane sulfonic acid(PFBS)	Perfluoro-3,7-dimethyloctanoic acid (P37DMOA)
Benzo(b)fluoranthene	Total PCB	β-HCH	Perfluorohexane sulfonic acid(PFHxS)	N-Methyl perfluorooctane sulfonamidoacetic acid (MeFOSAA)
Benzo(k)fluoranthene	**Dioxins and Furans**	δ-HCH	Perfluoroheptane sulfonic acid(PFHpS)	N-Ethyl perfluorooctane sulfonamidoacetic acid (EtFOSAA
Benzo(j) fluoranthene	2378-TCDF	γ-HCH	Perfluorooctane sulfonic acid(PFOS)	7H-perfluoroheptanoic acid (HPFHpA)
Benzo(a)pyrene	2378-TCDD	Dicofol	Perfluorodecane sulfonic acid(PFDS)	4:2 Fluorotelomer sulfonic acid(4:2 FTS)
Indeno(1.2.3-cd)pyrene	12378-PeCDF	Hexachlorbenzene	6:2 Fluorotelomer sulfonic acid(6:2 FTS)	10:2 Fluorotelomer sulfonic acid (10:2 FTS)
Dibenzo(a.h)anthracene	23478-PeCDF	Chlordecone	8:2 Fluorotelomer sulfonic acid(8:2 FTS)	
Benzo(g.h.i)perylene	12378-PeCDD	Aldrin		
Polybrominated diphenyl ethers	123478-HxCDF	Dieldrin		

BDE 28	123678-HxCDF	Endrin		
BDE 47	123478-HxCDD	Chlordane cis		
BDE 99	123678-HxCDD	Chlordane trans		
BDE 100	123789-HxCDD	Pentachloroben zene		
BDE 153	123789-HxCDF	Heptachlor		
BDE 154	234678-HxCDF	Heptachlor epoxide		
BDE 183	1234678-HpCDF	o,p DDE		
BDE 28	1234678-HpCDD	p,p DDE		
Chlorinated organic substances	1234789-HpCDF	o,pDDD		
Pentachlorophenol	OCDD	p,p DDD		
Hexachloro - 1,3-butadiene	OCDF	o,p DDT		
		p,p DDT		
		Mirex		

Conceptual Site Model (CSM)

A key step in risk assessment for proper site characterization is the conceptual site model (CSM), which identifies sources of contamination, pathways, and possible receptors that may be affected. Also, the conceptual site model describes physical, chemical, and biological processes that occur or can occur at a contaminated site. CSM identifies transport, migration, and actual/potential impacts of contamination (in soil, air, groundwater, surface water, and sediments) to human and/or ecological receptors. Development of the CSM will help identify investigative data gaps in the characterization process and can ultimately support remedial decision-making (Annex 1).

Sampling campaign

Sampling was realized through two campaigns: on August 22-24, 2023 and October 4, 2023. at three locations in Tivat Bay and one in Risan Bay:

1. Porto Montenegro (Tivat Bay)
2. Shipyard and marina „NAVAR“ (Tivat Bay)
3. Airport Tivat (Location near Aeroport) (Tivat Bay)
   and
4. Port of Risan (Risan Bay)

Sampling was conducted following the detailed sampling plan and methodology.:

- MEST EN ISO 5667-1:2012, Water quality - Sampling - Part 1: Guidance on the design of sampling programmes and sampling techniques
- ISO 5667-12:2017, Water quality — Sampling — Part 12: Guidance on sampling of bottom sediments from rivers, lakes and estuarine areas
- MEST EN ISO 5667-15:2012, Water quality - Sampling - Part 15: Guidance on the preservation and handling of sludge and sediment samples
- MEST EN ISO 5667-19:2012, Water quality - Sampling - Part 19: Guidance on sampling in marine sediments
- WFD Guidance document on surface water chemical monitoring (No. 19)
- WFD Guidance document on chemical monitoring of sediments and biota (No 25)
- UNEP/MED WG.482/11 - Monitoring Guidelines/Protocols for Sampling and Sample Preservation of Sediment for IMAP Common Indicator 17: Heavy and Trace Elements and Organic Contaminant

Criteria for risks assessment

The Ecological Risk Assessment (ERA) emerges as a crucial tool in exploring a complex network of environmental risks associated with the pollutants load into the environment. Through its systematic examination of stressors, ERA plays an important role in identifying, quantifying, and understanding the multifaceted challenges posed by these environmental stressors. Analysis of sediments has an important place in environmental research, because they act like a sink for many of the pollutants that accumulate over time. These pollutants, ranging from heavy metals to organic contaminants, are deposited in sediments through various pathways, reflecting the environmental conditions and human activities that have left an imprint on aquatic ecosystems. By evaluating the potential risks of sediment contaminants, ERA helps to identify areas of concern, assess the severity of the contamination, and determine appropriate strategies for remediation and management.

In the domain of ecological risk assessments, a tiered framework is frequently employed to optimize the evaluation process. Decision criteria play a crucial role within this framework, influencing the depth and scope of the assessment. The initial screening tier 1, in which predetermined decision criteria are used, enables a rapid assessment to determine the existence of potential risks posed by different contaminants. As part of an ERA and/or in a tiered assessment scheme, Sediment quality guidelines (SQGs) are an appropriate tool for screening tier 1 to assess the potential toxic effect of sediments based on the comparison of the concentration of pollutants, obtained by analysis with Sediment quality guidelines.

The objective of Tier 2 is to assess whether sediments present an acceptable or unacceptable risk in terms of potential adverse effects on the environment and human health. This phase involves a detailed examination of extent of any environmental or health-related risks associated with the sediments under consideration. In the second tier of assessment, a comprehensive evaluation is conducted to analyse the risks associated with contaminant transport, bioaccumulation, toxicity, and the impact on the benthic community. Should any of the outcomes from the Lines of Evidence (LOEs) in this tier surpass established maximum criteria, it signals a need for management intervention on that assessment site. The results obtained from individual ecological indicators are synthesized and interpreted using a decision matrix, providing a systematic approach based on the integrated assessment of multiple factors.

Tier 1 risk assessment

Tier 1 sediment risk assessment serves as the initial stage in evaluating the potential risks associated with sediment contamination. This screening level involves a systematic and relatively rapid assessment that employs predetermined decision criteria to ascertain the presence or absence of potential risks posed by various contaminants. A common approach for conducting a screening sediment risk assessment is to compare available chemical data on sediments with SQGs. The focus is on identifying areas of concern and prioritizing them based on the frequency and degree to which established sediment quality guidelines (SQGs) are exceeded. This prioritization is determined by assessing the frequency and degree to which the established guidelines are exceeded. The SQGs were categorized based on their intended purpose into three groups: those indicating a threshold effect concentration below which adverse effects are unlikely, those denoting a probable effect concentration above which adverse effects are likely, and a third category representing an extreme effect concentration above which adverse effects typically occur. Since there are no SQGs (Site-Specific Quality Guidelines) specifically tailored for the Mediterranean region, screening levels of environmental risk assessment were carried out using guidelines developed for other regions.

In the assessment of the sediments from Tivat Bay and Risan Port, values obtained by the chemical analysis were first compared to the two sets of empirically derived type of guidelines. Two sets of seawater Sediment Quality Guidelines (SQGs), which were used, known as ERLs (Effects Range Low) and ERMs (Effects Range Median), as well as TELs (Threshold Effects Level) and PELs (Probable Effects Level), were established by Long et al. (1995) and MacDonald et al. (1996), respectively. The establishment of both sets of Sediment Quality Guidelines (SQGs) entailed a process of conducting in-depth statistical analyses on harmonized datasets comprising chemistry and biological information. These datasets were sourced from an extensive compilation of studies conducted in the field, laboratory, and through modelling efforts. The majority of the data used in deriving the guidelines were drawn from field studies where mixtures of substances were present in the samples. This deliberate approach aimed to maximize the applicability of the SQGs to real-world situations characterized by the occurrence of contaminant mixtures. Additionally, data from published studies on various toxicological endpoints were incorporated to enhance the SQGs' applicability.

ERL and ERM values were derived by Long et al. (1995) exclusively from chemical concentrations associated with adverse effects. These values represent concentrations below which adverse effects were rarely observed, providing an estimation of the low end of the effects range. On the other hand, calculations of TEL and PEL values, as proposed by MacDonald et al. (1996), considered concentrations associated with both effects and no observed effects. The ERM and PEL values signify chemical concentrations situated toward the middle of the effects range and above, indicating the threshold above which adverse effects are likely to occur. This approach in deriving SQGs reflects a comprehensive understanding of the complex relationships between chemical concentrations and their potential ecological impacts in seawater environments.

The Threshold Effect Level (TEL) signifies the sediment concentration of a pollutant below which adverse impacts on aquatic organisms are not anticipated. TEL serves as a reference point for evaluating the potential ecological risk linked to pollutant contamination. On the other hand, the Probable Effect Level (PEL) designates the sediment concentration of a pollutant above which adverse ecological effects are likely to manifest. PEL is utilized to

pinpoint areas of concern. These two values delineate three distinct ranges: concentrations below TEL (where adverse effects are infrequent), concentrations within the range of TEL-PEL (where adverse effects are possible), and concentrations surpassing PEL (where adverse effects are likely). Effects Range Low (ER-L) marks the lower limit of the concentration range at which detrimental effects on a specific organism or ecosystem are probable, or it indicates concentrations below which toxic effects are rarely observed or predicted. Effects Range Median (ER-M) denotes the median or central value within the concentration range where adverse effects are expected to occur. It represents the concentration at which 50% of the assessed organisms or ecosystems are projected to encounter harmful effects. ER-M is employed as a central reference in risk assessments and is often considered a more realistic estimate of the concentration at which adverse effects are prone to manifest in comparison to ER-L.
Two sets of sediment quality guidelines (SQG) for metals, polycyclic aromatic hydrocarbons, organochlorine pesticides and polychlorinated biphenyls which were used for the initial risk assessment of sediments for Tivat and Risan Bay are presented in the table 4.

Table 4. SQGs for elements and organic compounds based on ER-L/ER-M and TEL/PEL values

	ER-L/ER-M-based type guidelines		**TEL/PEL-based type guidelines**	
Contaminant	**ER-L**	**ER-M**	**TEL**	**PEL**
Metals **(mg/kg dry wt.)**				
Cadmium	1.2	9.6	0.68	4.21
Chromium	81	370	52.3	160
Copper	34	270	18.7	108
Lead	46.7	218	30.2	112
Mercury	0.15	0.71	0.13	0.7
Nickel	20.9	51.6	15.9	42.8
Silver	1.0	3.7	0.73	1.77
Zinc	150	410	124	271
Metalloids **(mg/kg dry wt.)**				
Arsenic	8.2	70	7.24	41.6
Organics **(µg/kg dry wt.)**				
Acenapthene	16	500	6.71	88.9
Anthracene	85	1100	46.9	245
Fluorene	19	540	21.2	144

	ER-L/ER-M-based type guidelines		TEL/PEL-based type guidelines	
Contaminant	**ER-L**	**ER-M**	**TEL**	**PEL**
Naphthalene	160	2100	34.6	391
Phenanthrene	240	1500	86.7	544
Low molecular weight PAHs	552	3160	312	1442
Benzo(a)anthracene	261	1600	74.8	693
Benzo(a)pyrene	430	1600	88.8	763
Dibenzo(a.h)anthracene	63.4	260	6.22	135
Chrysene	384	2800	108	846
Fluoranthene	600	5100	113	1494
Pyrene	665	2600	153	1398
High molecular weight PAHs	1700	9600	655	6676
Total PAHs	4022	44792	1684	16770
Total DDT	1.58	46.1	3.89	51.7
Dieldrin	0.02	8	0.72	4.3
Chlordane	0.5	6	2.26	4.79
Total PCBs	22.7	180	21.6	189

In the initial stages of a risk assessment, a cautious approach to prevent erroneously declaring areas safe when they may actually require remedial action is taken. In that sense, more protective values (the lower set of values) were used for contaminant of concern (e.g for sum of PAHs PEL value is 16770 µg/kg dw and ER-M value is 44792 µg/kg dw –in this case while determining the possibility of adverse effects, the PEL value will be considered as an upper threshold).

In the first level of the assessment, the focus was on comparing the average concentration of each hazardous substance with the specified threshold value, rather than using the highest level observed at the most polluted sampling station (maximum level). This approach is taken because the objective is to evaluate the comprehensive risk associated with an entire area, as opposed to solely considering the risk based on data from a single sampling point. Sediments can be considered to pose an acceptable risk if the average concentration of each hazardous substance in all samples is lower than the TEL/ER-L value, and no single concentration exceeds the TEL/ER-L value for two times. If the average concentration of hazardous substance in the sediment of assessed area exceeds TEL/ER-L value or single

concentration exceeds TEL/ER-L value for two or more times the adverse effects could be considered as possible, and if the average concentration exceeds PEL/ER-M the adverse effects are likely.

The second approach, which was used in assessment of sediment for Tivat Bay and Port of Risan, is comparison with two French Sediment quality guideline values. This approach was chosen due to the similarities between the two countries, both being Mediterranean. The French regulations employed for managing contaminated sediments are structured around two threshold levels, N1 and N2, which define acceptable concentrations of contaminants in bulk sediment. Those sediment quality guidelines (SQGs) encompass a range of substances, including metals such as arsenic (As), cadmium (Cd), copper (Cu), nickel (Ni), lead (Pb), zinc (Zn), mercury (Hg), and chromium (Cr), total polycyclic aromatic hydrocarbons (ΣPAHs) and total polychlorinated biphenyls (ΣPCBs). The term "Total PAHs" refers to the cumulative concentration of 13 specific polycyclic aromatic hydrocarbons. These include Fluorene, Phenanthrene, Anthracene, Fluoranthene, Pyrene, Benzo(a)anthracene, Chrysene, Benzo(b)fluoranthene, Benzo(a)pyrene, Benzo(k) fluoranthene, Dibenzo(ah)anthracene, Benzo(ghi)perylene and Indeno(1,2,3-cd) pyrene. The term total PCBs refer to the sum total PCBs concentration expressed as Aroclor 1260.The two threshold levels of the above listed contaminants are presented in table 5.

Table 5. List of contaminants and selected French SQGs expressed in mg/kg dw

Parameters	**N1**	**N2**
Hg	0.4	0.8
As	25	50
Cd	1.2	2.4
Cr	90	180
Cu	45	90
Pb	100	200
Ni	37	74
Zn	276	552
Total PCB	0.5	1
Sum 13 PAHs	1.5	15

In assessing contamination level of the sediment in the studied area using French thresholds, two key indicators: ∑QN1 and QPECm were employed. ∑QN1 is calculated as the sum of individual ratios, each representing the contaminant concentration relative to the French N1 legal level (PEC value). This cumulative sum provides a comprehensive overview of the potential impact of various contaminants on the aquatic environment. The general sediment risk quotient, QPECm, is determined by averaging the ∑QN1 values for a specific sediment and then dividing this average by the total number of pollutants studied, in this case ten. This calculation is in accordance with the guidelines outlined in the French regulations for the management of marine dredged sediment.

$$QPECm = (\Sigma\ n\ i=1\ (Ci/PECi\ ))/n \quad (1)$$

where *QPECm* is a general sediment risk quotient, a quotient that predicts the toxic effect of contaminants in the whole sediment,
Ci is the contaminant concertation obtained in our research,
n is the number of measured contaminants.

The QPECm is calculated by averaging the individual contaminant ratios (∑QN1) for a given sediment and subsequently dividing this average by the total number of contaminants studied. The interpretation of the QPECm values provides a screening indication of the sediment's toxicity. If the QPECm is less than one, it signifies that the contaminant concentrations in the sediment from the examined area fall below the established thresholds, suggesting a non-toxic condition. Conversely, if the QPECm is greater than one, it serves as a warning signal, indicating the potential toxicity of the sediment to the studied marine environment.

Contamination factor (CF) and enrichment factor (EF)

In order to assess the risk of metals, methods that are mainly based on the literature were used. Some methods are identical, and some complement each other, while others look at the intermediate impact, and some focus on the evaluation of the impact on the end point.

Contamination factor (CF) is an individual pollution index that reflects the sediment contamination level by certain HM when comparing with its level in a reference sediment environment:
CFi = CSi/ CBi
where CFi represents the contamination factor for metal (i), CSi and CBi are the metal concentrations in the sediment and reference samples. Four classes of CF to reveal contamination level by HM:

- CF < 1 (low degree of contamination),
- 1 ≤ CF < 3 (moderate degree of contamination),
- 3 ≤ CF < 6 (considerable degree of contamination),
- CF > 6 (very high degree of contamination).

The ***Metals Pollution Load Index (MPLI)*** assesses the status of sediment contamination by a group of Heavy Metals, considering the synergistic effect of all the studied heavy metals. The MPLI is calculated using the formula:
MPLI = (CF1× CF2× CF3× ….. × CFn)1/n
where CFn is the contamination factor of metal, n is the number of metals (n = 9 in the current study).
Three categories of MPLI to reflect sediment quality:

- MPLI < 1 (perfection),
- MPLI = 1 (baseline levels of contamination),
- MPLI > 1 (deterioration of site quality).

Enrichment factors (EFs) are used to estimate the anthropogenic proportion of heavy metals. EF is defined as the relative ratio of the concentration of the target metal to a reference metal, which is assumed to be barely affected by anthropogenic sources, such as Al, Fe, Ca, Mg and Mn. The EF can be calculated as:
EF = [Ci/CFe]S/[Ci/ CFe]B

where [Ci/CFe]S is a concentration ratio of a heavy metal (i) to iron (Fe, normalized element) in the studied site; while [Ci/ CFe]B is a concentration ratio of a metal (i) to Fe in the referent location. Five categories of Enrichment Factor (EF) used to assess sediment enrichment by Heavy Metals (HM):

- EF < 2: Deficiency to minimal enrichment
- 2 ≤ EF ≤ 5: Moderate enrichment
- 5 < EF ≤ 20: Significant enrichment
- 20 < EF ≤ 40: Very high enrichment
- EF > 40: Extremely high enrichment

Organotin compounds – SQG

The assessment of risks associated with marine sediment, particularly in samples collected from ports, is notably challenging due to the presence of tributyltin. Elevated levels of tributyltin (TBT) in sediment are commonly linked to commercial ports, harbors, shipyards and marinas. Organotins, including TBT, exhibit toxicity to numerous marine organisms, even at extremely low concentrations.

The OSPAR Environmental Quality Standard (EQS) was initially derived from the Swedish EQS. The national Environmental Quality Standard (EQS) for tributyltin (TBT) in sediment has been set by the Swedish Agency of Marine and Water Management (SwAM) at 1,6ug/kg dw. This standard, derived from ecotoxicity studies on benthic organisms. This established EQS is anticipated to provide protective measures for both freshwater and marine sediment-dwelling species, underlining the comprehensive approach taken in the risk assessment process. Assessment Factor (AF) of 10 was deemed adequate for the risk assessment, supported by comprehensive effect data from three chronic freshwater studies involving various sediment-dwelling species. These species represented diverse living conditions, enhancing the robustness of the assessment. The marine dataset, comprising four chronic studies with different species, also justified the application of AF 10. However, the EQS value for TBT has been recently replaced with the Danish EQS which is even lower, reflecting the adoption of the latter due to the availability of updated data. The primary threshold value for sediment was lowered from 1.6 µg /kg dw to 1.3 µg /kg dw sediment (5% TOC) based on new analyses carried out. Due to the harmful effects of tributyltin (TBT) on organisms and its persistence in the aquatic environment, TBT has been globally prohibited since 2008. This ban was implemented through the International Convention on the Control of Harmful Anti-fouling Systems on Ships, reflecting a global effort to mitigate the environmental impact of TBT-containing anti-fouling systems. Although banned long time ago, TBT, because it exhibits only moderate degradability in sediment, it is foreseen that threshold values will be consistently exceeded in numerous locations like ports, marinas etc. Consequently, in many instances, directing remedial actions exclusively at sediment due to TBT contamination may yield limited benefits. A threshold value of 35 µg TBT/kg , as per Norwegian guidelines for risk assessment of contaminated sediments will be used to assess the contamination of sediment from Tivat Bay and Port of Risan.

Tier 2 risk assessment

The next step, level 2 of the risk assessment is to determine whether the sediments pose an acceptable risk regarding environmental and health-related adverse effects. Several lines of evidence were used to assess the risk of the toxicity of the analyzed sediment on the marine ecosystem of Tivat Bay and Port of Risan. The first one is using biotests with different endpoints, the second one is the assessment of bioaccumulation of the contaminants in the mussel tissue of Mediterranean mussel (*Mytilys Galloprovinciallis*).

Toxicity tests play a crucial role in detecting potential harmful effects of substances that may not be covered by routine chemical analyses or in assessing the complex interactions between various substances, emphasizing the need to understand the combined impact of different contaminants in the ecosystem. Substances that individually may fall below regulatory threshold values can collectively exert harmful effects on the ecosystem when combined. By evaluating the cumulative impact, toxicity tests will provide more comprehensive understanding of the potential risks.

In the tier 2 of risk assessment, the following toxicity tests will be considered in order to evaluate toxicity that contaminants present in the sediment for Tivat Bay and Port of Risan pose to the ecosystem:

1. Microtox Solid phase toxicity with Vibrio fischeri, ISO 11348
2. Alga growth inhibition test (Skeletonema sp.), ISO 10253
3. Acute lethal toxicity to marine copepods (Acartia tonsa), ISO 14669
4. Sediment-reworker, acute toxicity, Corophium sp., OSPAR 2006/ ISO 16712

The Microtox® solid-phase test is a sensitive method based on the bioluminescence of the marine bacterium Vibrio fishery, which can be activated or inhibited in the presence of a toxic substance. This test allows for the screening of a large number of toxins and effluents in a short period. The results are expressed as percentages of inhibition or activation of luminescence compared to the control for minor effects or as EC50: Effective Concentration causing a 50% decrease in bioluminescence compared to the control value.

The method for determining the inhibition of growth of the unicellular marine algae Skeletonema sp. by substances and mixtures present in seawater or environmental water samples (such as effluents, elutriates, etc.) is designed to assess the impact of various compounds on the growth of these algae. This method is particularly suitable for testing substances that are easily soluble in water and do not undergo significant degradation or elimination from the test medium through other mechanisms. The objective is to evaluate the potential inhibitory effects of the tested substances on the growth of Skeletonema sp. in a controlled aquatic environment.

The method for determining the acute toxicity of port sediments concerning the marine copepod is derived from the ISO/DIS 14669 standardized protocol for marine copepods Acartia tonsa, Tisbe battagliai, and Nitocra spinipes. This standard is intended for assessing the toxicity of soluble chemical substances in effluents, seawater, or estuarine waters. The 50% copepodite mortality rate (LC50) is then expressed in grams of dry sediment per liter.

The test Sediment-reworker, acute toxicity, Corophium sp involves exposing adult amphipods to the sediments to be tested, either as they are or diluted with sediments from the same source as the animals, for a duration of 10 days. Throughout the 10-day exposure, deceased amphipods are counted and removed at the end of the experiment. The results are expressed in terms of CL20 (concentration causing 20% mortality), calculated based on dry sediment.

Assessment of bioaccumulation of the contaminants in the mussel tissue

As bioindicators of marine ecosystem pollution, shells and benthic fish are commonly used, with shells being more suitable for several reasons. They possess a pronounced bioaccumulation capacity, a very low level of enzyme activity capable of metabolizing persistent organic contaminants, are attached to the substrate, immobile, have a long lifespan, are stress-resistant, and are easy to sample. Due to their feeding habits, filtering seawater, shells have the ability to accumulate certain types of contaminants, including PAHs, organochlorine pesticides, PCBs, heavy metals etc.

The analysis of tissue of Mediterranean mussel *M. Galloprovincialis* from areas of examination will be conducted to assess the bioavailability of contaminants and their potential negative effect on the biota. The likelihood of surpassing a biota standard is primarily influenced by the concentration of substances present in both the sediment and/or suspended particulate matter. This tendency is a result of partitioning dynamics across water, sediment, and organic matter. The distribution and interaction of these substances among these environmental compartments play a crucial role in determining the potential impact on biota.

The assessment criteria that were used for biota is given in the UNEP/MAP guide UNEP/MED WG.563/7 New/Updated IMAP Assessment Criteria for Nutrients, Contaminants and Marine Litter) (6). The threshold value for the assessment of contaminants in biota will be the EAC values. EAC values are the concentrations above which significant adverse effects on the environment or human health are most likely to occur. Conversely, EAC values are defined as the concentrations below which it is unlikely that unexpected or unacceptable biological effects will occur in exposed marine species. Given it was impossible to develop EACs specific for the Mediterranean, it was agreed to use the criteria developed by OSPAR and NOAA/USEPA (ERL values) (Long et al. 1995), as the EAC values for the Mediterranean. The EAC values agreed in Decisions IG.22/7 and IG.23/6 are as follows: EAC values for TM, PAHs and organochlorinated contaminants (PCBs and pesticides) i.e., NOAAs ERLs (for TM, PAH and pesticides in sediments) and the ECs from EU Directives to protect human health (for TM and organic contaminants in biota). The EAC values for trace metals (TM) present in marine organisms, as supported by Decisions IG.22/7 and IG.23/6, represent the concentrations in fish and seafood that are advised as safe dietary limits for human consumption in terms of human health. These limits are derived from specific EU Directives that govern the maximum allowable levels of certain contaminants in food items, namely, EC/EU 1881/2006 and its subsequent amendment 629/2008. As for the EAC values concerning organic contaminants like polycyclic aromatic hydrocarbons (PAHs) and organochlorinated contaminants in mussels, these values are drawn from OSPAR recommendations. Mediterranean EAC values for trace metals, PAHs, PCBs, Pesticides in biota are shown in tables 6,7 and 8, respectively.

Table 6. Mediterranean EAC values for trace metals in biota, as endorsed by Decision IG.23/6

Mediterranean EAC values for trace metals in sediments and biota		
TM	**#MedEAC**	**#MedEAC**
	***M. galloprovincialis,* µg/kg dry wt**	***M. barbatus,* µg/kg wet wt**
	IG.23/6	IG.23/6
Cd	5000	50
Hg	2500	1000
Pb	7500	300

Table 7. Mediterranean EAC values for Polycyclic Aromatic Hydrocarbons (PAHs) in biota

	Biota Mussels, µg/kg dw	
PAH compounds	**EAC** IG.22/7 and IG.23/6 - OSPAR**	**OSPAR**
Naphthalene		340
Phenanthrene	1700	
Anthracene	290	
Fluoranthene	110	
Pyrene	100	
Benzo[a]anthracene	80	
Benzo(k)fluoranthene	260	
Benzo[a]pyrene	600	
Benzo[g,h,i]perylene	110	

Table 8. Mediterranean EAC values for organochlorinated contaminants (PCBs and pesticides) biota

PCBs	**Mussel**	**Fish**
	EAC IG.22/7 and IG.23/6 (µg/kg dry wt)**	**EAC** IG.22/7 and IG.23/6 (µg/kg lipid)**
PCB28	3.2	64
PCB52	5.4	108
PCB101	6	120
PCB118	1.2	24
PCB138	15.8	316
PCB153	80	1600
PCB180	24	480

PCBs	Mussel	Fish
	EAC IG.22/7 and IG.23/6 (µg/kg dry wt)**	**EAC** IG.22/7 and IG.23/6 (µg/kg lipid)**
Pesticides		
γ-HCH (Lindane)	1.45	11 µg/kg ww
DDE(p,p')	5-50	
Hexachlorobenzene		
Dieldrin	5-50	

Data interpretation TIER I

Results of analysis are in Annex 2 of this report.

Porto Montenegro

Results of metal analysis

Figure 1 and 2 show a graphic review of the concentrations of **mercury and arsenic** in the sediment samples sampled at the Porto Montenegro site in relation to the values of two types of sediment quality guidelines (SQG).

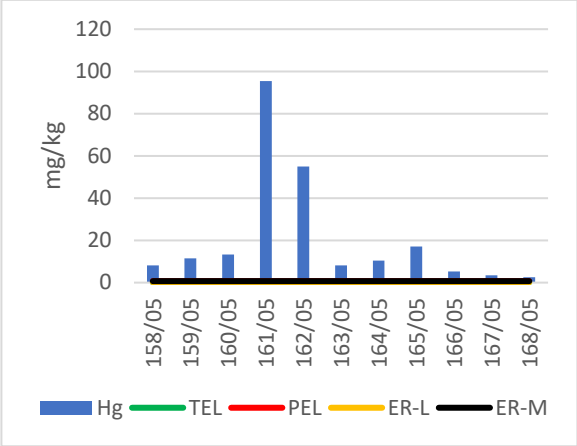


Figure 5 Mercury concentration in Porto Montenegro by sampling location in relation to TEL, PEL, ER-L and ER-M values

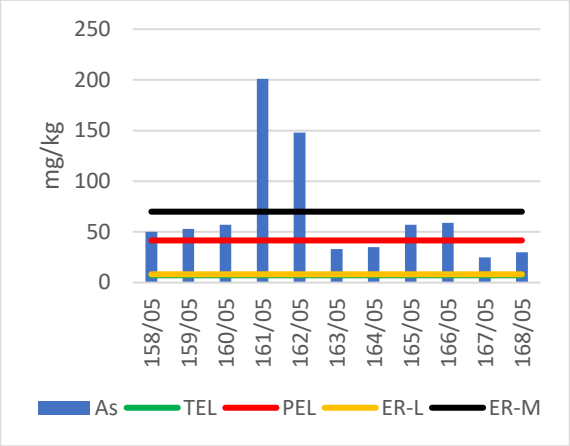


Figure 2 Arsenic concentration in Porto Montenegro by sampling location in relation to TEL, PEL, ER-L and ER-M values

The mercury content at all sampling locations in Porto Montenegro significantly exceeds both the PEL and ER-M values.

The arsenic content at all sampling sites in Porto Montenegro significantly exceeds both TEL and ER-L values. The arsenic content in two locations exceeds the ER-M, while in 5 samples the arsenic content exceeds the PEL value.

Figure 3 and 4 show a graphic review of the concentrations of **cadmium and chromium** in the sediment samples sampled at the Porto Montenegro site in relation to the values of two types of sediment quality guidelines (SQG).

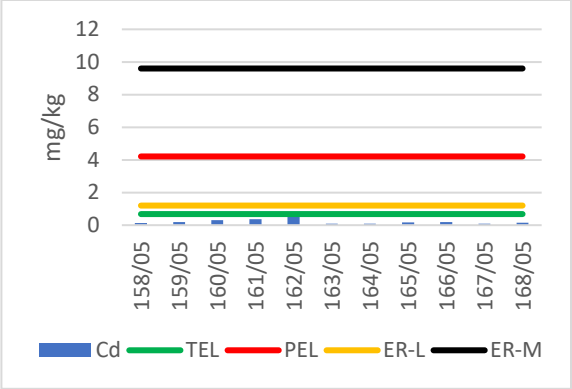


Figure 3 Cadmium concentration in Porto Montenegro by sampling location in relation to TEL, PEL, ER-L and ER-M values

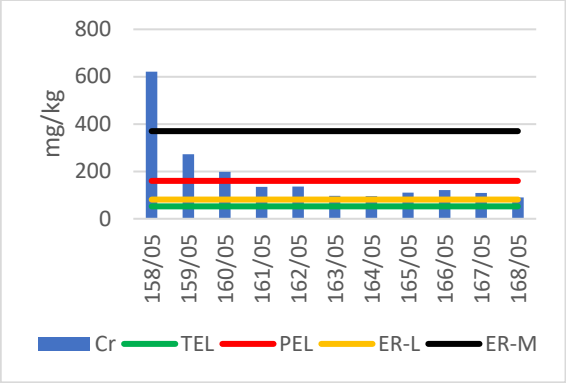


Figure 4 Chromium concentration in Porto Montenegro by sampling location in relation to TEL, PEL, ER-L and ER-M values

The results of the sediment analysis show that the cadmium content at all sampling locations of Porto Montenegro is below both the TEL and ER-L values.
The chromium content at all sampling locations of Porto Montenegro exceeds both the TEL and ER-L values.
The measured values of chromium content from two locations exceed the PEL value and one of the measured values exceeds both the PEL and ER-M value.

Figure 5 and 6 show a graphic review of the concentrations of **copper and nickel** in the sediment samples sampled at the Porto Montenegro site in relation to the values of two types of sediment quality guidelines (SQG).

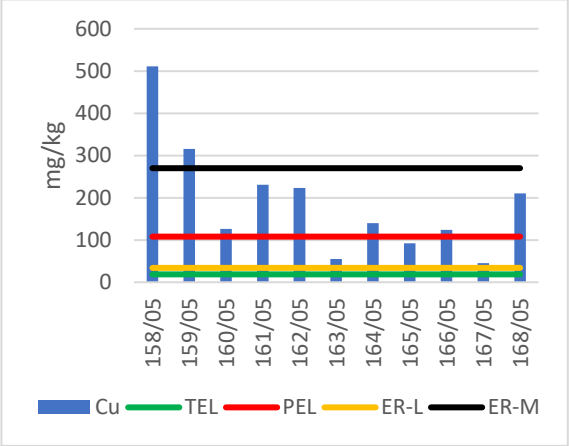


Figure 5 Copper concentration in Porto Montenegro by sampling location in relation to TEL, PEL, ER-L and ER-M values

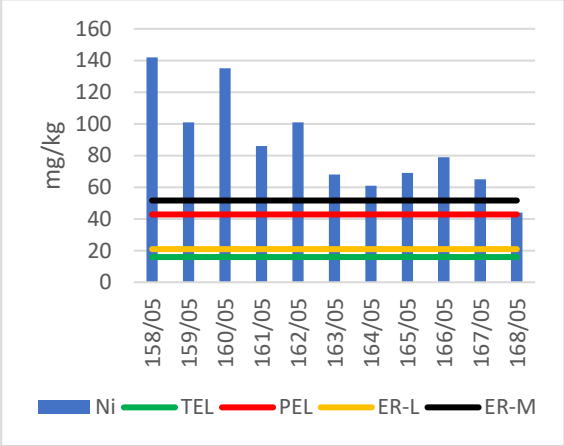


Figure 6 Nickel concentration in Porto Montenegro by sampling location in relation to TEL, PEL, ER-L and ER-M values

The results of the sediment analysis show that the copper content at all sampling locations of Porto Montenegro exceeds both the TEL and ER-L values. The copper content from most locations exceeds the PEL value and two of the measured values also exceeds the ER-M value.

The nickel content at most sampling locations of Porto Montenegro exceeds prescribed both the PEL and ER-M values.

Figure 7 and 8 show a graphic review of the concentrations of **lead and zinc** in the sediment samples sampled at the Porto Montenegro site in relation to the values of two types of sediment quality guidelines (SQG).

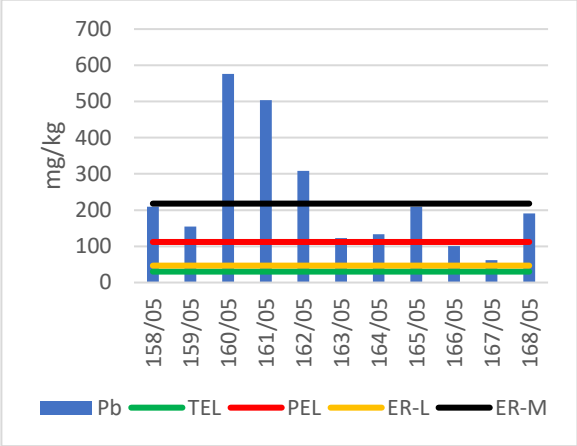


Figure 7 Lead concentration in Porto Montenegro by sampling location in relation to TEL, PEL, ER-L and ER-M values

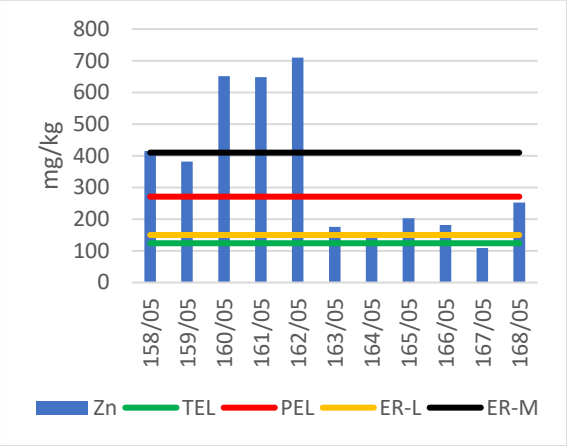


Figure 8 Zinc concentration in Porto Montenegro by sampling location in relation to TEL, PEL, ER-L and ER-M values

The lead content in most samples from the Porto Montenegro location exceeds the PEL value. The content of zinc within the harbor waters from the Porto Montenegro location exceeds the PEL value. Zinc content at three tested samples, within the harbor waters, is higher than the prescribed ER-M value.

Results of organic contaminants analysis

Polychlorinated biphenyls

Figure 9 show a graphic review of the concentrations of **total PCBs** in the sediment samples sampled at the Porto Montenegro site in relation to the values of two types of sediment quality guidelines (SQG).

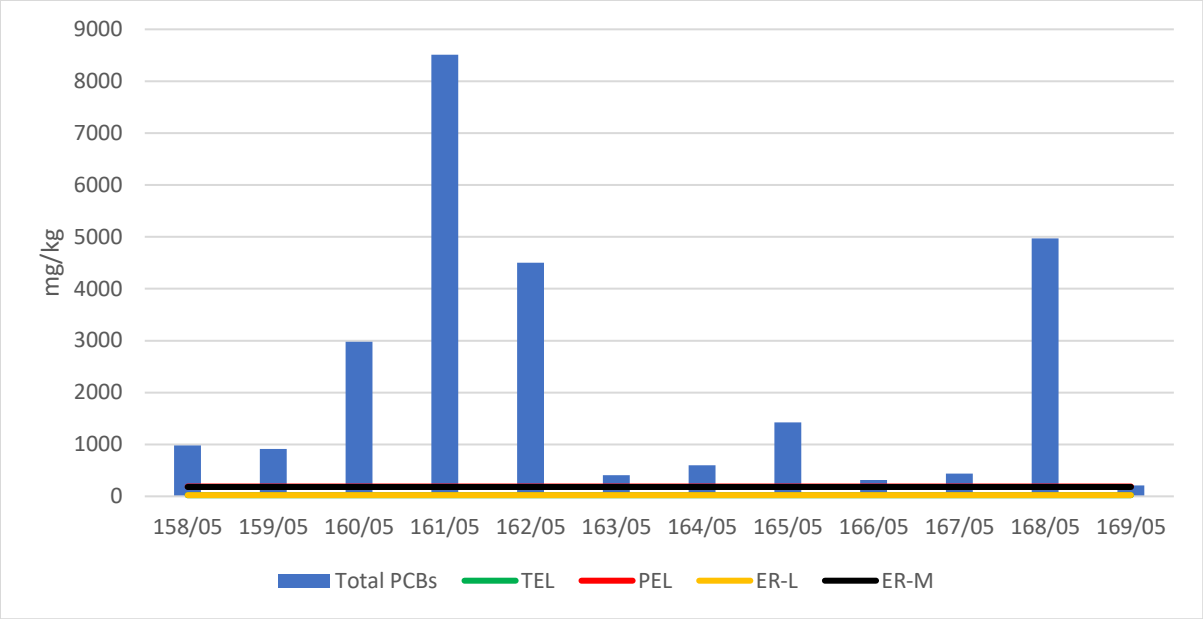


Figure 9 Total PCBs concentration in Porto Montenegro by sampling location in relation to TEL, PEL, ER-L and ER-M values

The total PCBs content in all samples from the Porto Montenegro location exceeds the prescribed PEL and ER-M values.

Polyaromatic hydrocarbons

Figure 10 and 11 show a graphic review of the concentrations of **acenaphthene and acenaphthylene** in the sediment samples sampled at the Porto Montenegro site in relation to the values of sediment quality guidelines (SQG).

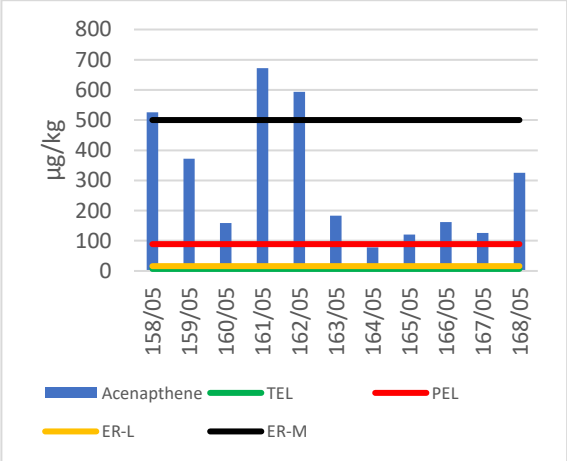


Figure 10 Acenaphthene concentration in Porto Montenegro by sampling location in relation to TEL, PEL, ER-L and ER-M values

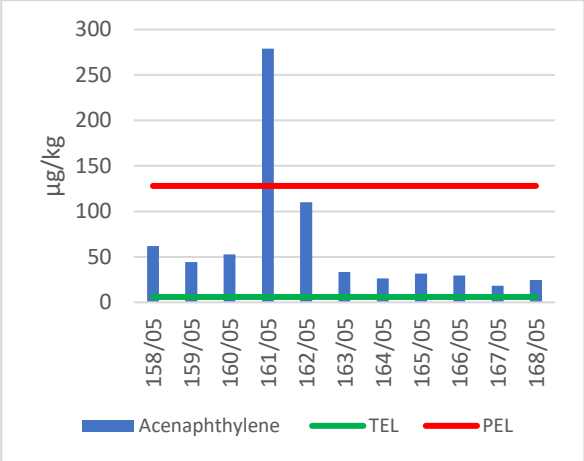


Figure 11 Acenaphthylene concentration in Porto Montenegro by sampling location in relation to TEL, PEL, ER-L and ER-M values

The acenaphthene content at most of the sampling locations in Porto Montenegro exceeds PEL value, while ER-M value exceeds at three locations.

The acenaphthylene content at all sampling locations in Porto Montenegro exceeds TEL value while PEL value exceeds only one location.
Figure 12 and 13 show a graphic review of the concentrations of **anthracene and fluorene** in the sediment samples sampled at the Porto Montenegro site to the values of two types of sediment quality guidelines (SQG).

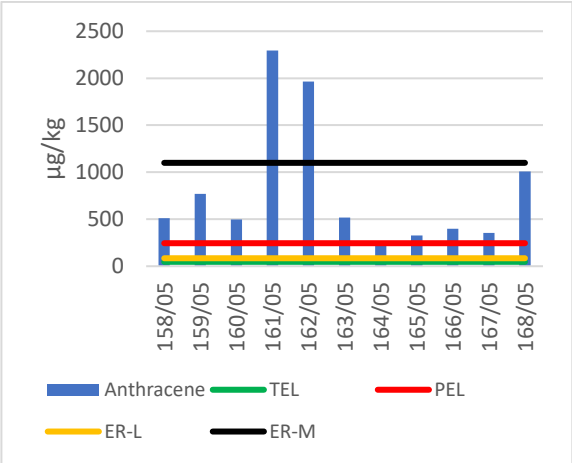


Figure 12 Anthracene concentration in Porto
Montenegro by sampling location
in relation to TEL, PEL, ER-L and ER-M values

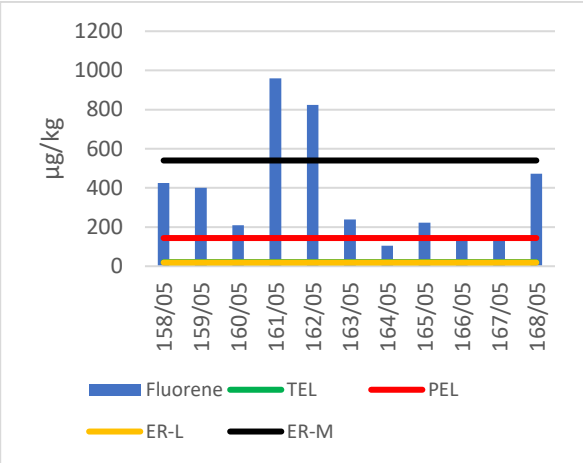


Figure 13 Fluorene concentration in Porto
Montenegro by sampling location
in relation to TEL, PEL, ER-L and ER-M values

The anthracene content at all sampling locations in Porto Montenegro exceeds PEL value, while ER-M value exceeds two locations.
The fluorene content at most of the sampling locations in Porto Montenegro exceeds PEL value, while ER-M value exceeds at two locations.

Figure 14 and 15 show a graphic review of the concentrations of **2-methylnaphthalene and naphthalene** in the sediment samples sampledat the Porto Montenegro site, in relation to the values of sediment quality guidelines (SQG).

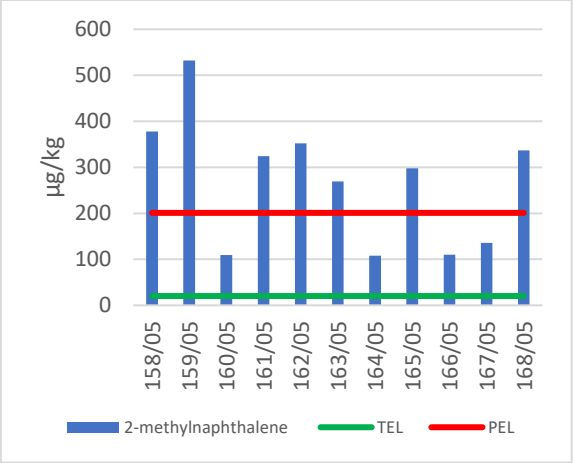


Figure 14 2-methylnaphthalene concentration in Porto Montenegro by sampling location
in relation to TEL, PEL, ER-L and ER-M values

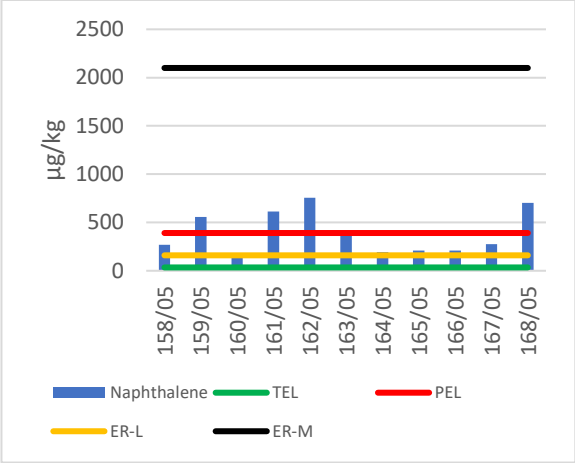


Figure 15 Naphthalene concentration in Porto
Montenegro by sampling location
in relation to TEL, PEL, ER-L and ER-M values

The content of the 2-methylnaphthalene at all sampling locations in Porto Montenegro exceeds TEL value and most of them also exceeds PEL value.
The naphthalene content at all sampling locations in Porto Montenegro exceeds TEL and ER-L values while PEL value exceeds four sampling location. All concentrations of naphthalene are below of ER-M value.

Figure 16 and 17 show a graphic review of the concentrations of **phenanthrene and benzo(a)anthracene** in the sediment samples sampled at the Porto Montenegro site in relation to the values of two types of sediment quality guidelines (SQG).

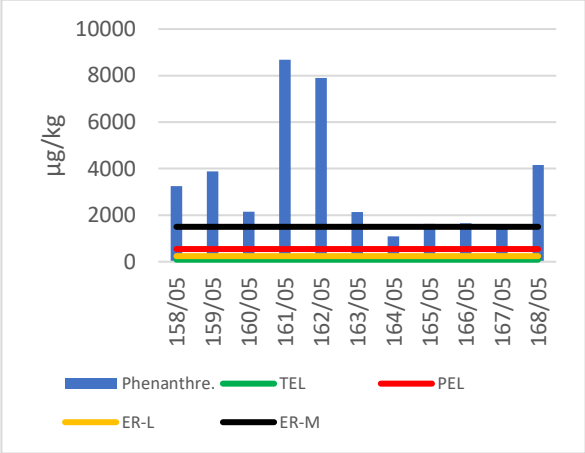


Figure 16 Phenanthrene concentration in Porto
Montenegro by sampling location
in relation to TEL, PEL, ER-L and ER-M values

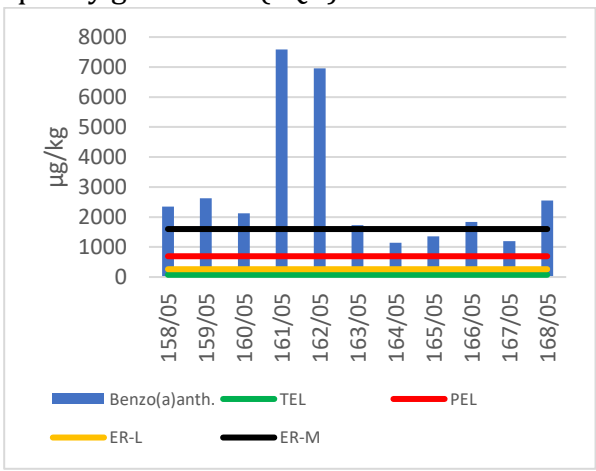


Figure 17 Benzo(a)anthracene concentration in Porto Montenegro by sampling location
in relation to TEL, PEL, ER-L and ER-M values

The phenanthrene content at all sampling locations in Porto Montenegro significantly exceeds PEL value while most locations also exceed ER-M value.

The benzo(a)anthracene content at all sampling locations in Porto Montenegro significantly exceeds PEL value while most locations also exceed ER-M value.

Figure 18 and 19 show a graphic review of the concentrations of **benzo(a)pyrene and dibenzo(a,h)anthracene** in the sediment samples sampled at the Porto Montenegro site in relation to the values of two types of sediment quality guidelines (SQG).

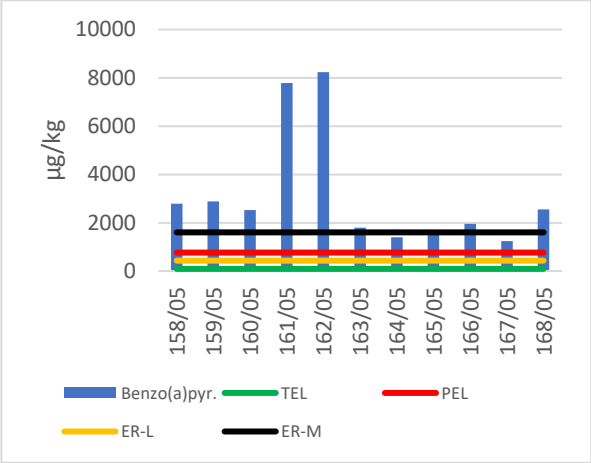


Figure 18 Benzo(a)pyrene concentration in Porto
Montenegro by sampling location
in relation to TEL, PEL, ER-L and ER-M values

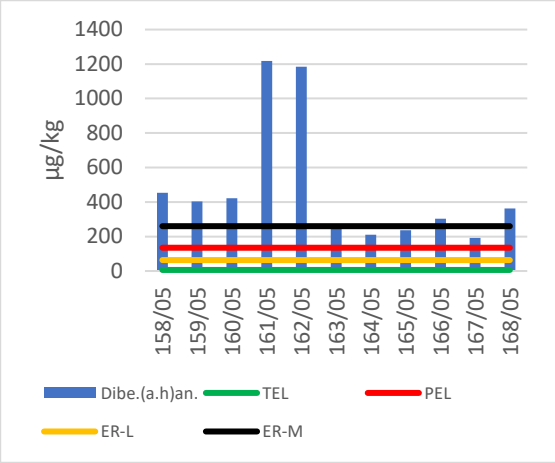


Figure 19 Dibenzo(a,h)anthrac. concentration in Porto Montenegro by sampling location
in relation to TEL, PEL, ER-L and ER-M values

The benzo(a)pyrene and dibenzo(a.h)anthracene content at all sampling locations in Porto Montenegro significantly exceeds PEL value while most locations also exceed ER-M value.

Figure 20 and 21 show a graphic review of the concentrations of **chrysene and fluoranthene** in the sediment samples sampled at the Porto Montenegro site in relation to the values of two types of sediment quality guidelines (SQG).

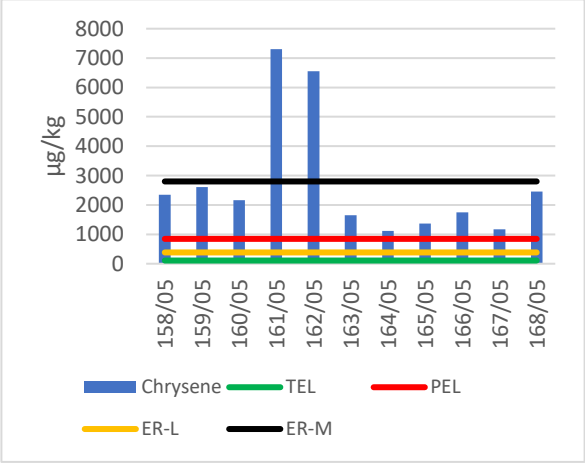


Figure 20 Chrysene concentration in Porto Montenegro by sampling location
in relation to TEL, PEL, ER-L and ER-M values

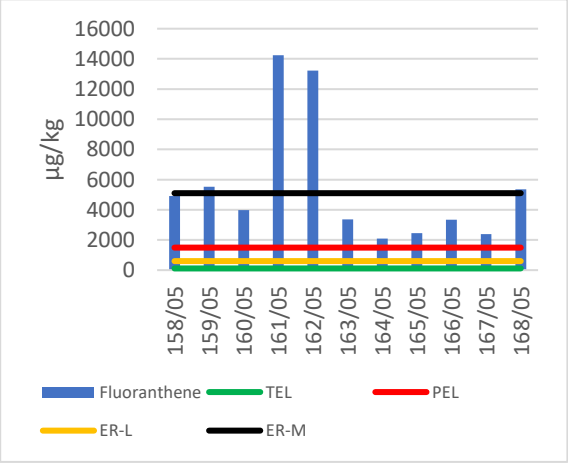


Figure 21 Fluoranthene concentration in Porto
Montenegro by sampling location
in relation to TEL, PEL, ER-L and ER-M values

The chrysene content at all sampling locations in Porto Montenegro significantly exceeds PEL value while ER-M value exceed two locations which are located within the harbor waters.

The fluoranthene content at all sampling locations in Porto Montenegro also significantly exceeds PEL value while ER-M value exceed four locations. Two locations with highest concentration of fluoranthene are located within the harbor waters.

Figure 22 and 23 show a graphic review of the concentrations of **pyrene and sum low molecular weight PAHs** in the sediment samples sampled at the Porto Montenegro site in relation to the values of two types of sediment quality guidelines (SQG).

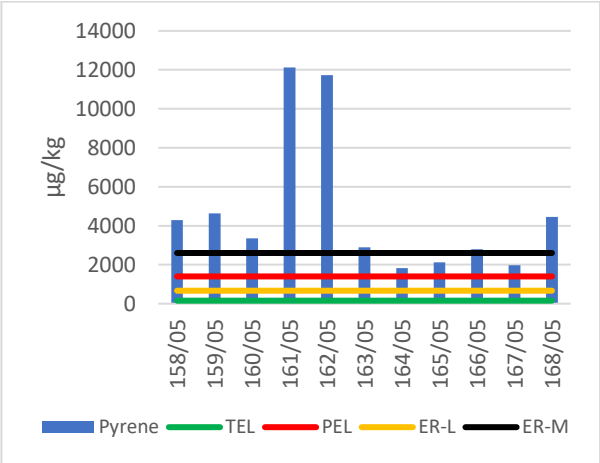


Figure 22 Pyrene concentration in Porto Montenegro by sampling location in relation to TEL, PEL, ER-L and ER-M values

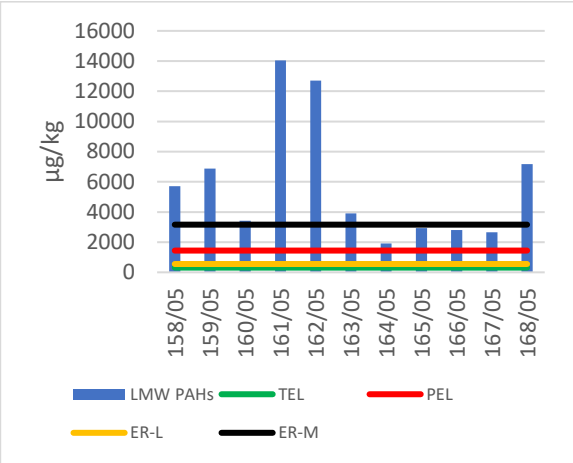


Figure 23 Sum LMW PAHs concentration in Porto Montenegro by sampling location in relation to TEL, PEL, ER-L and ER-M values

The pyrene content at all sampling locations in Porto Montenegro significantly exceeds PEL value while ER-M value exceed most of researched locations.
The sum low molecular weight PAHs content at all sampling locations in Porto Montenegro significantly exceeds PEL value while ER-M value exceed seven locations.

Figure 24 and 25 show a graphic review of the concentrations of **sum high molecular weight PAHs and total PAHs** in the sediment samples sampled at the Porto Montenegro site in relation to the values of two types of sediment quality guidelines (SQG).

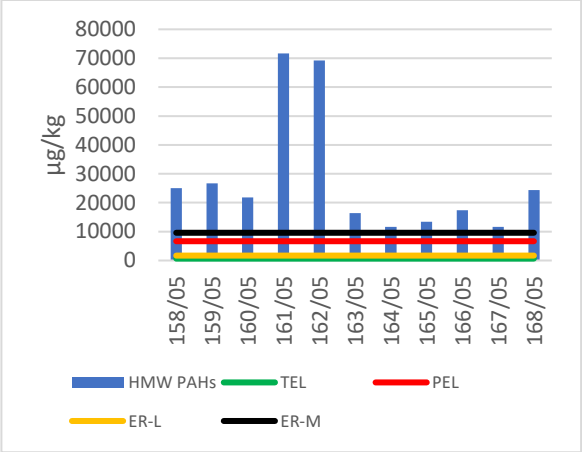


Figure 24 Sum HMW PAHs concentration in Porto
Montenegro by sampling location
in relation to TEL, PEL, ER-L and ER-M values

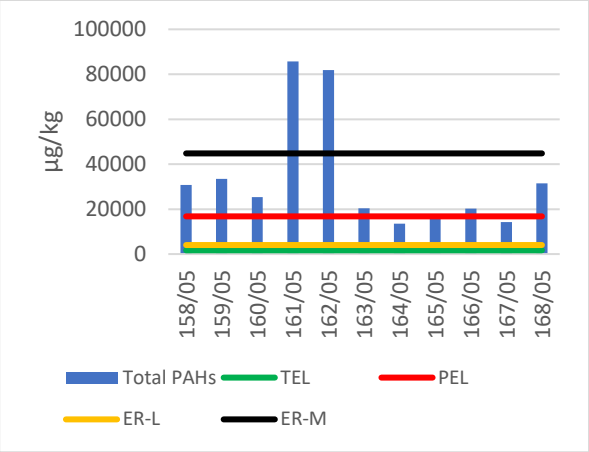


Figure 25 Total PAHs concentration in Porto
Montenegro by sampling location
in relation to TEL, PEL, ER-L and ER-M values

The sum of high molecular weight PAHs content at all sampling locations in Porto Montenegro significantly exceeds PEL and ER-M values.
The total PAHs content at most of the sampling locations in Porto Montenegro exceeds PEL value, while ER-M value exceeds at two locations.

Organochlorine pesticides

Figure 26 and 27 show a graphic review of the concentrations of **total DDT** (sum of p,p'-DDT, p,p'DDD, pp'DDE, o, p'DDT, o,p'DDD and o,p'DDE) and **p,p'DDE** in the sediment samples sampled at the Porto Montenegro site in relation to the values of sediment quality guidelines (SQG).

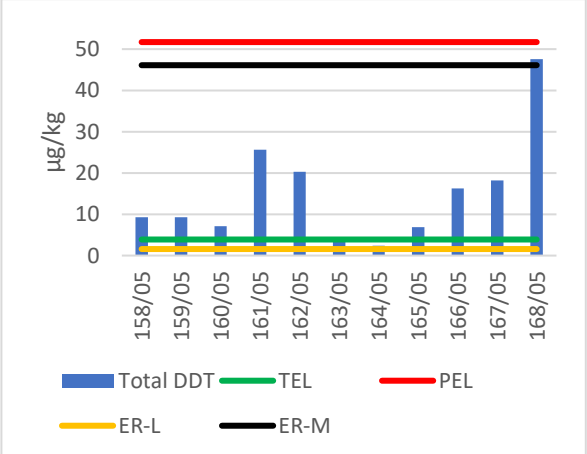


Figure 26 Total DDT concentration in Porto
Montenegro by sampling location
in relation to TEL, PEL, ER-L and ER-M values

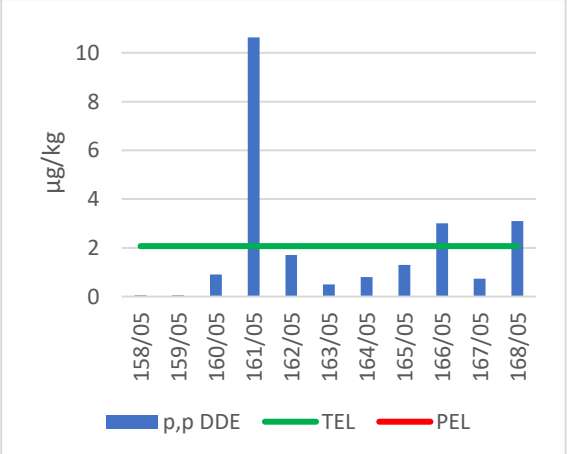


Figure 27 p,p DDE concentration in Porto
Montenegro by sampling location
in relation to TEL and PEL values

The total DDT content at all sampling locations in Porto Montenegro exceeds both the TEL and ER-L values

Only on one location, the concentration of total DDT exceeds ER-M value. There is no exceedance of PEL value for any of the sampling locations.

The p,p'DDE content at 3 sampling locations exceeds TEL value but it is significantly lower than the PEL value.

Figure 28 and 29 show a graphic review of the concentrations of **p,p'DDD and p,p'DDT** in the sediment samples sampled at the Porto Montenegro site in relation to the values of sediment quality guidelines (SQG).

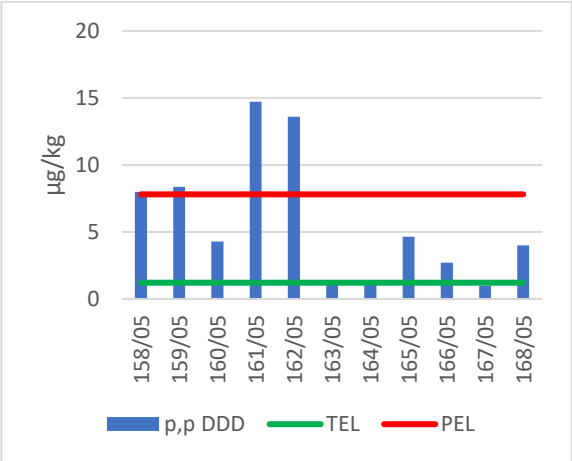


Figure 28 p,p DDD concentration in Porto Montenegro by sampling location in relation to TEL and PEL values

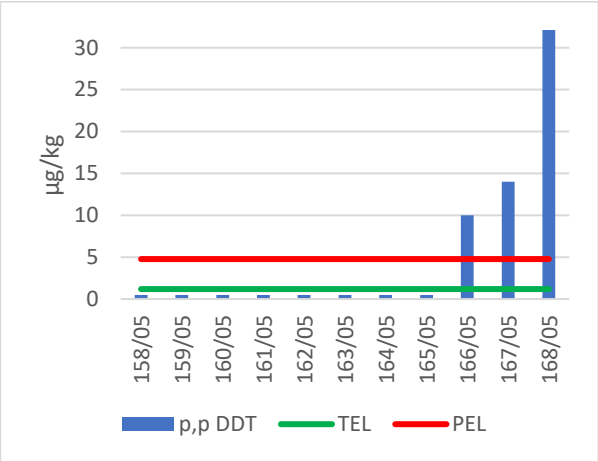


Figure 29 p,p DDT concentration in Porto Montenegro by sampling location in relation to TEL and PEL values

The p,p'DDD content significantly exceeds both TEL and PEL values at 4 sampling locations all sampling locations in Porto Montenegro. The two locations with the highest concentrations of p,p'DDD are located within the harbor waters.

The p,p'DDT content at three sampling locations from Porto Montenegro, exceeds the PEL value by 2 to 7 times while at other sampling location p,p'DDT content is below limit of quantification of methods.

Organotin compounds

Figure 30 show a graphic review of the concentrations of **tributyltin** in all sediment samples from Porto Montenegro location in relation with threshold value from Norwegian guidelines Risk assessment of contaminated sediments and CEFAS action levels for the disposal of dredged material.

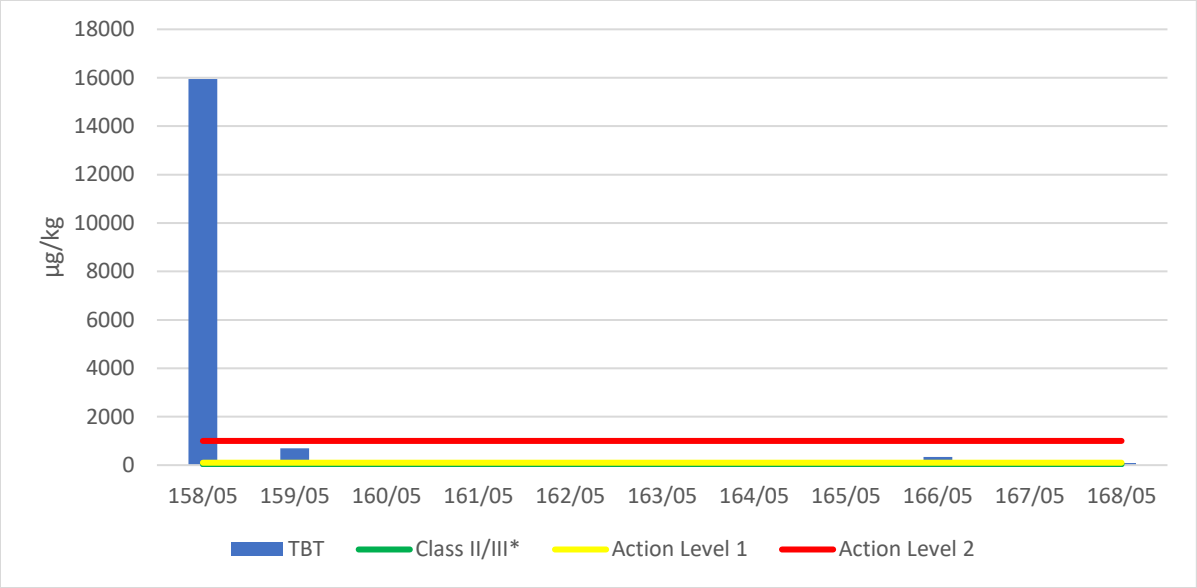


Figure 30 TBT concentration in Porto Montenegro by all sampling location in relation to threshold value

Figure 31 show a graphic review of the concentrations of **tributyltin** in sediment samples from Porto Montenegro location except the sample with significantly higher concentration (158/05) in relation with threshold value from Norwegian guidelines Risk assessment of contaminated sediments and CEFAS action levels for the disposal of dredged material.

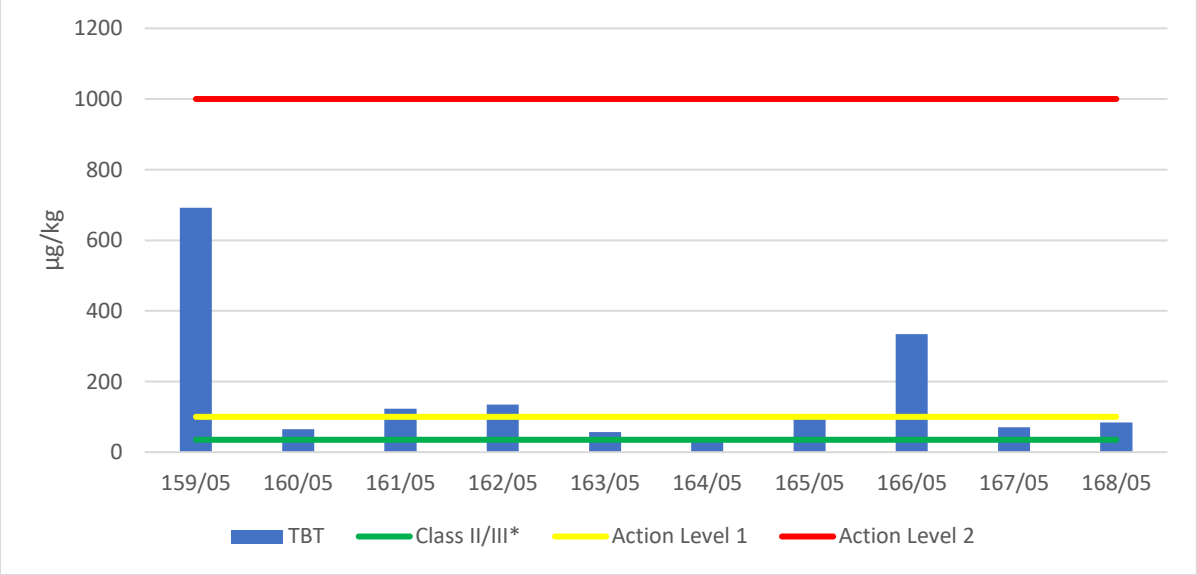
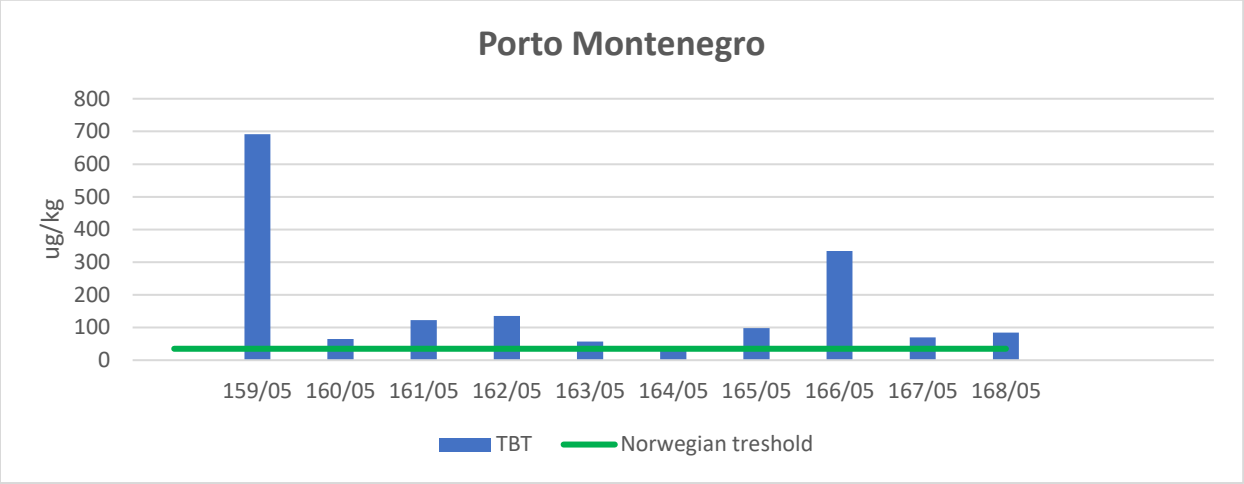


Figure 31 TBT concentration in Porto Montenegro by sampling location (except the sample with significantly higher concentration TBT (158/05)) in relation to threshold value

The TBT content at all sampling points in Porto Montenegro exceeds the threshold value from Norwegian guidelines Risk assessment of contaminated sediments. The TBT content at four sampling locations exceeds the CEFAS Action 1 levels for the disposal of dredged material and on one sampling location significantly exceeds Action 2 level.

Because the extremely high concentration of TBT compared to other sampling points from the same area, on figure 31a graphic representation of the concentrations of tributyltin in sediment samples from Porto Montenegro location except the sample with significantly higher concentration is presented.

Figure 321a. Graphic representation of the concentrations of tributyltin in sediment samples from Porto Montenegro location except the sample with significantly higher concentration compared to other samples from the same location (158/05) and average value of tributyltin in relation with threshold value from Norwegian guidelines Risk assessment of contaminated sediments (M-1132, 2018).



If we consider inside and outside assessment areas of Porto Montenegro as divided in the assessment of PAHs, PCBs and elements, sub-area 1 and sub-area 2 it can be concluded that the average concentration of TBT in area 1 is 3391ug/kg dw, and an average concentration of TBT in sub-area 2 is 114ug/kg dw. The average concentration of TBT in sub-area 1 is 97 times higher than threshold value, and in the sub-area 2 the TBT exceeds the threshold value for 3,2 times. In conclusion, both assessment sub areas exceed the threshold value, meaning that the concentration of TBT in the analyzed sediment pose a significant threat to the ecosystem.

Figure 32. show a graphic review of the concentrations of **dibutyltin** in all sediment samples from Porto Montenegro location in relation with threshold value from Norwegian guidelines Risk assessment of contaminated sediments and CEFAS action levels for the disposal of dredged material.

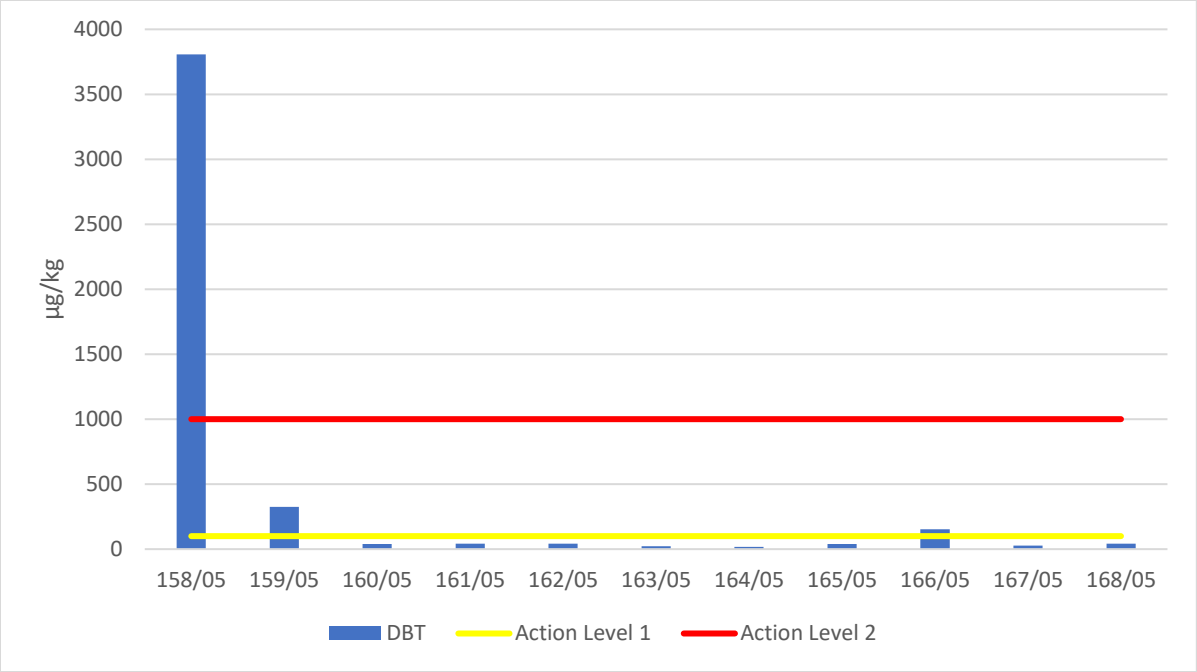


Figure 32 DBT concentration in Porto Montenegro by all sampling location in relation to threshold value

The DBT content at three sampling locations exceeds the CEFAS Action 1 levels for the disposal of dredged material and on one sampling location significantly exceeds Action 2 level.

Perfluorinated Compounds

All of the 54 analyzed perfluorinated compounds listed in the table 3, in sediment samples from all assessment locations Porto Montenegro, Airport Tivat, Shipyard and marina `Navar` are below limit of quantification, except Perfluorooctane sulfonic acid (PFOS) in one of the samples from the location Porto Montenegro. Namely, in sediment sample 161/05, the concentration of PFOS is 0,56ug/kg which is slightly above the limit of quantification of the method which is 0,5ug/kg.

Polychlorinated dibenzofurans and (PCDF) dibenzo-p-dioxins (PCDD)

Polychlorinated dibenzofurans and (PCDF) dibenzo-p-dioxins (PCDD) were determined to be below the limit of quantification in all analyzed sediment samples from all assessment *locations.*

Pentachlorophenol

Pentachlorophenol in all analyzed sediment samples from all assessment locations Porto Montenegro, Airport Tivat, Shipyard and marina `Navar` was below the limit of quantification of the method.

Contamination factor (CF) and enrichment factor (EF)

The Porto Montenegro location has low CF values in individual samples for cadmium, chromium, iron, and nickel. However, at this location, for a larger number of samples, the lead, arsenic, copper, and zinc content have CF values indicating considerable contamination. CF values for arsenic, copper, lead in several samples, and in all samples when it comes to mercury, are high, indicating very high contamination.

Table 9. Heavy metals contamination factor (CF) and metal pollution load index (MPLI)

		CF									MPLI
		Hg	As	Cd	Cr	Cu	Pb	Ni	Zn	Fe	
PORTO MONTENEGRO	158/05	39.51	2.94	0.36	5.29	13.63	4.32	1.54	3.37	1.11	**3.48**
	159/05	56.29	3.11	0.54	2.32	8.43	3.21	1.09	3.10	0.96	**3.00**
	160/05	64.63	3.35	0.88	1.69	3.36	11.92	1.46	5.28	1.03	**3.60**
	161/05	465.85	11.80	1.06	1.15	6.16	10.43	0.93	5.26	0.80	**4.92**
	162/05	268.29	8.69	1.65	1.16	5.95	6.37	1.09	5.76	0.87	**4.60**
	163/05	39.51	1.94	0.26	0.83	1.47	2.54	0.74	1.43	0.86	**1.56**
	164/05	51.22	2.06	0.26	0.82	3.73	2.75	0.66	1.25	0.81	**1.75**
	165/05	83.41	3.35	0.49	0.95	2.45	4.32	0.75	1.65	0.88	**2.25**
	166/05	25.37	3.46	0.54	1.03	3.31	2.09	0.86	1.48	0.88	**1.93**
	167/05	17.12	1.47	0.27	0.93	1.20	1.28	0.70	0.88	0.86	**1.20**
	168/05	12.29	1.76	0.43	0.77	5.60	3.95	0.48	2.04	0.72	**1.69**
	169/05	20.00	1.59	0.20	0.66	1.25	0.89	0.51	0.67	0.64	**1.00**
	170/05	1.98	0.76	0.40	1.22	1.23	0.74	1.37	1.01	1.04	**1.00**

Low contamination	Perfection
Moderate contamination	Baseline level of contamination
Considerable contamination	Deterioration of site quality
Very high contamination	

Two samples from the Porto Montenegro location are at the baseline level of contamination (MPLI = 1), while all other samples from this location, based on the value of the given index, indicate a deterioration of site quality.

The obtained EF values for heavy metals are shown in Table 10.

Table 10 Heavy metals enrichment factor (EF)

		Hg	As	Cd	Cr	Cu	Pb	Ni	Zn
PORTO MONTENEGRO	158/05	108.47	2.58	1.19	2.29	16.07	8.19	0.70	4.93
	159/05	178.60	3.17	2.09	1.16	11.48	7.02	0.57	5.24
	160/05	192.15	3.19	3.20	0.79	4.29	24.44	0.72	8.37
	161/05	1774.71	14.41	4.89	0.69	10.08	27.41	0.59	10.68
	162/05	944.51	9.81	7.09	0.64	8.99	15.48	0.64	10.81
	163/05	141.33	2.22	1.14	0.47	2.25	6.28	0.44	2.72
	164/05	192.41	2.47	1.17	0.48	6.02	7.13	0.41	2.50
	165/05	288.71	3.71	2.04	0.52	3.65	10.33	0.43	3.04
	166/05	88.67	3.88	2.30	0.57	4.96	5.04	0.50	2.75
	167/05	60.86	1.67	1.15	0.52	1.83	3.15	0.41	1.68
	168/05	51.95	2.39	2.20	0.51	10.16	11.52	0.33	4.61
	173/05	12.31	1.31	3.09	1.30	1.78	2.65	0.49	1.73
	174/05	14.74	1.38	3.58	0.65	1.57	2.45	0.52	1.69
	175/05	17.79	1.47	3.23	1.38	1.88	1.94	0.54	1.52
	176/05	7.32	1.18	2.69	0.92	1.61	2.14	0.56	1.63
	177/05	7.60	1.09	2.20	0.72	1.45	2.06	0.55	1.62

Deficiency to minimal enrichment

Moderate enrichment

Significant enrichment

Very high enrichment

Extremely high enrichment

Sediments at the Porto Montenegro location is extremely enriched with mercury (EF > 40), and in two samples, with lead as well. The results also indicate that most sediments from the Porto Montenegro location are highly enriched with copper, lead, zinc, and cadmium (20 < EF ≤ 40).

Shipyard and marina „Navar“

Results of metal analysis

Figure 33 and 34 show a graphic review of the concentrations of **mercury and arsenic** in the sediment samples sampled at the Shipyard and marina „Navar“site, in relation to the values of two types of sediment quality guidelines (SQG).

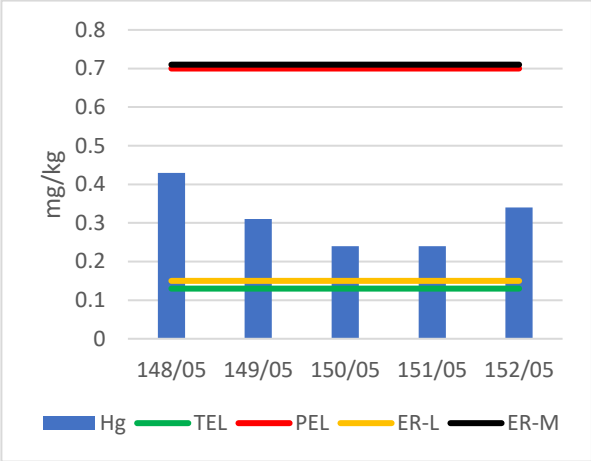


Figure 33 Mercury concentration in Shipyard and marina „Navar“ by sampling location
in relation to TEL, PEL, ER-L and ER-M values

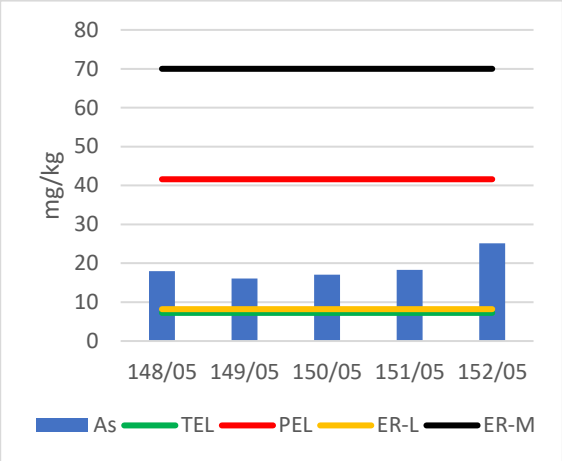


Figure 34 Arsenic concentration in Shipyard and marina „Navar“ by sampling location
in relation to TEL, PEL, ER-L and ER-M values

The mercury content at all sampling locations of Shipyard and marina „Navar“exceeds both the TEL and ER-L values, but is significantly lower than the prescribed PEL and ER-M values. The arsenic content at all sampling locations of Shipyard and marina „Navar“exceeds both the TEL and ER-L values, but is significantly lower than the prescribed PEL and ER-M values.

Figure 35 and 36 show a graphic review of the concentrations of **cadmium and chromium** in the sediment samples sampled at the Shipyard and marina „Navar“ site, as well as the average value of cadmium and chromium in relation to the values of two types of sediment quality guidelines (SQG).

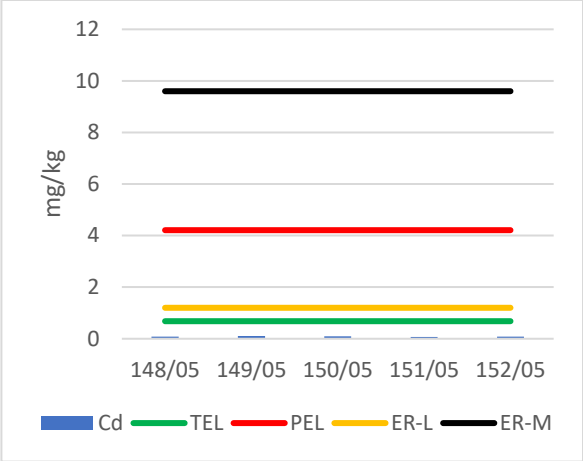


Figure 35 Cadmium concentration in Shipyard and marina „Navar“ by sampling location
in relation to TEL, PEL, ER-L and ER-M values

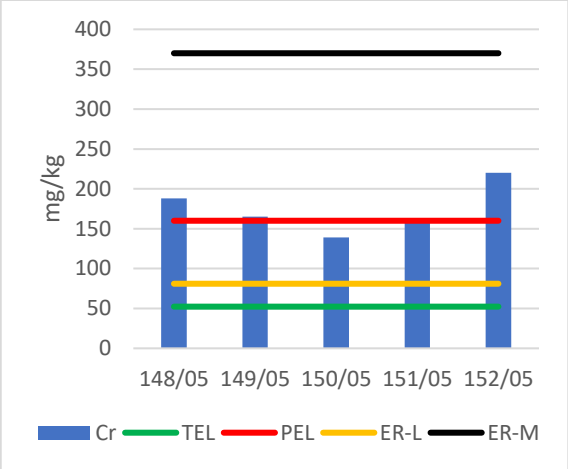


Figure 36 Chromium concentration in Shipyard and marina „Navar“ by sampling location
in relation to TEL, PEL, ER-L and ER-M values

The cadmium content at all sampling locations of Shipyard and marina „Navar“ is significantly below TEL and other referent values.
The chromium content at all sampling locations of Shipyard and marina „Navar“exceeds both the TEL and ER-L values. The average value and arsenic value from most researched locations exceed the PEL value, but all measured values are significantly lower than the ER-M value.

Figure 37 and 38 show a graphic review of the concentrations of **copper and nickel** in the sediment samples sampled at the Shipyard and marina „Navar“ site, in relation to the values of two types of sediment quality guidelines (SQG).

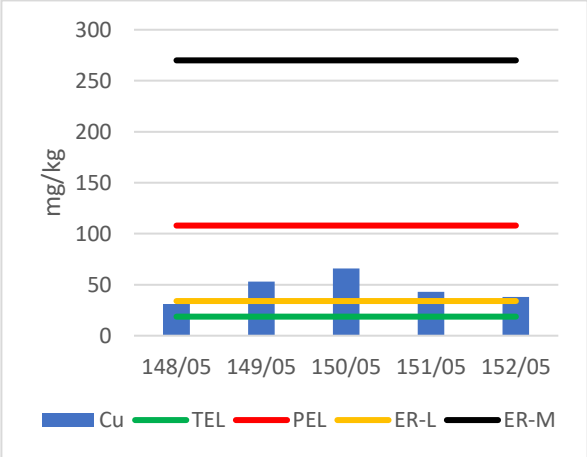


Figure 37 Copper concentration in Shipyard and marina „Navar“ by sampling location
in relation to TEL, PEL, ER-L and ER-M values

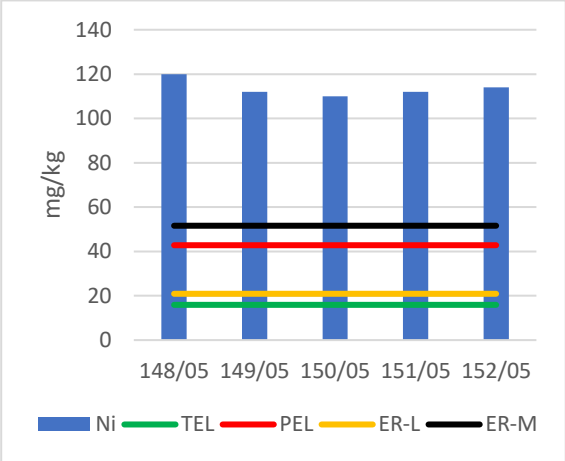


Figure 38 Nickel concentration in Shipyard and marina „Navar“ by sampling location
in relation to TEL, PEL, ER-L and ER-M values

The copper content at all sampling locations of Shipyard and marina “Navar” exceeds both the TEL and ER-L values, but is significantly lower than the prescribed PEL and ER-M values.

The nickel content at all sampling locations of Shipyard and marina “Navar” exceeds both the PEL and ER-M values.

Figure 39 and 40 show a graphic review of the concentrations of **lead and zinc** in the sediment samples sampled at the Shipyard and marina „Navar“ site, in relation to the values of two types of sediment quality guidelines (SQG).

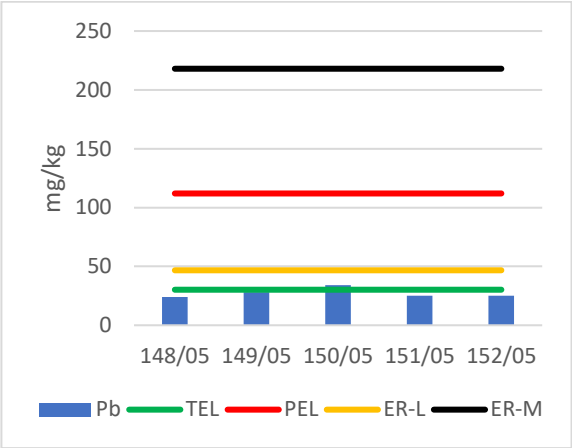


Figure 39 Lead concentration in Shipyard and marina „Navar“ by sampling location in relation to TEL, PEL, ER-L and ER-M values

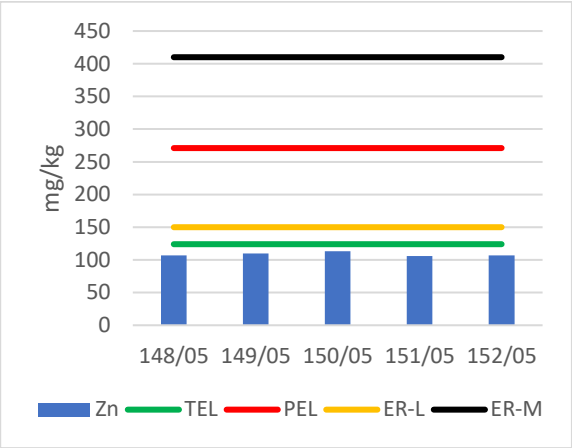


Figure 40 Zinc concentration in Shipyard and marina „Navar“ by sampling location in relation to TEL, PEL, ER-L and ER-M values

The lead content at all sampling locations of Shipyard and marina “Navar” exceeds the TEL value, except at one location, but is significantly lower than the prescribed PEL and ER-M values.

The zinc content at all sampling locations of Shipyard and marine “Navar” is below the TEL values, except at one location but it is lower than ER-L, PEL and ER-M values.

Results of organic contaminants analysis

Polychlorinated biphenyls

Figure 41 show a graphic review of the concentrations of **total PCBs** in the sediment samples sampled at the Shipyard and marina „Navar“ site, in relation to the values of two types of sediment quality guidelines (SQG).

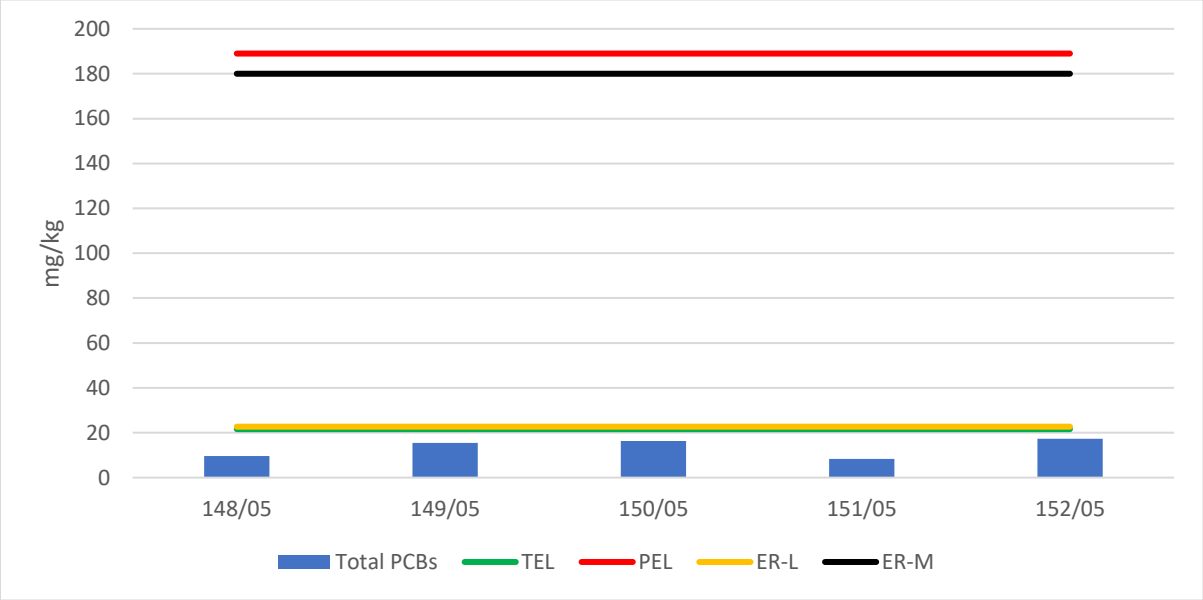


Figure 41 Total PCBs concentration in Shipyard and marina „Navar“ by sampling location in relation to TEL, PEL, ER-L and ER-M values

The total PCBs content in all samples from the Shipyard and marina „Navar“ location is below the prescribed TEL and ER-L values.

Polyaromatic hydrocarbons

Figure 42 and 43 show a graphic review of the concentrations of **acenaphthene and acenaphthylene** in the sediment samples sampled at the Shipyard and marina „Navar“ site, in relation to the values of sediment quality guidelines (SQG).

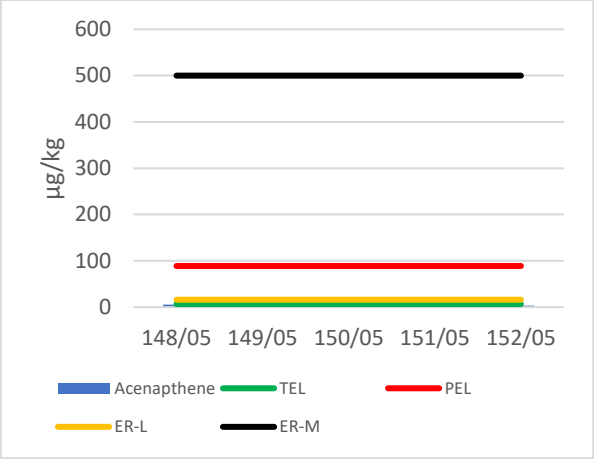


Figure 42 Acenaphthene concentration in Shipyard and marina „Navar“ by sampling location
in relation to TEL, PEL, ER-L and ER-M values

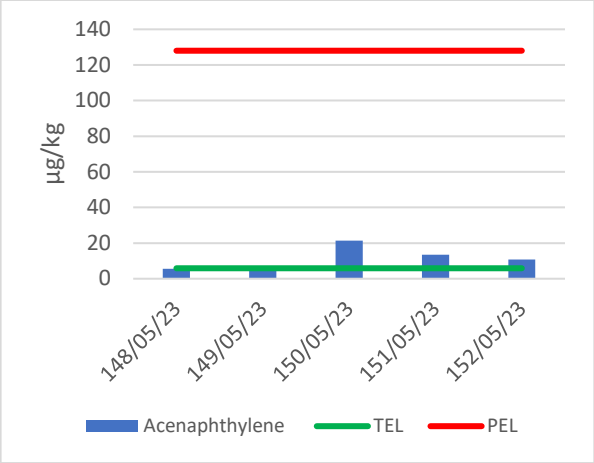


Figure 43 Acenaphthylene concentration in Shipyard and marina „Navar“ by sampling location
in relation to TEL and PEL values

The acenaphthene content at locations of Shipyard and marina „Navar“ slightly exceeds the TEL value at one sampling location. The acenaphthene content at other sampling locations is below of TEL and ER-L values.

The acenaphthylene content at locations of Shipyard and marina „Navar“exceeds TEL value at four sampling locations but these values are below than the prescribed PEL value.

Figure 44 and 45 show a graphic review of the concentrations of **anthracene and fluorene** in the sediment samples sampled at the Shipyard and marina „Navar“ site, in relation to the values of two types of sediment quality guidelines (SQG).

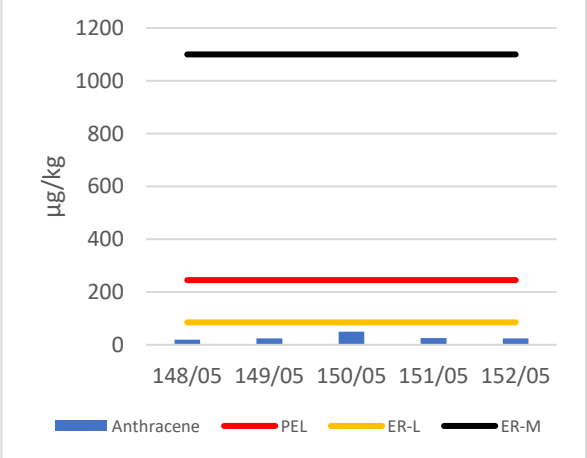


Figure 44 Anthracene concentration in Shipyard and marina „Navar“ by sampling location
in relation to TEL, PEL, ER-L and ER-M values

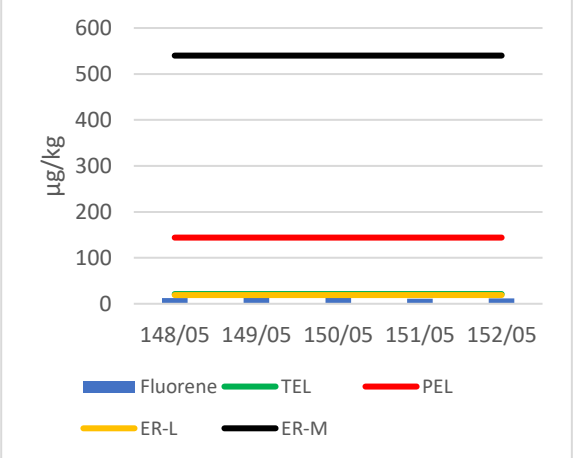


Figure 45 Fluorene concentration in Shipyard and marina „Navar“ by sampling location
in relation to TEL, PEL, ER-L and ER-M values

The anthracene content at locations of Shipyard and marina „Navar“ slightly exceeds the TEL value at one sampling location. Anthracene content at other sampling locations is below of TEL and ER-L values.
The fluorene content at locations of Shipyard and marina „Navar“ exceeds TEL and ER-L values at one sampling location while at other sampling locations is below of TEL and ER-L values.

Figure 46 and 47 show a graphic review of the concentrations of 2**-methylnaphthalene and naphthalene** in the sediment samples sampled at the Shipyard and marina „Navar“ site in relation to the values of sediment quality guidelines (SQG).

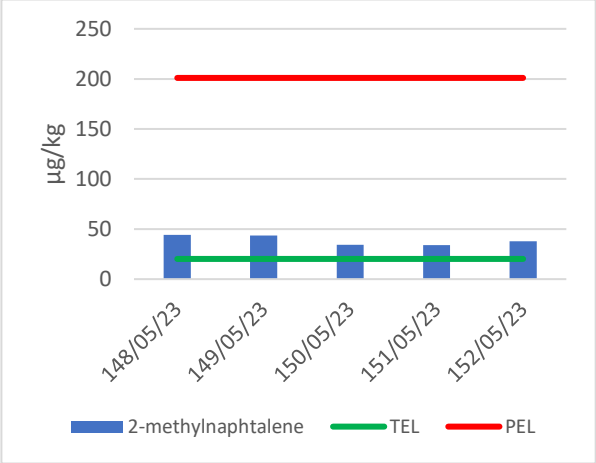


Figure 46 2-methylnaphthalene concentration in Shipyard and marina „Navar“ by sampling location
in relation to TEL and PEL values

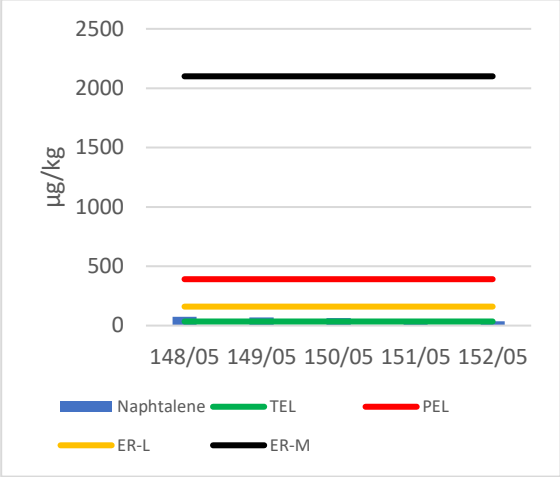


Figure 47 Naphthalene concentration in Shipyard and marina „Navar“ by sampling location
in relation to TEL, PEL, ER-L and ER-M values

The 2-methylnaphthalene content at all sampling sites in Shipyard and marina “Navar” location exceeds TEL values but is significantly below the prescribed PEL value.

The naphthalene content at locations of Shipyard and marina „Navar“ exceeds the TEL value at most sampling location but it is below of ER-L, PEL and ER-M values.

Figure 48 and 49 show a graphic review of the concentrations of **phenanthrene and benzo(a)anthracene** in the sediment samples sampled at the Shipyard and marina „Navar“ site, in relation to the values of two types of sediment quality guidelines (SQG).

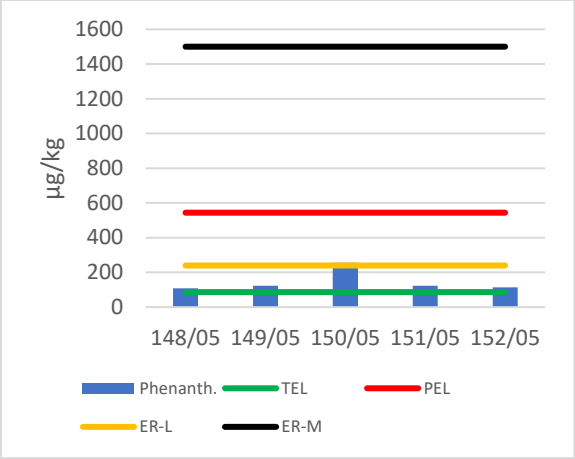


Figure 48 Phenanthrene concentration in Shipyard and marina „Navar“ by sampling location
in relation to TEL, PEL, ER-L and ER-M values

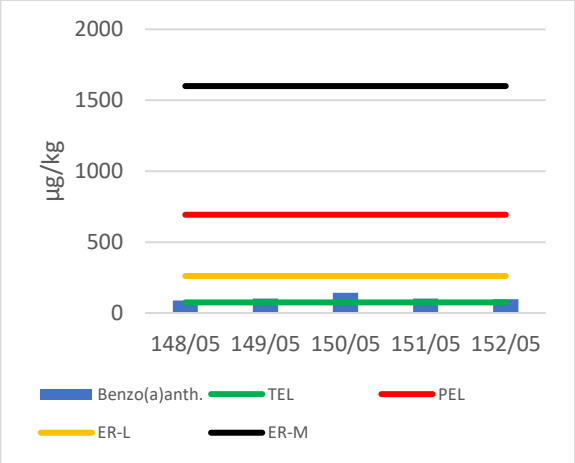


Figure 49 Benzo(a)anthracene concentration in Shipyard and marina „Navar“ by sampling location
in relation to TEL, PEL, ER-L and ER-M values

The phenanthrene content at all sampling locations of Shipyard and marina „Navar“ exceeds the TEL value and ER-L value at one sampling location but is significantly lower than the prescribed PEL and ER-M values.

The benzo(a)anthracene content at locations of Shipyard and marina „Navar“ exceeds the TEL value at all sampling location but these values are below the prescribed ER-L, PEL and ER-M values.

Figure 50 and 51 show a graphic review of the concentrations of **benzo(a)pyrene and dibenzo(a,h)anthracene** in the sediment samples sampled at the Shipyard and marina „Navar“ site, in relation to the values of two types of sediment quality guidelines (SQG).

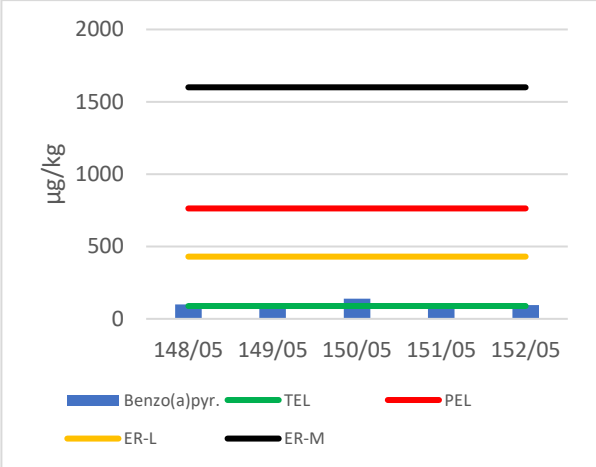


Figure 50 Benzo(a)pyrene concentration in Shipyard and marina „Navar“ by sampling location
in relation to TEL, PEL, ER-L and ER-M values

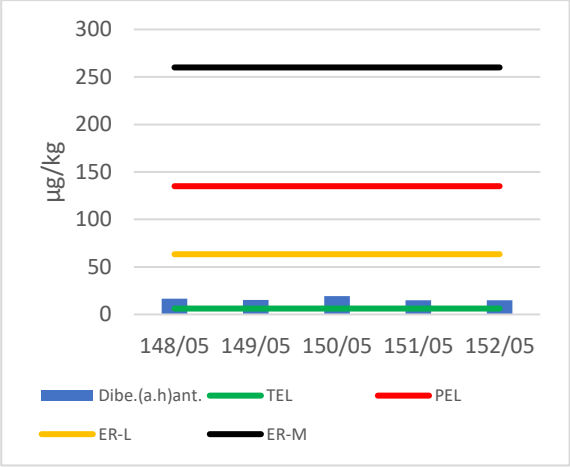


Figure 51 Dibenzo(a,h)anthracen concentration in Shipyard and marina „Navar“ by sampling location
in relation to TEL, PEL, ER-L and ER-M values

The benzo(a)pyrene content at locations of Shipyard and marina „Navar“ exceeds the TEL value at all sampling location. However, all obtained values for benzo(a)pyrene are lower than the prescribed PEL, ER-L and ER-M values.
The dibenzo(a.h)anthracene content at locations of Shipyard and marina „Navar“ exceeds the TEL value at all sampling locations, but these values are below the prescribed ER-L, PEL and ER-M values.

Figure 52 and 53 show a graphic review of the concentrations of **chrysene and fluoranthene** in the sediment samples sampled at the Shipyard and marina „Navar“ site, in relation to the values of two types of sediment quality guidelines (SQG).

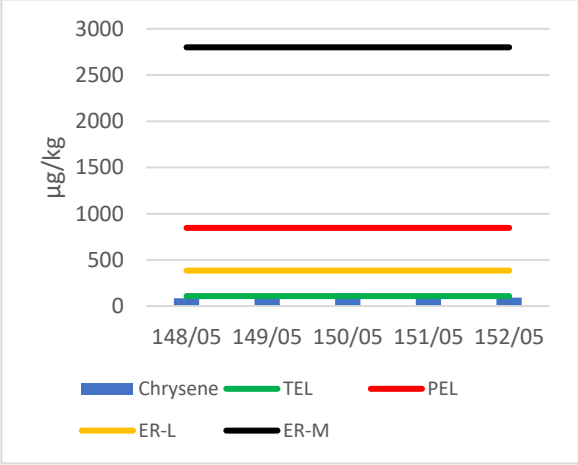


Figure 52 Chrysene concentration in Shipyard and marina „Navar“ by sampling location
in relation to TEL, PEL, ER-L and ER-M values

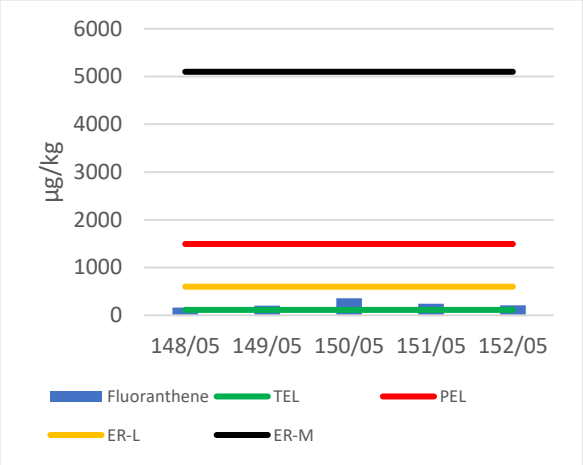


Figure 53 Fluoranthene concentration in Shipyard and marina „Navar“ by sampling location
in relation to TEL, PEL, ER-L and ER-M values

The chrysene content at locations of Shipyard and marina „Navar“exceeds the TEL value at one sampling location while on other locations are below the TEL value. All obtained values for chrysene are lower than the prescribed PEL, ER-L and ER-M values.
The fluoranthene content at locations of Shipyard and marina „Navar“exceeds the TEL value at all sampling locations, but these values are below the prescribed ER-L, PEL and ER-M values.

Figure 54 and 55 show a graphic review of the concentrations of **pyrene and sum low molecular weight PAHs** in the sediment samples sampled at the Shipyard and marina „Navar“ site, in relation to the values of two types of sediment quality guidelines (SQG).

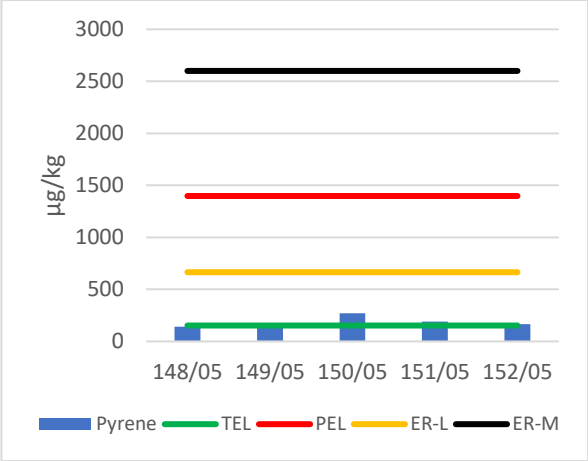


Figure 54 Pyrene concentration in Shipyard and marina „Navar“ by sampling location in relation to TEL, PEL, ER-L and ER-M values

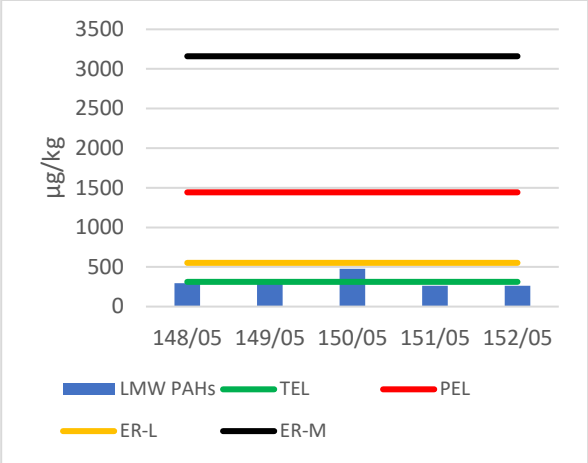


Figure 55 Sum LMW PAHs concentration in Shipyard and marina „Navar“ by sampling location in relation to TEL, PEL, ER-L and ER-M values

The pyrene content at locations of Shipyard and marina „Navar“ exceeds the TEL value at four sampling location but these values are below the prescribed ER-L, PEL and ER-M values. The sum low molecular weight PAHs content at locations of Shipyard and marina „Navar“ exceeds the TEL value at two sampling locations while on other locations are below the TEL value. All values of sum low molecular weight PAHs are below than the prescribed ER-L, PEL and ER-M values.

Figure 56 and 57 show a graphic review of the concentrations of **sum high molecular weight PAHs and total PAHs** in the sediment samples sampled at the Shipyard and marina „Navar“ site, in relation to the values of two types of sediment quality guidelines (SQG).

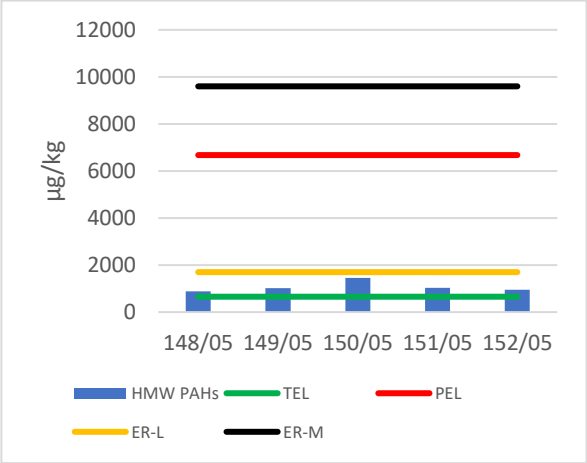


Figure 56 Sum HMW PAHs concentration in Shipyard and marina „Navar“ by sampling location in relation to TEL, PEL, ER-L and ER-M values

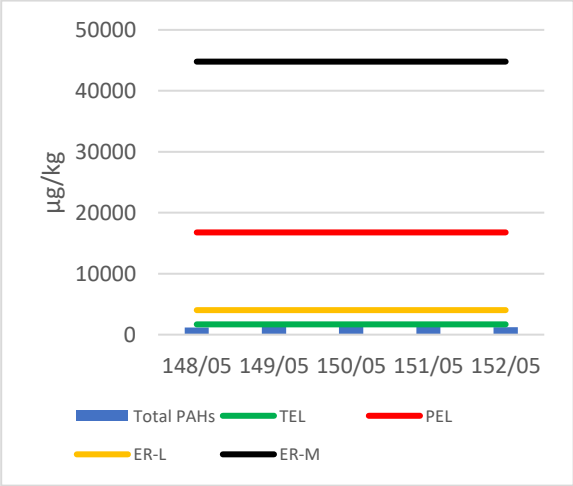


Figure 57 Total PAHs concentration in Shipyard and marina „Navar“ by sampling location in relation to TEL, PEL, ER-L and ER-M values

The sum high molecular weight PAHs content at locations of Shipyard and marina „Navar“ exceeds the TEL value at all sampling location but these values are below than the prescribed ER-L, PEL and ER-M values.
The total PAHs content at locations of Shipyard and marina „Navar“ slightly exceeds the TEL value at one sampling location. The total PAHs content at other sampling locations is below of TEL and ER-L values.

Organochlorine pesticides

Figure 58 and 59 show a graphic review of the concentrations of **total DDT** (sum of p,p'-DDT, p,p'DDD, pp'DDE, o, p'DDT, o,p'DDD and o,p'DDE) and **p,p'DDE** in the sediment samples sampled at the Shipyard and marina „Navar“ site, in relation to the values of sediment quality guidelines (SQG).

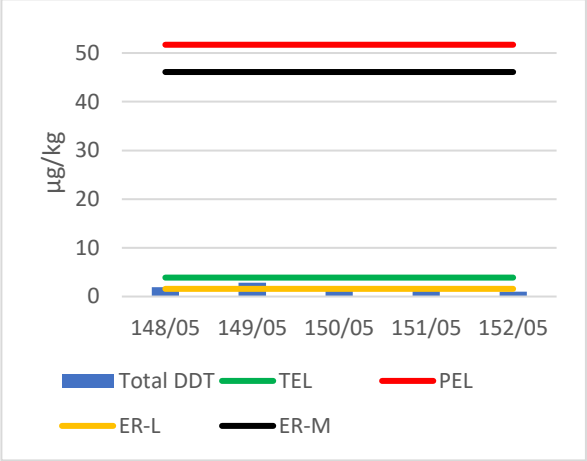


Figure 58 Total DDT concentration in Shipyard and marina „Navar“ by sampling location
in relation to TEL, PEL, ER-L and ER-M values

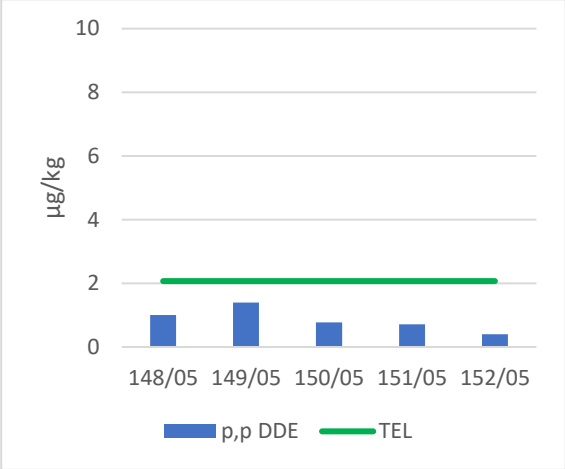


Figure 59 p,p DDE concentration in Shipyard and marina „Navar“ by sampling location
in relation to TEL and PEL values

The total DDT content at locations of Shipyard and marina „Navar“ exceeds the ER-L value at two sampling locations while on other locations are below the TEL, PEL and ER-M values.
The p,p'DDE content at all sampling locations on Shipyard and marina `Navar` location is bellow than TEL as wel as PEL values.

Figure 60 show a graphic review of the concentrations of **p,p'DDD** in the sediment samples sampled at the Shipyard and marina „Navar“ site, in relation to the values of sediment quality guidelines (SQG).

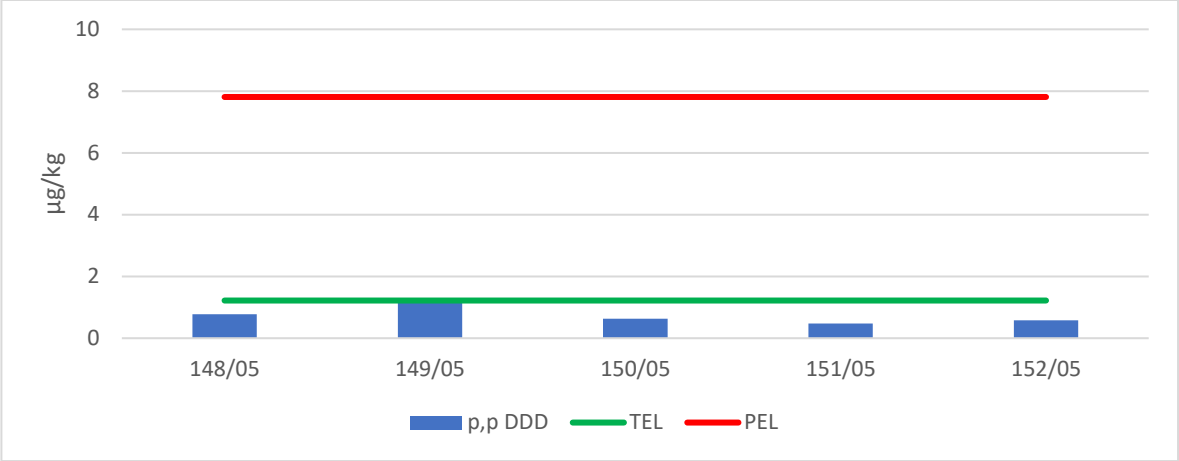


Figure 60 p,p DDD concentration in Shipyard and marina „Navar“ by sampling location in relation to TEL and PEL values

The p,p'DDD content at locations of Shipyard and marina „Navar“ slightly exceeds the TEL value at one sampling location. The p,p'DDD content at other sampling locations is below of TEL and ER-L values.

Organotin compounds

Figure 61 and 62 show a graphic review of the concentrations of **tributyltin and dibutyltin** in all sediment samples from Shipyard and marina „Navar“ location in relation with threshold value from Norwegian guidelines Risk assessment of contaminated sediments and CEFAS action levels for the disposal of dredged material.

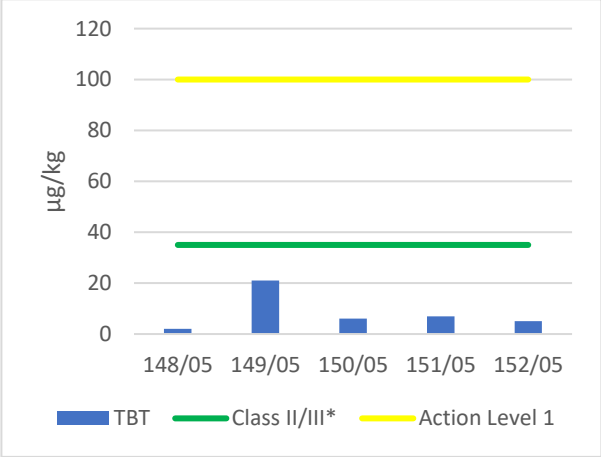


Figure 61 TBT concentration in Shipyard and marina „Navar“ by sampling location in relation to threshold value

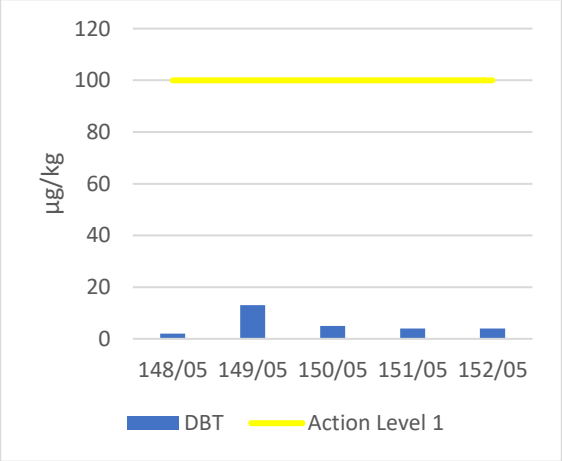
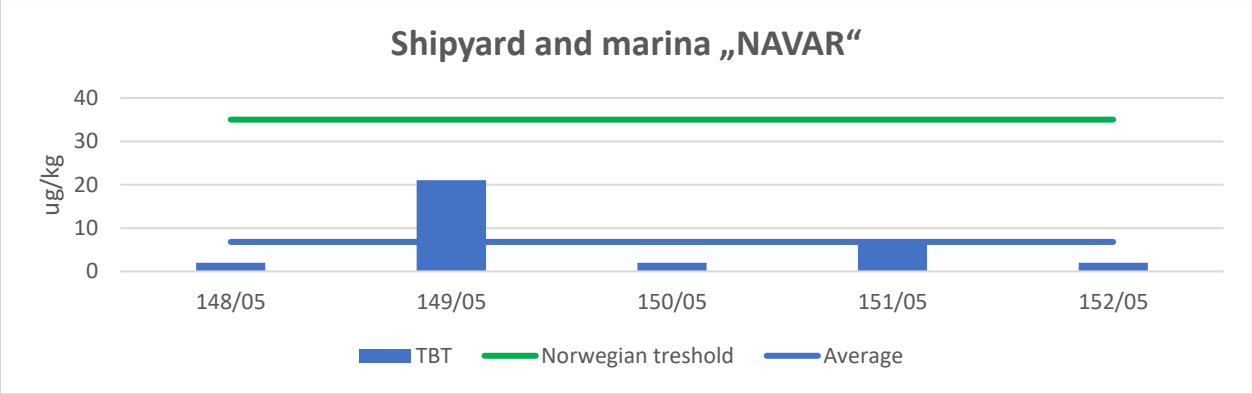


Figure 62 DBT concentration in Shipyard and marina „Navar“ by sampling location in relation to threshold value

The TBT and DBT content at all sampling points on Shipyard and marina „Navar“ location is below the threshold value from Norwegian guidelines Risk assessment of contaminated sediments and CEFAS action levels for the disposal of dredged material.

In Figure 62a, the concentrations of tributyltin in sediment samples collected from the Shipyard and Marina "NAVAR" location re illustrated. The graph includes the average value of tributyltin, providing a comparative perspective with the threshold value outlined in the Norwegian guidelines.

Figure 62a. Graphic representation of the concentrations of tributyltin in sediment samples from Shipyard and marina „NAVAR“ in relation with threshold value from Norwegian guidelines Risk assessment of contaminated sediments (M-1132, 2018).



It can be seen from the graph, that the average concentration of TBT in the whole sampling area calculated to be 21ug/kg dw at Shipyard and marina „NAVAR“ is below the Norwegian threshold value, and that no single concentration from sampling points does not exceed the treshold. This observation leads to a conclusion that the levels of TBT in the sediment at Shipyard and Marina "NAVAR" are within acceptable limits according to the Norwegian guidelines.

Contamination factor (CF) and enrichment factor (EF)

For the “Navar” locations, CF values for cadmium, lead, iron, and zinc at the “Navar” location in all samples show a low degree of contamination, while CF values for other tested metals are in the range of 1.0 ≤ CF < 3.0, indicating moderate contamination. The value of the MPLI (Metal Pollution Load Index), indicating a synergistic effect of all the studied heavy metals, for the location “Navar” is < 1, corresponding to the class of perfection

Table 11. Heavy metals contamination factor (CF) and metal pollution load index (MPLI)

		CF									
		Hg	As	Cd	Cr	Cu	Pb	Ni	Zn	Fe	**MPLI**
NAVAR	148/05	2.10	1.06	0.23	1.60	0.83	0.50	1.30	0.87	0.86	**0.88**
	149/05	1.51	0.95	0.29	1.41	1.41	0.58	1.21	0.89	0.74	**0.90**
	150/05	1.17	1.00	0.28	1.18	1.76	0.70	1.19	0.92	0.69	**0.89**
	151/05	1.17	1.07	0.18	1.39	1.15	0.52	1.21	0.86	0.72	**0.80**
	152/05	1.66	1.47	0.22	1.87	1.01	0.52	1.24	0.87	0.78	**0.91**

	Low contamination		Perfection
	Moderate contamination		Baseline level of contamination
	Considerable contamination		Deterioration of site quality
	Very high contamination		

Sediments from the Navar are significant enriched with mercury.

Table 12 Heavy metals enrichment factor (EF)

		Hg	As	Cd	Cr	Cu	Pb	Ni	Zn
NAVAR	148/05	7.46	1.21	0.98	0.90	1.26	1.22	0.77	1.65
	149/05	6.29	1.26	1.44	0.92	2.52	1.66	0.83	1.98
	150/05	5.20	1.43	1.49	0.83	3.36	2.16	0.88	2.17
	151/05	5.00	1.47	0.95	0.93	2.10	1.52	0.86	1.96
	152/05	6.49	1.85	1.03	1.15	1.70	1.40	0.80	1.81

Deficiency to minimal enrichment
Moderate enrichment
Significant enrichment
Very high enrichment
Extremely high enrichment

Airport Tivat

Results of metal analysis

Figure 63 and 64 show a graphic review of the concentrations of **mercury** and **arsenic** in the sediment samples sampled at the Airport Tivat site, in relation to the values of two types of sediment quality guidelines (SQG).

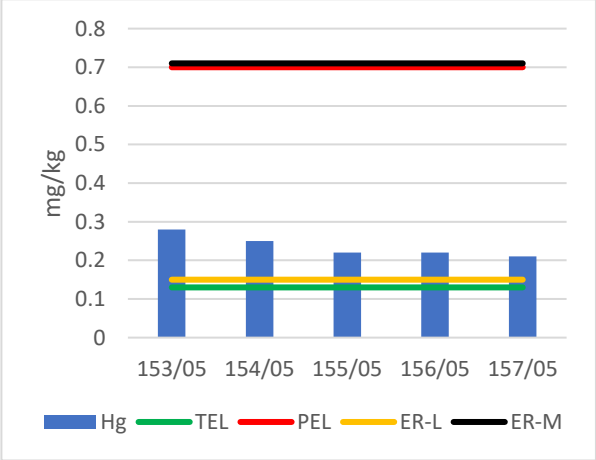


Figure 63 Mercury concentration in Airport Tivat by sampling location in relation to TEL, PEL, ER-L and ER-M values

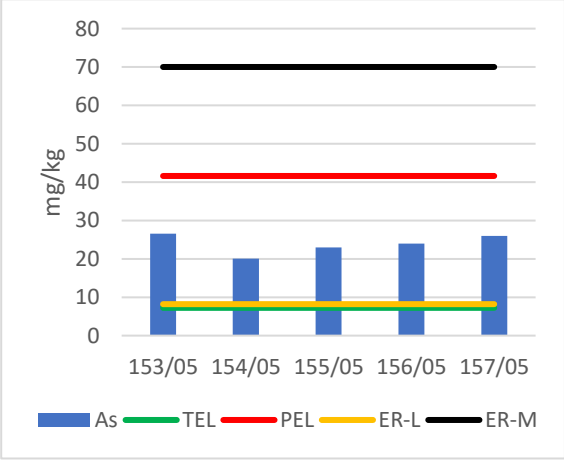


Figure 64 Arsenic concentration in Airport Tivat by sampling location in relation to TEL, PEL, ER-L and ER-M values

The content of mercury and arsenic at all sampling points of Tivat Airport exceeds both the TEL and ER-L values, but is significantly lower than the prescribed PEL and ER-M values.

Figure 65 and 66 show a graphic review of the concentrations of **cadmium and chromium** in the sediment samples sampled at the Airport Tivat site, in relation to the values of two types of sediment quality guidelines (SQG).

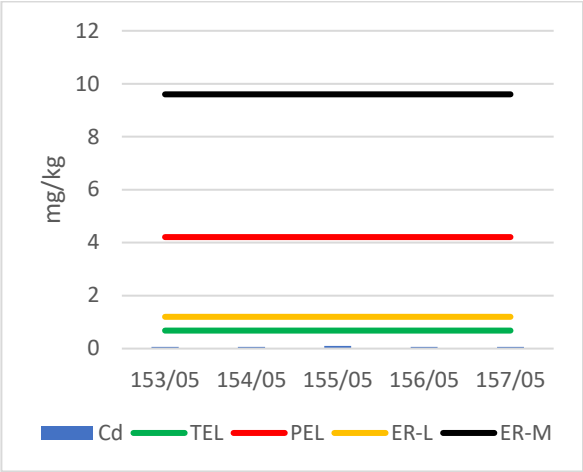


Figure 65 Cadmium concentration in Airport Tivat by sampling location in relation to TEL, PEL, ER-L and ER-M values

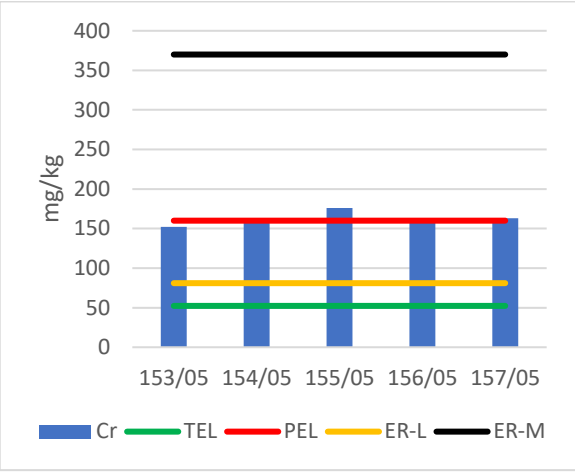
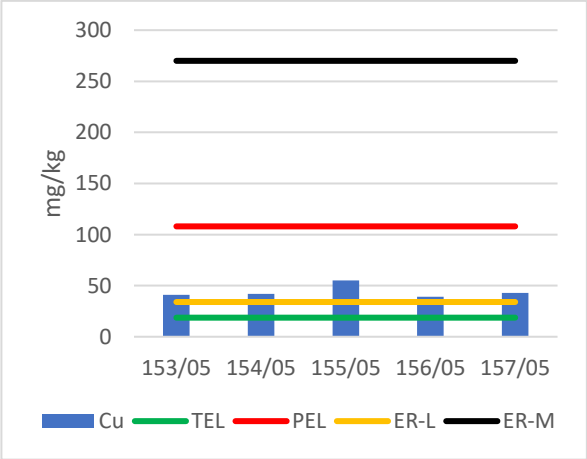


Figure 66 Chromium concentration in Airport Tivat by sampling location in relation to TEL, PEL, ER-L and ER-M values

The cadmium content at all sampling locations of Tivat Airport is significantly below TEL and other referent values.
The chromium content at all sampling locations of Airport Tivat exceeds both the TEL and ER-L values. The average value of chromium and values from most sampling points exceed the PEL value, but all measured values are significantly lower than the ER-M value.

Figure 67 and 68 show a graphic review of the concentrations of **copper and nickel** in the sediment samples sampled at the Airport Tivat site, in relation to the values of two types of sediment quality guidelines (SQG).



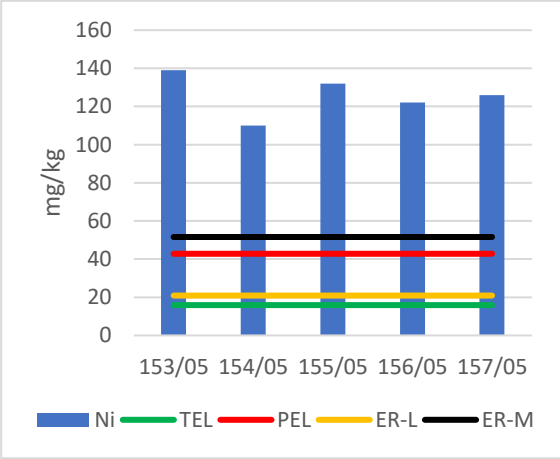


Figure 67 Copper concentration in Airport Tivat by sampling location in relation to TEL, PEL, ER-L and ER-M values

Figure 68 Nickel concentration in Airport Tivat by sampling location in relation to TEL, PEL, ER-L and ER-M values

The copper content at all sampling locations of Airport Tivat exceeds both the TEL and ER-L values, but is significantly lower than the PEL and ER-M values.
The nickel content at all sampling locations of Airport Tivat exceeds prescribed both the PEL and ER-M values.

Figure 69 and 70 show a graphic review of the concentrations of **lead** and **zinc** in the sediment samples sampled at the Airport Tivat site in relation to the values of two types of sediment quality guidelines (SQG).

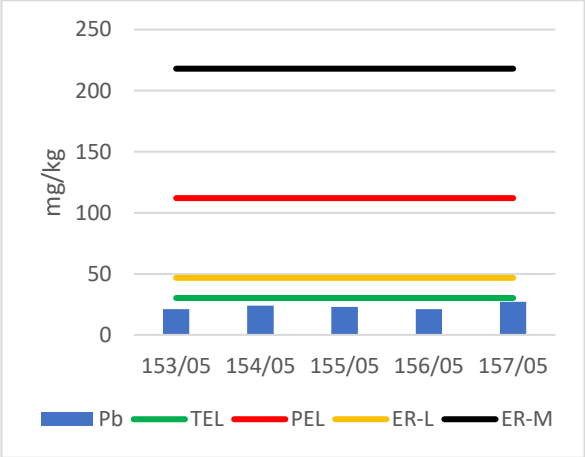


Figure 69 Lead concentration in Airport Tivat by sampling location in relation to TEL, PEL, ER-L and ER-M values

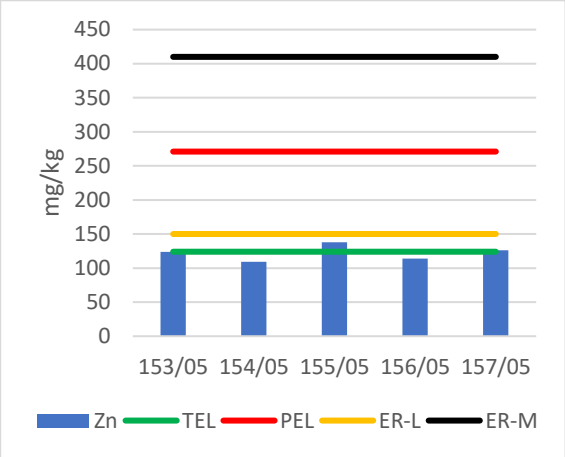


Figure 70 Zinc concentration in Airport Tivat by sampling location in relation to TEL, PEL, ER-L and ER-M values

The lead content at all sampling locations of Tivat Airport is below the TEL and ER-L values.
The zinc content at several sampling locations of Airport Tivat exceeds the TEL value, but all measured values of zinc content are significantly lower than the prescribed PEL and ER-M values.

Results of organic contaminants analysis

Polychlorinated biphenyls

Figure 71 show a graphic review of the concentrations of total PCBs in the sediment samples sampled at the Airport Tivat site, as well as the average value of total PCBs in relation to the values of two types of sediment quality guidelines (SQG).

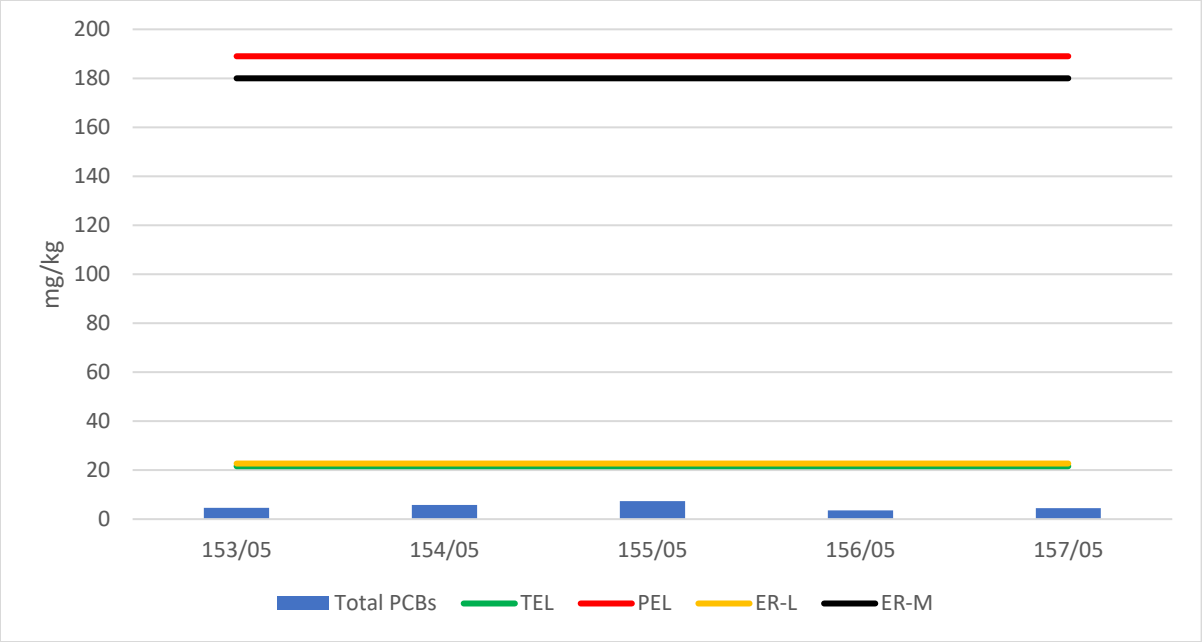


Figure 71 Total PCBs concentration in Airport Tivat by sampling location in relation to TEL, PEL, ER-L and ER-M values

The total PCBs content in all samples sampled from the Airport Tivat location is below the prescribed TEL and ER-L values.

Polyaromatic hydrocarbons

Figure 72 and 73 show a graphic review of the concentrations of **acenaphthene** and **acenaphthylene** in the sediment samples sampled at the Airport Tivat site in relation to the values of sediment quality guidelines (SQG).

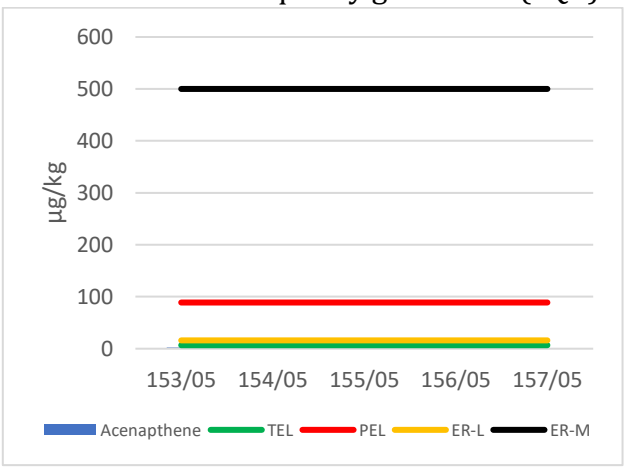


Figure 72 Acenaphthene concentration in Airport Tivat by sampling location in relation to TEL, PEL, ER-L and ER-M values

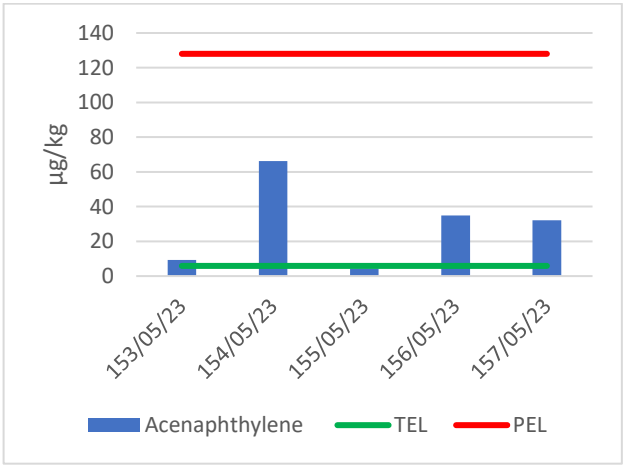


Figure 73 Acenaphthylene concentration in Airport Tivat by sampling location in relation to TEL and PEL values

The acenaphthene content at locations of Airport Tivat slightly exceeds the TEL value at one sampling location. The acenaphthene content at other sampling locations is below of TEL and ER-L values.
The acenaphthylene content at locations of Airport Tivat exceeds TEL value at four sampling locations but these values are below than the prescribed PEL value.

Figure 74 and 75 show a graphic review of the concentrations of **anthracene** and **fluorene** in the sediment samples sampled at the Airport Tivat site in relation to the values of two types of sediment quality guidelines (SQG).

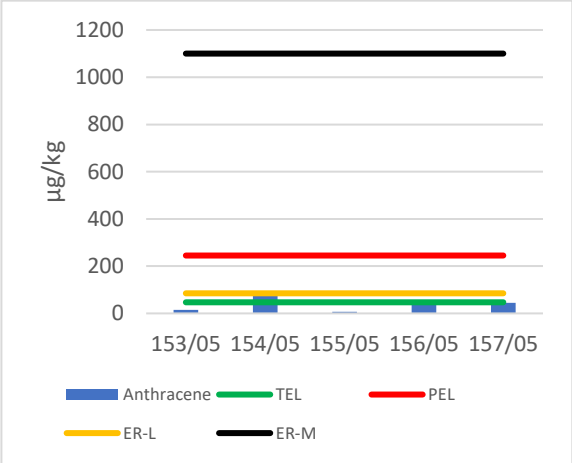


Figure 74 Anthracene concentration in Airport Tivat by sampling location in relation to TEL, PEL, ER-L and ER-M values

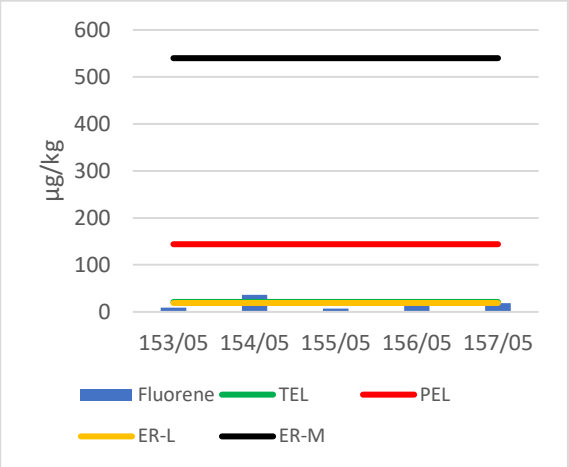


Figure 75 Fluorene concentration in Airport Tivat by sampling location in relation to TEL, PEL, ER-L and ER-M values

The anthracene content at locations of Tivat Airport exceeds TEL value at two sampling location and ER-L value at one sampling location. The anthracene content at other sampling locations is below of TEL and ER-L values.

The fluorene content at locations of Tivat Airport exceeds TEL and ER-L values at two sampling locations while at other sampling locations is below of TEL and ER-L values.
Figure 76 and 77 show a graphic review of the concentrations of **2-methylnaphthalene** and **naphthalene** in the sediment samples sampled at the Airport Tivat site in relation to the values of sediment quality guidelines (SQG).

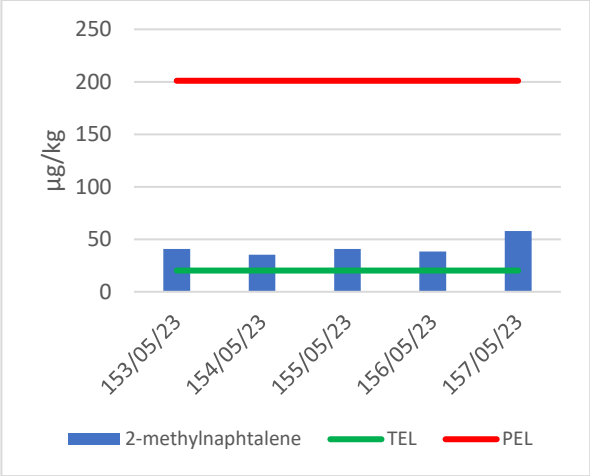


Figure 76 2-methylnaphthalene concentration
in Airport Tivat by sampling location
in relation to TEL and PEL, values

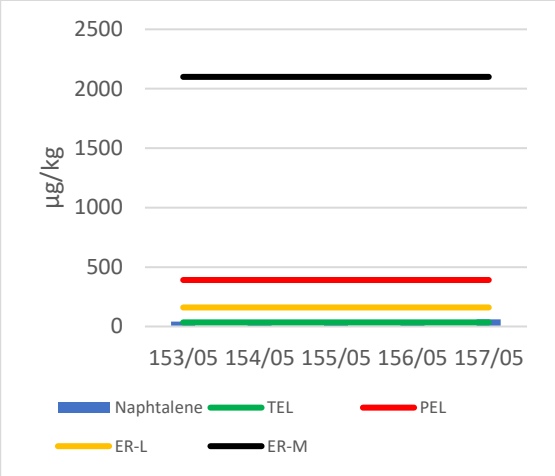


Figure 77 Naphthalene concentration
in Airport Tivat by sampling location
in relation to TEL, PEL, ER-L and ER-M
values

The 2-methylnaphthalene content at all sampling locations in Porto Montenegro exceeds TEL value and most of them also exceeds PEL value.

The naphthalene content at locations of Tivat Airport exceeds the TEL value at most sampling location but it is below of ER-L, PEL and ER-M values.

Figure 78 and 79 show a graphic review of the concentrations of **phenanthrene** and **benzo(a)anthracene** in the sediment samples sampled at the Airport Tivat site in relation to the values of two types of sediment quality guidelines (SQG).

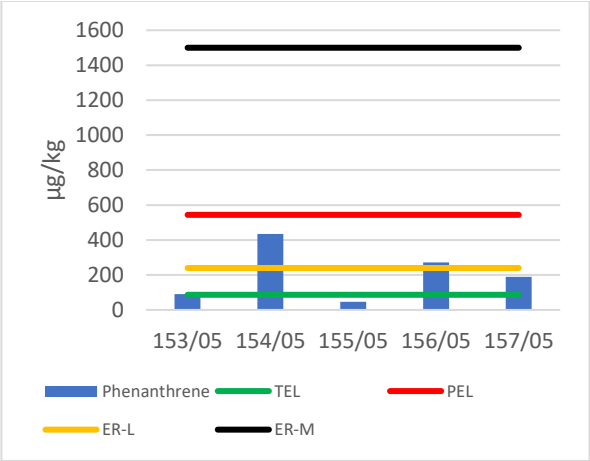


Figure 78 Phenanthrene concentration in
Airport Tivat by sampling location
in relation to TEL, PEL, ER-L and ER-M
values

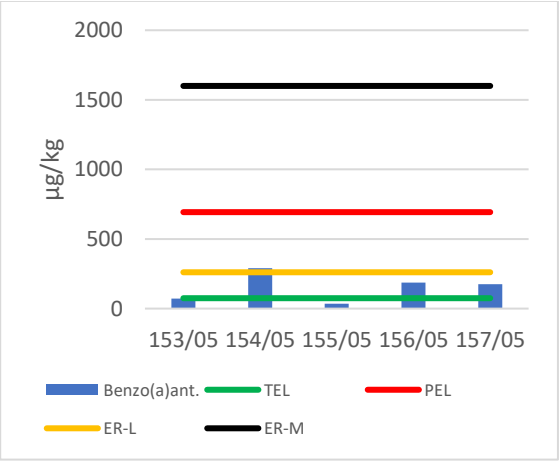


Figure 79 Benzo(a)anthracene
concentration in Airport Tivat by
sampling location
in relation to TEL, PEL, ER-L and ER-M
values

The phenanthrene content at locations of Tivat Airport exceeds TEL value at two sampling location and and ER-L value at one sampling location but all values are significantly lower than the prescribed PEL and ER-M values.
The benzo(a)anthracene content at locations of Tivat Airport exceeds the TEL value at three sampling locations and ER-L value at one sampling location. However, all obtained values for benzo(a)anthracene are lower than the prescribed PEL and ER-M values.

Figure 80 and 81 show a graphic review of the concentrations of **benzo(a)pyrene** and **dibenzo(a,h)anthracene** in the sediment samples sampled at the Airport Tivat site in relation to the values of two types of sediment quality guidelines (SQG).

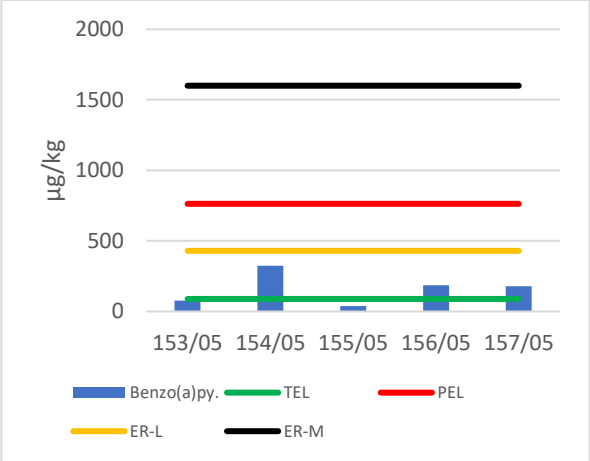


Figure 80 Benzo(a)pyrene concentration in Airport Tivat by sampling location in relation to TEL, PEL, ER-L and ER-M values

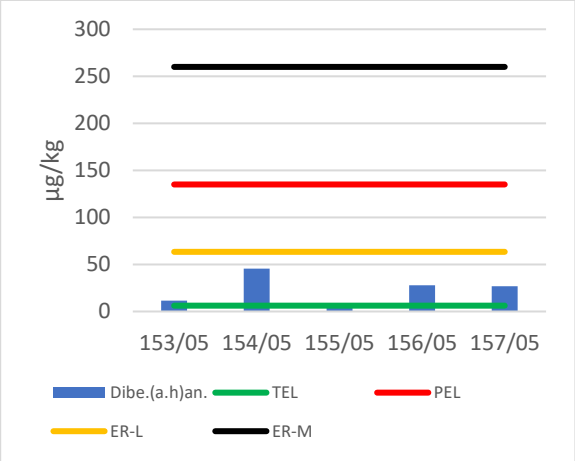


Figure 81 Dibenzo(a,h)anthracen concentration in Airport Tivat by sampling location in relation to TEL, PEL, ER-L and ER-M values

The benzo(a)pyrene content at locations of Airport Tivat exceeds the TEL value at three sampling location. However, all obtained values for benzo(a)pyrene are lower than the prescribed PEL, ER-L and ER-M values.
The dibenzo(a.h)anthracene content at locations of Airport Tivat exceeds the TEL value at all sampling locations, but obtained values are lower than the prescribed PEL, ER-L and ER-M values.

Figure 82 and 83 show a graphic review of the concentrations of **chrysene** and **fluoranthene** in the sediment samples sampled at the Airport Tivat site in relation to the values of two types of sediment quality guidelines (SQG).

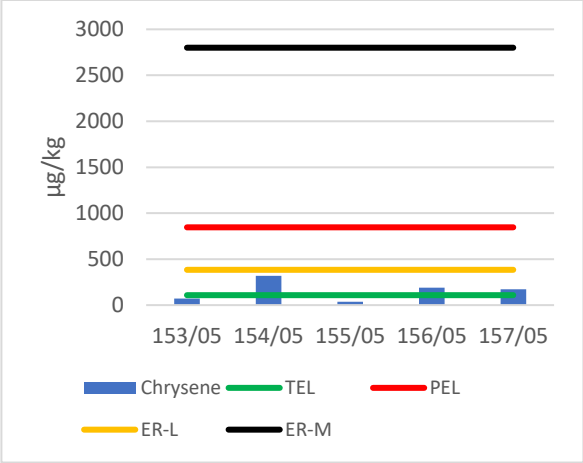


Figure 82 Chrysene concentration in Airport Tivat by sampling location in relation to TEL, PEL, ER-L and ER-M values

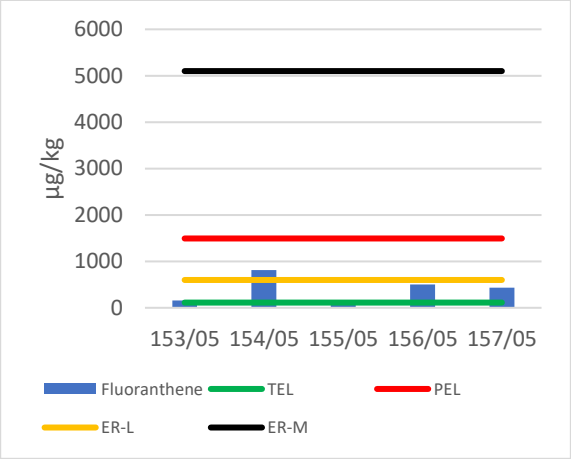


Figure 83 Fluoranthene concentration in Airport Tivat by sampling location in relation to TEL, PEL, ER-L and ER-M values

The chrysene content at locations of Airport Tivat exceeds the TEL value at all sampling locations, but these values are below the prescribed ER-L, PEL and ER-M values.
The fluoranthene content at locations of Tivat Airport exceeds TEL values at four sampling locations and ER-L value at one sampling location but all obtained concentrations of fluoranthene are below of PEL and ER-M values.

Figure 84 and 85 show a graphic review of the concentrations of **pyrene** and **sum low molecular weight PAHs** in the sediment samples sampled at the Airport Tivat site in relation to the values of two types of sediment quality guidelines (SQG).

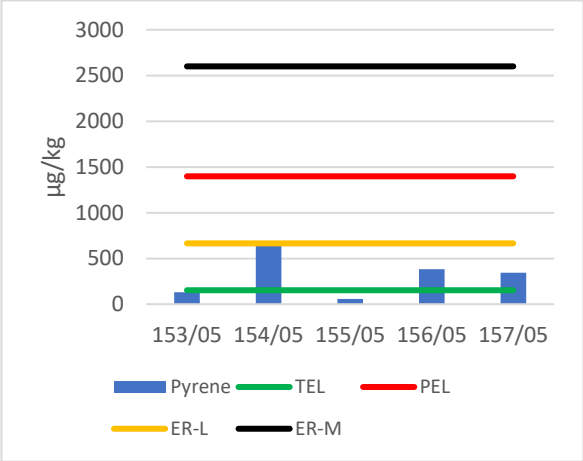


Figure 84 Pyrene concentration in Airport Tivat by sampling location in relation to TEL, PEL, ER-L and ER-M values

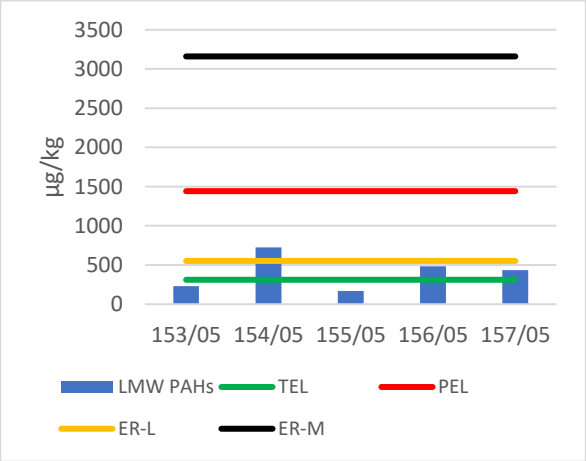


Figure 85 Sum LMW PAHs concentration in Airport Tivat by sampling location in relation to TEL, PEL, ER-L and ER-M values

The pyrene content at locations of Tivat Airport exceeds the TEL value at three sampling locations, however all obtained values for pyrene are lower than the ER-L, PEL and ER-M values.

The sum low molecular weight PAHs content at locations of Tivat Airport exceeds TEL values at three sampling locations and ER-L value at one sampling location but all obtained concentrations of sum low molecular weight PAHs are below of PEL and ER-M values.

Figure 86 and 87 show a graphic review of the concentrations of **sum high molecular weight PAHs** and **total PAHs** in the sediment samples sampled at the Airport Tivat site in relation to the values of two types of sediment quality guidelines (SQG).

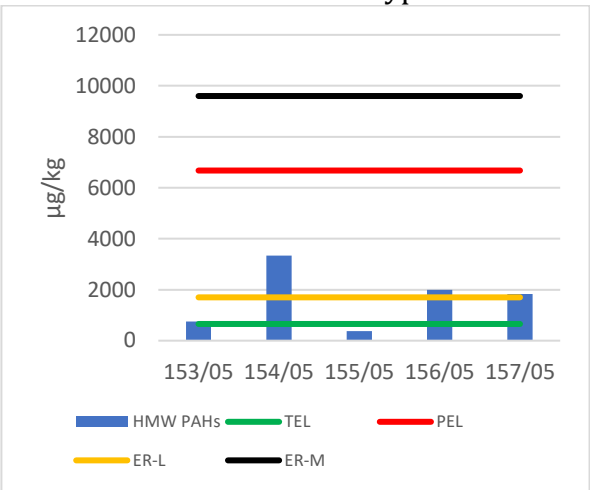


Figure 86 Sum HMW PAHs concentration in Airport Tivat by sampling location in relation to TEL, PEL, ER-L and ER-M values

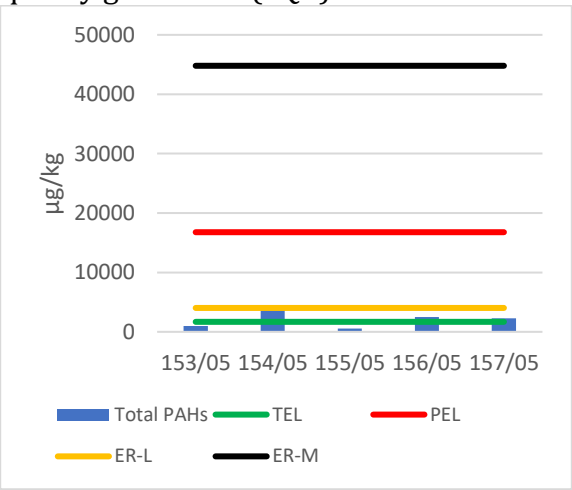


Figure 87 Total PAHs concentration in Airport Tivat by sampling location in relation to TEL, PEL, ER-L and ER-M values

The sum high molecular weight PAHs content at locations of Tivat Airport exceeds TEL values at four sampling locations and ER-L value at three sampling location but all obtained concentrations of high molecular weight PAHs are below of PEL and ER-M values.
The total PAHs content at locations of Tivat Airport exceeds the TEL value at three sampling locations and ER-L value at one sampling location. However, all obtained values for total PAHs are lower than the PEL and ER-M values.

Organochlorine pesticides

Figure 88 and 89 show a graphic review of the concentrations of **total DDT** (sum of p,p'-DDT, p,p'DDD, pp'DDE, o, p'DDT, o,p'DDD and o,p'DDE) and **p,p'DDE** in the sediment samples sampled at the Airport Tivat site in relation to the values of sediment quality guidelines (SQG).

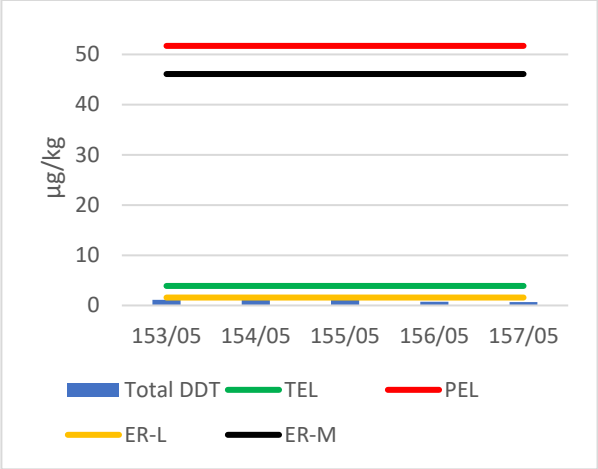


Figure 88 Total DDT concentration in Airport Tivat by sampling location in relation to TEL, PEL, ER-L and ER-M values

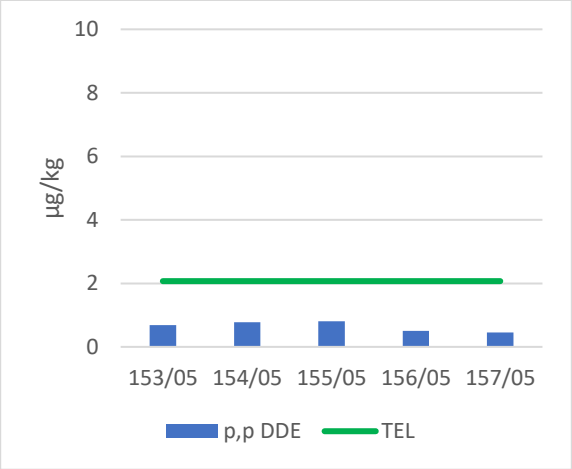


Figure 89 p,p DDE concentration in Airport Tivat by sampling location in relation to TEL and PEL values

The total DDT content in all samples sampled from the Airport Tivat location is below the prescribed TEL and ER-L values.
The p,p'DDE content at all sampling points on Airport Tivat location is below the TEL as wel as PEL values.

Figure 90 show a graphic review of the concentrations of **p,p'DDD** in the sediment samples sampled at the Airport Tivat site, in relation to the values of sediment quality guidelines (SQG).

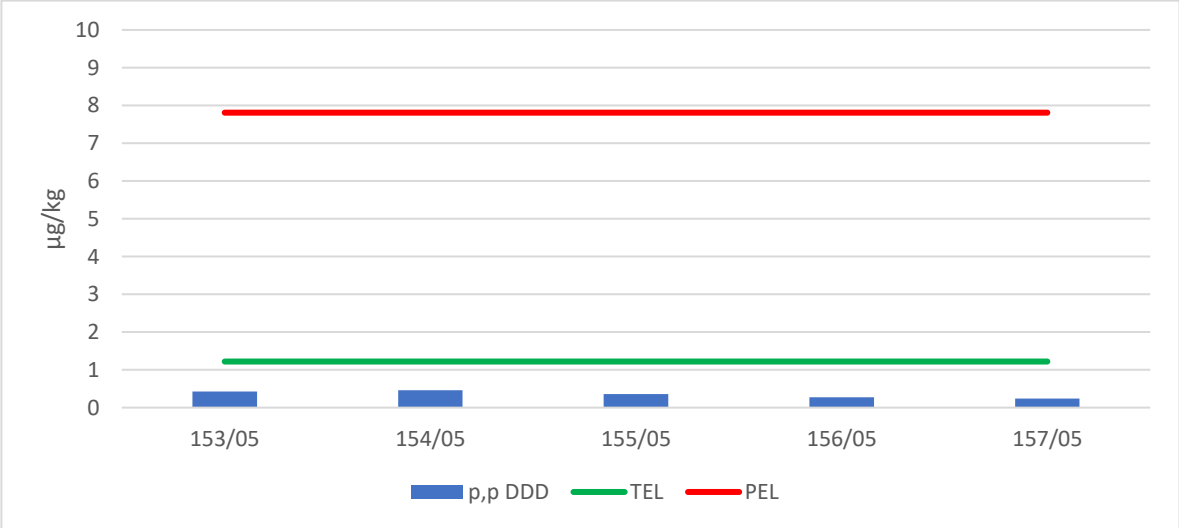


Figure 90 p,p DDD concentration in Airport Tivat by sampling location in relation to TEL and PEL values

The average concentration of p,p'DDD as well as concentrations of p, p'DDD in all sampling points in Airport Tivat is below both TEL and PEL values.

Organotin compounds

Figure 91 and 92 show a graphic review of the concentrations of **tributyltin and dibutyltin** in all sediment samples from Airport Tivat location in relation with threshold value from Norwegian guidelines Risk assessment of contaminated sediments and CEFAS action levels for the disposal of dredged material.

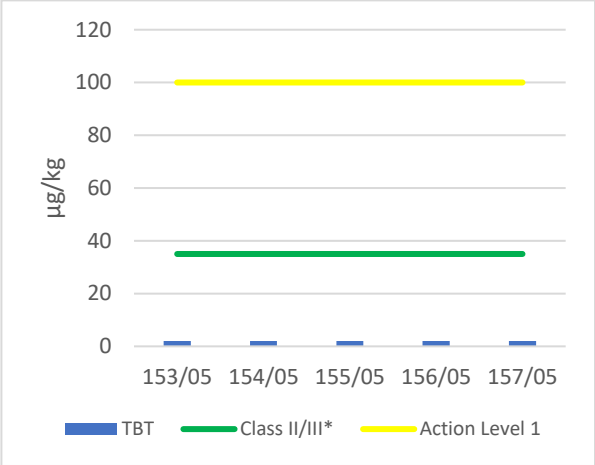


Figure 91 TBT concentration in Airport Tivat by sampling location in relation to threshold value

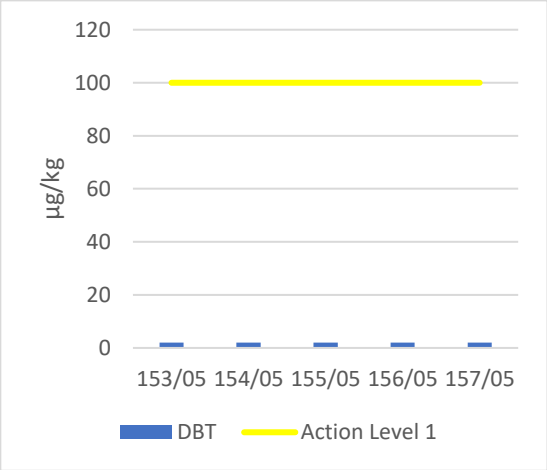


Figure 92 DBT concentration in Airport Tivat by sampling location in relation to threshold value

The TBT and DBT content at all sampling points on Airport Tivat location is below the threshold value from Norwegian guidelines Risk assessment of contaminated sediments and CEFAS action levels for the disposal of dredged material.

The results from the analysis conducted at the Airport Tivat location reveal a positive environmental status concerning the concentration of tributyltin (TBT). In all samples taken, the TBT levels were consistently found to be below the limit of quantification. This observation is indicative of a good environmental condition at the Airport Tivat site in terms of TBT contamination.

Contamination factor (CF) and enrichment factor (EF)

For the Airport Tivat, CF values for cadmium, lead, iron, and zinc at the Navar location in all samples show a low degree of contamination, while CF values for other tested metals are in the range of $1.0 \leq CF < 3.0$, indicating moderate contamination.

The value of the MPLI (Metal Pollution Load Index), indicating a synergistic effect of all the studied heavy metals, for the locations Airport Tivat, is < 1, corresponding to the class of perfection.

Table 12. Heavy metals contamination factor (CF) and metal pollution load index (MPLI)

		CF									
		Hg	As	Cd	Cr	Cu	Pb	Ni	Zn	Fe	**MPLI**
AERODROM TIVAT	153/05	1.37	1.56	0.19	1.29	1.09	0.43	1.51	1.01	0.82	**0.88**
	154/05	1.22	1.18	0.18	1.37	1.12	0.50	1.19	0.88	0.71	**0.81**
	155/05	1.07	1.35	0.27	1.50	1.47	0.48	1.43	1.12	0.70	**0.92**
	156/05	1.07	1.41	0.17	1.38	1.04	0.43	1.32	0.93	0.73	**0.80**
	157/05	1.02	1.53	0.18	1.39	1.15	0.56	1.37	1.02	0.80	**0.87**

	Low contamination		Perfection
	Moderate contamination		Baseline level of contamination
	Considerable contamination		Deterioration of site quality
	Very high contamination		

Sediments from the Airport Tivat location are moderate enriched with mercury. None of the tested samples can be classified as deficiency to minimal enrichment (EF < 2) regarding mercury content:

Table 13 Heavy metals enrichment factor (EF)

		Hg	**As**	**Cd**	**Cr**	**Cu**	**Pb**	**Ni**	**Zn**
	152/05	6.49	1.85	1.03	1.15	1.70	1.40	0.80	1.81
AERODROM TIVAT	153/05	5.11	1.87	0.88	0.76	1.76	1.12	0.93	2.00
	154/05	5.26	1.63	0.94	0.93	2.08	1.48	0.85	2.03
	155/05	4.71	1.90	1.45	1.04	2.76	1.44	1.04	2.62
	156/05	4.50	1.89	0.86	0.91	1.87	1.26	0.92	2.07
	157/05	3.91	1.87	0.82	0.83	1.88	1.47	0.86	2.08

	Deficiency to minimal enrichment
	Moderate enrichment
	Significant enrichment
	Very high enrichment
	Extremely high enrichment

Port of Risan

Results of metal analysis

Figure 93 and 94 show a graphic review of the concentrations of **mercury and arsenic** in the sediment samples sampled at the Port of Risan site, in relation to the values of two types of sediment quality guidelines (SQG).

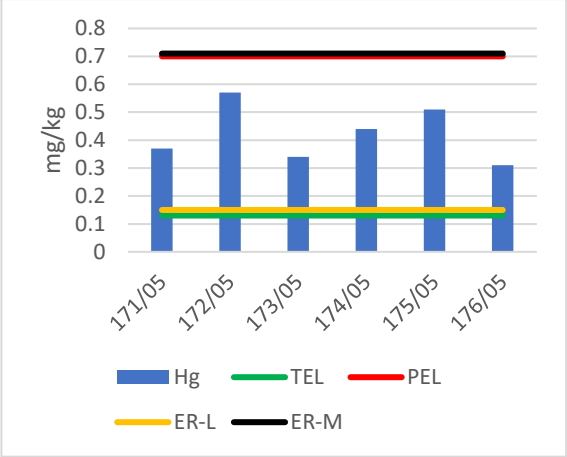


Figure 93 Mercury concentration in Port of Risan by sampling location in relation to TEL, PEL, ER-L and ER-M values

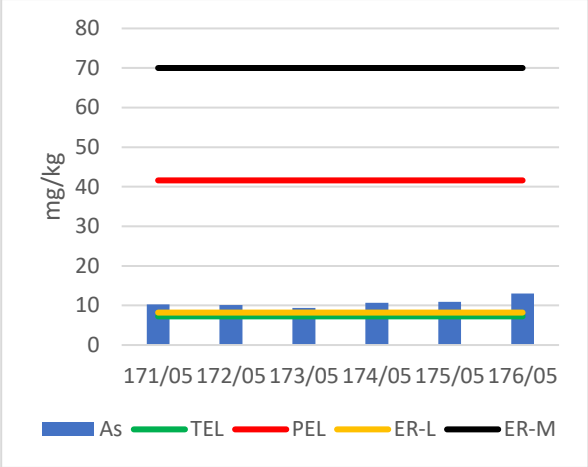


Figure 94 Arsenic concentration in Port of Risan by sampling location in relation to TEL, PEL, ER-L and ER-M values

The mercury content at the all-sampling locations in Port of Risan exceeds both TEL and ER-L values, but is lower than the PEL and ER-M values.

The arsenic content at all sampling locations of Port of Risan exceeds both the TEL and ER-L values, but is significantly lower than the PEL and ER-M values.

Figure 95 and 96 show a graphic review of the concentrations of **cadmium and chromium** in the sediment samples sampled at the Port of Risan site, in relation to the values of two types of sediment quality guidelines (SQG).

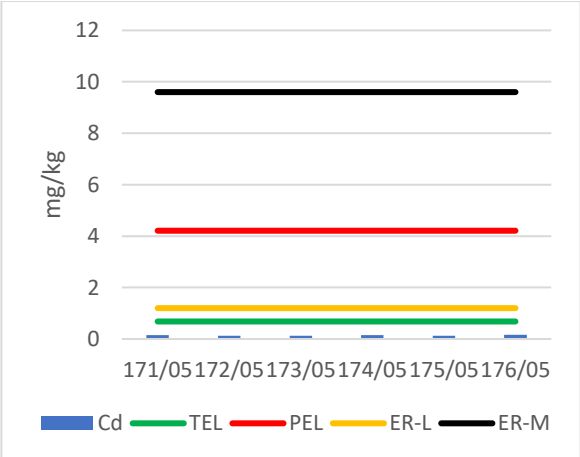


Figure 95 Cadmium concentration in Port of Risan by sampling location in relation to TEL, PEL, ER-L and ER-M values

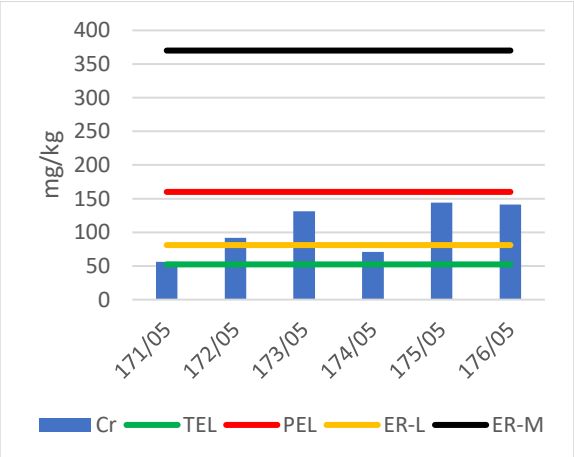


Figure 96 Chromium concentration in Port of Risan by sampling location in relation to TEL, PEL, ER-L and ER-M values

The cadmium content at all sampling locations of Port of Risan significantly below TEL, ER-L, PEL and ER-M values.
The chromium content at all sampling locations of Port of Risan exceeds the TEL value and at most of location exceeds the ER-L values.
Figure 97 and 98 show a graphic review of the concentrations of **copper and nickel** in the sediment samples sampled at the Port of Risan site, l in relation to the values of two types of sediment quality guidelines (SQG).

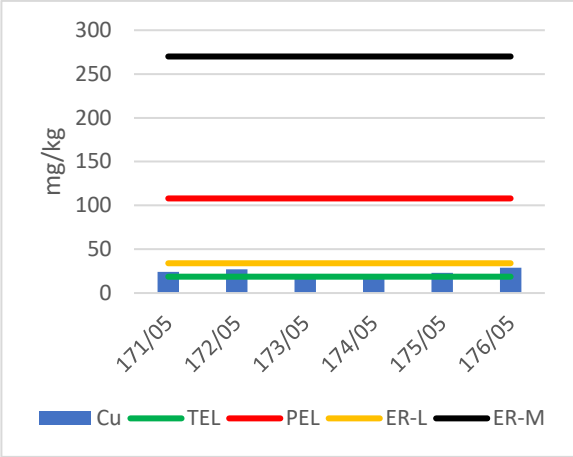


Figure 97 Copper concentration in Port of Risan by sampling location in relation to TEL, PEL, ER-L and ER-M values

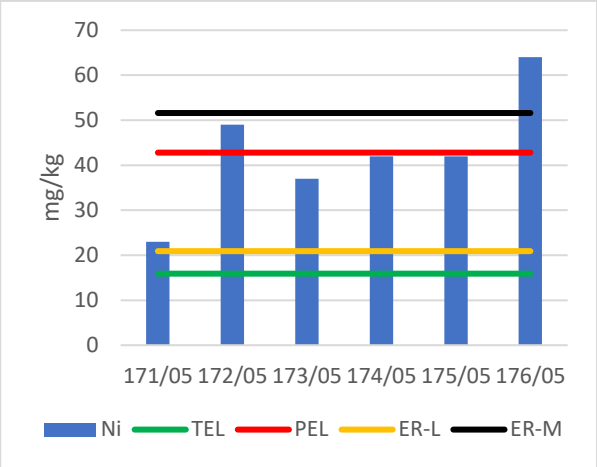


Figure 98 Nickel concentration in Port of Risan by sampling location in relation to TEL, PEL, ER-L and ER-M values

The copper content at all sampling locations of Port of Risan exceeds both the TEL and ER-L values, but is significantly lower than the prescribed PEL and ER-M values.
The nickel content at all sampling locations of Port of Risan exceeds both the TEL and ER-L values. The measured values of nickel content from several locations exceed the PEL value and from one sampling point exceeds the ER-M value.

Figure 99 and 100 show a graphic review of the concentrations of **lead and zinc** in the sediment samples sampled at the Port of Risan site, in relation to the values of two types of sediment quality guidelines (SQG).

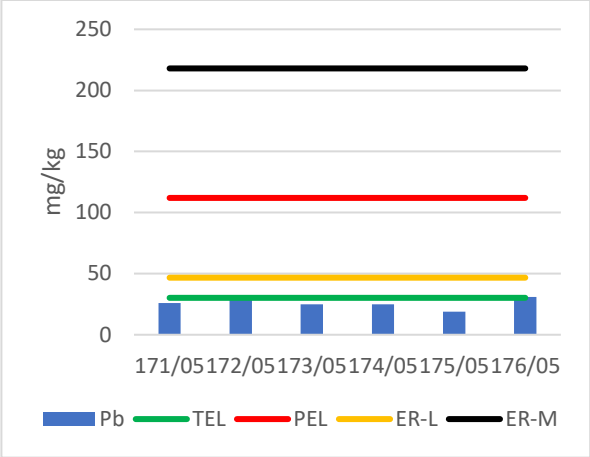


Figure 99 Lead concentration in Port of Risan by sampling location in relation to TEL, PEL, ER-L and ER-M values

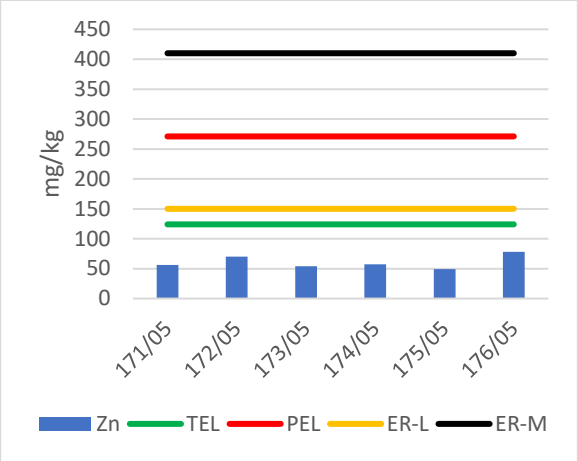


Figure 100 Zinc concentration in Port of Risan by sampling location in relation to TEL, PEL, ER-L and ER-M values

The lead content at several sampling locations of Port of Risan exceeds the TEL value, but all measured values of lead content are significantly lower than the prescribed PEL and ER-M values.
The results of the sediment analysis show that the zinc content at all sampling locations of Port of Risan is below the TEL and ER-L values.

Results of organic contaminants analysis

Polychlorinated biphenyls

Figure 101 show a graphic review of the concentrations of **total PCBs** in the sediment samples sampled at the Port of Risan site, in relation to the values of two types of sediment quality guidelines (SQG).

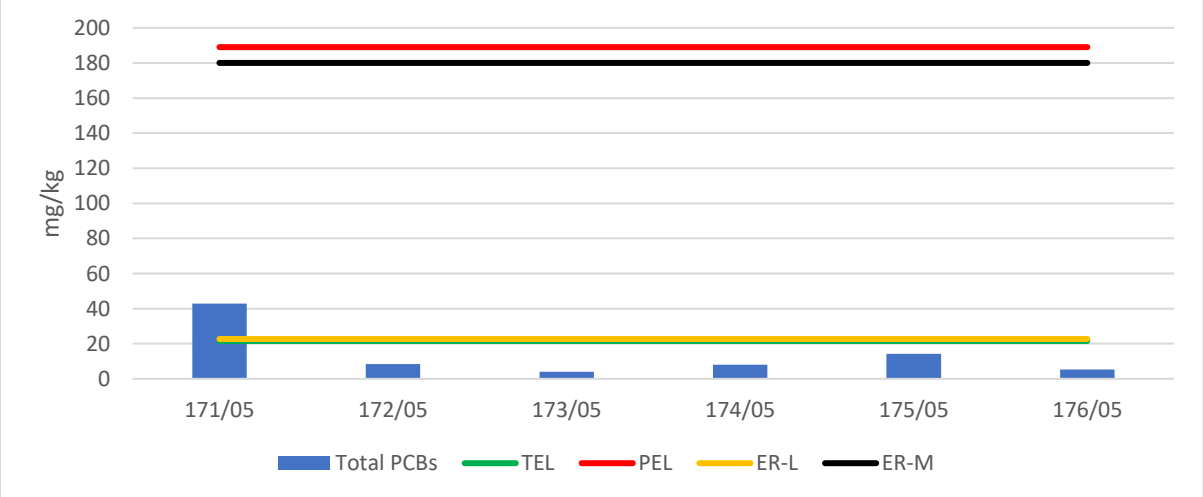


Figure 101 Total PCBs concentration in Port of Risan by sampling location in relation to TEL, PEL, ER-L and ER-M values

The total PCBs content only at one sampling location exceeds the TEL and ER-L values while on other locations the total PCBs content is lower than the prescribed TEL and ER-L values.

Polyaromatic hydrocarbons

Figure 102 and 103 show a graphic review of the concentrations of **acenaphthene and acenaphthylene** in the sediment samples sampled at the Port of Risan site, in relation to the values of sediment quality guidelines (SQG).

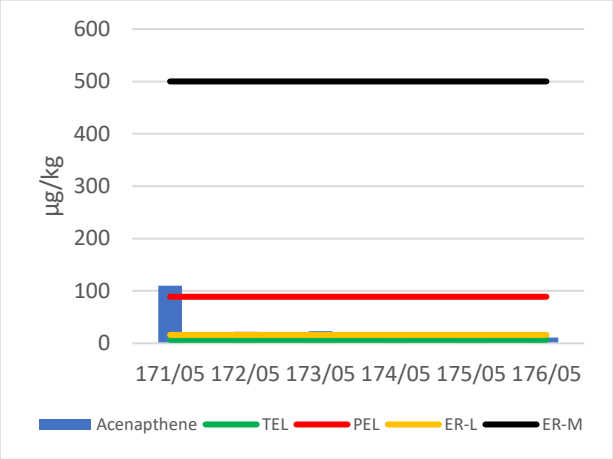


Figure 102 Acenaphthene concentration in Port of Risan by sampling location in relation to TEL, PEL, ER-L and ER-M values

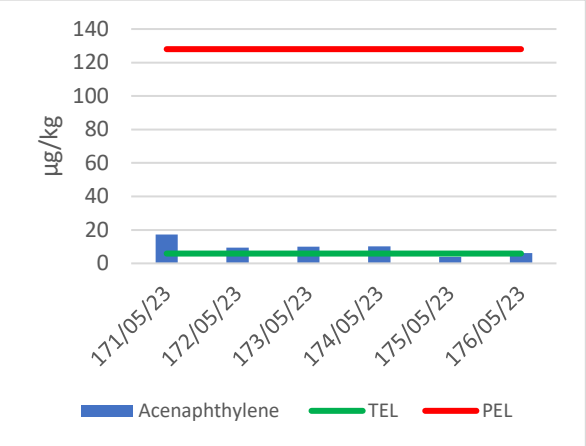


Figure 103 Acenaphthylene concentration in Port of Risan by sampling location in relation to TEL and PEL values

The acenaphthene content at five sampling locations of Port of Risan exceeds the TEL value and at three locations ER-L value, but all these values are significantly lower than the prescribed PEL and ER-M values.

The acenaphthylene content at five sampling locations in Port of Risan exceeds the TEL value, but these values are significantly lower than the PEL value.

Figure 104 and 105 show a graphic review of the concentrations of **anthracene and fluorene** in the sediment samples sampled at the Port of Risan site, in relation to the values of two types of sediment quality guidelines (SQG).

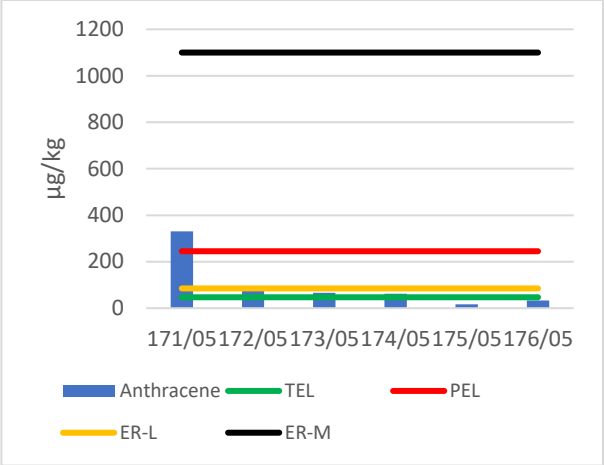


Figure 104 Anthracene concentration in Port of Risan by sampling location in relation to TEL, PEL, ER-L and ER-M values

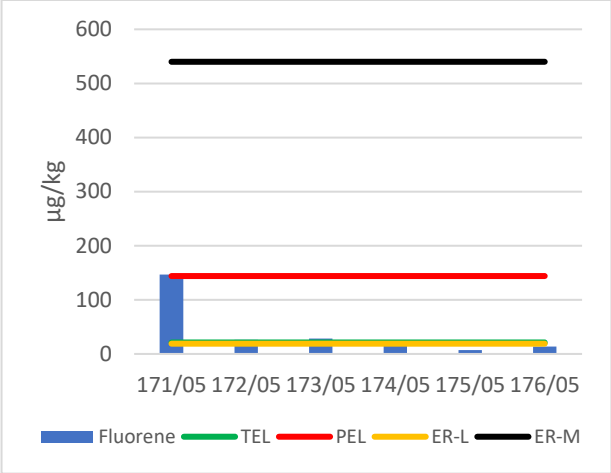


Figure 105 Fluorene concentration in Port of Risan by sampling location in relation to TEL, PEL, ER-L and ER-M values

The anthracene content at most of sampling location in Port of Risan exceeds TEL value and on one sampling location exceeds the PEL value.
The results of the sediment analysis show that the fluorene content at locations of Port of Risan exceeds PEL value at one sampling locations. In most of the tested samples from this location the fluorine content exceeds the TEL and ER-L values, but is significantly lower than the PEL and ER-M values.

Figure 106 and 107 show a graphic review of the concentrations of **2-methylnaphthalene and naphthalene** in the sediment samples sampled at the Port of Risan site, in relation to the values of sediment quality guidelines (SQG).

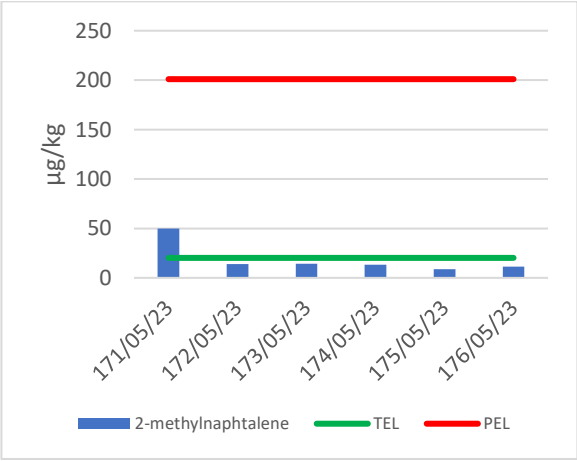


Figure 106 2-methylnaphthalene concentration in Port of Risan by sampling location in relation to TEL and PEL, values

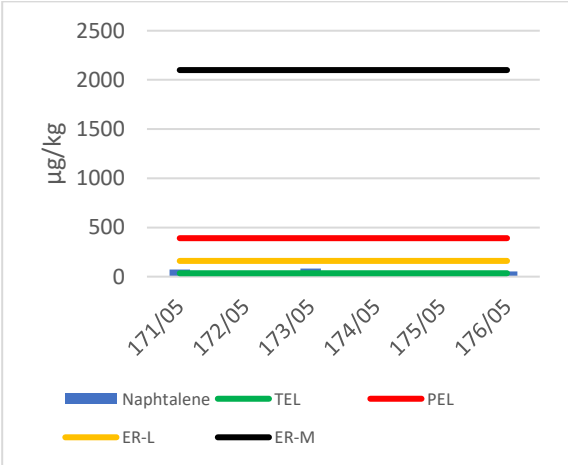


Figure 107 Naphthalene concentration in Port of Risan by sampling location in relation to TEL, PEL, ER-L and ER-M values

The content of 2-methylnaphthalene in sediment samples from the Port of Risan location is mostly below the TEL value. The 2-methylnaphthalene content exceed the TEL value at one sampling point but its content is lower than the prescribed PEL value.
The naphthalene content in all examined samples from the Port of Risan location was significantly lower than the prescribed TEL and ER-L values.

Figure 108 and 109 show a graphic review of the concentrations of **phenanthrene and benzo(a)anthracene** in the sediment samples sampled at the Port of Risan site in relation to the values of two types of sediment quality guidelines (SQG).

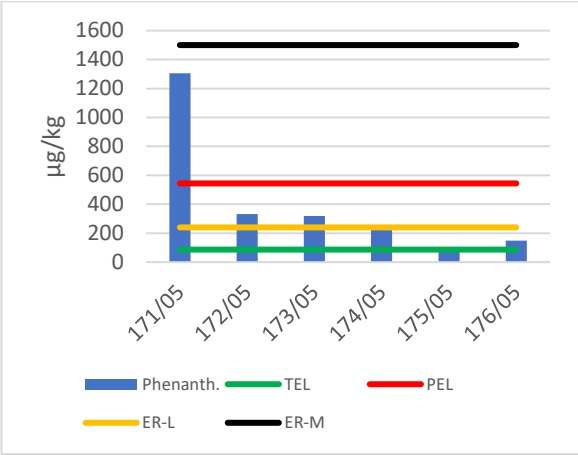


Figure 108 Phenanthrene concentration in Port of Risan by sampling location
in relation to TEL, PEL, ER-L and ER-M values

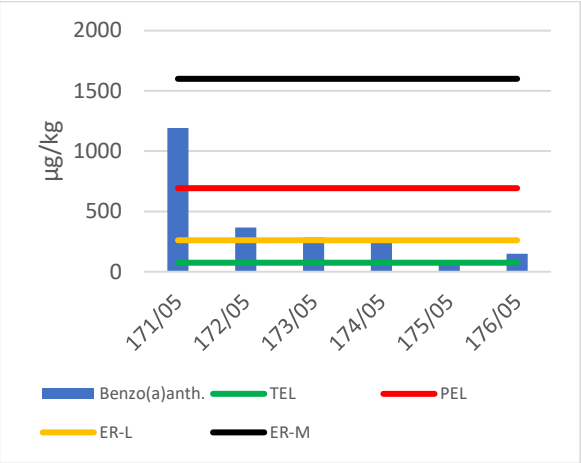


Figure 109 Benzo(a)anthracene concentration in Port of Risan by sampling location
in relation to TEL, PEL, ER-L and ER-M values

The phenanthrene and benzo(a)anthracene content at most of sampling locations in Port of Risan exceeds TEL and ER-L values and at one sampling location their content exceeds the PEL value.

Figure 110 and 111 show a graphic review of the concentrations of **benzo(a)pyrene and dibenzo(a,h)anthracene** in the sediment samples sampled at the Port of Risan site, in relation to the values of two types of sediment quality guidelines (SQG).

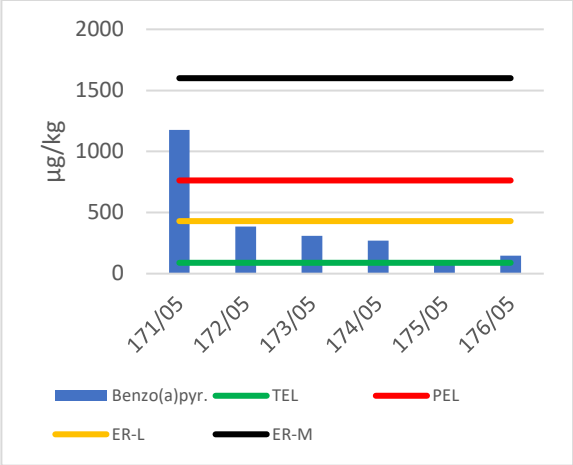


Figure 110 Benzo(a)pyrene concentration
in Port of Risan by sampling location
in relation to TEL, PEL, ER-L and ER-M values

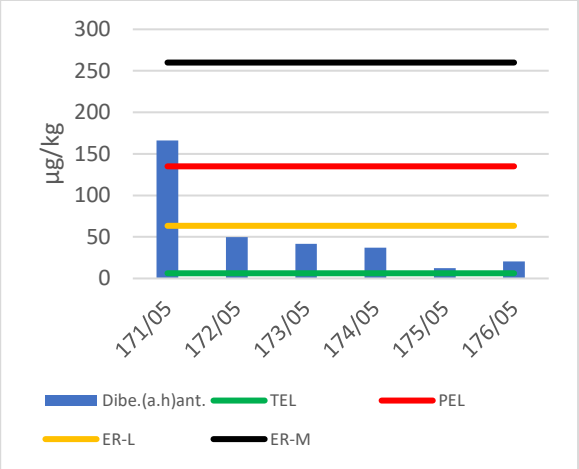


Figure 111 Dibenzo(a,h)anthracen concentration
in Port of Risan by sampling location
in relation to TEL, PEL, ER-L and ER-M values

The benzo(a)pyrene content at most of locations of Port of Risan exceeds the TEL value and PEL value at one location.
The dibenzo(a.h)anthracene content at most of Port of Risan locations exceeds the TEL value. The content of dibenzo(a.h)anthracene exceeds PEL value at one sampling point of Port of Risan location.

Figure 112 and 113 show a graphic review of the concentrations of **chrysene and fluoranthene** in the sediment samples sampled at the Port of Risan site, in relation to the values of two types of sediment quality guidelines (SQG).

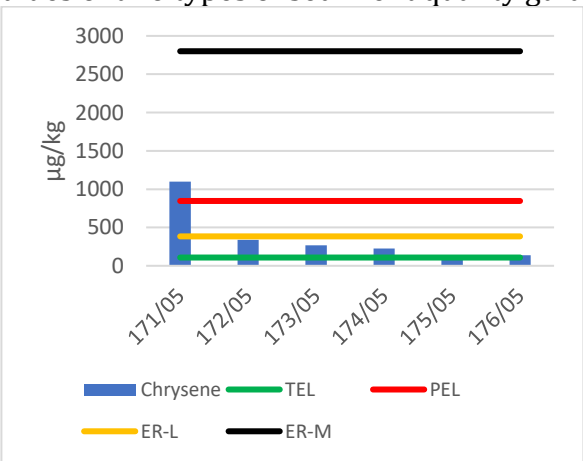


Figure 112 Chrysene concentration
in Port of Risan by sampling location
in relation to TEL, PEL, ER-L and ER-M values

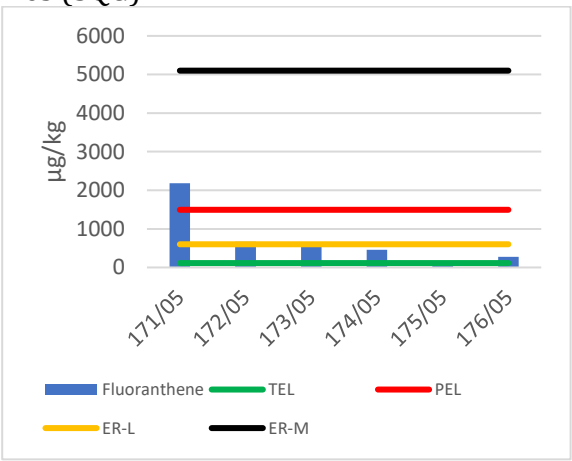


Figure 113 Fluoranthene concentration
in Port of Risan by sampling location
in relation to TEL, PEL, ER-L and ER-M values

The chrysene content exceeds PEL value at one sampling point in Port of Risan locations and TEL value at most of research sampling points.

At all sampling points from the Port of Risan location the content of fluoranthene exceeds the TEL value as well as ER-L value at three sampling locations. Sample from one sampling point contains an amount of fluoranthene higher than the prescribed PEL value.

Figure 114 and 115 show a graphic review of the concentrations of **pyrene and sum low molecular weight PAHs** in the sediment samples sampled at the Port of Risan site, in relation to the values of two types of sediment quality guidelines (SQG).

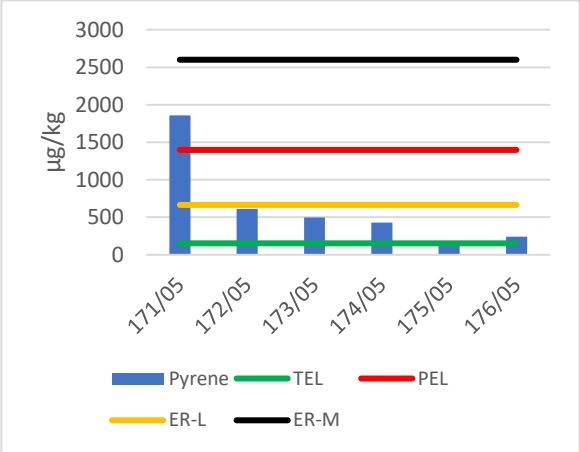


Figure 114 Pyrene concentration in Port of Risan by sampling location in relation to TEL, PEL, ER-L and ER-M values

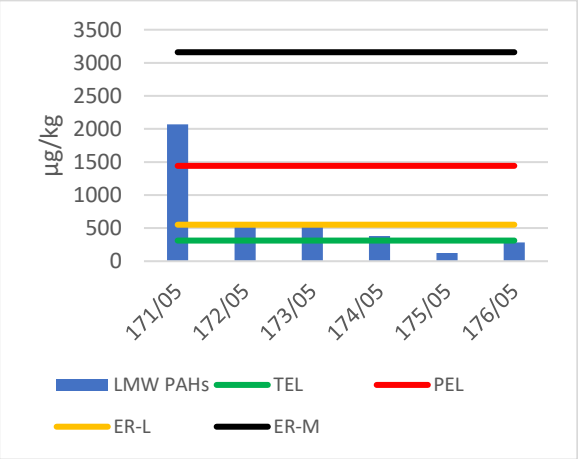


Figure 115 Sum LMW PAHs concentration in Port of Risan by sampling location in relation to TEL, PEL, ER-L and ER-M values

The pyrene and sum of low molecular weight PAHs content exceeds PEL value at one sampling point as well as TEL value at most of research sampling points in Port of Risan.

Figure 116 and 117 show a graphic review of the concentrations of **sum high molecular weight PAHs and total PAHs** in the sediment samples sampled at the Port of Risan site, in relation to the values of two types of sediment quality guidelines (SQG).

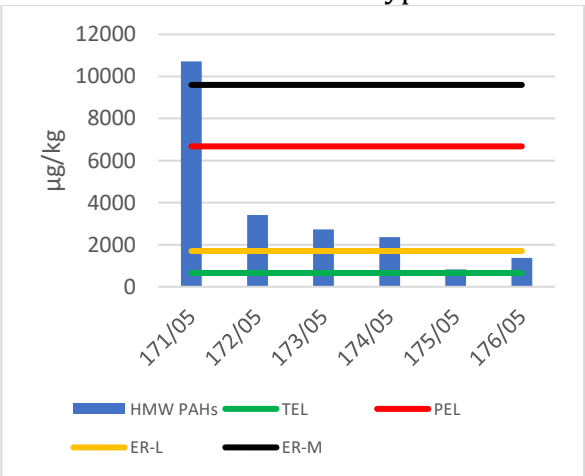


Figure 116 Sum HMW PAHs concentration in Port of Risan by sampling location in relation to TEL, PEL, ER-L and ER-M values

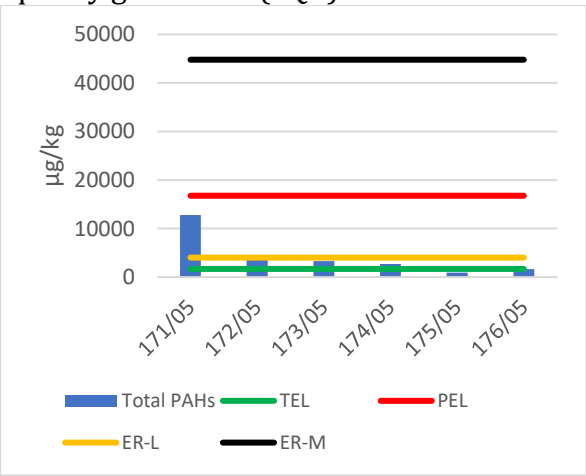


Figure 117 Total PAHs concentration in Port of Risan by sampling location in relation to TEL, PEL, ER-L and ER-M values

The sum of high molecular weight PAHs content in all samples from the Port of Risan location exceeds the defined TEL value as well as the ER-L value on most of researched locations.
The total PAHs content at locations of Port of Risan exceeds the TEL value at four sampling locations and ER-M value at one sampling location. However, all obtained values for total PAHs are lower than the prescribed PEL and ER-M values.

Organochlorine pesticides

Figure 118 and 119 show a graphic review of the concentrations of **total DDT** (sum of p,p'-DDT, p,p'DDD, pp'DDE, o, p'DDT, o,p'DDD and o,p'DDE) and **p,p'DDE** in the sediment samples sampled at the Port of Risan site, in relation to the values of sediment quality guidelines (SQG).

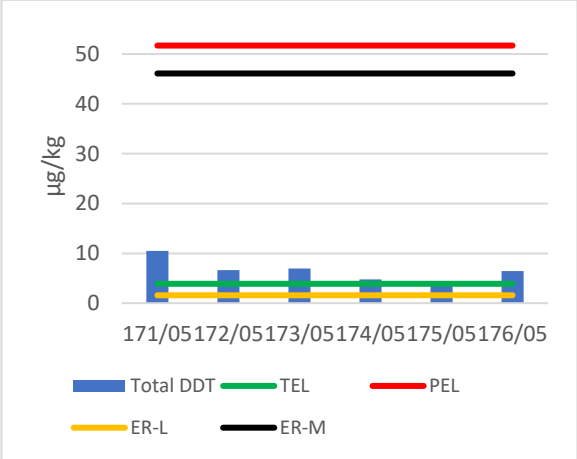


Figure 118 Total DDT concentration in Port of Risan by sampling location in relation to TEL, PEL, ER-L and ER-M values

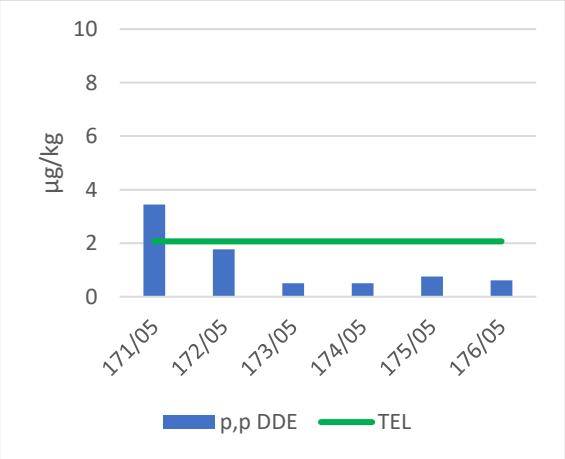


Figure 119 p,p DDE concentration in Port of Risan by sampling location in relation to TEL and PEL values

The total DDT content in all samples sampled from the Port of Risan location exceeds TEL and ER-L values but below and ER-M and PEL values.
The p,p'DDE content at two sampling points on Port of Risan location exceeds the TEL values.

Figure 120 and 121 show a graphic review of the concentrations of **p,p'DDD and p,p'DDT** in the sediment samples sampled at the Porto Montenegro site, in relation to the values of sediment quality guidelines (SQG).

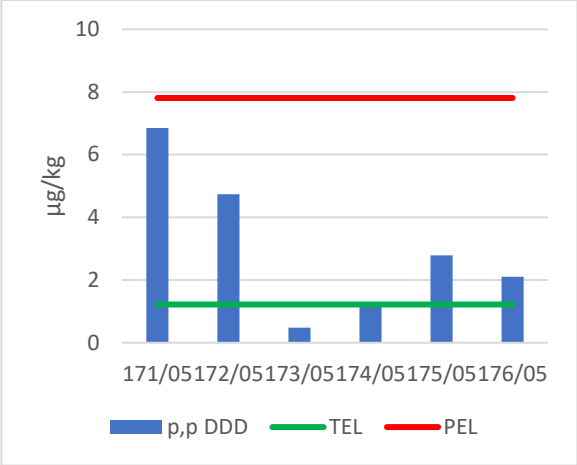


Figure 120 p,p DDD concentration in Porto
Montenegro by sampling location
in relation to TEL and PEL values

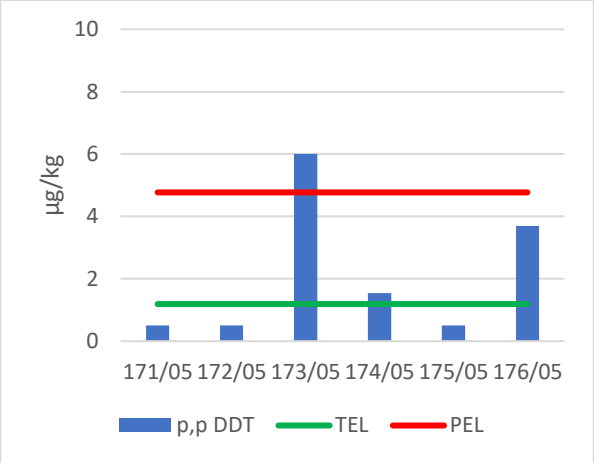


Figure 121 p,p DDT concentration in Porto
Montenegro by sampling location
in relation to TEL and PEL values

Based on the results of sediment analysis, it can be concluded that on location Port of Risan, the average concentration of p,p'DDD is above the TEL but below PEL value.
The average concentration of p,p'DDT in Port of Risan is above TEL but below PEL value. On two locations the concentration of p,p'DDT is above the PEL value

Organotin compounds

Figure 122 and 123 show a graphic review of the concentrations of **tributyltin and dibutyltin** in all sediment samples from Port of Risan location in relation with threshold value from Norwegian guidelines Risk assessment of contaminated sediments and CEFAS action levels for the disposal of dredged material.

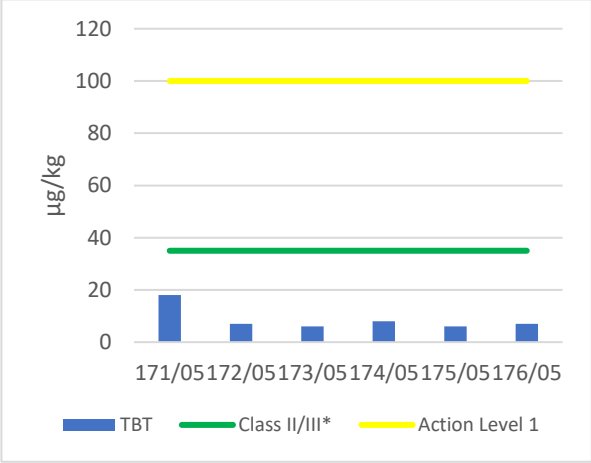


Figure 122 TBT concentration in
Port of Risan by sampling location
in relation to threshold value

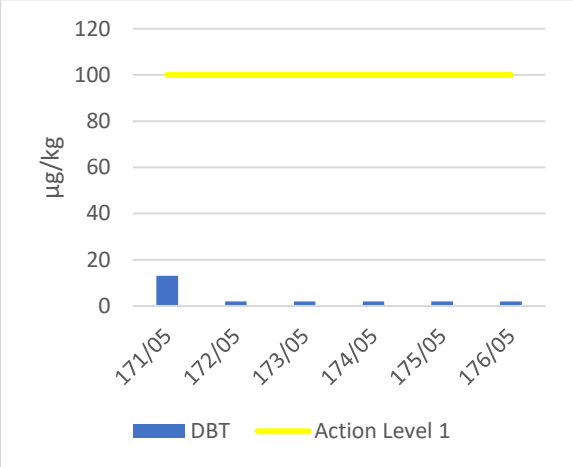
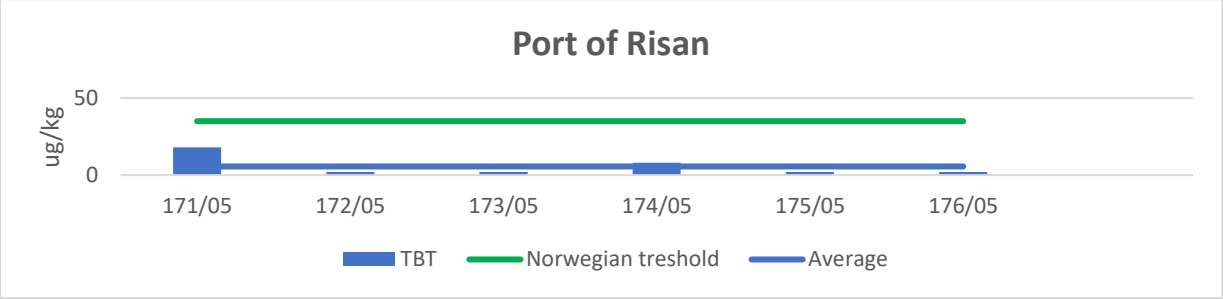


Figure 123 DBT concentration in
Port of Risan by sampling location
in relation to threshold value

The TBT and DBT content at all sampling points on Port of Risan location is below the threshold value from Norwegian guidelines Risk assessment of contaminated sediments and CEFAS action levels for the disposal of dredged material.

Figure 124. shows a graphic representation of the concentrations of tributyltin in all sediment samples from location Port Risan and average value of tributyltin in relation with threshold value from Norwegian guidelines Risk assessment of contaminated sediments (M-1132, 2018).

Figure 124. Graphic representation of the concentrations of tributyltin in all sediment samples from location Port Risan and average value of tributyltin in relation with threshold value from Norwegian guidelines Risk assessment of contaminated sediments (M-1132, 2018).



In the assessment area of the Port of Risan, the average concentration of tributyltin (TBT) stands at 5.6 µg/kg dry weight, a value significantly below the Norwegian threshold of 35 µg/kg dry weight. Notably, the highest concentration of TBT, analyzed at sampling point 171/05, is recorded at 18 µg/kg dry weight, still well below the specified threshold. These findings collectively indicate a commendable environmental status for the Port of Risan concerning TBT pollution.

Contamination Factor (CF)and Enrichment factor (EF)

For most metals at the Port of Risan, CF < 1 was obtained, indicating a low degree of contamination. An exception is chromium in several samples, which is at a level of moderate contamination, and mercury, which is at a level of moderate contamination in all samples. The value of the MPLI (Metal Pollution Load Index), indicating a synergistic effect of all the studied heavy metals is < 1, corresponding to the class of perfection.

Table 12. Heavy metals contamination factor (CF) and metal pollution load index (MPLI)

		CF									
		Hg	As	Cd	Cr	Cu	Pb	Ni	Zn	Fe	**MPLI**
Port of Risan	171/05	1.80	0.60	0.43	0.48	0.64	0.54	0.25	0.45	0.29	**0.51**
	172/05	2.78	0.59	0.37	0.78	0.72	0.66	0.53	0.57	0.49	**0.69**
	173/05	1.66	0.55	0.34	1.12	0.56	0.52	0.40	0.44	0.41	**0.58**
	174/05	2.15	0.63	0.43	0.60	0.53	0.52	0.46	0.46	0.45	**0.59**
	175/05	2.49	0.64	0.37	1.23	0.61	0.39	0.46	0.40	0.43	**0.62**
	176/05	1.51	0.76	0.46	1.20	0.77	0.64	0.69	0.63	0.63	**0.76**
	177/05	1.32	0.59	0.31	0.79	0.59	0.52	0.57	0.53	0.53	**0.60**

Low contamination
Moderate contamination
Considerable contamination
Very high contamination
Perfection
Baseline level of contamination
Deterioration of site quality

Sediments from the Risan port location is also significant enriched with mercury. None of the tested samples can be classified as deficiency to minimal enrichment (EF < 2) regarding mercury content.

Table 13 Heavy metals enrichment factor (EF)

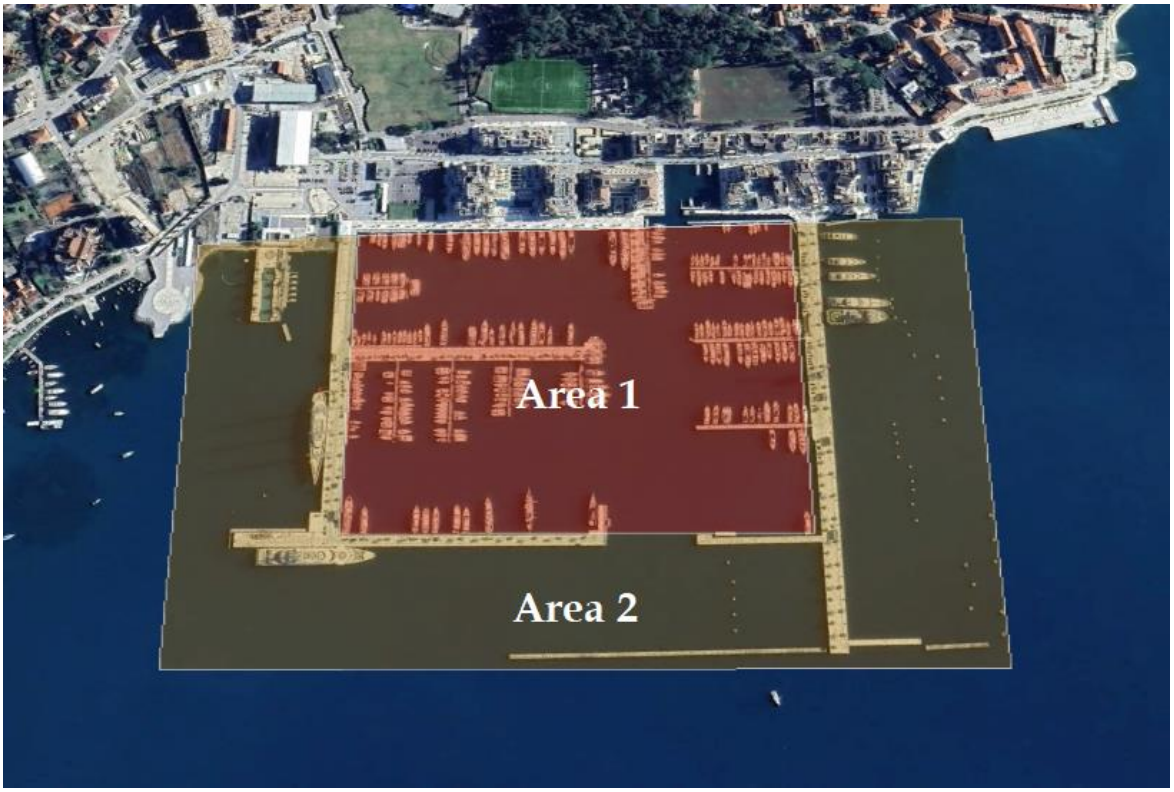
		Hg	**As**	**Cd**	**Cr**	**Cu**	**Pb**	**Ni**	**Zn**
Port of Risan	171/05	19.05	2.05	5.49	0.79	2.90	3.92	0.44	2.56
	172/05	17.39	1.19	2.82	0.77	1.93	2.86	0.55	1.89
	173/05	12.31	1.31	3.09	1.30	1.78	2.65	0.49	1.73
	174/05	14.74	1.38	3.58	0.65	1.57	2.45	0.52	1.69
	175/05	17.79	1.47	3.23	1.38	1.88	1.94	0.54	1.52
	176/05	7.32	1.18	2.69	0.92	1.61	2.14	0.56	1.63
	177/05	7.60	1.09	2.20	0.72	1.45	2.06	0.55	1.62

Deficiency to minimal enrichment
Moderate enrichment
Significant enrichment
Very high enrichment
Extremely high enrichment

Interpretation of the results according to French SQGs

Porto Montenegro

Based on the results of analysis of sediment samples from location Porto Monenegro, two sub-areas can be defined in the area which was examined. The sub-areas are defined according to different levels of contamination with analyzed chemicals. The first one (PM1) is an 0,16km^2 area inside the port which consists of the sampling points with protocol numbers 158-162/05, and the second one is the surrounding area outside the gates which consists of sampling points with protocol numbers 163-168/05 and has the area of 0,28km^2. Two assessment areas of location Porto Montenegro are shown on map 5.



Map 5 Assessment areas of location Porto Montenegro

In table 14 the average values for elements as well as sum of 13 PAHs and sum of PCBs expressed as Aroclor 1260 are presented for both assessment areas together with risk quotient QN1 and QN2 which determines how many times the average value is above the SQG N1 and N2, respectively. The risk quotient QN1 is less than 1 if contaminant concentration is less than the N1 level. If the contaminant risk quotient is above 1, the sample is considered contaminated and it has to be further assessed in terms of toxicity. If the measured average concentration exceeds the N2 level, the sample is considered highly contaminated. Dredged sediment disposal would be allowed offshore for the sediment which contaminant

concentrations is lower than level N2, but if the concentrations are higher, disposal may be prohibited.

Table 14. Average values for elements, ∑PAHs and ∑PCBs expressed in mg/kg dw and calculated risk quotients QN1 and QN2 for the location Porto Montenegro

	Hg	**As**	**Cd**	**Cr**	**Cu**	**Pb**	**Ni**	**Zn**	**∑PAHs**	**∑PCBs**
Area 1	36.7	102	0.3	273	281	350	113	561	48.2	3.6
QN1A1	91.7	4.1	0.3	3.0	6.3	3.5	3.1	2.0	32.1	7.2
QN2A1	45.8	2.0	0.1	1.5	3.1	1.8	1.5	1.0	3.2	3.6
Area 2	7.8	39.8	0.1	104	111	137	64.3	179	18.0	1.4
QN1A2	19.6	1.6	0.1	1.2	2.5	1.4	1.7	0.6	12	2.7
QN2A2	9.8	0.8	0.1	0.6	1.2	0.7	0.9	0.3	1.2	1.4

The general sediment risk quotient QPECm represents the averaged ∑QN1 value for a sediment sample divided by the number of all pollutants studied. In the context of the evaluation conducted in the Porto Montenegro location, the resulting general sediment risk quotients for two assessment sub-areas are provided in Table xxx. This quantitative measure, QPECm, assumes a value less than 1 when the mean concentration of contaminants within the sediment falls below the designated N1 threshold. Conversely, a QPECm value exceeding 1 indicates that the contaminant concentration surpasses the N1 level, signifying an elevated ecological risk associated with the sediment in question.The calculated general sediment risk quotients for two assesment sub-areas of Porto Montenegro location, are given in table 15.

Table 15 ∑QN1 and QPECm for Porto Montenergo study location

	Area 1	Area 2
∑QN1	153	43.3
QPECm	15.3	4.3

Interpretation of the results for Porto Montenegro sub-area 1

The average concentrations for elements in Porto Montenegro sub-area 1 is 36,7; 102; 0.3; 273; 281; 350; 113; and 561 for Mercury, Arsenic, Cadmium, Chromium, Copper, Lead, Nickel and Zinc respectively. As it can be seen from the table 15 risk quotients for level 1, QN1 is exceeded for every element except for Cadmium. For Mercury, the risk quotient QN1 is extremely high, being 91,7 and QN2 45,8 which points out high level of contamination in the sub-area 1 with this element. All examined elements, except Cadmium and Zinc, for which the average concentration for sub-area 1 is equal to level 2, area also above QN2.
The average sum of 13 PAHs, including Fluorene, Phenanthrene, Anthracene, Fluoranthene, Pyrene, Benzo(a)anthracene, Chrysene, Benzo(b)fluoranthene, Benzo(a)pyrene, Benzo(k) fluoranthene, Dibenzo(a,h)anthracene, Benzo(g,h,i)perylene and Indeno(1,2,3-cd) pyrene for sub-area 1 is 48,2 mg/kg dw, which is 32,1 times above the level N1, giving the risk

quotient QN1 32,1. Also, this average concentration is above the level 2, with QN2 value of 3,2.
Sum of PCBs expressed as Aroclor 1260, in the sub-area 1 is 3,6 mg/kg dw, which is above the level 1 and 2, having the calculated risk quotients QN1 7,2 and QN2 3,6.

In the assessment of sub-area 1 within Porto Montenegro, the cumulative average value for ∑QN1, considering the analyzed pollutants, is determined to be 153. This summation accounts for the individual risk quotients associated with each of the 10 pollutants under consideration. To derive the general sediment risk quotient, denoted as QPECm, this accumulated value is divided by the total number of pollutants assessed, which in this case is 10. Consequently, the calculated QPECm for sub-area 1 stands at 15,3. This numerical representation of the general sediment risk quotient provides an indicator of the potential ecological risks associated with the sediment in this specific area, with a value exceeding 1 suggesting a higher-than-threshold concentration of contaminants and an associated elevated risk to the ecosystem.

Interpretation of the results for Porto Montenegro sub-area 2

The average concentrations for elements in Porto Montenegro sub-area 2 is 7,8; 39,8 ;0,1; 104; 111; 137; 64,3 and 179 for Mercury, Arsenic, Cadmium, Chromium, Copper, Lead, Nickel and Zinc respectively. The calculated risk quotients for level 1, QN1 is exceeded for every element except for Cadmium and Zinc in this sub-area. All examined elements, except Mercury and Copper, with risk quotients QN2 9,8 and 1,2 respectively, are below the level 2.
The average sum of 13 PAHs, including Fluorene, Phenanthrene, Anthracene, Fluoranthene, Pyrene, Benzo(a)anthracene, Chrysene, Benzo(b)fluoranthene, Benzo(a)pyrene, Benzo(k) fluoranthene, Dibenzo(a,h)anthracene, Benzo(g,h,i)perylene and Indeno (1,2,3-cd) pyrene for sub-area 2 is 18 mg/kg having the calculated risk quotient QN1 12. Also, this average concentration is above the level 2, with QN2 value of 1,2 but it is about 3 times lower than in sub-area 1.
Sum of PCBs expressed as Aroclor 1260, in the sub-area 2 is 1,4 mg/kg dw, which is above the level 1 and 2, having the calculated risk quotients QN1 2,8 and QN2.
The sum of the average values for ∑QN1 for sub-area 2, considering the analyzed pollutants, is calculated to be 43.3. Upon dividing this cumulative value by the total number of assessed pollutants (10), the resulting general sediment risk quotient (QPECm) for sub-area 2 is determined to be 4.3. A comparative analysis between the two sub-areas underscores notable differences in their respective ecological risk profiles. Sub-area 1, with a ∑QN1 of 153 and a QPECm of 15,3 exhibits a higher general sediment risk quotient, indicating a comparatively elevated concentration of contaminants and a heightened potential ecological risk. On the other hand, sub-area 2, with a ∑QN1 of 43.3 and a QPECm of 4.3, reflects a lower general sediment risk quotient, suggesting a relatively lower concentration of contaminants and a reduced potential ecological risk when compared to sub-area 1, but still elevated potential risk having in mind the QPECm>1.

Shipyard and marina „Navar“

The results of the sediment analysis on the location Shipyard and marina „Navar“, compared with the French SQGs levels 1 and 2 and risk quotients QN1 and QN2 with the ∑QN1 and general sediment risk quotient QPECm are given in table 16.

Table 16 QN1, QN2, ∑QN1 and ∑QN1 for Shipyard and marina „Navar“

	„Navar“ average value(mg/kg dw)	**QN1**	**QN2**
Hg	0.31	0.78	0.39
As	18.9	0.76	0.38
Cd	0.08	0.07	0.03
Cr	175	1.9	0.97
Cu	46.2	1.0	0.51
Pb	27.2	0.27	0.14
Ni	114	3.1	1.5
Zn	107	0.39	0.20
∑PAHs	1.2	0.80	0.08
∑PCBs	0.013	0.03	0.01
∑QN1	9.14		
∑QN1	0.9		

The average concentrations of Mercury, Arsenic, Cadmium, Chromium, Copper, Lead, Nickel and Zinc on location Shipyard and marina „Navar“, were 0,31mg/kg dw; 18,9 mg/kg dw; 0,08mg/kg dw, 175 mg/kg dw; 46,2 mg/kg dw; 27,2 mg/kg dw; 114 mg/kg dw and 107 mg/kg dw respectively. However, Chromium stands out with a concentration of 175 mg/kg dw, exceeding the N1 level and resulting in a risk quotient (QN1) of 1.9. Similarly, Nickel, with an average concentration of 114 mg/kg dw, also surpasses the N1 threshold, yielding a risk quotient (QN1) of 3.1. On the other hand, Copper has the concentration corresponding to level 1. Notably, all other examined elements, except for Nickel, fall below the threshold value N2. For Nickel, the risk quotient (QN2) is calculated at 1.5, emphasizing its potential ecological impact.

The average sum of 13 PAHs, including Fluorene, Phenanthrene, Anthracene, Fluoranthene, Pyrene, Benzo(a)anthracene, Chrysene, Benzo(b)fluoranthene, Benzo(a)pyrene, Benzo(k) fluoranthene, Dibenzo(a,h)anthracene, Benzo(g,h,i)perylene and Indeno (1,2,3-cd) pyrene for location Shipyard and marina „Navar“, is 1,2 mg/kg. The calculated risk quotients (QN1 and QN2) are indicative of a low ecological risk associated with PAH contamination at this location, with values of 0.8 and 0.08, respectively. This suggests that the Shipyard and marina "Navar" are not significantly polluted with PAHs.

Furthermore, the sum of polychlorinated biphenyls (PCBs) expressed as Aroclor 1260 at the same location is notably low, measuring 0.01 mg/kg dw. This concentration is significantly below the established threshold level (N1), resulting in a risk quotient (QN1) of 0.03. The low-risk quotient signifies the minimal ecological risk associated with PCB contamination at

this location. The combined evaluation of PAHs and PCBs indicates that the Shipyard and marina "Navar" currently maintains a relatively low level of pollution with these contaminants, reflecting a positive environmental quality status in terms of these specific pollutants, when compared with French SQGs.

In the assessment of Shipyard and marina "Navar", the cumulative average value for ∑QN1, considering the analyzed pollutants, is determined to be 9,14. This summation reflects the individual risk quotients associated with each of the 10 pollutants considered in the assessment. To ascertain the general sediment risk quotient for the location (QPECm), this cumulative value is then divided by the total number of pollutants assessed, resulting in a QPECm of 0.9. The relatively low QPECm value suggests that, on the whole, the Shipyard and marina "Navar" exhibit a low ecological risk concerning the considered pollutants.

Airport Tivat

The results of the sediment analysis on the location Airport Tivat, compared with the French SQGs levels 1 and 2 and risk quotients QN1 and QN2 with the ∑QN1 and general sediment risk quotient QPECm are given in table 17.

Table 17 QN1, QN2, ∑QN1 and ∑QN1 expressed in mg/kg dw

	Airport Tivat average value (mg/kg dw)	**QN1**	**QN2**
Hg	0.24	0.59	0.30
As	23.9	0.96	0.48
Cd	0.07	0.06	0.03
Cr	163	1.81	0.90
Cu	44.0	0.98	0.49
Pb	23.2	0.23	0.12
Ni	126	3.40	1.70
Zn	122	0.44	0.22
∑PAHs	1.9	1.3	0.13
∑PCBs	0.005	0.01	0.005
∑QN1	9.8		
∑QN1	0.98		

The average concentrations of Mercury, Arsenic, Cadmium, Chromium, Copper, Lead, Nickel and Zinc on location Airport Tivat, were 0,24mg/kg dw; 23,9 mg/kg dw; 0,07 mg/kg dw; 163 mg/kg dw; 163 mg/kg dw; 44 mg/kg dw; 23,2 mg/kg dw; 126 mg/kg dw and 122 mg/kg dw; respectively. The calculated risk quotient QN1 indicates that Chromium and Nickel exceed the N1 threshold values, with QN1 values of 1,8 and 3,4, respectively. Additionally, Nickel surpasses the N2 threshold level with a QN2 value of 1.7. In contrast, the concentrations of Mercury, Arsenic, Cadmium, Copper, Lead, and Zinc are all below the established N1 threshold values. Based on the results of the analysis and comparison with French levels N1 and N2, there is a need for specific attention to Chromium and Nickel contamination at

Airport Tivat, while highlighting the relatively lower ecological risk associated with the other examined elements.

The evaluation of polycyclic aromatic hydrocarbons (PAHs) at Airport Tivat indicates an average sum of 13 PAHs, including Fluorene, Phenanthrene, Anthracene, Fluoranthene, Pyrene, Benzo(a)anthracene, Chrysene, Benzo(b)fluoranthene, Benzo(a)pyrene, Benzo(k) fluoranthene, Dibenzo(a,h)anthracene, Benzo(g,h,i)perylene and Indeno(1,2,3-cd) pyrene at a concentration of 1,9 mg/kg dw. The calculated risk quotient QN1 for PAHs at this location is 1,3, signifying that the concentration exceeds level 1 but falls below level 2, with the risk quotient QN2 at 0,13. This indicates that the ecological risk associated with PAH contamination exists at the location Airport Tivat. The sum of polychlorinated biphenyls (PCBs) expressed as Aroclor 1260 is notably low, measuring 0,005 mg/kg dw. This concentration is well below the established threshold level (N1), resulting in a risk quotient (QN1) of 0,01. The low-risk quotient underscores the minimal ecological risk associated with PCB contamination at this site.

In the assessment of Airpot Tivat in the sense of cumulative risk posed by examined contaminants, average value for ∑QN1, considering the analysed pollutants, is determined to be 9,8, With the general risk quotient QPECm of 0,98.

The ∑QN1 and QPECm values provide an overall perspective on the ecological risk at Airport Tivat, considering the combined impact of multiple contaminants. Considering that the QPECm value of 0,98 is slightly below 1 environmental risk associated with the examined pollutants is moderate.

Port of Risan

The results of the sediment analysis on the location Port of Risan, compared with the French SQGs levels 1 and 2 and risk quotients QN1 and QN2 with the ∑QN1 and general sediment risk quotient QPECm are given in table 18.

Table 18 QN1, QN2, ∑QN1 and ∑QN1 expressed in mg/kg dw

	Port of Risan (mg/kg dw)	**QN1**	**QN2**
Hg	0.42	1.1	0.53
As	10.7	0.43	0.21
Cd	0.14	0.12	0.06
Cr	106	1.2	0.59
Cu	24.0	0.53	0.27
Pb	26.3	0.26	0.13
Ni	42.8	1.2	0.58
Zn	60.7	0.22	0.11
∑PAHs	4.0	2.7	0.27
∑PCBs	0.014	0.03	0.01
∑QN1	7.7		
∑QN1	0.77		

The average concentrations of Mercury, Arsenic, Cadmium, Chromium, Copper, Lead, Nickel and Zinc on location Port of Risan, were 0,42mg/kg dw; 10,7mg/kg dw; 0,14 mg/kg dw; 106mg/kg dw; 24,0 mg/kg dw; 26,3 mg/kg dw; 42,8 mg/kg dw; 42,8 mg/kg dw and 60,7 mg/kg dw, respectively. The calculated risk quotient QN1 indicates that Mercury, Chromium and Nickel exceed the N1 threshold values, with QN1 values of 1,1, 1,2 and 1,2 respectively. None of the analyzed elements does not surpass the level 2 threshold value.

Sum concentration of polycyclic aromatic hydrocarbons (PAHs) at Port of Risan (Fluorene, Phenanthrene, Anthracene, Fluoranthene, Pyrene, Benzo(a)anthracene, Chrysene, Benzo(b) fluoranthene, Benzo(a)pyrene, Benzo(k) fluoranthene, Dibenzo(a,h)anthracene, Benzo(g,h,i)perylene) and Indeno (1,2,3-cd) pyrene is 4,0 mg/kg dw. The calculated risk quotient QN1 for PAHs at this location is 2,7, signifying that the concentration exceeds level 1 but falls below level 2, with the risk quotient QN2 at 0,27. This indicates that the ecological risk associated with PAH contamination exists at the location Port of Risan. However, the sum of polychlorinated biphenyls (PCBs) expressed as Aroclor 1260 is 0,014 mg/kg dw. This concentration is well below the established threshold level (N1), resulting in a risk quotient (QN1) of 0,03 indicated that there is no ecological risk at this location regarding PCBs.

In the assessment of Port of Risan, considering the cumulative risk posed by the examined contaminants, the average value for ∑QN1 is determined to be 7,7. To derive the general sediment risk quotient (QPECm), this cumulative value is then divided by the total number of pollutants assessed, resulting in a QPECm of 0,77. Notably, with a QPECm of 0,77, the assessment suggests that there is no significant ecological risk for the ecosystem in the area of Port Risan posed by the assessed contaminants in the sediment.

Grain size analysis

Sediments are multi-phase solids containing silicates, carbonates, hydroxides/oxides, sulfates and organic substances as major components. The essential factors influencing the heavy metal and organic pollutants contents in sediments include the physical and chemical properties in which grain size is a main control parameter.

The grain size of marine sediment plays a crucial role in influencing the concentration and distribution of contaminants within aquatic ecosystems. This relationship is very importance in the context of sediment quality assessments and the understanding of pollutant transport and fate.

The grain size of marine sediment directly impacts the surface area and porosity of the sediment. Fine-grained sediments, such as silts and clays, have a higher surface area compared to coarse-grained sediments like sands. This increased surface area provides more binding sites for contaminants to adsorb onto, leading to higher concentrations of pollutants in finer sediments.

Contaminants, such as heavy metals, organic pollutants, and nutrients, exhibit varying affinities for different sediment grain sizes. Fine sediments often have a higher cation exchange capacity, enhancing the retention of positively charged contaminants. Additionally, the cohesive nature of fine sediments allows for the accumulation and retention of contaminants over time.

Sediment grain size affects both the availability of oxygen and microbial activity within sediments. Fine sediments may have lower oxygen penetration and higher organic matter content, creating anaerobic conditions that influence the degradation and transformation of heavy metals and organic pollutants. Microbial processes, such as biodegradation and mineralization, play a role in determining the heavy metals and persistence of organic pollutants in sediments.

Moreover, the grain size distribution influences sediment transport dynamics. Fine sediments tend to settle more slowly and can be easily resuspended, leading to the re-release of previously adsorbed contaminants into the water column. This phenomenon has implications for the overall mobility and bioavailability of contaminants within marine ecosystems.

Results of grain size analysis-Porto Montenegro

Marine sediments are silt and sand, with different contents of the clay fraction (Table 19).

Table 19 Granulometric composition -Porto Montenegro

Area	**Fraction**		
	(0.06-2.0 mm)- sand	(0.002-0.06mm)-silt	<0.002mm-clay
Area 1	53 %	28 %	19 %
Area 2	46 %	34 %	20 %

Results of grain size analysis-NAVAR

Marine sediments are clayey silt, with different contents of the sand fraction. According to the diagrams of granulometric composition, the percentage representation of certain fractions of marine sediments of the seabed is: 9% sand, 67% silt and 24% clay (Table 12).

Table 20 Granulometric composition - NAVAR

Laboratory ID	**Fraction (mm)**		
	0.06-2.0-sand	0.002-0.06-silt	<0.002-clay
149/05/23	9 %	67 %	24 %

Results of grain size analysis-Airport Tivat

Marine sediments are silt and clay, with different contents of the sand fraction. According to the granulometric composition diagrams, the percentage representation of certain fractions of marine sediments of the seabed is: 5-23% sand, 57-63% silt and 19-32% clay (Table 21).

Table 21 Granulometric composition -Airport Tivat

Laboratory ID	**Fraction (mm)**		
	0.06-2.0-sand	0.002-0.06-silt	<0.002-clay
157/05/23	11 %	57 %	32 %
154/05/23	23 %	58 %	19 %
153/05/23	5 %	63 %	32 %
Average	13%	59%	28%

Results of grain size analysis-Port of Risan

Marine sediments are sand and silt, slightly clayey. According to the diagrams of the granulometric composition, the percentage representation of marine sediment fractions of the seabed is: 44-65% sand, 28-44% silt and 7-15% clay (Table 22).

Table 22 Granulometric composition – Port of Risan

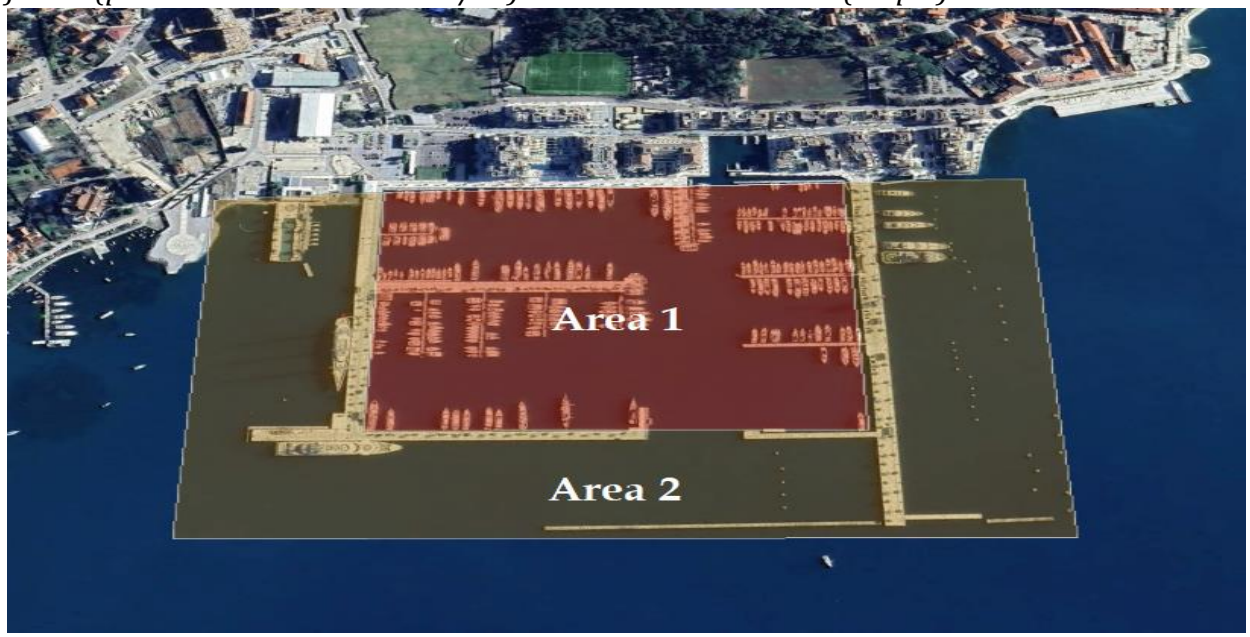
Laboratory ID	**Fraction (mm)**		
	0.06-2.0-sand	0.002-0.06-silt	<0.002-clay
174/05/23	44 %	41 %	15 %
173/05/23	44 %	44 %	12 %
171/05/23	65 %	28 %	7 %
Average	51%	38%	11%

Summary (TIER 1)

The summary results of the analysis and the conclusions reached on the basis of the conducted research are given by location.

Porto Montenegro

Pollution of the seabed at the Porto Montenegro location is a consequence of ship overhaul activities in the former Naval Technical Overhaul Institute "Sava Kovačević" such as paint stripping and its application. This was a source of contamination with heavy metals, primarily mercury, copper, arsenic, lead and zinc as well as PCBs, OTC and PAHs contamination. Marine paint has historically contained metals and OTC to provide antifouling, anticorrosive, biocide, and longevity properties to paint. PCBs were added to marine paint to give the paint better adhesive properties and to provide anti-corrosion protection from moisture, chemicals and flames. Also, they have been introduced as by-products during the production of various pigments used in paint. Paint stripping and washing of ships/boats were source of TPH and PAHs contamination. Residues of oil and petroleum derivatives from ship's hull during washing and paint stripping, were transported into sea water and sediment.
On the basis of the results of the analysis of sediment samples, that is, according to the levels of contaminants determined at the locations of Porto Montenegro, two subareas can be defined. The first (Area 1) is an area of 0.16 km2 inside the harbor consisting of the sampling site (protocol numbers 158-162/05) and the second (Area 2) is the surrounding area outside the jetties (protocol numbers 163-168/05) whose area is 0.28 km2 (Map 6).



Map 6 Assessment areas of location Porto Montenegro

In table 22 are presented the average values for metals (mg/kg dw) as well as sum of 13 PAHs, total PCBs and total DDT (µg/kg dw) for both assesment areas togehter with risk quotient QTEL, QPEL, QER-L and QER-M which determines how many times the average value of contaminents is above the threshold values of two types of sediment quality guidelines-SQG (the TEL/PEL-based type and ER-L/ER-M-based type).

Table 22. Average values for metals, ∑PAHs, ∑PCBs, Total DDT and calculated risk quotients for Area 1 and Area 2 for the location Porto Montenegro

Area 1	**Hg**	**As**	**Cd**	**Cr**	**Cu**	**Pb**	**Ni**	**Zn**	**∑PAHs**	**∑PCBs**	**Total DDT**
Cav	36.7	101.8	0.32	272.6	281.4	350.4	113	561.2	38029.1	3578	14.3
QTELA1	282.3	14.1	0.47	5.2	15.0	11.6	7.1	4.5	22.6	165.6	3.68
QPELA1	52.4	2.4	0.08	1.7	2.6	3.1	2.6	2.1	2.3	18.9	0.28
QER-LA1	244.7	12.4	0.3	3.4	8.3	7.5	5.4	3.7	9.5	157.6	9.1
QER-MA1	51.7	1.5	0.03	0.7	1.04	1.6	2.2	1.4	0.8	19.9	0.31
Area 2	**Hg**	**As**	**Cd**	**Cr**	**Cu**	**Pb**	**Ni**	**Zn**	**∑PAHs**	**∑PCBs**	**Total DDT**
Cav	7.8	39.8	0.13	104	111	136.5	64.3	179.3	14528.6	1358	15.8
QTELA2	60.0	5.5	0.19	2.0	5.9	4.5	4.0	1.4	8.6	62.9	4.1
QPELA2	11.1	0.96	0.03	0.7	1.03	1.2	1.5	0.7	0.9	7.2	0.31
QER-LA2	52.0	4.9	0.11	1.3	3.3	2.9	3.1	1.2	3.6	59.8	10.0
QER-MA2	11.0	0.6	0.01	0.3	0.4	0.6	1.2	0.4	0.3	7.5	0.34

Average concentration is below the TEL/ER-L or PEL/ER-M values
Average concentration is above the TEL/ER-L values but below the PEL/ER-M values
Average concentration is above the TEL/ER-L and PEL/ER-M values

*Based on the results of sediment analysis at **sub-area 1** in the Porto Montenegro location, comparison of the determined average contaminant concentrations with the threshold values (the TEL/PEL-based type and ER-L/ER-M-based type) and calculated risk quotients the following can be concluded:*

- *the average mercury content exceeds the limit value of PEL and ER-M about 52 times, which indicates that the sediment in this zone is extremely enriched with mercury*
- *the average content of other metals (arsenic, chromium, copper, nickel, lead and zinc) exceeds the PEL values in the range of 1.7-3.1 times, while the ER-M values exceeds in range of 1.04-2.2 times*
- *the average content of cadmium is below the TEL and ER-L values*

- *the average content of the sum of 13 PAHs exceeds the PEL value 2.3 times, while the content of the sum of 13 PAHs is below the ER-M value.*
- *the average content of total PCBs exceeds the PEL and ER-M values 19 times, which indicates a high level of PCBs in the sediment*
- *the average content of the total DDT is above the TEL and ER-L but below the PEL and ER-M*
- *the average content of metals and organic contaminants (PAHs, PCBs) is significantly higher in the inner part of the port water area compared to the outer part of the port water area*
- *the average concentration of metals in the inner part of the port water area is 2 to 5 times higher (mercury-4.7 x; arsenic-2.6 x; cadmium-2.4 x; chromium-2.6 x; copper-2.5 x ; lead-2.6 x; nickel-1.8 x; zinc-3.1 x) in relation to the outer part of the port water area*
- *the average concentration of organic contaminants (PAHs, PCBs) in the inner part of the port water area is about 3 times higher (Total PAHs-2.7 x; Total PCBs-2.6 x) compared to the outer part of the port water area*

All of the above indicates that the average content of the tested contaminants exceeds the limit values of PEL and ER-M, above which harmful effects on aquatic organisms are likely and this requires additional tests such as toxicity testing and biota analysis.

*Based on the results of sediment analysis at **sub-area 2** in the Porto Montenegro location, comparison of the determined average contaminant concentrations with the threshold values (the TEL/PEL-based type and ER-L/ER-M-based type) and calculated risk quotients the following can be concluded:*

the average mercury content exceeds the limit value of PEL and ER-M 11 times, which indicates that the sediment in this zone is extremely enriched with mercury

the average content of nickel exceeds the PEL and ER-M values, while the average content of copper and lead slightly exceeds PEL values

the average content of arsenic, cadmium, chromium and zinc is below the TEL and ER-L values

the average content of sum of 13 PAHs is below the TEL and ER-L values

the average content of total PCBs exceeds the PEL and ER-M values 7 times, which indicates a high level of PCBs in the sediment

the average content of the total DDT is above the TEL and ER-L but below the PEL and ER-M

As in the case of area 1, taking into account that the average content of the tested contaminants exceeds the limit values of PEL and ER-M, above which harmful effects on organisms living in water are likely, additional tests such as toxicity tests and biota analysis are necessary.

In assessing contamination level of the sediment in the studied area using French thresholds, two key indicators: $\sum QN1$ and QPECm were employed. $\sum QN1$ is calculated as the sum of individual ratios, each representing the contaminant concentration relative to the French N1 legal level (PEC value). This cumulative sum provided a comprehensive overview of the

potential impact of various studied contaminants on the aquatic environment. The general sediment risk quotient, QPECm, which was determined by averaging the ∑QN1 values of contaminants in sediment and then divided by total number of pollutants studied, which in this case was 10.

Both assessment sub-areas of Porto Montenegro have a significantly high-risk quotient ∑QN1, 153 and 43,3 respectively, but it can be emphasized that the sub-area 1 risk quotient ∑QN1 is 3,5 times higher than in sub-area 2., having proportionally the same ration of QPECm quotients 15,3 and 4,3. Both values suggests that the sediment from these areas are contaminated with diverse organic and inorganic pollutants. If individual risk quotients for elements are considered, it can be seen that in whole area of Porto Montenegro there is a high level of contamination with Mercury. In the sub-area 1, Mercury concentration is more than 90 times higher than the French threshold value N1, and 45 times higher than the N2 level. All the examined elements except for Cadmium in sub-area 1 are above threshold values N1 and N2, and in the case of sub-area all elements besides Cadmium and Zinc are above threshold value N1. Sediments at the Porto Montenegro location is extremely enriched with mercury (EF > 40), and in two samples, with lead as well. The results also indicate that most sediments from the Porto Montenegro location are highly enriched with copper, lead, zinc, and cadmium (20 < EF ≤ 40).

Shipyard and marina „NAVAR“

In table 23 are presented the average values for metals (mg/kg dw) as well as sum of 13 PAHs, total PCBs and total DDT (µg/kg dw), togehter with risk quotient QTEL, QPEL, QER-L and QER-M which determines how many times the average value of contaminents is above the threshold values of two types of sediment quality guidelines-SQG (the TEL/PEL-based type and ER-L/ER-M-based type)

Table 23. Average values for metals, ∑PAHs, ∑PCBs, Total DDT and calculated risk quotients for the location Shipyard and marina „NAVAR“

	Cav	QTEL	QPEL	QER-L	QER-M
Hg	0.31	2.40	0.45	2.08	0.44
As	18.9	2.61	0.45	2.30	0.27
Cd	0.08	0.12	0.02	0.07	0.01
Cr	175	3.35	1.09	2.16	0.47
Cu	46.2	2.47	0.43	1.36	0.17
Pb	27.2	0.90	0.24	0.58	0.12
Ni	113.6	7.14	2.65	5.44	2.20
Zn	108.6	0.88	0.40	0.72	0.26
∑PAHs	1056.9	0.63	0.06	0.26	0.02
∑PCBs	13.4	0.62	0.07	0.59	0.07
Total DDT	1.7	0.44	0.03	1.08	0.04

Based on the results of sediment analysis at Shipyard and marina „Navar" location, comparison of the determined average contaminant concentrations with the threshold values (the TEL/PEL-based type and ER-L/ER-M-based type) and calculated risk quotients the following can be concluded:
the average content of Hg, As, Cr and Cu is above the TEL and ER-L values
the average content of Ni is above the PEL and ER-M values, while the average content of Cr is slightly above the PEL value
the average content of sum of 13 PAHs and total PCB is below the TEL and ER-L values
the average content of the total DDT is above the ER-L but below the TEL, PEL and ER-M
The present evaluation of Shipyard and Marina "Navar" indicates a commendably low level of pollution associated with the analysed contaminants. This observation suggests a favourable environmental quality status concerning these specific pollutants, particularly when benchmarked against the established French Sediment Quality Guidelines (SQGs). From all analysed elements Chromium and Nickel have the concentrations which are above the threshold value N1 and Copper concentration lies in range with the N1 level. PAHs and PCBs on the location Shipyard and Marina "Navar" are below the N1 threshold value. The cumulative average value for ∑QN1 in the assessment of Shipyard and Marina "Navar" is calculated at 9.14 resulting in a QPECm of 0.9.
In order to determine the origin of certain elements (chromium and nickel), an enrichment factor was determined. Additionally, in order to confirm the obtained results, a sequential analysis will be carried out. The enrichment factor indicates that these are metals whose high content can be associated with natural origin. If the sequential analysis confirms the above, it can be concluded that in accordance with the obtained relatively low QPECm value, on the whole, the Shipyard and marina "Navar" exhibit a low ecological risk concerning the considered pollutants.

Tivat Airport

In table 24 are presented the average values for metals (mg/kg dw) as well as sum of 13 PAHs, total PCBs and total DDT (µg/kg dw), together with risk quotient QTEL, QPEL, QER-L and QER-M which determines how many times the average value of contaminants is above the threshold values of two types of sediment quality guidelines-SQG (the TEL/PEL-based type and ER-L/ER-M-based type)

Table 24. Average values for metals, ∑PAHs, ∑PCBs, Total DDT and calculated risk quotients for the location Tivat Airport

	Cav	QTEL	QPEL	QER-L	QER-M
Hg	0.24	1.85	0.34	1.60	0.34
As	23.9	3.30	0.57	2.91	0.34
Cd	0.07	0.10	0.02	0.06	0.01
Cr	162.8	3.11	1.02	2.01	0.44
Cu	44	2.35	0.41	1.29	0.16
Pb	23.2	0.77	0.21	0.50	0.11
Ni	125.8	7.91	2.94	6.02	2.44

Zn	122.2	0.99	0.45	0.81	0.30
∑PAHs	1801	1.07	0.11	0.45	0.04
∑PCBs	5.2	0.24	0.03	0.23	0.03
Total DDT	1.1	0.28	0.02	0.70	0.02

Based on the results of sediment analysis at Tivat Airport location, comparison of the determined average contaminant concentrations with the threshold values (the TEL/PEL-based type and ER-L/ER-M-based type) and calculated risk quotients the following can be concluded:
the average content of Hg, As, Cr and Cu is above the TEL and ER-L values
the average content of Ni is above the PEL and ER-M values, while the average content of Cr is slightly above the PEL value
the average content of the sum of 13 PAHs is slightly above the TEL but below the ER-L, PEL and ER-M values
the average content of total PCB is below the TEL and ER-L values
the average content of total DDT is below the TEL and ER-L values
On the location Airport Tivat, from all analysed elements Chromium has the concentration which is above the threshold value N1, but below threshold value N2 and the concentration on Nickel is above even the threshold N2. The assessment of polycyclic aromatic hydrocarbons (PAHs) at Airport Tivat reveals an average sum of 13 PAHs, with a concentration of 1.9 mg/kg dry weight. The calculated risk quotient QN1 for PAHs at this site is 1,3, indicating that the concentration exceeds level 1 but remains below level 2, with the risk quotient QN2 measured at 0,13. In the evaluation of Airport Tivat concerning the cumulative risk posed by the examined contaminants, the average value for ∑QN1, considering the analysed pollutants, is determined to be 9.8. Additionally, the general risk quotient QPECm is calculated at 0.98.
As in the location very close to the Shipyard and Marina "Navar", the determined EF indicates the natural origin of nickel and chromium. Certainly, the same will be confirmed by sequential analysis. Therefore, it can be concluded that, in accordance with the obtained relatively low QPECm value, location Airport Tivat shows a low ecological risk with regard to the considered pollutants.

Port of Risan

In table 25 are presented the average values for metals (mg/kg dw) as well as sum of 13 PAHs, total PCBs and total DDT (µg/kg dw), together with risk quotient QTEL, QPEL, QER-L and QER-M which determines how many times the average value of contaminants is above the threshold values of two types of sediment quality guidelines-SQG (the TEL/PEL-based type and ER-L/ER-M-based type).

Table 25 Average values for metals, ∑PAHs, ∑PCBs, Total DDT and calculated risk quotients for the location Porto of Risan

	Cav	QTEL	QPEL	QER-L	QER-M
Hg	0.42	3.3	0.60	2.8	0.60
As	10.7	1.5	0.26	1.3	0.15
Cd	0.14	0.21	0.03	0.12	0.01
Cr	105.8	2.0	0.66	1.3	0.29
Cu	24	1.3	0.22	0.71	0.09
Pb	26.3	0.87	0.23	0.56	0.12
Ni	42.8	2.7	1.00	2.05	0.83
Zn	60.6	0.49	0.22	0.40	0.15
∑PAHs	3183	1.9	0.19	0.79	0.07
∑PCBs	13.9	0.64	0.07	0.61	0.08
Total DDT	6.5	1.67	0.13	4.11	0.14

Based on the results of sediment analysis at Port of Risan location, comparison of the determined average contaminant concentrations with the threshold values (the TEL/PEL-based type and ER-L/ER-M-based type) and calculated risk quotients the following can be concluded:
the average content of Hg, As, Cr and Ni is above the TEL and ER-L values, while the average content of Cu is only above the TEL value
the average content of all tested metals is below the PEL and ER-M values
the average content of the sum of 13 PAHs is above the TEL but below the ER-L, PEL and ER-M values
the average content of total PCB is below the TEL and ER-L values
the average content of the total DDT is above the TEL and ER-L but below the PEL and ER-M

The calculated risk quotient QN1 indicates that mercury, chromium and nickel exceed the N1 threshold values, on the location Port of Risan, but none of the analyzed elements does not surpass the level 2 threshold value. The risk assessment for polycyclic aromatic hydrocarbons (PAHs) at the Port of Risan reveals a presence of ecological risk associated with PAH contamination with average concentration of 13 PAHs 4mg/kg dry weight, which is 2,7 times above the threshold N1.
The low QPECm value obtained (0.77), as a whole, determines the location of Luka Risan as a location with a low ecological risk in terms of the considered pollutants.

PAHs, or polycyclic aromatic hydrocarbons, are among the most widespread organic pollutants in the marine ecosystem. They enter the sea through coastal activities, accidental oil spills from ships, river discharges, and atmospheric deposition. Due to their low solubility in water and hydrophobic nature, PAHs tend to attach to inorganic and organic matter on suspended particles and sediment. Only a very small amount of PAHs dissolves in water. PAHs can originate from petrogenic or pyrogenic sources, by process of formation. PAHs originating from petrogenic sources consist mainly of low molecular weight compounds, typically with two or three fused benzene rings. These compounds are characterized by an abundance of substituted PAHs, particularly homologues that contain two to three alkyl carbons. In contrast, PAHs derived from pyrogenic sources exhibit a higher molecular weight, featuring compounds with four to six rings. This distinction in molecular structure serves as a clear marker for differentiating PAHs from petrogenic and pyrogenic origins.

The ratio of concentrations of phenanthrene and anthracene, fluoranthene and pyrene, as well as benzo(a)anthracene and chrysene provide information about whether the pollution with PAHs originates from pyrogenic or petrogenic processes. Ratios of phenanthrene/anthracene > 10, fluoranthene/pyrene > 1, benzo(a)anthracene/chrysene > 0.9 indicate pyrogenic origin, whereas ratios of phenanthrene/anthracene < 10, fluoranthene/pyrene < 1, benzo(a)anthracene/chrysene < 0.9 suggest petrogenic origin (1). In the table 26 the ratios of average concentrations of phenanthrene/anthracene, fluoranthene/pyrene and benzo(a)anthracene/chrysene are shown for two assessment sub-areas of Porto Montenegro, sampling location, Shipyard and marina „Navar", Airport Tivat location and Port of Risan.

Table 26 The ratios of average concentrations of phenanthrene/anthracene, fluoranthene/pyrene and benzo(a)anthracene/chrysene in the analysed sediment samples

	Area 1 Porto Montenergo	Area 2 Porto Montenergo	Navar	Airport Tivat	Port of Risan
Phe/Ant	4.9	4.3	5.1	5.5	4.2
Flu/Py	1.2	1.2	1.2	1.2	1.1
BaA/Chr	1.0	1.0	1.0	1.0	1.1

In Porto Montenegro, the ratio of phenanthrene/anthracene is <10 which indicates petrogenic origin. However, a more comprehensive understanding emerges when considering additional ratios. The fluoranthene/pyrene ratio stands at 1,2, while the benzo(a)anthracene/chrysene ratio is 1,0. Both values indicate a substantial contribution from pyrogenic processes, implying sources beyond petrogenic influences, respectively, shows that PAH contamination in this location originates also from pyrogenic processes.

At the Shipyard and marina "Navar," the phenanthrene/anthracene ratio is 5.1, further affirming a petrogenic origin. Yet, the fluoranthene/pyrene and benzo(a)anthracene/chrysene

ratios, at 1.2 and 1.0 respectively, suggest a combined contamination from both petrogenic and pyrogenic sources.

Similar patterns are observed at the Airport Tivat and Port of Risan sampling locations. The phenanthrene/anthracene ratios are 5.2 and 4.2, indicating primarily petrogenic origins. However, the fluoranthene/pyrene and benzo(a)anthracene/chrysene ratios surpass 1 and 0.9, respectively, pointing towards an influence of pyrogenic sources.

In conclusion, the comprehensive analysis of selected indicator polycyclic aromatic hydrocarbon (PAH) ratios within the examined region proves a clear mix of pyrogenic and petrogenic sources contributing to PAH contamination. The observed uniformity in the ratios of specific PAH indicators across the entire study area underscores the widespread influence of both pyrogenic and petrogenic processes. The merging of these contaminant sources is particularly relevant in the context of the prevalent maritime activities, notably the considerable traffic of vessels in the examined area.

Methylmercury content

Mercury (Hg) is one of the most toxic metals found in the environment, and methylmercury (MeHg) represents its most bioavailable form in marine environments. In marine settings, MeHg is generated from inorganic mercury (Hg) through microbial processes, particularly by sulfate- and iron-reducing bacteria during methylation. Abiotic processes also contribute to MeHg production, with methylcobalamin serving as the methyl group donor. Additionally, conditions such as low oxygen levels (resulting in negative Eh values), the presence of organic matter, and limited light availability promote the transformation of Hg into MeHg. The results of MeHg and Hg content, as well as the MeHg/Hg ratios, are presented in Table 27.

Table 27 The results of MeHg and Hg content and the MeHg/Hg ratios

		Hg	***Me-Hg***	***Me-Hg/Hg***
		mg/kg	***ug/kg***	***%***
NAVAR	*148/05*	*0.43*	*0.471*	*0.11*
AERODROM TIVAT	*157/05*	*0.21*	*0.807*	*0.38*
PORTO MONTENEGRO	*161/05*	*95.5*	*13.3*	*0.01*
	165/05	*17.1*	*6.76*	*0.04*
	168/05	*2.52*	*1.41*	*0.06*
LUKA RISAN	*171/05*	*0.37*	*0.982*	*0.27*
	174/05	*0.44*	*1.36*	*0.31*

In this study, the methylmercury content was assessed in eight samples (four from Porto Montenegro, two from Luka Risan, and one each from Navar and Tivat Airport). Unlike total mercury (HgTOT), information regarding MeHg concentrations in sediments is limited. The determined MeHg content in the examined samples ranged from 0.47 to 13.3 µg/kg. Samples

from Porto Montenegro exhibited higher methylmercury content compared to those from other locations. However, when considering the MeHg/Hg ratio, this percentage is lowest in samples with the highest mercury concentration. Typically, MeHg constitutes less than 1.7% of the total mercury in marine sediments. Among the examined samples, the highest percentage of MeHg in Hg was 0.38%, found in the Tivat Airport sample. Different MeHg concentrations in samples may be attributed to variations in microbial activity at different sediment sampling points. For the analyzed samples, a very high positive correlation was observed between the mercury and methylmercury content, with a Pearson coefficient of 0.96.

Data interpretation TIER 2

Contamination factor (CF), metal pollution load index (MPLI) and enrichment factor (EF) - Summary

Table number 28 gives a summary of the contamination factor (CF) and metal pollution load index (MPLI)

Table 28. Heavy metals contamination factor (CF) and metal pollution load index (MPLI)

		CF									
		Hg	As	Cd	Cr	Cu	Pb	Ni	Zn	Fe	**MPLI**
NAVAR	148/05	2.10	1.06	0.23	1.60	0.83	0.50	1.30	0.87	0.86	**0.88**
	149/05	1.51	0.95	0.29	1.41	1.41	0.58	1.21	0.89	0.74	**0.90**
	150/05	1.17	1.00	0.28	1.18	1.76	0.70	1.19	0.92	0.69	**0.89**
	151/05	1.17	1.07	0.18	1.39	1.15	0.52	1.21	0.86	0.72	**0.80**
	152/05	1.66	1.47	0.22	1.87	1.01	0.52	1.24	0.87	0.78	**0.91**
AIRPORT TIVAT	153/05	1.37	1.56	0.19	1.29	1.09	0.43	1.51	1.01	0.82	**0.88**
	154/05	1.22	1.18	0.18	1.37	1.12	0.50	1.19	0.88	0.71	**0.81**
	155/05	1.07	1.35	0.27	1.50	1.47	0.48	1.43	1.12	0.70	**0.92**
	156/05	1.07	1.41	0.17	1.38	1.04	0.43	1.32	0.93	0.73	**0.80**
	157/05	1.02	1.53	0.18	1.39	1.15	0.56	1.37	1.02	0.80	**0.87**
PORTO MONTENEGRO	158/05	39.51	2.94	0.36	5.29	13.63	4.32	1.54	3.37	1.11	**3.48**
	159/05	56.29	3.11	0.54	2.32	8.43	3.21	1.09	3.10	0.96	**3.00**
	160/05	64.63	3.35	0.88	1.69	3.36	11.92	1.46	5.28	1.03	**3.60**
	161/05	465.85	11.80	1.06	1.15	6.16	10.43	0.93	5.26	0.80	**4.92**
	162/05	268.29	8.69	1.65	1.16	5.95	6.37	1.09	5.76	0.87	**4.60**
	163/05	39.51	1.94	0.26	0.83	1.47	2.54	0.74	1.43	0.86	**1.56**
	164/05	51.22	2.06	0.26	0.82	3.73	2.75	0.66	1.25	0.81	**1.75**
	165/05	83.41	3.35	0.49	0.95	2.45	4.32	0.75	1.65	0.88	**2.25**
	166/05	25.37	3.46	0.54	1.03	3.31	2.09	0.86	1.48	0.88	**1.93**

	167/05	17.12	1.47	0.27	0.93	1.20	1.28	0.70	0.88	0.86	**1.20**
	168/05	12.29	1.76	0.43	0.77	5.60	3.95	0.48	2.04	0.72	**1.69**
	169/05	20.00	1.59	0.20	0.66	1.25	0.89	0.51	0.67	0.64	**1.00**
	170/05	1.98	0.76	0.40	1.22	1.23	0.74	1.37	1.01	1.04	**1.00**
Port of Risan	171/05	1.80	0.60	0.43	0.48	0.64	0.54	0.25	0.45	0.29	**0.51**
	172/05	2.78	0.59	0.37	0.78	0.72	0.66	0.53	0.57	0.49	**0.69**
	173/05	1.66	0.55	0.34	1.12	0.56	0.52	0.40	0.44	0.41	**0.58**
	174/05	2.15	0.63	0.43	0.60	0.53	0.52	0.46	0.46	0.45	**0.59**
	175/05	2.49	0.64	0.37	1.23	0.61	0.39	0.46	0.40	0.43	**0.62**
	176/05	1.51	0.76	0.46	1.20	0.77	0.64	0.69	0.63	0.63	**0.76**
	177/05	1.32	0.59	0.31	0.79	0.59	0.52	0.57	0.53	0.53	**0.60**

Low contamination	Perfection
Moderate contamination	Baseline level of contamination
Considerable contamination	Deterioration of site quality
Very high contamination	

The CF (contamination factor) values for all tested metals are generally higher in samples from the Porto Montenegro location compared to other locations (Airport Tivat, Navar, and Port of Risan). For most metals at the Port of Risan location, CF < 1 was obtained, indicating a low degree of contamination. An exception is chromium in several samples, which is at a level of moderate contamination, and mercury, which is at a level of moderate contamination in all samples. For the Airport Tivat and Navar locations, CF values for cadmium, lead, iron, and zinc at the Navar location in all samples show a low degree of contamination, while CF values for other tested metals are in the range of 1.0 ≤ CF < 3.0, indicating moderate contamination.

The Porto Montenegro location has low CF values in individual samples for cadmium, chromium, iron, and nickel. However, at this location, for a larger number of samples, the lead, arsenic, copper, and zinc content have CF values indicating considerable contamination. CF values for arsenic, copper, lead in several samples, and in all samples when it comes to mercury, are high, indicating very high contamination.

The value of the MPLI (Metal Pollution Load Index), indicating a synergistic effect of all the studied heavy metals, for the locations Airport Tivat, Navar, and Port of Risan is < 1, corresponding to the class of perfection. According to the value of this factor, two samples from the Porto Montenegro location are at the baseline level of contamination (MPLI = 1), while all

other samples from this location, based on the value of the given index, indicate a deterioration of site quality.

The obtained EF values for heavy metals are shown in Table 29.

Table 29 Heavy metals enrichment factor (EF)

		Hg	As	Cd	Cr	Cu	Pb	Ni	Zn
NAVAR	148/05	7.46	1.21	0.98	0.90	1.26	1.22	0.77	1.65
	149/05	6.29	1.26	1.44	0.92	2.52	1.66	0.83	1.98
	150/05	5.20	1.43	1.49	0.83	3.36	2.16	0.88	2.17
	151/05	5.00	1.47	0.95	0.93	2.10	1.52	0.86	1.96
	152/05	6.49	1.85	1.03	1.15	1.70	1.40	0.80	1.81
AIRPORT TIVAT	153/05	5.11	1.87	0.88	0.76	1.76	1.12	0.93	2.00
	154/05	5.26	1.63	0.94	0.93	2.08	1.48	0.85	2.03
	155/05	4.71	1.90	1.45	1.04	2.76	1.44	1.04	2.62
	156/05	4.50	1.89	0.86	0.91	1.87	1.26	0.92	2.07
	157/05	3.91	1.87	0.82	0.83	1.88	1.47	0.86	2.08
PORTO MONTENEGRO	158/05	108.47	2.58	1.19	2.29	16.07	8.19	0.70	4.93
	159/05	178.60	3.17	2.09	1.16	11.48	7.02	0.57	5.24
	160/05	192.15	3.19	3.20	0.79	4.29	24.44	0.72	8.37
	161/05	1774.71	14.41	4.89	0.69	10.08	27.41	0.59	10.68
	162/05	944.51	9.81	7.09	0.64	8.99	15.48	0.64	10.81
	163/05	141.33	2.22	1.14	0.47	2.25	6.28	0.44	2.72
	164/05	192.41	2.47	1.17	0.48	6.02	7.13	0.41	2.50
	165/05	288.71	3.71	2.04	0.52	3.65	10.33	0.43	3.04
	166/05	88.67	3.88	2.30	0.57	4.96	5.04	0.50	2.75
	167/05	60.86	1.67	1.15	0.52	1.83	3.15	0.41	1.68
	168/05	51.95	2.39	2.20	0.51	10.16	11.52	0.33	4.61
	169/05	96.15	2.44	1.18	0.50	2.59	2.95	0.41	1.73

	170/05	5.82	0.72	1.43	0.56	1.55	1.51	0.66	1.59
Port of Risan	171/05	19.05	2.05	5.49	0.79	2.90	3.92	0.44	2.56
	172/05	17.39	1.19	2.82	0.77	1.93	2.86	0.55	1.89
	173/05	12.31	1.31	3.09	1.30	1.78	2.65	0.49	1.73
	174/05	14.74	1.38	3.58	0.65	1.57	2.45	0.52	1.69
	175/05	17.79	1.47	3.23	1.38	1.88	1.94	0.54	1.52
	176/05	7.32	1.18	2.69	0.92	1.61	2.14	0.56	1.63
	177/05	7.60	1.09	2.20	0.72	1.45	2.06	0.55	1.62

Deficiency to minimal enrichment

Moderate enrichment

Significant enrichment

Very high enrichment

Extremely high enrichment

Sediments at the Porto Montenegro location is extremely enriched with mercury (EF > 40), and in two samples, with lead as well. The results also indicate that most sediments from the Porto Montenegro location are highly enriched with copper, lead, zinc, and cadmium (20 < EF ≤ 40). Sediments from the location Port of Risan and several from Navar and Airport locations are also moderate to significant enriched with mercury.

The order of abundance of the average EF values is similar at all investigated locations are: $EF^{Hg} > EF^{Pb} > EF^{Cu} > EF^{Zn} \leftrightarrow EF^{As} > EF^{Cd} > EF^{Cr} \leftrightarrow EF^{Ni}$.

Results of sequential extraction procedure

Based on the results of the sequential extraction procedure, a risk assessment can be done - by calculating the so-called risk assessment code (RAC), i.e. the percentage of elements found in the exchangeable, i.e. carbonate fraction. It is considered that sediment containing less than 1% of total metals in the exchangeable and carbonate fraction is safe for the environment, that is, there is no risk for the environment (table 30). Sediment that releases, for example, 50% of total metals from the same fraction is considered highly dangerous for the environment and metals can easily be included in the food chain. Unlike the content of total or pseudo-total content of elements that do not provide a clear picture of the possible origin, nor of the way of their attachment to the sediment, based on the results of the sequential extraction procedure, such an assessment can be made. Also, based on the results of the sequential extraction procedure, the origin of the metal in the sediment can be estimated. It is considered that metals in the

adsorptive, exchangeable and carbonate phase, are more weakly bound, more easily and quickly bioavailable, and are therefore of anthropogenic origin. Metals in the inert, residual fraction indicate a natural origin.

Table 30. Risk assessment based on the percentage of metals in the exchangeable and carbonate fraction of sediments in relation to the total concentration of metals in the sediment.

Risk assessment	**Criteria (%)**
None	<1
Low	1-10
Medium	11-30
High	31-50
Very high	>50

The most popular sequential procedure used in research is the Tessier scheme. Tessier's procedure foresees the division of elements into five defined fractions:
exchangeable, bound to carbonates and specifically sorbed; bound to iron and manganese oxides; related to organic matter and sulphides; the rest (Tessier et al., 1979). As with other sequential extraction schemes, the availability of elements decreases over time extraction, so the first phase is the most labile and accessible to the plant, and the fifth phase represents the least mobile elements that cannot be mobilized in a normal period of time under natural conditions. That amount of elements is obtained by extraction using strong acids, e.g. aqua regia.
Samples were selected from the Porto Montenegro location, specifically from the inner part of the port, where the highest enrichment factor values were observed (159/05, 160/05, 161/05, 162/05). Additionally, one sample (170/05) was taken from a distant location where enrichment factor values ranged from deficiency to minimal enrichment. The results of the sequential analysis, for five tested samples of sediment, are given in Table 31. Values that were below the detection limit of the method are presented as half the value of the detection limit.

Table 31 Sequential analysis results of sediment samples

		Cd	Cr	Cu	Ni	Zn	As	Pb
		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
159/05	Sum	0.230	276	336	103	357	53	136
	Extract 1	0.005	0.020	0.530	0.047	0.180	0.050	0.059
	Extract 2	0.005	0.020	2.240	0.540	1.60	0.050	4.52
	Extract 3	0.010	15.7	2.69	12.9	169	7.00	63
	Extract 4	0.010	13.8	265	1.33	79	0.600	13.5
	Extract 5	0.200	246	66	88	107	45	55
160/05	Sum	0.381	179	144	142	621	53	530
	Extract 1	0.018	0.020	0.480	0.018	0.725	0.050	0.676
	Extract 2	0.013	0.020	1.43	0.164	23	0.050	29
	Extract 3	0.120	13.6	3.68	9.35	336	6.44	194
	Extract 4	0.010	8.94	90	1.40	93	0.500	44
	Extract 5	0.220	156	48	131	168	46	263
161/05	Sum	0.417	119	262	79	511	226	514

	Extract 1	0.020	0.020	0.540	0.014	0.807	0.050	0.510
	Extract 2	0.013	0.020	2.25	0.153	27	0.050	24
	Extract 3	0.024	14	3.38	6.82	267	39	208
	Extract 4	0.010	10	203	1.75	70	1.18	46
	Extract 5	0.350	94	53	70	146	186	235
162/05	Sum	0.710	111	243	84	803	166	326
	Extract 1	0.005	0.020	0.530	0.020	0.810	0.920	0.260
	Extract 2	0.005	0.020	1.57	0.150	27	0.050	11
	Extract 3	0.240	0.090	2.69	6.82	267	39	133
	Extract 4	0.010	12	192	1.02	146	1.27	34
	Extract 5	0.450	99	46	76	362	125	148
170/05	Sum	0.180	160	43	135	144	17	37
	Extract 1	0.005	0.020	0.200	0.204	0.020	0.099	0.020
	Extract 2	0.005	0.020	0.300	0.300	0.480	0.050	0.875
	Extract 3	0.010	6.30	1.79	2.15	21	3.03	16
	Extract 4	0.010	6.00	4.70	2.15	4.90	0.58	4.40
	Extract 5	0.150	148	36	130	118	13	16

The first phase involves highly mobile ions. The results indicate that a specific percentage of cadmium was present in samples 160/05 and 161/05 during this phase, while it was not detected in the other samples. The percentage distribution of cadmium across extraction phases is given in Figure 125. While in sample 170/05, the percentage of cadmium in the fifth phase is similar to that in samples 159/05 and 161/05. In samples 160/05 and 162/05, a significant percentage of cadmium is present even in the third phase of extraction (about 30%). The enrichment factor value for cadmium was highest in sample 162/05.

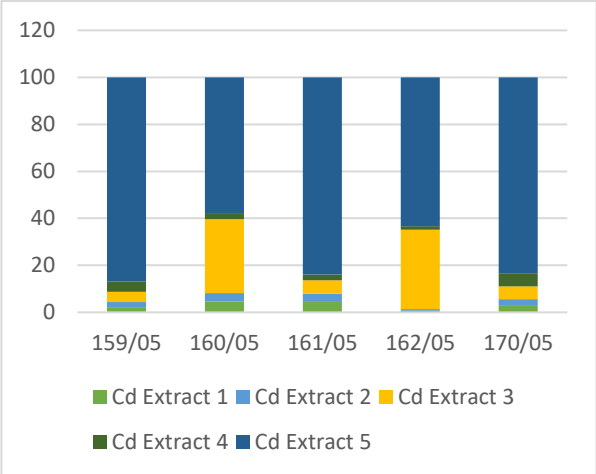


Figure 125 The percentage distribution of cadmium across extraction phases

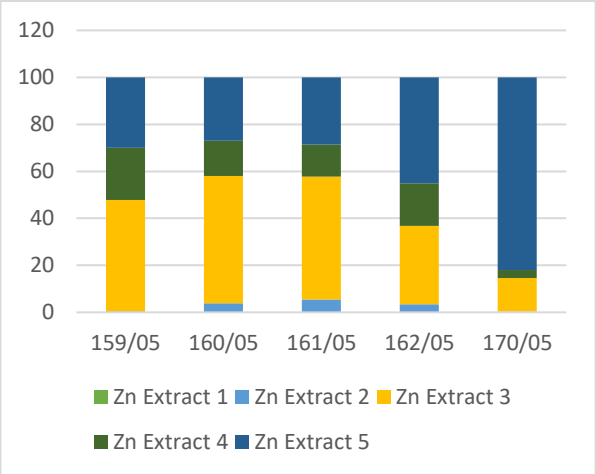


Figure 126 The percentage distribution of zinc across extraction phases

In the second phase, there is also a presence of 3 - 5% of the total zinc in samples 160/05, 161/05, 162/05. The enrichment factor values for zinc in these samples indicated significant enrichment, while the value of this factor for sample 159/05 was close to the boundary of

moderate-significant enrichment. Figure 126 presents the percentage distribution of the determined zinc content across extraction phases. While in the reference sample, the largest amount of zinc, 82%, is bound in the fifth phase. In the other samples, a smaller amount is found in this phase (27-45%), and a significant percentage of the total zinc content in these samples is present in the third (33-54%) and fourth phases (14-22%). The third phase consists of ions with moderate mobility, primarily bound to iron and manganese oxides. Besides the significant percentage of zinc in the third phase, all samples showed a high percentage of the total lead content. However, the same distribution was also found in the reference sample.

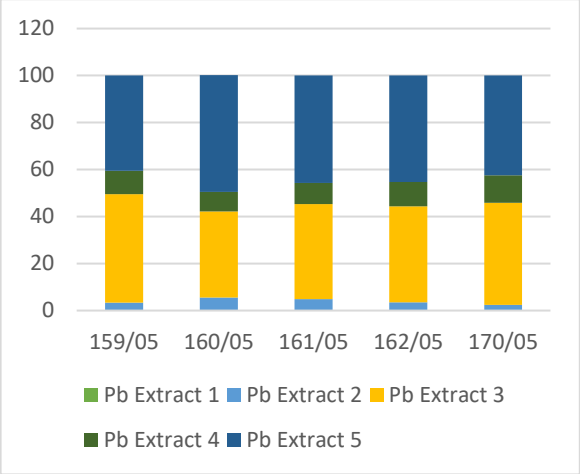


Figure 127 The percentage distribution of lead across extraction phases

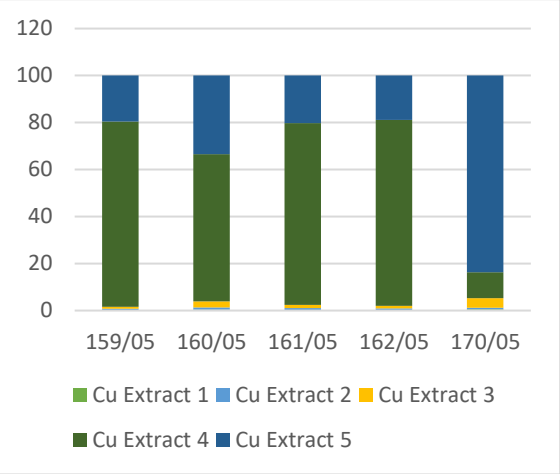


Figure 128 The percentage distribution of coper across extraction phases

Although the enrichment factor values in samples 160/05 and 161/05 indicated very high enrichment, the percentage distribution of lead content in the extracts of these samples is very similar to that in the other two samples and in the reference sample. The only indication of a higher bioavailability of lead in these samples is a slightly higher percentage (about 5%) present in the second phase (compared to 2% in the reference sample). Figure 127 provides a graphical representation of the percentage distribution of lead content in the tested samples.

The reactions to obtain the fourth-phase extract are directed towards the destruction of organic matter, providing information about the presence of moderately mobile cations. In this extract, a high percentage of copper (63-80% of the total copper content) was identified in all samples except for sample 170/05, where the majority of copper was bound in the fifth phase (84%).

Figure 128 shows the percentage distribution of copper across extraction phases. Samples 159/05, 161/05, and 162/05 had slightly enriched values of the factor, and in them, a very similar distribution of copper in the extraction phases is noticeable. Whereas in sample 160/05, a somewhat higher percentage of copper was present in the fifth phase, and the enrichment factor value was at the level of moderate enrichment.

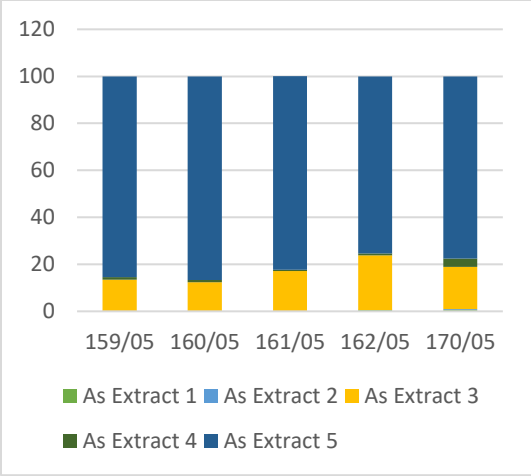


Figure 129 The percentage distribution of arsenic across extraction phases

Although the enrichment factor values for samples 161/05, 162/05 in terms of arsenic content were at the level of significant enrichment, and for samples 159/05, 160/05 at the level of moderate enrichment, the percentage ratio of arsenic in these samples is very similar to the reference sample 170/05 (Figure 129).

More than 85% of the total present nickel and more than 80% of the total present chromium are bound in the fifth phase of extraction (Figures 130 and 131), confirming the determined enrichment factor values for these two elements, which in all samples were at the level of deficient - minimal enrichment.

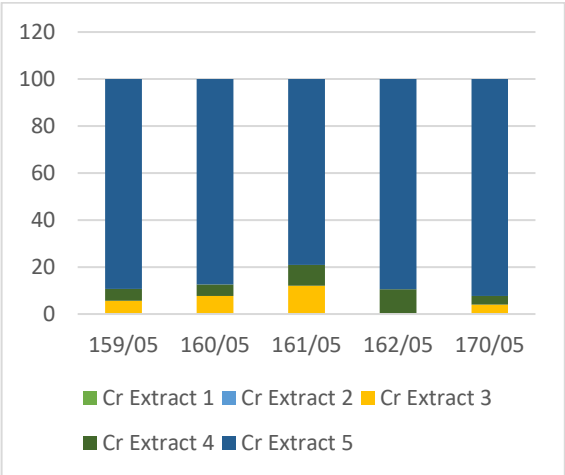


Figure 130 The percentage distribution of chromium across extraction phases

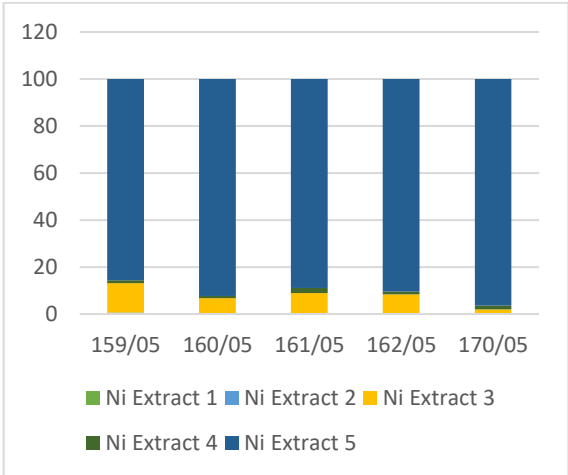


Figure 131 The percentage distribution of nickel across extraction phases

Distinct differences in the distribution of certain metals were observed between sediment samples from the inner part of Porto Montenegro and samples taken approximately two

kilometres away from this location. These differences are most pronounced in the case of copper and zinc. As the results of the calculated enrichment factors for these metals in the given samples indicated significant enrichment, this may suggest that the observed copper and zinc content in these samples is a result of anthropogenic activities.

According to the criteria from Table 23, the determined concentrations of chromium, copper, nickel, and arsenic can be categorized as non-risk. Meanwhile, the concentrations of cadmium, zinc, and lead fall into the low-risk category.

Assessment of bioaccumulation of the contaminants in the mussel tissue

Sediment-relevant substances encompass a range of pollutants and chemicals present in sediment that can have environmental implications. These substances include heavy metals, pesticides, polycyclic aromatic hydrocarbons (PAHs), and polychlorinated biphenyls (PCBs), dioxins and furans, among others. Substances relevant with respect to human risks typically involve pollutants that may pose threats to human health through direct exposure or consumption of contaminated water and seafood. Those substances can bioaccumulate in the tissues of organisms higher up in the food chain, leading to potential adverse effects. Understanding the presence and levels of these substances is crucial for assessing and managing environmental risks, safeguarding human health, and preserving the ecosystem. The accumulation of substances in living organisms, known as bioaccumulation, is widely recognized as an important factor in comprehending and identifying their potential environmental hazard.

For contaminants to induce adverse effects in biota, they must undergo bioaccumulation, a process in which the uptake of these substances exceeds their elimination, leading to concentrations surpassing a threshold at the specific site of action. This concept is fundamental in assessing the environmental impact of metals and organic contaminants understanding the conditions under which they can pose risks to ecosystems

Contaminants of concern for examined areas in Tivat bay and Port of Risan have been determined in Tier 1 of the risk assessment. The identified contaminants at the location Porto Montenegro that surpass the threshold values and have the potential for bioaccumulation are several heavy metals, PCBs and PAHs. At the location Port of Risan all analyzed contaminants were below PEL and ERM threshold values, but the calculated risk quotient QN1 indicated that Mercury, Chromium and Nickel exceed the TEL and ER-L threshold values. Analysis of polycyclic aromatic hydrocarbons (PAHs) at the Port of Risan reveals a presence of potential ecological risk associated with PAH levels, which were above TEL but below the ER-L, PEL and ER-M values.

As bioindicators of marine ecosystem pollution, mussels and benthic fish are commonly used, with mussels being more suitable for several reasons. They possess a pronounced bioaccumulation capacity, very low levels of enzymes capable of metabolizing persistent organic contaminants, are attached to substrates, immobile, have a long lifespan, stress-resistant, easily sampled and are widely distributed. On the other hand, fish metabolize certain contaminants, such as polycyclic aromatic hydrocarbons, strongly, thereby limiting their use as a relevant indicator of marine ecosystem pollution by these contaminants.

Bioaccumulation in the assessment area of Tivat bay and Port of Risan has been evaluated directly in field-collected mussels, Mytilus galloprovincialis.

Sampling of mussels Mytilus galloprovincialis was conducted in December 2023 on 2 locations. In the first one, Porto Montenegro, 3 samples were collected. One sample was collected from the outside area, namely assessment sub-area 2, and 2 sub-samples from sub-area 1 which were merged as one composite sample. From location Risan, one representative composite sample was collected.

Samples of mussels were taken at selected locations using a scalpel. The mussels were packed in in plastic bags, in such a way as to be protected from external contamination. The samples were labeled and transported to the laboratory in a portable refrigerator. In the laboratory, the mussels were rinsed with distilled water, and their size was measured in order to select individuals of approximately 3,5-4cm for the analysis. Subsequently, the mussel meat was separated from the shell strained into containers with grids. The samples were then homogenized. The moisture content was determined in all sample's recalculation of the concentrations of the investigated contaminants on a dry matter basis.

For the analysis of organic contaminants, the samples were lyophilized prior to analysis and the moisture content was again determined.

For the determination of PCBs mussel samples were extracted using a Soxhlet apparatus for 18 hours with 80 ml of n-hexane. The extract was filtered through filter paper and sodium sulfate, evaporated using a rotary evaporator, and then concentrated to 1 ml under a stream of nitrogen. The concentrated extract cleaned-up on a chromatographic column packed with acidic silica gel. The extraction of PAHs from mussel samples was performed using the QuEChERS method (Quick, Easy, Cheap, Effective, Rugged, Safe). PAHs were extracted from the sample using ethyl acetate. The clean-up was done on the glass chromatographic column filled with silica gel as the adsorbent. The samples were eluted from the columns with a mixture of hexane:dichloromethane. Following clean-up, the samples were evaporated and analysed on gas gromatograph coupled with mass spectrometer.

Determination of the content of heavy metals in mussel samples was conducted using Atomic Absorption Spectroscopy (AAS) and Inductively Coupled Plasma (ICP) methods after sample digestion through microwave-assisted digestion in the presence of a mixture of nitric acid and hydrogen peroxide. An exception is the method for mercury content determination, which was carried out using a Mercury Analyzer (AMA), where no prior chemical preparation of the sample is required. Before analysis, the samples were be mechanically homogenized. For metal analysis, the edible portion was prepared without any shell residues.

Results of analysis of mussel samples

Porto Montenegro

The results of two composite samples representing mussels from two sub-areas of Porto Montenegro are shown in table 32

Table 32. The results of analysis of mussel samples from Porto Montenegro

Location of sampling	Porto Montenegro-area 1	Porto Montenegro-area 2	Threshold values		Method
Date of sampling	15.12.2023.	15.12.2023.	MED EAC*	EAC**	
Laboratory number	3287/02	3288/02			
Parametar	Results of analysis	Results of analysis			
Trace elements [mg/kg DW]					
Mercury	0.55	0.27	2.5		AMA-114
Cadmium	0.88	0.64	5		MEST EN14084
Lead	4.7	2.9	7.5		MEST EN14084
Arsenic	30	25			MEST EN14084
Copper	67.3	12.1			MEST EN14084
Nickel	1.7	1.7			MEST EN14084
Chromium	16.6	1.8			MEST EN14084
Zinc	210	157			MEST EN14084
Polycyclic Aromatic Hydrocarbons [µg/kg DW]					
Naphtalene	13.8	12.5			Quechers-PAH
2-methylnaphtalene	3.1	1.3			Quechers-PAH
1-methylnaphtalene	2.7	1.3			Quechers-PAH
Acenaphtylene	0.89	<0.5			Quechers-PAH
Acenaphtene	2.3	1.2			Quechers-PAH
Fluorene	<0.5	2.3			Quechers-PAH

Phenanthrene	6.8	5.0		1700	Quechers-PAH
Anthracene	0.77	0.87		290	Quechers-PAH
Fluoranthene	18.7	22.6		110	Quechers-PAH
Pyrene	24.6	30.5		100	Quechers-PAH
Benzo(a)anthracene	9.3	9.3		80	Quechers-PAH
Chrysene	17.5	20.5			Quechers-PAH
Benzo(b)fluoranthene	27.7	20.0			Quechers-PAH
Benzo(k)fluoranthene	12.0	8.44		260	Quechers-PAH
Benzo(a)pyrene	9.0	6.1		600	Quechers-PAH
Indeno(1.2.3-cd)pyrene	11.9	6.7			Quechers-PAH
Dibenzo(a.h)anthracene	<0.5	<0.5			Quechers-PAH
Benzo(g.h.i)perylene	12.6	7.9		110	Quechers-PAH
Total PAHs	174	157			Quechers-PAH
Polychlorinated biphenyls [µg/kg DW]					
PCB 18	<0.05	<0.05			AOAC 983.21
PCB 31	<0.05	<0.05			AOAC 983.21
PCB 28	<0.05	<0.05		3.2	AOAC 983.21
PCB 52	<0.05	<0.05		5.4	AOAC 983.21
PCB 44	<0.05	<0.05			AOAC 983.21
PCB 101	5.6	4.2		6	AOAC 983.21
PCB 149	8.2	6.0			AOAC 983.21
PCB 118	1.4	2.0		1.2	AOAC 983.21
PCB 153	20.6	15.7		80	AOAC 983.21

PCB 138	9.6	7.2		15.8	AOAC 983.21
PCB 180	4.6	2.0		24	AOAC 983.21
PCB 194	<0.05	<0.05			AOAC 983.21
Organotin compounds [µg/kg DW]					
Monobuthyl-tin	5.1	3.1			ISO 23161-mod
Dibuthyl- tin	16.1	6.9			ISO 23161-mod
Tributhyl-tin	66.8	29.9			ISO 23161-mod
Monooctyl-tin	14.5	2.1		12***	ISO 23161-mod
Tetrabuthyl-tin	<2	<2			ISO 23161-mod
Dioctyl-tin	8.3	<2			ISO 23161-mod
Triphenyl-tin	<2	<2			ISO 23161-mod
Tricyclohexyl-tin	<2	<2			ISO 23161-mod

* Med EAC values equal to the maximum regulatory levels for contaminants in foodstuffs as provided in EC/EU 1881/2006 and 629/2008 Directives except for mercury which is not included in EU directives, but adopted by OSPAR
** EAC IG.22/7 and IG.23/6
***CEMP Assessment Report 2013

The obtained results of analysis of Mediterranean mussels from Porto Montenegro and Port of Risan were compared with environmental assessment criteria (EAC). Environmental Assessment Criteria (EAC) values serve as benchmarks in environmental risk assessment. EAC

values are defined as the concentrations below which it is unlikely that unexpected or unacceptable biological effects will occur in exposed marine species. The Environmental Assessment Criteria (EAC) values, as officially endorsed for toxic metals such as Cadmium (Cd), Mercury (Hg), and Lead (Pb), along with organic contaminants including Polycyclic Aromatic Hydrocarbons (PAHs), Polychlorinated Biphenyls (PCBs), and pesticides, as specified in Decisions IG.22/7 and IG.23/6, are applied within the Mediterranean region. The Mediterranean Environmental Assessment Criteria (MedEAC) are positioned within the low and mid-range when compared to global criteria, presenting a favorable balance for environmental assessment. Notably, these values align with European Union (EU) regulations, providing a harmonized approach to environmental standards. The crucial aspect lies in their consistent application throughout the region, emphasizing the need for unified regulatory measures. It is essential to underscore that these values were collectively agreed upon at the EU level, taking into account the unique ecosystem characteristics of the Mediterranean Sea. These MedEAC values exhibit specificity by being tailored to different taxa, including fish, mussels, and crustaceans, as well as being species-specific. This approach reflects a comprehensive understanding of the diverse marine life within the Mediterranean, ensuring a more accurate and effective evaluation of environmental health.

The metals Mercury, Lead and Cadmium are in the samples on both locations below the respective EAC values. It can be noted that the concentration of metals in mussel from the first sub-area is approximately 2 times higher than the ones in the sub-area 2, which is in accordance with the average values of the examined metals in sediment.

The concentrations of PAHs in both samples from 2 sub-areas were also far below the EAC values. Benzo(a)pyren, which is considered as the most toxic PAH was 9ug/kg dw in sample from sub-area 1, and 6,1ug/kg dw in sample from sub-area 2, which is about 100 times lower than the EAC value.

All examined PCB congeners (PCB18, PCB28, PCB 31, PCB52, PCB 44, PCB101, PCB149, PCB153, PCB138, PCB180, PCB194) in mussel samples were below the EAC value, except for PCB 118 for which there was an exceedance of EAC value for both sub-areas. In mussel sample from sub-are 1 the concentration of PCB 118 was 1,4ug/kg and in sample from sub-area 2ug/kg dw, while the EAC is 1,2ug/kg dw for this congener.

The average concentration of tributyltin(TBT) in mussel tissue for both assessment sub areas of Porto Montenegro is above the EAC value. Concentration of TBT in mussels from sub-area 1 is 66.8ug/kg dw which is 5,5 times higher than the EAC value for TBT, while in the tissue of mussels from sub-area 2 is around 2,5 times higher than EAC value, 29.9ug/kg dw.

The concentration of TBT degradation products monobutyltin (MBT) and dibutyltin (DBT) was in the sample from sub-are 1 16,1ug/kg dw and 5,1 ug/kg dw, with the similar ratio in sample from sub-area 2 6,9ug/kg dw and 3,1 ug/kg dw, respectively. Comparing the ratio of tributyltin to other butyltins as monobutyltin and dibutyltin in both samples the same pattern can be observed. In composite mussel sample from sub-area 1, the amount of TBT corresponds to the 75,9% of the total butyltins in the sample, and the amount of TBT in composite sample from sub-area 2 corresponds to the 74,9% of the total butyltins in the sample (sum of TBT MBT and DBT). From the ratio of TBT to MBT and DBT it can be concluded that there is still fresh input of TBT on this assessment location.

Regarding the bioavailability of contaminants of concern (Mercury, Lead, Cadmium, PCBs, PAHs and organotin compounds) and taking into account the concentrations of these contaminants in sediment samples on the same locations it can be concluded that they are bioavailable but not in the amount in which they pose significant risks to the environment.

Bioavailability indicates the potential for these contaminants to be taken up by living organisms, precisely mussels Mytilus galloprovincialis, but the current concentrations fall within acceptable thresholds, except for PCB 118 and tributyltin. If the location Porto Montenegro as considered as whole, average value for PCB 118 in mussels was 1,7ug/kg/dw which is l,4times higher than threshold value, and the average concentration of tributyltin in mussels from Porto Montenegro is 48,4ug/kg dw which is 4 times higher than the EAC value for TBT.

The calculation of the correlation of the concentrations of hazardous substances in mussels and in sediment from the assessment location Porto Montenegro showed strong correlation between organic contaminants and moderate to strong correlation for heavy metals. Namely, Pearson`s coefficient for the polycyclic aromatic hydrocarbons for mussel samples from sub-area 1 and sediment samples from the same sub-area was calculated to be 0,69, and for mussels from sub-area 2 and the sediment was 0,77. The correlation coefficient ranges from -1 to 1. A coefficient closer to 1 indicates a strong positive correlation, while a coefficient closer to -1 indicates a strong negative correlation. Both coefficients (0,69 and 0,77) are positive, suggesting a positive correlation between the concentrations of PAHs in mussel samples and sediment samples in both sub-areas. The values (0,69 and 0, 77) are relatively high, indicating a reasonably strong and positive correlation between the concentrations of PAHs in mussels and sediment.

The Pearson`s coefficient for PCB congeners in mussel and sediment samples was 0,88 and 0,87 for sub-areas respectively. The values 0,88 and 0,87 are very close to 1, indicating a very strong positive correlation between the concentrations of PCB congeners in mussel samples and sediment samples in both sub-areas.

The Pearson`s coefficient for organotin compounds in mussel and respective sediment samples in sub-area 1 was 0,96, and for the sub-area 2 0,95. These coefficients suggest an exceptionally strong positive correlation between the concentrations of organotin compounds in mussel samples and the corresponding sediment samples in both sub-areas. A correlation coefficient close to 1 signifies that as the concentrations of organotin compounds increase in mussel samples, there is a nearly perfect linear relationship with the concentrations found in the sediment samples. Pearson`s coefficient for heavy metals in sub area-1 was 0,78 which implies strong positive correlation between metals in mussels and sediment from that area. The coefficient of 0.61 in sub-area 2 suggests a moderate positive correlation, indicating lower, but still noticeable positive relationship between the concentrations of heavy metals in mussels and sediment in this area.

These results highlight consistent and robust associations between the concentrations of organic hazardous substances in mussels and sediment across sub-areas. The positive correlations underscore the potential for bioaccumulation and suggest common sources or transport mechanisms for these contaminants in the assessed aquatic environment.

Port of Risan

The results of the mussels sample sampled at the location of Port Of Risan are shown in table 33.

Table 33. The results of analysis of mussel sample from Port of Risan

Location of sampling	Port of Risan	Threshold values		Method
Date of sampling	15.12.2023.	EAC*	EAC**	
Laboratory number	3290/02			
Parametar	Results of analysis			
Trace elements [mg/kg DW]				
Mercury	0.18	2.5		AMA-114
Cadmium	1.2	5		MEST EN14084
Lead	2.3	7.5		MEST EN14084
Arsenic	14.2			MEST EN14084
Copper	10			MEST EN14084
Nickel	2.1			MEST EN14084
Chromium	2.5			MEST EN14084
Zinc	110			MEST EN14084
Polycyclic Aromatic Hydrocarbons [µg/kg DW]				
Naphtalene	<0.5			Quechers-PAH
2-methylnaphtalene	<0.5			Quechers-PAH
1-methylnaphtalene	<0.5			Quechers-PAH
Acenaphtylene	<0.5			Quechers-PAH
Acenaphtene	<0.5			Quechers-PAH
Fluorene	<0.5			Quechers-PAH
Phenanthrene	16.4		1700	Quechers-PAH
Anthracene	<0.5		290	Quechers-PAH

Fluoranthene	2.7		110	Quechers-PAH
Pyrene	2.9		100	Quechers-PAH
Benzo(a)anthracene	8.7		80	Quechers-PAH
Chrysene	3.1			Quechers-PAH
Benzo(b)fluoranthene	10.6			Quechers-PAH
Benzo(k)fluoranthene	<0.5		260	Quechers-PAH
Benzo(a)pyrene	<0.5		600	Quechers-PAH
Indeno(1.2.3-cd)pyrene	<0.5			Quechers-PAH
Dibenzo(a.h)anthracene	<0.5			Quechers-PAH
Benzo(g.h.i)perylene	<0.5		110	Quechers-PAH
Total PAHs	44.5			Quechers-PAH
Polychlorinated biphenyls [µg/kg DW]				
PCB 18	<0.05			AOAC 983.21
PCB 31	<0.05			AOAC 983.21
PCB 28	<0.05		3.2	AOAC 983.21
PCB 52	<0.05		5.4	AOAC 983.21
PCB 44	<0.05			AOAC 983.21
PCB 101	0.39		6	AOAC 983.21
PCB 149	0.79			AOAC 983.21
PCB 118	<0.05		1.2	AOAC 983.21
PCB 153	<0.05		80	AOAC 983.21
PCB 138	<0.05		15.8	AOAC 983.21
PCB 180	<0.05		24	AOAC 983.21
PCB 194	<0.05			AOAC 983.21
Organotin compounds [µg/kg DW]				
Monobutyl-tin	<2			ISO 23161-mod
Dibutyl- tin	8.2			ISO 23161-mod
Tributyl-tin	29.1		12***	ISO 23161-mod
Monooctyl-tin	5.0			ISO 23161-mod

Tetrabutyl-tin	<2			ISO 23161-mod
Dioctyl-tin	13.2			ISO 23161-mod
Triphenyl-tin	<2			ISO 23161-mod
Tricyclohexyl-tin	<2			ISO 23161-mod

* Med EAC values equal to the maximum regulatory levels for contaminants in foodstuffs as provided in EC/EU 1881/2006 and 629/2008 Directives except for mercury which is not included in EU directives, but adopted by OSPAR
** EAC IG.22/7 and IG.23/6
***CEMP Assessment Report 2013

The mussel samples collected from the Port of Risan had concentrations of Mercury, Lead, and Cadmium that were found to be below the Environmental Assessment Criteria (EAC values). Additionally, the levels of Polycyclic Aromatic Hydrocarbons (PAHs) in the same samples were also determined to be below the established EAC values. In the assessment of Polychlorinated Biphenyls (PCBs), all examined congeners (PCB18, PCB28, PCB 31, PCB52, PCB 44, PCB153, PCB138, PCB180, PCB194), with the exception of PCB 101 and PCB 149, were below the limit of quantification for the applied analytical method. Notably, the concentrations of PCB 101 and PCB 149 were far below the respective EAC values, indicating a favorable environmental quality status in the Port of Risan with regards to these contaminants when considering mussels as bioindicators.

The concentration of tributyltin (TBT) in the mussel composite sample which was harvested in Port of Risan was 29.1ug/kg dw, which is 2,4 times higher than EAC value 12ug/kg dw from the CEMP Assessment.

In assessing the bioavailability of concerning contaminants Mercury, Lead, Cadmium, PCBs, PAHs, and organotin compounds in sediment samples from location Port of Risan, it is evident that the concentrations found do not reach levels that pose significant risks to the environment. This suggests that, at present, the environmental levels of these contaminants do not pose a substantial risk to the health and well-being of the ecosystem in this line of evidence.

The concentration of TBT found in mussels from Port of Risan represents 78% of total butyltin concentration in the sample, from which it can be concluded that the mussels are exposed to the fresh input of TBT. The concentration of monobutyltin was below the limit of quantification of the method, while the concentration of dibutyltin was 8,2ug/kg dw.

The utilization of organotin compounds as a marine antifoulant has been prohibited by the International Convention on the Control of Harmful Anti-fouling Systems on Ships (3) The ban is primarily attributed to the substantial toxicity of tri-substituted organotin, with effects in the aquatic environment observed at concentrations below 1 nanogram per liter. Notably, the most toxic compound in this category is tributyltin (TBT). The lingering presence of tributyltin (TBT) sediment legacy remains linked to maritime infrastructures such as ports. Organotin, being lipid-soluble, possess a tendency to easily adsorb into the fatty tissues of marine biota. This

persistence of TBT in sediments and its bioaccumulation potential underscores the enduring environmental impact. Due to its moderate to low degradability in sediment, tributyltin (TBT) is anticipated to consistently surpass threshold values in various locations especially ports and marinas as Porto Montenegro and Port of Risan. As a result, focusing remedial efforts solely on sediment to address TBT contamination may yield limited benefits in many cases as it was concluded in the Norwegian guidelines for risk assessment of contaminated sediments (2018).

Summary – TIER 2

The CF (contamination factor) values for all tested metals are generally higher in samples from the Porto Montenegro location compared to other locations (Airport Tivat, Navar, and Port of Risan). For most metals at the Port of Risan location, CF < 1 was obtained, indicating a low degree of contamination. An exception is chromium in several samples, which is at a level of moderate contamination, and mercury, which is at a level of moderate contamination in all samples. For the Airport Tivat and Navar locations, CF values for cadmium, lead, iron, and zinc at the Navar location in all samples show a low degree of contamination, while CF values for other tested metals are in the range of 1.0 ≤ CF < 3.0, indicating moderate contamination.

The Porto Montenegro location has low CF values in individual samples for cadmium, chromium, iron, and nickel. However, at this location, for a larger number of samples, the lead, arsenic, copper, and zinc content have CF values indicating considerable contamination. CF values for arsenic, copper, lead in several samples, and in all samples when it comes to mercury, are high, indicating very high contamination.

The value of the MPLI (Metal Pollution Load Index), indicating a synergistic effect of all the studied heavy metals, for the locations Airport Tivat, Navar, and Port of Risan is < 1, corresponding to the class of perfection. According to the value of this factor, two samples from the Porto Montenegro location are at the baseline level of contamination (MPLI = 1), while all other samples from this location, based on the value of the given index, indicate a deterioration of site quality.

Sediments at the Porto Montenegro location is extremely enriched with mercury (EF > 40), and in two samples, with lead as well. The results also indicate that most sediments from the Porto Montenegro location are highly enriched with copper, lead, zinc, and cadmium (20 < EF ≤ 40). Sediments from the location Port of Risan and several from Navar and Airport locations are also moderate to significant enriched with mercury.

The order of abundance of the average EF values is similar at all investigated locations are: $EF^{Hg} > EF^{Pb} > EF^{Cu} > EF^{Zn} \leftrightarrow EF^{As} > EF^{Cd} > EF^{Cr} \leftrightarrow EF^{Ni}$.

Distinct differences in the distribution of certain metals were observed between sediment samples from the inner part of ***Porto Montenegro*** *and samples taken approximately two kilometres away from this location. These differences are most pronounced in the case of copper and zinc. As the results of the calculated enrichment factors for these metals in the given samples indicated significant enrichment, this may suggest that the observed copper and zinc content in these samples is a result of anthropogenic activities.*

According to the criteria from Table 23, the determined concentrations of chromium, copper, nickel, and arsenic can be categorized as non-risk. Meanwhile, the concentrations of cadmium, zinc, and lead fall into the low-risk category. The metals Mercury, Lead and Cadmium are in the mussel samples on both locations (two sub-areas in Porto Montenegro) below the respective EAC values. The concentrations of PAHs in both mussel samples from 2 sub-areas in Porto Montenegro were also far below the EAC values. Benzo(a)pyren, which is considered as the most toxic PAH was 9 ug/kg dw in sample from sub-area 1, and 6,1ug/kg dw in sample from sub-area 2, which is about 100 times lower than the EAC value.

Almost all examined PCB congeners (PCB18, PCB28, PCB 31, PCB52, PCB 44, PCB101, PCB149, PCB153, PCB138, PCB180, PCB194) in mussel samples were below the EAC value.
The average concentration of tributyltin(TBT) in mussel tissue for both assessment sub areas of Porto Montenegro is above the EAC value.
Regarding the bioavailability of contaminants of concern (Mercury, Lead, Cadmium, PCBs, PAHs and organotin compounds) and taking into account the concentrations of these contaminants in sediment samples on the same locations it can be concluded that they are bioavailable but not in the amount in which they pose significant risks to the environment. Bioavailability indicates the potential for these contaminants to be taken up by living organisms, precisely mussels Mytilus galloprovincialis, but the current concentrations fall within acceptable thresholds, except for PCB 118 and tributyltin. If the location Porto Montenegro as considered as whole, average value for PCB 118 in mussels was 1,7ug/kg/dw which is l,4times higher than threshold value, and the average concentration of tributyltin in mussels from Porto Montenegro is 48,4ug/kg dw which is 4 times higher than the EAC value for TBT.
The calculation of the correlation of the concentrations of hazardous substances in mussels and in sediment from the assessment location Porto Montenegro showed strong correlation between organic contaminants and moderate to strong correlation for heavy metals. Namely, there is a positive correlation between the concentrations of PAHs in mussel samples and sediment samples in both sub-areas. A very strong positive correlation is between the concentrations of PCB congeners in mussel samples and sediment samples in both sub-areas.
The Pearson`s coefficient shows an exceptionally strong positive correlation between the concentrations of organotin compounds in mussel samples and the corresponding sediment samples in both sub-areas.
These results highlight consistent and robust associations between the concentrations of organic hazardous substances in mussels and sediment across sub-areas. The positive correlations underscore the potential for bioaccumulation and suggest common sources or transport mechanisms for these contaminants in the assessed aquatic environment.

The mussel samples collected from the ***Port of Risan*** *had concentrations of Mercury, Lead, and Cadmium that were found to be below the Environmental Assessment Criteria (EAC values). Additionally, the levels of Polycyclic Aromatic Hydrocarbons (PAHs) in the same samples were also determined to be below the established EAC values. In the assessment of Polychlorinated Biphenyls (PCBs), all examined congeners (PCB18, PCB28, PCB 31, PCB52, PCB 44, PCB153, PCB138, PCB180, PCB194), with the exception of PCB 101 and PCB 149, were below the limit of quantification for the applied analytical method. Notably, the concentrations of PCB 101 and PCB 149 were far below the respective EAC values, indicating a favorable environmental quality*

status in the Port of Risan with regards to these contaminants when considering mussels as bioindicators.

In assessing the bioavailability of concerning contaminants Mercury, Lead, Cadmium, PCBs, PAHs, and organotin compounds in sediment samples from location Port of Risan, it is evident that the concentrations found do not reach levels that pose significant risks to the environment. This suggests that, at present, the environmental levels of these contaminants do not pose a substantial risk to the health and well-being of the ecosystem in this line of evidence.

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Annex 1

CONCEPTUAL SITE MODEL

Introduction

A key step in risk assessment for proper site characterization is the conceptual site model (CSM), which identifies sources of contamination, pathways, and possible receptors that may be affected. Also, the conceptual site model describes physical, chemical, and biological processes that occur or can occur at a contaminated site. CSM identifies transport, migration, and actual/potential impacts of contamination (in soil, air, groundwater, surface water, and sediments) to human and/or ecological receptors. Development of the CSM will help identify investigative data gaps in the characterization process and can ultimately support remedial decision-making.

Porto Montenegro

Location and Site History Summary

Porto Montenegro is a nautical resort with a luxury marina for yachts located in the Boka Bay in Montenegro, in the town of Tivat, on the site of the former Naval Technical Overhaul Institute "Sava Kovačević".

The Naval Technical Overhaul Institute (shipyard) "Sava Kovačević" was a military institution intended for the overhaul of ships and other naval technical equipment, the development and production of spare parts and military equipment that was in the armament of the Navy of the Yugoslav Army. In addition to overhauling ships, the Institute also overhauled military weapons and provided civilian ship overhaul services. A schematic view of the facilities in the Naval Technical Overhaul Institute "Sava Kovačević" is shown in Figure 1. Figure 2. shows the former Naval Technical Overhaul Institute "Sava Kovačević" and the current marina and nautical resort Porto Montenegro.

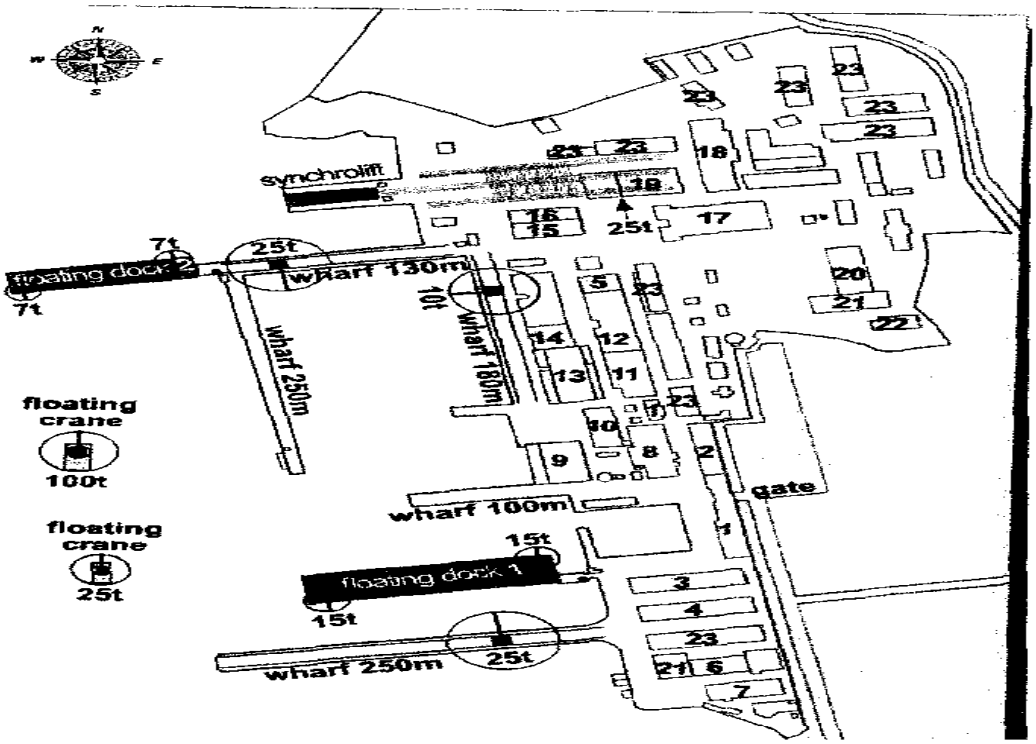

Figure 1. A schematic view of the facilities in the Naval Technical Overhaul Institute

Legend:

1. offices
2. auxiliary workshops
3. chemical and mechanical workshop
4. carpentry workshop
5. hydraulic workshop
6. workshop for accumulators
7. ropes workshop
8. forge and smelter
9. boat workshop
10. workshop for marine equipment
11. machine shop
12. mechanical workshop
13. steel workshop
14. pipeline workshop
15. paint shop and lacquer shop
16. workshop for explosives
17. workshop for diesel machines
18. workshop for vehicles
19. ship repair hall
20. electrical workshop
21. electronics workshop
22. technological laboratory
23. warehouse

Figure 2. Naval Technical Overhaul Institute "Sava Kovačević" (1,2) and the current marina and nautical resort Porto Montenegro (3,4).

Identified sources and types of pollution

Taking into account that Porto Montenegro is a nautical resort with a luxury marina for yachts, activities in the former shipyard are the main source of pollution in this location. The area of the former shipyard is divided into multiple primary source areas and each source is connected to shipyard work. Different activities in different areas can caused different types and level of contamination. Most of the following identified sources of pollution are related to activities to the former Naval Technical Overhaul Institute and a smaller part with activities in Porto Montenegro:

S1-Former warehouses and repair workshops

Warehouses and repair workshops in shipyard, can have various sources of pollution if environmental management practices are not adequately implemented. Some warehouses and repair workshops were close to the docks, some on the mainland a bit far from the docks. Potential sources of pollution in shipyards related to warehouses and repair workshops are:

Chemical Storage and Handling:
Source: Storage of paints, solvents, cleaning agents, and other chemicals used in ship repair.

Impact: Improper handling, storage, or disposal of chemicals can lead to soil and water contamination.

Waste Disposal Practices:
Source: Inadequate waste management and disposal practices for materials such as paints, solvents, and scrap metals.
Impact: Improper disposal can lead to soil and water pollution, as well as impact air quality.

Anti-fouling Paints:
Source: Use of anti-fouling paints containing biocides to prevent marine growth on ship hulls.
Impact: Runoff from cleaning or painting activities can introduce toxic substances into water bodies.

Metalworking Operations:
Source: Metal cutting, welding, and grinding activities during ship repairs.
Impact: Metal particles and dust can contribute to air and water pollution if not properly controlled.

Stormwater Runoff:
Source: Runoff from shipyard surfaces, including roofs and paved areas, during rain events.
Impact: Stormwater can carry pollutants, including chemicals and heavy metals, into soil and nearby water bodies.

S2- Former Boat Lift Work Area
The boat lift work area can be associated with specific sources of pollution if environmental management practices are not effectively implemented.

Abrasive Blasting:
Source: Use of abrasive blasting for paint removal.
Impact: The process can generate airborne particulate matter, including heavy metals from the boat's surface.

Anti-fouling Paints:
Source: Removal of old anti-fouling paints from boat hulls.
Impact: Dust and debris generated during paint stripping can contain toxic substances, including heavy metals and biocides affecting marine ecosystems.

Paint Application:
Source: Application of new paint coatings on boat surfaces.
Impact: Overspray, drips, or spills during the paint application process can lead to contamination of sediment and water.

Oil and Fuel Handling:
Source: Handling, transfer, and storage of oils and fuels associated with boats.
Impact: Spills, leaks, or improper disposal can result in oil pollution in the water and sediment.

Waste Disposal Practices:
Source: Inadequate waste management and disposal practices for materials such as paints, solvents, and scrap metals.
Impact: Improper disposal can lead to soil and water pollution and negatively impact air quality.

Bilge Water Discharge:
Source: Discharge of bilge water from boats lifted for maintenance.
Impact: Bilge water may contain oils, fuels, and other contaminants, contributing to water and sediment pollution.

Metalworking Operations:
Source: Welding, cutting, and grinding activities during boat repairs or modifications.
Impact: Metal particles and dust released during these operations can contribute to air, sediment and water pollution.

Stormwater Runoff:
Source: Runoff from boat lift work areas, including paved surfaces during rain events.
Impact: Stormwater runoff can carry pollutants, including chemicals and heavy metals, into nearby water bodies.

S3- Former Ship Repair Work Area
The Ship Repair Work Area is former area were boats historically repaired. Ships repair was carried out either on the floating dock or on the shore. Ship repair work areas can have various potential sources of pollution if environmental management practices are not adequately implemented. Sources of contamination in ship repair work area were:

Abrasive Blasting and Sanding:
Source: Abrasive blasting and sanding of ship surfaces for cleaning or preparation for painting.
Impact: Generation of airborne particulate matter, including heavy metals, and potential contamination of soil, sediment and water.

Paint Stripping and Application:
Source: Stripping and applying paint during ship repair.
Impact: Release of potentially toxic substances into the air, sediment and water during paint stripping and application.

Chemical Use in Repair Activities:
Source: Use of chemicals such as solvents, cleaners, and coatings during ship repair.
Impact: Improper handling, storage, or disposal of chemicals can lead to soil, sediment and water contamination.

Welding and Metalworking:
Source: Welding and metalworking activities during ship repairs.
Impact: Emission of metal particles, fumes, and dust, contributing to air and potentially water pollution.

Waste Disposal Practices:
Source: Inadequate waste management and disposal practices for materials such as paints, solvents, and scrap metals.
Impact: Improper disposal can lead to sediment, soil and water pollution and negatively impact air quality.

Stormwater Runoff:
Source: Runoff from ship repair work areas, including paved surfaces during rain events.
Impact: Stormwater runoff can carry pollutants, including chemicals and heavy metals, into soil and nearby water bodies.

S4-Former Debris Dumping Area
Former debris dumping area is an area formerly used for dumping of miscellaneous boat parts and other waste like used grit from sand blasting. This area was near the shoreline and it was potential source of pollution of soil, sediment and water related to:

Paint and Coating Debris:
Source: Discarding waste materials from paint removal and coating processes.
Impact: Residual paints may contain toxic substances that can leach into the environment, affecting soil, sediment and water quality.

Hazardous Waste Dumping:
Source: Incorrect disposal of hazardous waste materials in the debris dumping area.
Impact: Hazardous substances can leach into the soil and pose risks to both the environment and human health.

Metal Scraps and Residues:
Source: Improper disposal of metal scraps, residues, and remnants from ship repair and construction activities.
Impact: Heavy metals from the metal debris can leach into the soil, leading to soil contamination.

S5-Curent Petroleum Storage Tank Area
Petroleum Storage Tank Area has 800,000 liters of storage capacity and can be source of contamination due to:

Fuel Spills and Leaks:
Source: Accidental spills or leaks from fuel storage tanks, pipelines, or during fuel transfer operations.

Impact: Contamination of sediment and groundwater with petroleum hydrocarbons, leading to potential environmental and ecological risks.

Overfilling During Fueling:
Source: Overfilling of boat fuel tanks during refueling operations.
Impact: Spills and runoff can occur, contributing to sediment and surface water contamination.
Stormwater Runoff:
Source: Runoff from the petroleum storage area during rain events.
Impact: Contaminated runoff can carry pollutants into water body and sea sediment impacting aquatic ecosystems.

Fuel Transfer Pipelines:
Source: Leaks or failures in pipelines used for transferring fuel.
Impact: Pipeline leaks can lead to the release of large volumes of petroleum products, impacting water, sediment and potentially air quality.

Release and Transport Mechanisms

The potential sources of contamination and transport mechanisms within the source areas include:

Paint stripping and application:

Paint stripping and application can be source of contamination with heavy metals, primarily copper, mercury, arsenic, lead and zinc as well as PCBs, TPH, OTC and PAHs contamination. Marine paint has historically contained metals and OTC to provide antifouling, anticorrosive, biocide, and longevity properties to paint. Paint chips can fall to the ground and be mobilized by stormwater, wind, and vehicles moving on the site. Additionally, metals can leach from paint into atmospheric water and further into the sediment.

PCBs were added to marine paint starting in the 1940's to give the paint better adhesive properties and to provide anti-corrosion protection from moisture, chemicals and flames (approximately 2% composition of paint). Also, they have been introduced as by-products during the production of various pigments used in paint.

Paint stripping and washing of ships/boats are source of TPH and PAHs contamination. Residues of oil and petroleum derivatives can be found on the ship's hull and during washing and paint stripping, residue can be transported by wind and stormwater.

Boat building and maintenance area:

Boat maintenance may include working with petroleum products including diesel and oil. Paints containing metals and OTC and lubricants containing PAHs were also used. During the shipyard's history, it is likely that some amount of petroleum, paint, lubricants or other maintenance-related fluids were spilled or drained in the area where work was being

conducted, like floating docks, near the lift where the boats are removed from the water, maintenance and boat construction buildings and the machine shop.

A large source of contaminants can be from purging bilge water as boats were hauled out of the water. Bilge water could contain engine oil, lubricants, fuel, coolant and other hazardous substances. Maintenance of older engines could contribute to the spread of petroleum and PAHs across the site.

The machine shop:

Machine shops can be source of TPH, PAH, semi-volatile organic compounds and metals. The leaks, spills and drains can cause soil, surface water and sediment contamination.

Waste dumping site:

Dumping miscellaneous different boat parts and waste grit was a source of many different contaminants like heavy metals, OTC, PCBs and PAHs. Lubricants on engine parts could be a source of petroleum and PAHs. All of these pollutants reached the soil contaminating it over time. Rain mobilized contaminants via infiltration and leaching to atmospheric water and further in marine ecosystem. Fugitive dust from waste grit may be mobilized by wind to surface water and sediment.

Current Petroleum Storage Tank Area:

Elevated concentrations of TPH and PAHs can be results of leaks or spills associated with the operation during fueling or leaks due to poor maintenance. Leaks can contaminate seawater and sediment in the area of current Petroleum Storage Tank.

In table 1. is shown the relationship between a chemical source, exposure pathway and potential receptor at site Porto Montenegro, which mostly originate from activities in the former shipyard "Sava Kovačević".

Table 1. Relationship between a chemical source, exposure pathway and potential receptor

Source and hazards	Pathway	Receptor
S1: Former warehouses and repair workshops * • Metals • PCBs • PAHs • TPH	P1: Vertical migration of pollutants into soil P2: Horizontal migration through ground or/and stormwater P3: Direct exposure (ingestion, inhalation, dermal contact) P4: Migration through air	R1: Soil R2: Sediment R3: Sea water R4: Stormwater R5: Air R6: Aquatic plants/organisms R7: Human beings
S2: Former Boat Lift Work Area • Metals • PCBs • PAHs	P1: Vertical migration of pollutants into sediment P2: Horizontal migration through ground or/and stormwater P3: Direct exposure (ingestion,	R1: Sediment R2: Sea water R3: Stormwater R4: Air R5: Aquatic plants/organisms

Source and hazards	Pathway	Receptor
• TPH • OTC	inhalation, dermal contact) P4: Migration through air	R6: Human beings
S3: Former Ship Repair Work Area • PAHs • PCBs • Metals • TPH • OTC	P1: Vertical migration of pollutants into sediment P2: Direct exposure (ingestion, inhalation, dermal contact) P3: Horizontal migration through ground or/and stormwater P4: Migration through air	R1: Sediment R2: Sea water R3: Stormwater R4: Air R5: Aquatic plants/organisms R6: Human beings
S4: Former Debris Dumping Area • PAHs • PCBs • Metals • TPH • OTC	P1: Horizontal migration through ground or/and stormwater P2: Direct exposure (ingestion, dermal contact) P3: Vertical migration of pollutants into soil and sediment P4: Migration through air	R1: Soil R2: Sediment R3: Sea water R4: Stormwater R5: Air R6: Aquatic plants/organisms R7: Human beings
S5: Current Petroleum Storage Tank Area • TPH • VOC • PAHs	P1: Vertical migration of pollutants into sediment P2: Horizontal migration through ground or/and stormwater P3: Direct exposure (inhalation, dermal contact)	R1: Sediment R2: Sea water R3: Stormwater R4: Air R5: Aquatic plants/organisms R6: Human beings

* Chemical and mechanical workshop, workshop for accumulators, boat workshop, workshop for marine equipment, paint shop and lacquer shop, ship repair hall

Figures 3 and 4 show the former Naval Technical Overhaul Institute "Sava Kovačević" and the current marina and nautical resort Porto Montenegro and potential sources of pollution.

Figure 3. Sources of pollution in Naval Technical Overhaul Institute "Sava Kovačević"

Figure 4. Potential source of pollution in Porto Montenegro

Bearing in mind that historical pollution was caused by activities at the Naval Technical Overhaul Institute "Sava Kovačević", the CSM is given for previous and current activities (Figure 5 and 6).

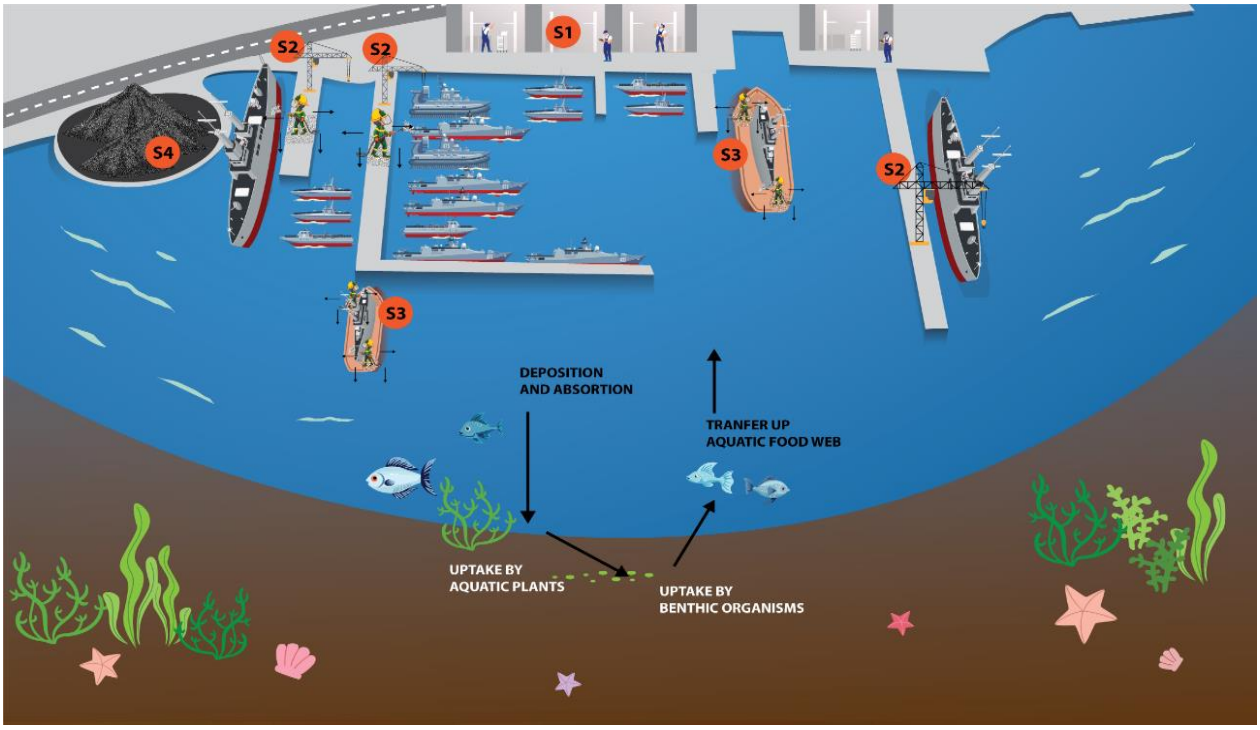

Figure 5. Schematic view of CSM for former Naval Technical Overhaul Institute "Sava Kovačević" with relationship between a chemical source, exposure pathway and potential receptor

Figure 6. Schematic view of CSM for Porto Montenegro with relationship between a chemical source, exposure pathway and potential receptor

Tivat Airport

Location and Site History Summary

Tivat Airport is situated in Boka Bay, in the municipality of Tivat, 4 km southeast of Tivat.. It was initially established as a military airfield in 1957 during the time of the former Yugoslavia. Over time, recognizing its potential for civil aviation, it transitioned into a civil airport.

Within Tivat airport, there is a control tower, a runway, a dock platform with 7 parking spaces, a passenger building, and areas of supporting services. Tivat Airport is characterized by the fact that more than 80% of traffic takes place during the summer tourist season.

Identified potential sources and types of pollution

S1-Aircraft operations

Aircraft operations at airports can contribute to various sources of pollution, impacting air quality, soil, and water. Here are potential sources of pollution associated with aircraft operations:

Aircraft Engine Emissions:
Source: Combustion of aviation fuel in aircraft engines during takeoff, landing, and taxiing.
Pollutants: Nitrogen oxides (NOx), particulate matter (PM), carbon monoxide (CO), sulfur dioxide (SO2), and volatile organic compounds (VOCs).

Aircraft Fueling Operations:
Source: Spills and leaks during aircraft fueling.
Pollutants: Jet fuel and other hydrocarbons that can contaminate soil and groundwater.

Aircraft Wash Water:
Source: Runoff from aircraft washing operations.
Pollutants: Cleaning agents, detergents, and potential contaminants from the aircraft surfaces.

Aircraft Maintenance Activities:
Source: Use of solvents, paints, and other chemicals in aircraft maintenance.
Pollutants: Hazardous materials, including volatile organic compounds (VOCs), that can contribute to air, water and soil pollution.

Aircraft Towing and Taxiing:
Source: Movement of aircraft on the ground using engines or vehicles.
Pollutants: Emissions from engines during ground operations.

Runway Rubber Deposits:
Source: Accumulation of rubber deposits on runways from landing aircraft.
Pollutants: Polycyclic aromatic hydrocarbons (PAHs) released during the degradation of rubber, impacting air, soil and water quality.

S2-Airport Vehicles

Airport vehicles can contribute to pollution through various sources, and addressing these issues is crucial for sustainable airport operations. Here are potential sources of pollution associated with airport vehicles:

Emissions from Ground Support Equipment (GSE):
Source: Diesel-powered GSE, including baggage tugs, fuel trucks, and ground power units.
Pollutants: Particulate matter, nitrogen oxides (NOx), carbon monoxide (CO), and volatile organic compounds (VOCs).

Aircraft Tugs and Tractors:
Source: Diesel or gasoline-powered towing vehicles for moving aircraft on the ground.
Pollutants: Emissions from internal combustion engines, contributing to air and soil pollution.

Service and Maintenance Vehicles:
Source: Vehicles used for maintenance, repairs, and services on the airfield.
Pollutants: Emissions from fuel combustion and potential leaks of oils and fluids.

Material Handling Equipment:
Source: Equipment used for loading and unloading cargo.
Pollutants: Emissions from engines and the potential for spills of hazardous materials.

Runway Sweepers and Cleaners:
Source: Vehicles used for cleaning runways and taxiways.
Pollutants: Emissions from engines, and the potential for spreading debris and contaminants.

Fueling Operations:
Spills and leaks during fueling operations of airport vehicles can contaminate the soil and, if not managed properly, reach groundwater, surface water and nearshore waters and contaminate seawater and sediment.

S3-Stormwater Runoff

Stormwater runoff at airports can be a significant source of pollution due to the potential transport of various contaminants into water bodies and soil Here are some potential sources of pollution related to stormwater runoff at airports:

Runoff from Paved Surfaces:
Source: Runoff from runways, taxiways, aprons, and other paved surfaces.
Contaminants: Oil and grease from aircraft operations, heavy metals from brake and tire wear.

Fueling Areas:
Source: Runoff from fueling areas and fuel storage facilities.
Contaminants: Jet fuel and other hydrocarbons that can contribute to oil pollution.

Maintenance and Washing Operations:
Source: Runoff from aircraft and ground vehicle maintenance areas.
Contaminants: Cleaning agents, solvents, and other chemicals used in maintenance operations.

Vehicle Operations:
Source: Runoff from roads and parking lots.
Contaminants: Oil, heavy metals, and other pollutants from vehicle operations.

Runoff from Terminal Areas:
Source: Runoff from terminal buildings, including roofs and parking areas.
Contaminants: Pollutants such as oil, grease, and chemicals used in terminal facilities.

S4-Airport Petroleum Storage Tank Area

The Airport Petroleum Storage Tank Area can be a potential source of pollution due to various factors associated with the storage, handling, and potential release of petroleum products. Here are some possible sources of pollution and associated problems:

Fuel Spills and Leaks:
Source: Accidental spills or leaks from fuel storage tanks, pipelines, or during fuel transfer operations.
Impact: Contamination of soil and groundwater with petroleum hydrocarbons, leading to potential environmental and ecological risks.

Tank Corrosion and Aging Infrastructure:
Source: Corrosion or degradation of storage tanks and associated infrastructure over time.
Impact: Structural failures can lead to leaks and spills, releasing petroleum products into the surrounding environment.

Overfilling During Fueling:
Source: Overfilling of aircraft or vehicle fuel tanks during refueling operations.
Impact: Spills and runoff can occur, contributing to soil and surface water contamination.

Inadequate Maintenance Practices:
Source: Lack of regular maintenance or inspections of storage tanks and associated equipment.
Impact: Increased risk of equipment failure, leaks, or other issues that could result in pollution incidents.

Fuel Transfer Pipelines:
Source: Leaks or failures in pipelines used for transferring fuel.
Impact: Pipeline leaks can lead to the release of large volumes of petroleum products, impacting soil, water, sediment and potentially air quality.

S5- Firefighting activity

The use of firefighting foam, especially those containing per- and polyfluoroalkyl substances (PFAS) like perfluoro octane sulfonate (PFOS), can be a significant source of pollution at airport area. Possible sources of pollution and associated problems are:

Firefighting Foam Containing PFOS:

Source: Firefighting foam used during emergency response exercises or in the event of an actual fire.

Impact: PFOS is a persistent organic pollutant known for its environmental persistence and potential health hazards. When firefighting foam containing PFOS is used, it can result in the release of these substances into the environment.

Fire Training Areas:

Source: Designated areas for firefighter training exercises.

Impact: The repeated use of firefighting foam during training exercises can lead to the accumulation of PFAS in the soil and potential leaching into groundwater.

Fire Extinguisher Disposal:

Source: Improper disposal of expired or damaged fire extinguishers containing PFOS-based foam.

Impact: If fire extinguishers with PFOS foam are not disposed of properly, there's a risk of soil and water contamination.

Spills and Accidents:

Source: Accidental spills or discharges of firefighting foam during handling, storage, or firefighting operations.

Impact: Unintended releases of foam can result in contamination of soil and water in the vicinity.

In table 2. is shown the relationship between a chemical source, exposure pathway and potential receptor at site Tivat Airport.

Table 2. Relationship between a chemical source, exposure pathway and potential receptor

Source and hazards	**Pathway**	**Receptor**
S1: Aircraft operations • Metals • PAHs • TPH • VOC	P1: Vertical migration of pollutants into soil and sediment P2: Horizontal migration through ground or/and stormwater P3: Direct exposure (ingestion, inhalation, dermal contact) P4: Migration through air	R1: Soil R2: Sediment R3: Sea water R4: Stormwater R5: Air R6: Aquatic plants/organisms R7: Human beings

Source and hazards	Pathway	Receptor
S2: Airport Vehicles • PAHs • Metals • TPH • VOC	P1: Vertical migration of pollutants into soil and sediment P2: Direct exposure (ingestion, inhalation, dermal contact) P3: Horizontal migration through ground or/and stormwater P4: Migration through air	R1: Soil R2: Sediment R3: Sea water R4: Stormwater R5: Air R6: Aquatic plants/organisms R7: Human beings
S3: Stormwater Runoff • PAHs • Metals • TPH • PFAS	P1: Horizontal migration through ground or/and stormwater P2: Direct exposure (dermal contact) P3: Vertical migration of pollutants into soil and sediment	R1: Soil R2: Sediment R3: Sea water R4: Stormwater R5: Air R6: Aquatic plants/organisms R7: Human beings
S4: Airport Petroleum Storage Tank Area • PAHs • VOC • TPH	P1: Vertical migration of pollutants into soil and sediment P2: Direct exposure (ingestion, inhalation, dermal contact) P3: Horizontal migration through ground or/and stormwater P4: Migration through air	R1: Soil R2: Sediment R3: Sea water R4: Stormwater R5: Air R6: Aquatic plants/organisms R7: Human beings
S5: Firefighting activity • PFAS	P1: Vertical migration of pollutants into soil and sediment P2: Direct exposure (ingestion, dermal contact) P3: Horizontal migration through ground or/and stormwater	R1: Soil R2: Sediment R3: Sea water R4: Stormwater R5: Aquatic plants/organisms R7: Human beings

Figures 7. shows the area of Tivat Airport and potential sources of pollution. CSM for a location near airport Tivat is given in figure 8.

Figure 7. Airport Tivat

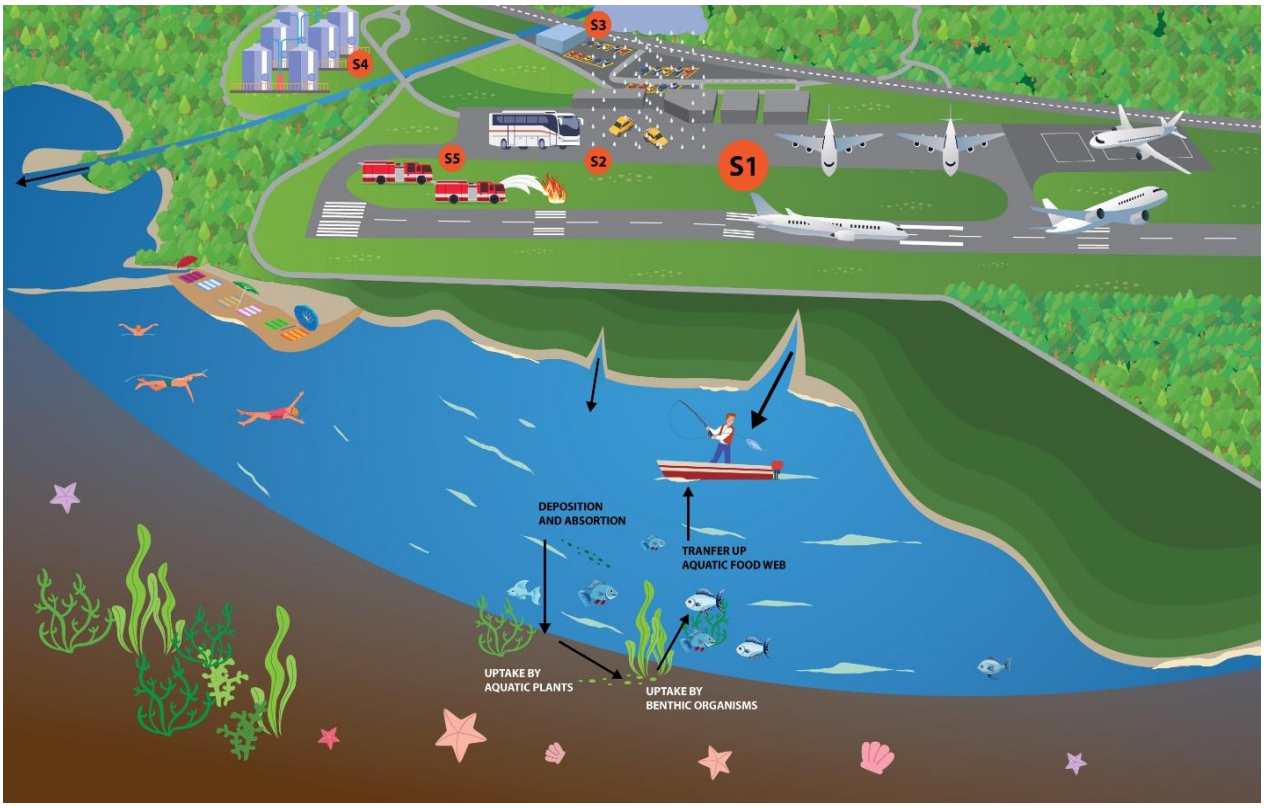

Figure 8, Schematic view of CSM for Tivat Airport with relationship between a chemical source, exposure pathway and potential receptor

Shipyard and Marina „NAVAR“

Location and Site History Summary

The shipyard and marina "Navar" is situated in the Boka Bay, in the municipality of Tivat, 3 km southeast of Tivat. It is a maritime facility offering services related to yacht building, repair, and storage. Shipyards are known for constructing, repairing, and maintaining boats. This includes activities such as hull maintenance, engine repairs, and painting. Marinas provide docking facilities for boats and yachts. They offer services such as mooring, fueling, electricity, and water supply for boats. Marinas have boat storage facilities, including wet slips for in-water storage and dry storage areas for boats that are not in use.

Identified sources and types of pollution

A yachting marina and shipyard can be associated with various sources of pollution, impacting both the marine environment and surrounding areas. Here are identified sources and types of pollution which can be associated with the Shipyard and Marina „Navar“

S1- Boat Repair Work Area

Boat repair work areas in shipyards can be associated with several potential sources of pollution if not managed properly. Here are possible sources of pollution in the boat repair work area:

Painting and Coating Operations:

Source: Application and removal of paints, coatings, and anti-fouling substances on boat hulls.
Impact: Airborne emissions and runoff during painting and cleaning processes can contribute to air, sediment, and water pollution with volatile organic compounds (VOCs), heavy metals, and biocides.

Fiberglass Repair:

Source: Sanding, cutting, and repairing fiberglass boat components.
Impact: Airborne fiberglass particulates can pose respiratory hazards, and runoff may introduce particles into the water.

Hull Cleaning and Barnacle Removal:

Source: Cleaning and scraping boat hulls to remove marine growth.
Impact: Runoff from cleaning activities may introduce contaminants into nearby water bodies.

Fueling and Oil Handling:

Source: Fueling operations, maintenance activities involving oils and lubricants.
Impact: Spills or leaks during fueling and maintenance can result in oil pollution in the water.

Waste Disposal:

Source: Improper disposal of waste materials, including paints, solvents, and scrap metals.

Impact: Soil, sediment and water pollution if waste is not properly managed, recycled, or disposed of.

Bilge Water Discharge:
Source: Discharge of bilge water containing oils and contaminants.
Impact: Release of pollutants into the water and sediment during bilge water discharge.

Ballast Water Treatment:
Source: Discharge of ballast water during repairs.
Impact: Ballast water discharge can contribute to the spread of contaminants and invasive species.

Stormwater Runoff:
Source: Runoff from boat repair work areas during rain events.
Impact: Stormwater runoff can transport various contaminants into nearby water body and sediment.

S2-Warehouses and repair workshops

Warehouses and repair workshops can contribute to various potential sources of pollution if environmental management practices are not properly implemented. Here are potential sources of pollution associated with warehouses and repair workshops:

Chemical Storage and Handling:
Source: Improper storage and handling of chemicals used in repair and maintenance activities.
Impact: Spills, leaks, or improper disposal of hazardous chemicals, solvents and cleaning agents can result in soil, sediment and water contamination.

Oil and Lubricant Storage:
Source: Storage and handling of oils, lubricants, and hydraulic fluids.
Impact: Accidental spills or leaks can lead to oil pollution in soil, sediment and water.

Metalworking Operations:
Source: Welding, cutting, and grinding activities in repair workshops.
Impact: Airborne metal particles and dust can contribute to air pollution, and runoff may introduce metals into water.

Paint and Coating Storage:
Source: Storage and handling of paints, coatings, and anti-fouling substances.
Impact: Improper storage or disposal can lead to air, sediment and water pollution with volatile organic compounds (VOCs), heavy metals and organic pollutants.

Waste Management Practices:
Source: Inadequate waste management and disposal practices for materials such as paints, solvents, and scrap metals.

Impact: Improper disposal can lead to soil, sediment and water pollution and negatively impact air quality.

Stormwater Runoff:
Source: Runoff from paved surfaces around warehouses and workshops during rain events.
Impact: Stormwater runoff can transport various pollutants into nearby water bodies and sediment

S3-Accidents and Spills

Accidents and spills in a marina and shipyard can pose significant environmental risks if not addressed promptly and effectively. Potential sources of pollution related to accidents and spills in a marina and shipyard are:

Oil Spills:
Source: Accidental release of oils and fuels from vessels, equipment, or storage areas.
Impact: Oil spills can lead to water and sediment pollution, impacting marine ecosystems and shorelines.

Chemical Spills:
Source: Accidental spills of chemicals used in boat repair, maintenance, or cleaning.
Impact: Contamination of soil, sediment and water with hazardous substances, posing risks to human health and the environment.

Boat accidents:
Source: Boat collisions may result in spills of oils, fuels, and other potentially hazardous substances into the water
Impact: Fuel and oil spills into water bodies and sediment can cause environmental pollution and potential harm to aquatic life.

Waste Handling Accidents:
Source: Accidents during the handling, storage, or transportation of hazardous waste materials.
Impact: Release of pollutants into the environment, leading to soil, sediment and water contamination.

Ballast Water Treatment:
Source: Accidental release of ballast water during boat repair or maintenance.
Impact: Introduction of non-native species and potential contamination from ballast water.

Firefighting Foam Releases:
Source: Accidental discharge of firefighting foam containing potentially harmful substances, such as per- and polyfluoroalkyl substances (PFAS).
Impact: Contamination of soil, sediment and water with firefighting foam constituents.

Spills from Cleaning Operations:

Source: Accidental spills of cleaning agents used in ship cleaning operations.
Impact: Introduction of pollutants into water bodies and soil.

Paint Spills:
Source: Accidental spills of paint or coatings during ship painting or repair.
Impact: Release of potentially toxic substances into the environment.

Hydraulic Fluid Leaks:
Source: Accidental leaks from hydraulic systems used in boat repair equipment.
Impact: Release of hydraulic fluids, which can be harmful to the environment.

In table 3. is shown the relationship between a chemical source, exposure pathway and potential receptor at site shipyard and marina "Navar".

Table 3. Relationship between a chemical source, exposure pathway and potential receptor

Source and hazards	**Pathway**	**Receptor**
S1: Boat Repair Work Area • PAHs • PCBs • Metals • TPH • OTC	P1: Vertical migration of pollutants into sediment P2: Direct exposure (ingestion, inhalation, dermal contact) P3: Horizontal migration through ground or/and stormwater P4: Migration through air	R1: Sediment R2: Sea water R3: Stormwater R4: Air R5: Aquatic plants/organisms R6: Human beings
S2: Warehouses and repair workshops • Metals • PCBs • PAHs • TPH	P1: Vertical migration of pollutants into soil P2: Horizontal migration through ground or/and stormwater P3: Direct exposure (ingestion, inhalation, dermal contact) P4: Migration through air	R1: Soil R2: Sediment R3: Sea water R4: Stormwater R5: Air R6: Aquatic plants/organisms R7: Human beings
S3: Accidents and Spills • TPH • Metals • PAHs • PFAS	P1: Vertical migration of pollutants into sediment P2: Horizontal migration through sea water P3: Direct exposure (ingestion, inhalation, dermal contact) P4: Migration through air	R1: Sediment R2: Air R3: Sea water R4: Aquatic plants/organisms R5: Human beings

Figure 9. shows the area of the shipyard and marina "Navar" and potential sources of pollution. CSM for the marina “Navar” location is given in Figure 10.

Figure 9. Shipyard and marina "Navar"

Figure 10. Schematic view of CSM for Shipyard and marina "Navar" with relationship between a chemical source, exposure pathway and potential receptor

Port of Risan

Location Overview

Port of Risan is situated in Boka Bay, in the Municipality of Kotor. Settlement Risan where the port is located is one of the oldest settlements in the Bay of Kotor, with a rich history dating back to ancient times. It is located 15 km from Kotor and 20 km from Herceg Novi.

Identified sources and types of pollution

A Port of Risan can be associated with various sources of pollution, impacting both the marine environment and surrounding areas. Here are identified sources and types of pollution which can be associated with the Port of Risan

Shipping Activities (S1):

Source: Shipping activities in the port involve various vessels, and these vessels can potentially discharge bilge water and ballast water containing chemicals and contaminants. This port is rated as a port for passenger and tourist traffic. Freight traffic is limited, because there is no space for storage, but there are data that cement was transported through this port, in the period 10 - 20 years ago, however, there are no precise data on this.

Impact: Transshipment of this type of materials can be the source of a significant amount of particles that, in addition to direct air pollution, can also lead to water, soil and sediment pollution through migration. Boat maintenance activities, including antifouling paint application and the potential release of harmful chemicals.

Land Traffic (S2):

Source: The port is bordered by a road along the coast, and there's an open parking area on the other side toward Hotel "Teuta."

Impact: Vehicles can leak fluids such as oil, fuel, and coolant onto road surfaces. Land traffic generates runoff from roads and parking lots, carrying various chemical pollutants such as oil, heavy metals, and chemicals into stormwater drainage systems. This contaminated runoff can eventually flow into nearby water bodies, including the marine environment.

Impact: As the runoff reaches the marine sediment, it can introduce pollutants directly into the sediment. missions from vehicles, especially those burning fossil fuels, release pollutants into the atmosphere. These pollutants can settle onto the ground and eventually be washed into marine sediments through rainfall. Common pollutants from land traffic include hydrocarbons, particulate matter, and heavy metals. Once in the sediment, these pollutants can accumulate over time.

Stormwater Runoff (S3):

Source: Stormwater runoff can have a significant impact on the chemical pollution of the Port of Risan, as it serves as a pathway for transporting various pollutants from the surrounding land and urban areas into the port's waters and sediment. Stormwater runoff collects pollutants, including oil, heavy metals, chemicals, and debris, from roads, parking lots, industrial areas, and urban environments as it flows towards the port. These contaminants can originate from various sources, such as vehicle emissions, industrial processes, and improper waste disposal. There are several stormwater outfalls in the harbor area, so if

stormwater systems are not properly managed or filtered, runoff can be discharged directly into harbor waters.
Impact: This can introduce a range of pollutants directly into the marine environment of the port, including the water column and sediment. Also, these waters can carry with them certain amounts of suspended particles that will settle in the sediment.

Construction Activities (S4):
Source: The reconstruction of Hotel Teuta in the vicinity of the Port of Risan could potentially impact the chemical pollution of the port. During the reconstruction process, there may be construction-related activities that could lead to chemical pollution. These activities might include excavation, demolition, painting, and the use of construction materials that can release chemicals or contaminants into the environment. Construction sites are known sources of sediment and chemical runoff. Rainfall can wash chemicals, sediment, and construction debris from the site into nearby stormwater drains and ultimately into the port. This runoff can carry pollutants like sediment, concrete washout, oil, and chemicals from construction materials.
Impact: Improper disposal of construction-related waste, such as paint, solvents, or unused construction materials, can lead to chemical pollution if these substances find their way into the port area. Excavation and grading during construction can disturb the soil, potentially releasing contaminants or pollutants that were previously buried or dormant.

Freshwater Tributaries (S5):
Source: The river Spila can potentially affect the chemical pollution of the Port of Risan. Rivers often carry sediment from their upstream areas. If the riverbed and banks are contaminated with chemicals or pollutants, the river can transport these contaminants downstream and deposit them in the port area.
Impact: Sediment deposition can contribute to the accumulation of pollutants in the marine sediments of the port. Runoff from agricultural areas or urban developments within the watershed can carry pollutants like fertilizers, pesticides, heavy metals, and chemicals into the river. During periods of heavy rainfall or flooding riverbanks are susceptible to erosion.

Sewage Discharge (S6):
Source: Since Risan does not have an organized sewerage system, municipal waste water can be a potential pollutant in the Port of Risan as well. When sewage is directly injected into the ground or disposed of through septic tanks, there is a risk of groundwater contamination. If septic systems are not properly maintained or if the soil and geological conditions are not suitable for adequate filtration and treatment, sewage pollutants can leach into groundwater.
Impact: This contaminated groundwater can eventually flow towards the marine environment, potentially introducing pollutants into harbor waters and sediment. Septic systems can contribute to nutrient pollution in the form of excess nitrogen and phosphorus. If these nutrients reach groundwater, they can be transported to the marine environment. Excessive levels of nutrients can lead to water quality problems such as eutrophication, harmful algal blooms and oxygen depletion, which can harm aquatic ecosystems and contribute to chemical imbalances in the water. Malfunctioning septic systems can release pathogens (bacteria, viruses, etc.) into the environment. These pathogens can pose a health

risk to both aquatic life and human activities in the port area. In addition to fecal matter, septic systems can also release household chemicals and pharmaceuticals into the environment. These chemicals can be transported through groundwater and surface water to the harbor area, potentially contributing to chemical pollution in marine sediments and the water column.

Accidents and Spills (S7):

Land traffic, including transportation of hazardous materials, presents the risk of accidents and spills. Chemical spills on roadways or near marine environments can lead to the direct release of hazardous substances into nearby waters, affecting marine sediments. Spills can occur during transportation accidents or incidents involving tanker trucks carrying chemicals. Regarding to shipping activities, accidents, including ship collisions, equipment failures, or tanker accidents, can result in sudden chemical releases into the port waters. In August 2018, it was recorded that a certain amount of oil had been released into the port of Risan water area, and the relevant services removed the stain.

Source and hazards	Pathway	Receptor
S1: Shipping Activities • Metals • PAHs • TPH • OTC • PCBs	P1: Vertical migration of pollutants into soil P2: Horizontal migration through ground or/and stormwater P3: Direct exposure (ingestion, inhalation, dermal contact) P4: Migration through air	R1: Sediment R2: Soil R3: Air R4: Sea water R5: Stormwater R6: Aquatic plants/organisms R7: Human beings
S2: Land Traffic • Metals • PAHs • TPH	P1: Migration through air P2: Vertical migration of pollutants into soil P3: Direct exposure (ingestion, inhalation, dermal contact) P4: Horizontal migration through ground or/and stormwater	R1: Air R2: Soil R3: Sediment R4: Sea water R5: Stormwater R6: Aquatic plants/organisms R7: Human beings
S3: Stormwater Runoff • Metals • PAHs • TPH • OTC • PCBs	P1: Horizontal migration through ground or/and stormwater P2: Vertical migration of pollutants into soil P3: Direct exposure (ingestion, inhalation, dermal contact) P4: Migration through air	R1: Stormwater R2: Sea water R3: Sediment R4: Aquatic plants/organisms R5: Human beings

S4: Construction Activities • Metals • PAHs • TPH • OTC • PCBs	P1: Migration through air P2: Vertical migration of pollutants into soil P3: Direct exposure (ingestion, inhalation, dermal contact) P4: Horizontal migration through ground or/and stormwater	R1: Air R2: Soil R3: Sediment R4: Sea water R5: Stormwater R6: Aquatic plants/organisms R7: Human beings
S5: Freshwater Tributaries • Metals • Nutrients	P1: Vertical migration of pollutants into soil P2: Horizontal migration through ground or/and stormwater P3: Direct exposure (ingestion, inhalation, dermal contact) P4: Migration through air	R1: Sea water R2: Stormwater R3: Sediment R4: Soil R5: Air R6: Aquatic plants/organisms R7: Human beings
S6: Sewage Discharge • Nutrients	P1: Direct exposure (ingestion, inhalation, dermal contact) P2: Horizontal migration through ground or/and stormwater P3: Vertical migration of pollutants into soil P4: Migration through air	
S7: Accidents and Spills	P1: Direct exposure (ingestion, inhalation, dermal contact) P2: Vertical migration of pollutants into soil P2: Horizontal migration through ground or/and stormwater P4: Migration through air	R1: Sediment R2: Soil R3: Air R4: Sea water R5: Stormwater R6: Aquatic plants/organisms R7: Human beings

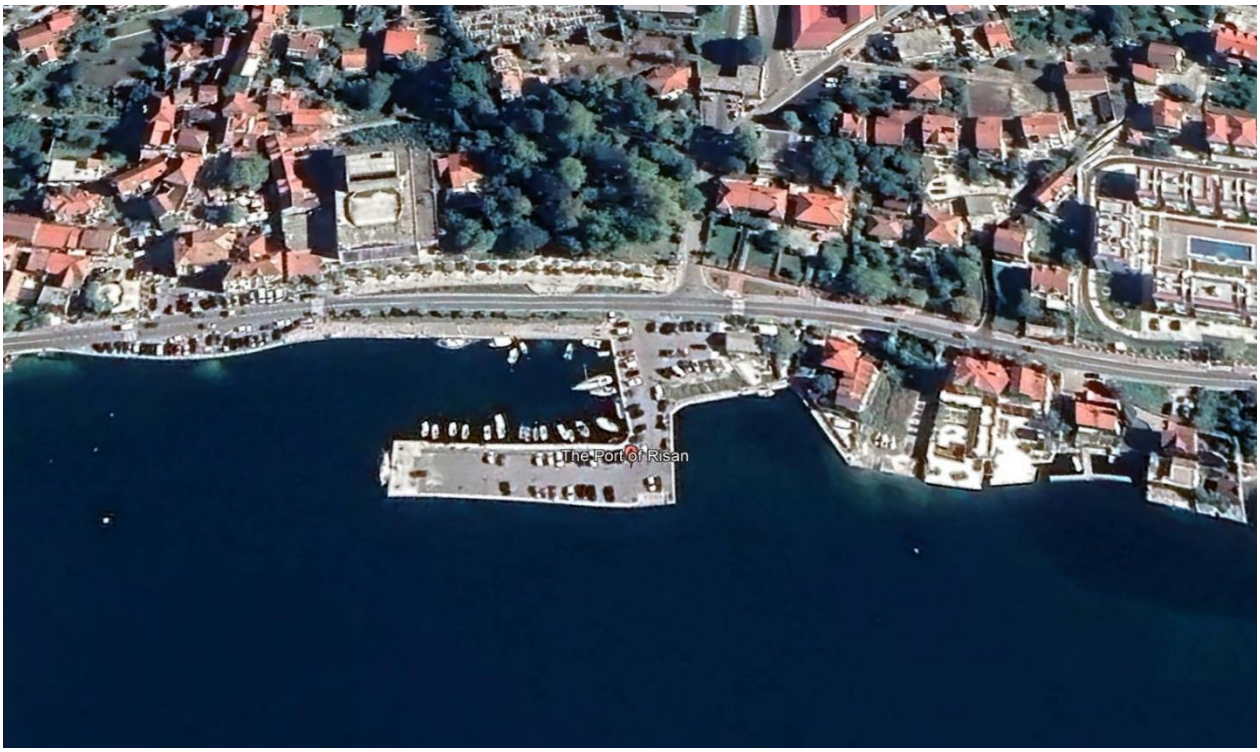

Figure 11. Port of Risan

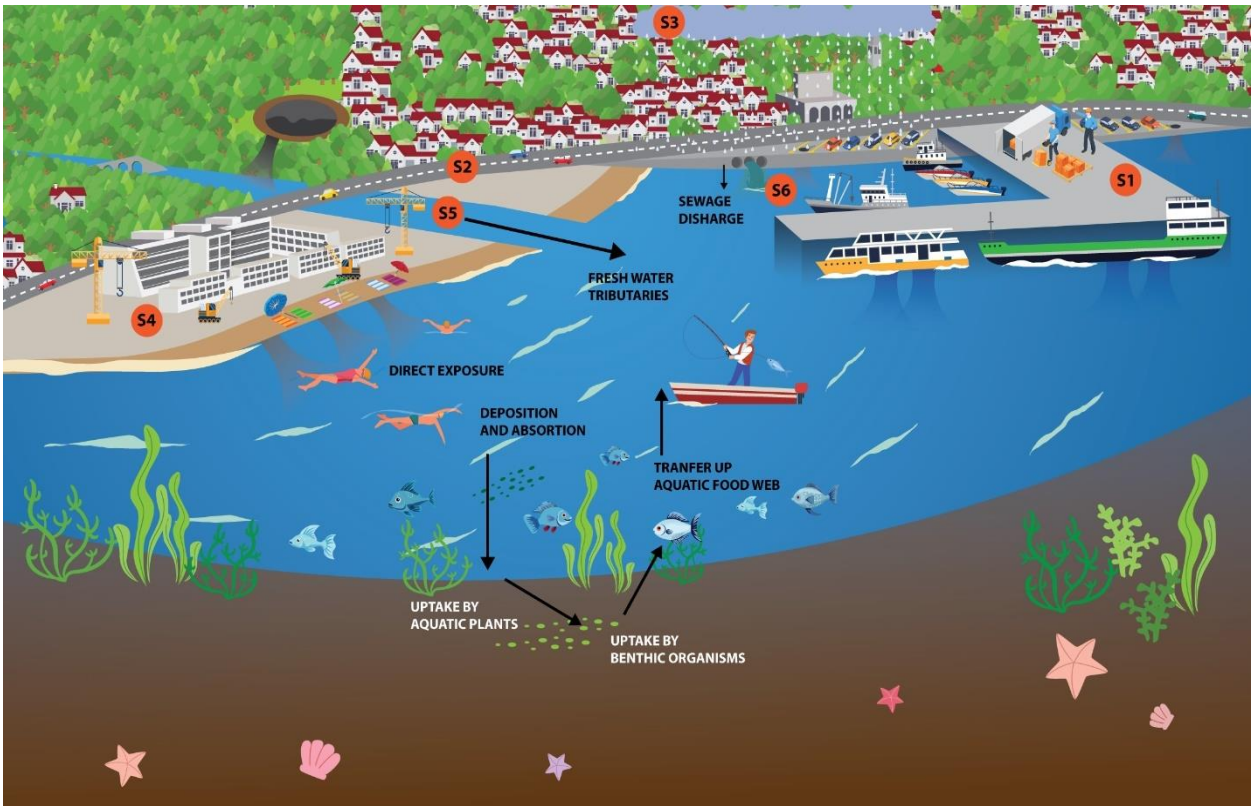

Figure 12. Schematic view of CSM for Port of Risan with relationship between a chemical source, exposure pathway and potential receptor

Tabular overview of results of analysis

Location of sampling	Navar, Tivat Bay	Navar, Tivat Bay	Navar, Tivat Bay	Navar, Tivat Bay	Navar, Tivat Bay	Sediment Quality Guidelines (SQGs)				Method
Date of sampling	22.08.2023.	22.08.2023.	22.08.2023.	22.08.2023.	22.08.2023.	TEL	PEL	ER-L	ER-M	
Laboratory number	148/05/23	149/05/23	150/05/23	151/05/23	152/05/23					
Coordinates*										
Sampling depth [m]	7,9	5,4	5,3	3,6	7,5					
Parametar	Results of analysis	Results of analysis	Results of analysis	Results of analysis	Results of analysis					
Trace elements [mg/kg DW]										
Mercury	0.43	0.31	0.24	0.24	0.34	0.13	0.7	0.15	0.71	AMA-112
Methyl mercury	-	-	0.000471	-	-					S-GC-36
Cadmium	0.079	0.1	0.097	0.064	0.076	0.68	4.21	1.2	9.6	IAEA-MEL-LPB
Lead	24	28	34	25	25	30.2	112	46.7	218	IAEA-MEL-LPB
Arsenic	18	16.1	17.1	18.3	25.1	7.24	41.6	8.2	70	IAEA-MEL-LPB
Copper	31	53	66	43	38	18.7	108	34	270	IAEA-MEL-LPB
Nickel	120	112	110	112	114	15.9	42.8	20.9	51.6	IAEA-MEL-LPB
Chromium	188	165	139	163	220	52.3	160	81	370	IAEA-MEL-LPB
Zinc	107	110	113	106	107	124	271	150	410	IAEA-MEL-LPB

Polycyclic Aromatic Hydrocarbons [µg/kg DW]										
Naphtalene	74.7	67.5	63.3	29.9	36.0	34.6	391	160	2100	EPA 8270D
2-methylnaphtalene	44.1	43.6	34.2	34.1	37.9	20.2	201			EPA 8270D
1-methylnaphtalene	28.3	28.2	22.0	21.5	23.4					EPA 8270D
Acenaphtylene	5.5	6.5	21.4	13.4	10.8	5.87	128			EPA 8270D
Acenaphtene	5.4	9.2	4.7	2.9	3.7	6.71	88.9	16	500	EPA 8270D
Fluorene	12.5	15.5	24.3	11.2	12.0	21.2	144	19	540	EPA 8270D
Phenanthrene	108	124	255	123	114	86.7	544	240	1500	EPA 8270D
Anthracene	19.1	24.8	50.3	25.4	23.9	46.9	245	85	1100	EPA 8270D
Fluoranthene	163	203	358	244	208	113	1494	600	5100	EPA 8270D
Pyrene	142	172	271	191	165	153	1398	665	2600	EPA 8270D
Benzo(a)anthracene	88.9	102	143	102	96.6	74.8	693	261	1600	EPA 8270D
Chrysene	84.2	104	141	102	90.6	108	846	384	2800	EPA 8270D
Benzo(b)fluoranthene	99.6	109	131	98.6	96.7					EPA 8270D
Benzo(k)fluoranthene	45.0	49.8	61.2	44.8	43.3					EPA 8270D
Benzo(j) fluoranthene	33.7	37.2	44.3	33.0	33.8					EPA 8270D
Benzo(a)pyrene	98.8	107	139	99.5	95.8	88.8	763	430	1600	EPA 8270D
Indeno(1.2.3-cd)pyrene	53.7	54.3	71.5	53.3	51.5					EPA 8270D
Dibenzo(a.h)anthracene	16.6	15.4	19.4	15.0	14.9	6.22	135	63.4	260	EPA 8270D
Benzo(g.h.i)perylene	59.5	63.0	76.4	55.0	55.8					EPA 8270D
Sum Low molecular weight PAHs	297	319	475	261	261	312	1442	552	3160	EPA 8270D
Sum High molecular weight PAHs	885	1016	1456	1038	953	655	6676	1700	9600	EPA 8270D
Total PAHs	1182	1336	1931	1299	1214	1684	16770	4022	44792	EPA 8270D

Polychlorinated biphenyls [µg/kg DW]										
PCB 18	0.44	0.46	0.39	0.13	<0.1					EPA 8270D
PCB 31	0.44	0.92	0.56	0.25	0.18					EPA 8270D
PCB 28	0.42	0.94	0.55	0.28	0.19					EPA 8270D
PCB 52	0.95	1.41	0.99	0.67	0.49					EPA 8270D
PCB 44	<0.1	0.47	0.29	0.12	<0.1					EPA 8270D
PCB 101	0.77	1.22	1.48	0.57	1.35					EPA 8270D
PCB 149	1.08	1.69	1.94	1.08	2.75					EPA 8270D
PCB 118	0.65	0.84	1.20	0.47	0.82					EPA 8270D
PCB 153	1.83	2.50	2.91	1.58	4.89					EPA 8270D
PCB 138	0.91	2.15	2.19	1.05	3.78					EPA 8270D
PCB 180	1.08	1.75	2.29	0.81	2.66					EPA 8270D
PCB 194	<0.1	<0.1	0.61	<0.1	<0.1					EPA 8270D
Total PCB	9.6	15.4	16.3	8.4	17.3	21.6	189	22.7	180	EPA 8080A
Organotin compounds [µg/kg DW]										
Monobuthyl-tin	-	12	-	4	-					ISO 23161:2009
Dibuthyl- tin	-	13	-	4	-					ISO 23161:2009
Tributhyl-tin	-	21	-	7	-					ISO 23161:2009
Monooctyl-tin	-	<4	-	<4	-					ISO 23161:2009
Tetrabuthyl-tin	-	<4	-	<4	-					ISO 23161:2009
Dioctyl-tin	-	<4	-	<4	-					ISO 23161:2009
Triphenyl-tin	-	4	-	<4	-					ISO 23161:2009
Tricyclohexyl-tin	-	<4	-	<4	-					ISO 23161:2009

Organochlorine pesticides [µg/kg DW]										
Alpha endosulfan	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Beta endosulfan	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
α-HCH	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
β-HCH	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
δ-HCH	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
γ-HCH	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Dicofol	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Hexachlorbenzene	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Chlordecone	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Aldrin	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Dieldrin	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Endrin	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Chlordane cis	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Chlordane trans	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Pentachlorobenzene	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Heptachlor	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Heptachlor epoxide	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
o,p DDE	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
p,p DDE	1.00	1.40	0.77	0.71	0.40					EPA 8270 D
o,pDDD	0.15	0.26	0.15	0.12	<0.1					EPA 8270 D
p,p DDD	0.78	1.20	0.63	0.48	0.58					EPA 8270 D
o,p DDT	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
p,p DDT	<1	<1	<1	<1	<1					EPA 8270 D
total DDT	1.93	2.86	1.55	1.31	0.98					EPA 8270 D
Mirex	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Polybrominated diphenyl ethers [µg/kg DW]										
BDE 28	<0.05	<0.05	<0.05	<0.05	<0.05					EPA 1614*
BDE 47	<0.05	<0.05	<0.05	<0.05	<0.05					EPA 1614*
BDE 99	<0.05	<0.05	<0.05	<0.05	<0.05					EPA 1614*
BDE 100	<0.05	<0.05	<0.05	<0.05	<0.05					EPA 1614*

BDE 153	<0.05	0.066	0.095	<0.05	0.085					EPA 1614*
BDE 154	<0.05	<0.05	<0.05	<0.05	<0.05					EPA 1614*
BDE 183	<0.1	0.26	0.22	<0.1	<0.1					EPA 1614*
Dioxins and Furans [µg/kg DW]										
2378-TCDF	<0.005	<0.005	<0.005	<0.005	<0.005					EPA 1613*
2378-TCDD	<0.005	<0.005	<0.005	<0.005	<0.005					EPA 1613*
12378-PeCDF	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
23478-PeCDF	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
12378-PeCDD	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
123478-HxCDF	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
123678-HxCDF	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
123478-HxCDD	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
123678-HxCDD	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
123789-HxCDD	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
123789-HxCDF	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
234678-HxCDF	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
1234678-HpCDF	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
1234678-HpCDD	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
1234789-HpCDF	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
OCDD	<0.05	<0.05	<0.05	<0.05	<0.05					EPA 1613*
OCDF	<0.05	<0.05	<0.05	<0.05	<0.05					EPA 1613*
Chlorinated organic substances [µg/kg DW]										
Pentachlorophenol	-	-	<20	<20	-					ISO 17182:2014*
Hexachloro - 1,3-butadiene	<1	<1	<1	<1	<1					EPA 5021A*

Perfluorinated Compounds [µg/kg DW]										
Perfluorobutanoic acid (PFBA)	-	-	<0.50	<0.50	-					S-PFCLMS02
Perfluoropentanoic acid (PFPeA)	-	-	<0.50	<0.50	-					S-PFCLMS02
Perfluorohexanoic acid (PFHxA)	-	-	<0.50	<0.50	-					S-PFCLMS02
Perfluoroheptanoic acid (PFHpA)	-	-	<0.50	<0.50	-					S-PFCLMS02
Perfluorooctanoic acid (PFOA)	-	-	<0.50	<0.50	-					S-PFCLMS02
Perfluorononanoic acid (PFNA)	-	-	<0.50	<0.50	-					S-PFCLMS02
Perfluorodecanoic acid (PFDA)	-	-	<0.50	<0.50	-					S-PFCLMS02
Perfluoroundecanoic acid (PFUnDA)	-	-	<0.50	<0.50	-					S-PFCLMS02
Perfluorododecanoic acid (PFDoDA)	-	-	<0.50	<0.50	-					S-PFCLMS02
Perfluorotridecanoic acid (PFTrDA)	-	-	<0.50	<0.50	-					S-PFCLMS02
Perfluorotetradecanoic acid (PFTeDA)	-	-	<0.50	<0.50	-					S-PFCLMS02
Perfluorobutane sulfonic acid (PFBS)	-	-	<0.50	<0.50	-					S-PFCLMS02

Perfluorohexane sulfonic acid (PFHxS)	-	-	<0.50	<0.50	-					S-PFCLMS02
Perfluoroheptane sulfonic acid (PFHpS)	-	-	<0.50	<0.50	-					S-PFCLMS02
Perfluorooctane sulfonic acid (PFOS)	-	-	<0.50	<0.50	-					S-PFCLMS02
Perfluorodecane sulfonic acid (PFDS)	-	-	<0.50	<0.50	-					S-PFCLMS02
6:2 Fluorotelomer sulfonic acid (6:2 FTS)	-	-	<0.50	<0.50	-					S-PFCLMS02
8:2 Fluorotelomer sulfonic acid (8:2 FTS)	-	-	<0.50	<0.50	-					S-PFCLMS02
Perfluorooctane sulfonamide (FOSA)	-	-	<0.50	<0.50	-					S-PFCLMS02
N-Methyl perfluorooctane sulfonamide (MeFOSA)	-	-	<0.50	<0.50	-					S-PFCLMS02
N-Ethyl perfluorooctane sulfonamide (EtFOSA)	-	-	<0.50	<0.50	-					S-PFCLMS02
N-Methyl perfluorooctane sulfonamidoethanol (MeFOSE)	-	-	<0.50	<0.50	-					S-PFCLMS02

N-Ethyl perfluorooctane sulfonamidoethanol (EtFOSE)	-	-	<0.50	<0.50	-					S-PFCLMS02
Perfluoropentane sulfonic acid (PFPeS)	-	-	<0.50	<0.50	-					S-PFCLMS02
Perfluorooctane sulfonamidoacetic acid (FOSAA)	-	-	<0.50	<0.50	-					S-PFCLMS02
Perfluorooctadecanoic acid (PFOcDA)	-	-	<5.0	<5.0	-					S-PFCLMS02
Perfluorononane sulfonic acid (PFNS)	-	-	<0.50	<0.50	-					S-PFCLMS02
Perfluorohexadecanoic acid (PFHxDA)	-	-	<5.0	<5.0	-					S-PFCLMS02
Perfluorododecane sulfonic acid (PFDoDS)	-	-	<0.50	<0.50	-					S-PFCLMS02
Perfluoro-3,7-dimethyloctanoic acid (P37DMOA)	-	-	<0.50	<0.50	-					S-PFCLMS02
N-Methyl perfluorooctane sulfonamidoacetic acid (MeFOSAA)	-	-	<0.50	<0.50	-					S-PFCLMS02
N-Ethyl perfluorooctane sulfonamidoacetic acid (EtFOSAA)	-	-	<0.50	<0.50	-					S-PFCLMS02

7H-perfluoroheptanoic acid (HPFHpA)	-	-	<0.50	<0.50	-					S-PFCLMS02
4:2 Fluorotelomer sulfonic acid (4:2 FTS)	-	-	<0.50	<0.50	-					S-PFCLMS02
10:2 Fluorotelomer sulfonic acid (10:2 FTS)	-	-	<0.50	<0.50	-					S-PFCLMS02
Perfluoropropane sulfonic acid (PFPrS)	-	-	<2.50	<2.50	-					S-PFCLMS02
2,3,3,3-tetrafluoro-2-(heptafluoropropoxy)propanoic acid (HFPO-DA)	-	-	<2.50	<2.50	-					S-PFCLMS02
2H,2H,3H,3H-perfluoroundecanoic acid (H4PFUnDA)	-	-	<5.0	<5.0	-					S-PFCLMS02
Perfluoroundecane sulfonic acid (PFUnDS)	-	-	<2.50	<2.50	-					S-PFCLMS02
Perfluorotridecane sulfonic acid (PFTrDS)	-	-	<2.50	<2.50	-					S-PFCLMS02
9-chlorohexadecafluoro-3-oxano nane-1-sulfonic acid (9Cl-PF3ONS)	-	-	<0.50	<0.50	-					S-PFCLMS02
11-chloroeicosafluoro-3-oxaunde cane-1-sulfonic acid (11Cl-PF3OUdS)	-	-	<0.50	<0.50	-					S-PFCLMS02

4,8-dioxa-3H-perfluorononanoic acid (DONA)	-	-	<0.50	<0.50	-					S-PFCLMS02
Perfluoro-3-methoxypropanoic acid (PFMPA)	-	-	<2.50	<2.50	-					S-PFCLMS02
Perfluoro-4-methoxybutanoic acid (PFMBA)	-	-	<2.50	<2.50	-					S-PFCLMS02
Perfluoro(2-ethoxyethane)sulfonic acid (PFEESA)	-	-	<2.50	<2.50	-					S-PFCLMS02
Perfluoro-4-ethylcyclohexanesulfonic acid (PFECHS)	-	-	<0.50	<0.50	-					S-PFCLMS02
2H,2H,3H,3H-perfluorohexanoic acid (3:3 FTCA)	-	-	<2.50	<2.50	-					S-PFCLMS02
2H,2H-perfluorooctanoic acid (6:2 FTCA)	-	-	<5.0	<5.0	-					S-PFCLMS02
2H,2H,3H,3H-perfluorooctanoic acid (5:3 FTCA)	-	-	<5.0	<5.0	-					S-PFCLMS02
2H-perfluoro-2-octenoic acid (6:2 FTUCA)	-	-	<5.0	<5.0	-					S-PFCLMS02
2H-perfluoro-2-decenoic acid (8:2 FTUCA)	-	-	<0.50	<0.50	-					S-PFCLMS02
2H,2H,3H,3H-perfluorodecanoic acid (7:3 FTCA)	-	-	<5.0	<5.0	-					S-PFCLMS02

2H,2H-perfluorodecanoic acid (8:2 FTCA)	-	-	<5.0	<5.0	-					S-PFCLMS02
Total Organic Carbon [%DW]	-	-	0.91		-					S-TOC1-CC
Granulometric analysis [%]										
(0.06-2.0)mm	-	9	-	-	-					
(0.002-0.06)mm	-	67	-	-	-					
<0.002 mm	-	24	-	-	-					

Location of sampling	Tivat Airport, Tivat Bay	Tivat Airport, Tivat Bay	Tivat Airport, Tivat Bay	Tivat Airport, Tivat Bay	Tivat Airport, Tivat Bay	Sediment Quality Guidelines (SQGs)				Method
Date of sampling	22.08.2023.	22.08.2023.	22.08.2023.	22.08.2023.	22.08.2023.	TEL	PEL	ER-L	ER-M	
Laboratory number	153/05/23	154/05/23	155/05/23	156/05/23	157/05/23					
Coordinates*										
Sampling depth [m]	6,5	4,2	2,7	3,0	2,3					
Parametar	Results of analysis	Results of analysis	Results of analysis	Results of analysis	Results of analysis					
Trace elements [mg/kg DW]										
Mercury	0.28	0.25	0.22	0.22	0.21	0.13	0.7	0.15	0.71	AMA-112
Methyl mercury	-	-	-	-	0.000807					S-GC-36
Cadmium	0.068	0.063	0.095	0.059	0.062	0.68	4.21	1.2	9.6	IAEA-MEL-LPB
Lead	21	24	23	21	27	30.2	112	46.7	218	IAEA-MEL-LPB
Arsenic	26.6	20.1	23	24	26	7.24	41.6	8.2	70	IAEA-MEL-LPB
Copper	41	42	55	39	43	18.7	108	34	270	IAEA-MEL-LPB
Nickel	139	110	132	122	126	15.9	42.8	20.9	51.6	IAEA-MEL-LPB
Chromium	152	161	176	162	163	52.3	160	81	370	IAEA-MEL-LPB
Zinc	124	109	138	114	126	124	271	150	410	IAEA-MEL-LPB
Polycyclic Aromatic Hydrocarbons [µg/kg DW]										

Naphtalene	40.6	32.4	38.6	40.1	58.9	34.6	391	160	2100	EPA 8270D
2-methylnaphtalene	40.7	35.3	40.7	38.2	57.9	20.2	201			EPA 8270D
1-methylnaphtalene	24.4	22.2	24.0	23.4	34.5					EPA 8270D
Acenaphtylene	9.2	66.2	4.3	34.9	32.2	5.87	128			EPA 8270D
Acenaphtene	2.5	7.2	1.3	1.5	<1	6.71	88.9	16	500	EPA 8270D
Fluorene	8.7	36.4	6.9	23.6	18.6	21.2	144	19	540	EPA 8270D
Phenanthrene	91.3	434	46.2	272	189	86.7	544	240	1500	EPA 8270D
Anthracene	14.8	89.5	7.2	48.1	44.5	46.9	245	85	1100	EPA 8270D
Fluoranthene	158	810	70.5	500	435	113	1494	600	5100	EPA 8270D
Pyrene	130	657	58.4	382	344	153	1398	665	2600	EPA 8270D
Benzo(a)anthracene	71.1	291	34.5	187	176	74.8	693	261	1600	EPA 8270D
Chrysene	71.7	319	37.2	188	173	108	846	384	2800	EPA 8270D
Benzo(b)fluoranthene	79.3	307	43.4	176	171					EPA 8270D
Benzo(k)fluoranthene	35.7	146	18.3	81.4	77.9					EPA 8270D
Benzo(j) fluoranthene	26.4	108	13.1	60.3	56.7					EPA 8270D
Benzo(a)pyrene	77.3	325	38.6	185	180	88.8	763	430	1600	EPA 8270D
Indeno(1.2.3-cd)pyrene	42.0	167	22.9	101	95.8					EPA 8270D
Dibenzo(a.h)anthracene	11.7	45.7	6.5	27.9	26.8	6.22	135	63.4	260	EPA 8270D
Benzo(g.h.i)perylene	45.7	168	26.6	101	93.7					EPA 8270D
Sum Low molecular weight PAHs	232	724	169	482	436	312	1442	552	3160	EPA 8270D
Sum High molecular weight PAHs	749	3343	370	1990	1830	655	6676	1700	9600	EPA 8270D
Total PAHs	981	4067	539	2472	2266	1684	16770	4022	44792	EPA 8270D
Polychlorinated biphenyls [µg/kg DW]										
PCB 18	0.13	0.10	0.13	<0.1	0.10					EPA 8270D

PCB 31	0.18	0.21	0.21	0.13	0.15					EPA 8270D
PCB 28	0.17	0.22	0.24	0.15	0.17					EPA 8270D
PCB 52	0.58	0.61	0.80	<0.1	0.54					EPA 8270D
PCB 44	<0.1	<0.1	<0.1	<0.1	0.29					EPA 8270D
PCB 101	0.31	0.45	0.59	0.35	0.22					EPA 8270D
PCB 149	0.78	0.70	1.12	0.75	0.58					EPA 8270D
PCB 118	0.53	0.37	0.40	<0.1	0.45					EPA 8270D
PCB 153	1.33	1.20	1.65	1.34	1.11					EPA 8270D
PCB 138	0.47	0.96	1.18	<0.1	<0.1					EPA 8270D
PCB 180	0.67	0.79	1.00	0.76	0.57					EPA 8270D
PCB 194	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270D
Total PCB	4.6	5.8	7.4	3.6	4.5	21.6	189	22.7	180	EPA 8080
Organotin compounds [µg/kg DW]										
Monobuthyl-tin			<4		6					ISO 23161:2009
Dibuthyl- tin			<4		<4					ISO 23161:2009
Tributhyl-tin			<4		<4					ISO 23161:2009
Monooctyl-tin			<4		<4					ISO 23161:2009
Tetrabuthyl-tin			<4		<4					ISO 23161:2009
Dioctyl-tin			<4		<4					ISO 23161:2009

Triphenyl-tin			<4		<4					ISO 23161:2009
Tricyclohexyl-tin			<4		<4					ISO 23161:2009
Organochlorine pesticides [µg/kg DW]										
Alpha endosulfan	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Beta endosulfan	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
α-HCH	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
β-HCH	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
δ-HCH	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
γ-HCH	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Dicofol	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Hexachlorbenzene	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Chlordecone	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Aldrin	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Dieldrin	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Endrin	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Chlordane cis	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D

Chlordane trans	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Pentachlorobenzene	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Heptachlor	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Heptachlor epoxide	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
o,p DDE	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
p,p DDE	0.69	0.78	0.81	0.50	0.45					EPA 8270 D
o,pDDD	<0.1	0.15	0.15	<0.1	<0.1					EPA 8270 D
p,p DDD	0.43	0.46	0.36	0.27	0.24					EPA 8270 D
o,p DDT	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
p,p DDT	<1	<1	<1	<1	<1					EPA 8270 D
total DDT	1.12	1.39	1.32	0.77	0.69					EPA 8270 D
Mirex	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Polybrominated diphenyl ethers [µg/kg DW]										
BDE 28	<0.05	<0.05	<0.05	<0.05	<0.05					EPA 1614*
BDE 47	<0.05	<0.05	<0.05	<0.05	<0.05					EPA 1614*
BDE 99	<0.05	<0.05	<0.05	<0.05	<0.05					EPA 1614*
BDE 100	<0.05	<0.05	<0.05	<0.05	<0.05					EPA 1614*
BDE 153	<0.05	0.090	<0.05	<0.05	<0.05					EPA 1614*
BDE 154	<0.05	<0.05	<0.05	<0.05	<0.05					EPA 1614*
BDE 183	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 1614*

Dioxins and Furans [µg/kg DW]										
2378-TCDF	<0.005	<0.005	<0.005	<0.005	<0.005					EPA 1613*
2378-TCDD	<0.005	<0.005	<0.005	<0.005	<0.005					EPA 1613*
12378-PeCDF	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
23478-PeCDF	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
12378-PeCDD	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
123478-HxCDF	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
123678-HxCDF	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
123478-HxCDD	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
123678-HxCDD	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
123789-HxCDD	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
123789-HxCDF	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
234678-HxCDF	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
1234678-HpCDF	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
1234678-HpCDD	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
1234789-HpCDF	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
OCDD	<0.05	<0.05	<0.05	<0.05	<0.05					EPA 1613*
OCDF	<0.05	<0.05	<0.05	<0.05	<0.05					EPA 1613*
Chlorinated organic substances [µg/kg DW]										
Pentachlorophenol		<20	<20		<20					ISO 17182:2014*
Hexachloro - 1,3-butadiene	<1	<1	<1	<1	<1					EPA 5021*
Perfluorinated Compounds [µg/kg DW]										
Perfluorobutanoic acid (PFBA)	-	<0.50	-	<0.50	<0.50					S-PFCLMS02

Perfluoropentanoic acid (PFPeA)	-	<0.50	-	<0.50	<0.50					S-PFCLMS02
Perfluorohexanoic acid (PFHxA)	-	<0.50	-	<0.50	<0.50					S-PFCLMS02
Perfluoroheptanoic acid (PFHpA)	-	<0.50	-	<0.50	<0.50					S-PFCLMS02
Perfluorooctanoic acid (PFOA)	-	<0.50	-	<0.50	<0.50					S-PFCLMS02
Perfluorononanoic acid (PFNA)	-	<0.50	-	<0.50	<0.50					S-PFCLMS02
Perfluorodecanoic acid (PFDA)	-	<0.50	-	<0.50	<0.50					S-PFCLMS02
Perfluoroundecanoic acid (PFUnDA)	-	<0.50	-	<0.50	<0.50					S-PFCLMS02
Perfluorododecanoic acid (PFDoDA)	-	<0.50	-	<0.50	<0.50					S-PFCLMS02
Perfluorotridecanoic acid (PFTrDA)	-	<0.50	-	<0.50	<0.50					S-PFCLMS02
Perfluorotetradecanoic acid (PFTeDA)	-	<0.50	-	<0.50	<0.50					S-PFCLMS02
Perfluorobutane sulfonic acid (PFBS)	-	<0.50	-	<0.50	<0.50					S-PFCLMS02
Perfluorohexane sulfonic acid (PFHxS)	-	<0.50	-	<0.50	<0.50					S-PFCLMS02
Perfluoroheptane sulfonic acid (PFHpS)	-	<0.50	-	<0.50	<0.50					S-PFCLMS02

Perfluorooctane sulfonic acid (PFOS)	-	<0.50	-	<0.50	<0.50					S-PFCLMS02
Perfluorodecane sulfonic acid (PFDS)	-	<0.50	-	<0.50	<0.50					S-PFCLMS02
6:2 Fluorotelomer sulfonic acid (6:2 FTS)	-	<0.50	-	<0.50	<0.50					S-PFCLMS02
8:2 Fluorotelomer sulfonic acid (8:2 FTS)	-	<0.50	-	<0.50	<0.50					S-PFCLMS02
Perfluorooctane sulfonamide (FOSA)	-	<0.50	-	<0.50	<0.50					S-PFCLMS02
N-Methyl perfluorooctane sulfonamide (MeFOSA)	-	<0.50	-	<0.50	<0.50					S-PFCLMS02
N-Ethyl perfluorooctane sulfonamide (EtFOSA)	-	<0.50	-	<0.50	<0.50					S-PFCLMS02
N-Methyl perfluorooctane sulfonamidoethanol (MeFOSE)	-	<0.50	-	<0.50	<0.50					S-PFCLMS02
N-Ethyl perfluorooctane sulfonamidoethanol (EtFOSE)	-	<0.50	-	<0.50	<0.50					S-PFCLMS02
Perfluoropentane sulfonic acid (PFPeS)	-	<0.50	-	<0.50	<0.50					S-PFCLMS02

Perfluorooctane sulfonamidoacetic acid (FOSAA)	-	<0.50	-	<0.50	<0.50					S-PFCLMS02
Perfluorooctadecanoic acid (PFOcDA)	-	<5.0	-	<5.0	<5.0					S-PFCLMS02
Perfluorononane sulfonic acid (PFNS)	-	<0.50	-	<0.50	<0.50					S-PFCLMS02
Perfluorohexadecanoic acid (PFHxDA)	-	<5.0	-	<5.0	<5.0					S-PFCLMS02
Perfluorododecane sulfonic acid (PFDoDS)	-	<0.50	-	<0.50	<0.50					S-PFCLMS02
Perfluoro-3,7-dimethyloctanoic acid (P37DMOA)	-	<0.50	-	<0.50	<0.50					S-PFCLMS02
N-Methyl perfluorooctane sulfonamidoacetic acid (MeFOSAA)	-	<0.50	-	<0.50	<0.50					S-PFCLMS02
N-Ethyl perfluorooctane sulfonamidoacetic acid (EtFOSAA)	-	<0.50	-	<0.50	<0.50					S-PFCLMS02
7H-perfluoroheptanoic acid (HPFHpA)	-	<0.50	-	<0.50	<0.50					S-PFCLMS02
4:2 Fluorotelomer sulfonic acid (4:2 FTS)	-	<0.50	-	<0.50	<0.50					S-PFCLMS02
10:2 Fluorotelomer sulfonic acid (10:2 FTS)	-	<0.50	-	<0.50	<0.50					S-PFCLMS02

Perfluoropropane sulfonic acid (PFPrS)	-	<2.50	-	<2.50	<2.50					S-PFCLMS02
2,3,3,3-tetrafluoro-2-(heptafluoropropoxy)propanoic acid (HFPO-DA)	-	<2.50	-	<2.50	<2.50					S-PFCLMS02
2H,2H,3H,3H-perfluoroundecanoic acid (H4PFUnDA)	-	<5.0	-	<5.0	<5.0					S-PFCLMS02
Perfluoroundecane sulfonic acid (PFUnDS)	-	<2.50	-	<2.50	<2.50					S-PFCLMS02
Perfluorotridecane sulfonic acid (PFTrDS)	-	<2.50	-	<2.50	<2.50					S-PFCLMS02
9-chlorohexadecafluoro-3-oxano nane-1-sulfonic acid (9Cl-PF3ONS)	-	<0.50	-	<0.50	<0.50					S-PFCLMS02
11-chloroeicosafluoro-3-oxaunde cane-1-sulfonic acid (11Cl-PF3OUdS)	-	<0.50	-	<0.50	<0.50					S-PFCLMS02
4,8-dioxa-3H-perfluorononanoic acid (DONA)	-	<0.50	-	<0.50	<0.50					S-PFCLMS02
Perfluoro-3-methoxypropanoic acid (PFMPA)	-	<2.50	-	<2.50	<2.50					S-PFCLMS02

Perfluoro-4-methoxybutanoic acid (PFMBA)	-	<2.50	-	<2.50	<2.50					S-PFCLMS02
Perfluoro(2-ethoxyethane)sulfonic acid (PFEESA)	-	<2.50	-	<2.50	<2.50					S-PFCLMS02
Perfluoro-4-ethylcyclohexanesulfonic acid (PFECHS)	-	<0.50	-	<0.50	<0.50					S-PFCLMS02
2H,2H,3H,3H-perfluorohexanoic acid (3:3 FTCA)	-	<2.50	-	<2.50	<2.50					S-PFCLMS02
2H,2H-perfluorooctanoic acid (6:2 FTCA)	-	<5.0	-	<5.0	<5.0					S-PFCLMS02
2H,2H,3H,3H-perfluorooctanoic acid (5:3 FTCA)	-	<5.0	-	<5.0	<5.0					S-PFCLMS02
2H-perfluoro-2-octenoic acid (6:2 FTUCA)	-	<5.0	-	<5.0	<5.0					S-PFCLMS02
2H-perfluoro-2-decenoic acid (8:2 FTUCA)	-	<0.50	-	<0.50	<0.50					S-PFCLMS02
2H,2H,3H,3H-perfluorodecanoic acid (7:3 FTCA)	-	<5.0	-	<5.0	<5.0					S-PFCLMS02
2H,2H-perfluorodecanoic acid (8:2 FTCA)	-	<5.0	-	<5.0	<5.0					S-PFCLMS02
Total Organic Carbon [%DW]	-	-	-	-	1.51					S-TOC1-CC

Granulometric analysis [%]										
(0.06-2.0)mm	5	23	-	-	11					
(0.002-0.06)mm	63	58	-	-	57					
<0.002 mm	32	19	-	-	32					

Location of sampling	Canal near the airport	Gradiošnica River, Avio Servis Tivat	Gradiošnica River, mouth into the sea	Sediment Quality Guidelines (SQGs)				Method
Date of sampling	04.10.2023.	04.10.2023.	04.10.2023.	TEL	PEL	ER-L	ER-M	
Laboratory number	222/05/23	223/05/23	224/05/23					
Coordinates*								
Parametar								
Trace elements [mg/kg DW]	Results of analysis	Results of analysis	Results of analysis					
Mercury								
Cadmium	0.089	0.09	0.155	0.13	0.7	0.15	0.71	AMA-112
Lead	0.045	0.27	0.155	0.68	4.21	1.2	9.6	IAEA-MEL-LPB
Arsenic	16	35	25	30.2	112	46.7	218	IAEA-MEL-LPB
Copper	7.2	5.3	6	7.24	41.6	8.2	70	IAEA-MEL-LPB
Nickel	18	156	49	18.7	108	34	270	IAEA-MEL-LPB
Chromium	38	117	63	15.9	42.8	20.9	51.6	IAEA-MEL-LPB
Zinc	100	137	104	52.3	160	81	370	IAEA-MEL-LPB
Polycyclic Aromatic Hydrocarbons [µg/kg DW]	45	92	86	124	271	150	410	IAEA-MEL-LPB
Naphtalene								
2-methylnaphtalene	29.9	8.7	27.4	34.6	391	160	2100	EPA 8270D

1-methylnaphtalene	29.1	8.2	26.1	20.2	201			EPA 8270D
Acenaphtylene	18.2	4.7	15.3					EPA 8270D
Acenaphtene	3.5	<1	2.7	5.87	128			EPA 8270D
Fluorene	1.9	2.2	3.5	6.71	88.9	16	500	EPA 8270D
Phenanthrene	6.8	3.7	6.7	21.2	144	19	540	EPA 8270D
Anthracene	50.4	28.1	66.7	86.7	544	240	1500	EPA 8270D
Fluoranthene	6.2	3.7	7.5	46.9	245	85	1100	EPA 8270D
Pyrene	56.8	39.4	80.7	113	1494	600	5100	EPA 8270D
Benzo(a)anthracene	46.0	40.2	74.0	153	1398	665	2600	EPA 8270D
Chrysene	24.9	20.1	35.6	74.8	693	261	1600	EPA 8270D
Benzo(b)fluoranthene	22.2	20.1	30.9	108	846	384	2800	EPA 8270D
Benzo(k)fluoranthene	28.4	22.0	43.6					EPA 8270D
Benzo(j) fluoranthene	11.6	9.4	19.0					EPA 8270D
Benzo(a)pyrene	24.2	19.7	37.9					EPA 8270D
Indeno(1.2.3-cd)pyrene	13.6	11.1	21.8	88.8	763	430	1600	EPA 8270D
Dibenzo(a.h)anthracene	3.7	2.5	5.2					EPA 8270D
Benzo(g.h.i)perylene	16.4	14.4	26.5	6.22	135	63.4	260	EPA 8270D
Sum Low molecular weight PAHs	29.9	8.7	27.4					EPA 8270D
Sum High molecular weight PAHs	146	59	156	312	1442	552	3160	EPA 8270D
Total PAHs	248	199	375	655	6676	1700	9600	EPA 8270D
Polychlorinated biphenyls [µg/kg DW]	394	258	531	1684	16770	4022	44792	EPA 8270D
PCB 18	<0.1	<0.1	<0.1					
PCB 31	<0.1	0.3	0.6					EPA 8270D
PCB 28	<0.1	0.5	1.1					EPA 8270D
PCB 52	<0.1	<0.1	0.6					EPA 8270D

PCB 44	<0.1	<0.1	0.9					EPA 8270D
PCB 101	0.3	0.7	1.3					EPA 8270D
PCB 149	0.4	1.1	1.7					EPA 8270D
PCB 118	<0.1	<0.1	<0.1					EPA 8270D
PCB 153	0.7	1.4	2.6					EPA 8270D
PCB 138	0.5	1.2	2.4					EPA 8270D
PCB 180	0.6	1.4	1.6					EPA 8270D
PCB 194	<0.1	<0.1	<0.1					EPA 8270D
Total PCB	2.7	7.2	15.7	21.6	189	22.7	180	EPA 8270D
Organotin compounds [µg/kg DW]								
Monobuthyl-tin	<4	<4	<4					ISO 23161:2009
Dibuthyl- tin	<4	<4	<4					ISO 23161:2009
Tributhyl-tin	<4	<4	<4					ISO 23161:2009
Monooctyl-tin	<4	<4	<4					ISO 23161:2009
Tetrabuthyl-tin	<4	<4	<4					ISO 23161:2009
Dioctyl-tin	<4	<4	<4					ISO 23161:2009
Triphenyl-tin	<4	<4	<4					ISO 23161:2009
Tricyclohexyl-tin	<4	<4	<4					ISO 23161:2009
Organochlorine pesticides [µg/kg DW]								
Alpha endosulfan	<0.1	<0.1	<0.1					EPA 8270 D

Beta endosulfan	<0.1	<0.1	<0.1					EPA 8270 D
α-HCH	<0.1	<0.1	<0.1					EPA 8270 D
β-HCH	<0.1	<0.1	<0.1					EPA 8270 D
δ-HCH	<0.1	<0.1	<0.1					EPA 8270 D
γ-HCH	<0.1	<0.1	<0.1					EPA 8270 D
Dicofol	<0.1	<0.1	<0.1					EPA 8270 D
Hexachlorbenzene	<0.1	<0.1	<0.1					EPA 8270 D
Chlordecone	<0.1	<0.1	<0.1					EPA 8270 D
Aldrin	<0.1	<0.1	<0.1					EPA 8270 D
Dieldrin	<0.1	<0.1	<0.1					EPA 8270 D
Endrin	<0.1	<0.1	<0.1					EPA 8270 D
Chlordane cis	<0.1	<0.1	<0.1					EPA 8270 D
Chlordane trans	<0.1	<0.1	<0.1					EPA 8270 D
Pentachlorobenzene	<0.1	<0.1	<0.1					EPA 8270 D
Heptachlor	<0.1	<0.1	<0.1					EPA 8270 D
Heptachlor epoxide	<0.1	<0.1	<0.1					EPA 8270 D
o,p DDE	<0.1	<0.1	<0.1					EPA 8270 D
p,p DDE	0.48	1.00	1.20					EPA 8270 D
o,pDDD	1.40	1.60	<0.1					EPA 8270 D
p,p DDD	0.36	0.70	0.75					EPA 8270 D
o,p DDT	<0.1	<0.1	<0.1					EPA 8270 D
p,p DDT	<1	<1	<1					EPA 8270 D
total DDT	2.24	3.30	1.95					EPA 8270 D
Mirex	<0.1	<0.1	<0.1					EPA 8270 D
Polybrominated diphenyl ethers [µg/kg DW]								
BDE 28	<0.05	<0.05	<0.05					
BDE 47	<0.05	0.068	<0.05					EPA 1614*

BDE 99	<0.05	0.124	<0.05					EPA 1614*
BDE 100	<0.05	<0.05	<0.05					EPA 1614*
BDE 153	<0.05	<0.05	<0.05					EPA 1614*
BDE 154	<0.05	<0.05	<0.05					EPA 1614*
BDE 183	<0.1	<0.1	<0.1					EPA 1614*
Dioxins and Furans [µg/kg DW]								
2378-TCDF	<0.005	<0.005	<0.005					EPA 1613*
2378-TCDD	<0.005	<0.005	<0.005					EPA 1613*
12378-PeCDF	<0.025	<0.025	<0.025					EPA 1613*
23478-PeCDF	<0.025	<0.025	<0.025					EPA 1613*
12378-PeCDD	<0.025	<0.025	<0.025					EPA 1613*
123478-HxCDF	<0.025	<0.025	<0.025					EPA 1613*
123678-HxCDF	<0.025	<0.025	<0.025					EPA 1613*
123478-HxCDD	<0.025	<0.025	<0.025					EPA 1613*
123678-HxCDD	<0.025	<0.025	<0.025					EPA 1613*
123789-HxCDD	<0.025	<0.025	<0.025					EPA 1613*
123789-HxCDF	<0.025	<0.025	<0.025					EPA 1613*
234678-HxCDF	<0.025	<0.025	<0.025					EPA 1613*
1234678-HpCDF	<0.025	<0.025	<0.025					EPA 1613*
1234678-HpCDD	<0.025	<0.025	<0.025					EPA 1613*
1234789-HpCDF	<0.025	<0.025	<0.025					EPA 1613*
OCDD	<0.05	<0.05	<0.05					EPA 1613*
OCDF	<0.05	<0.05	<0.05					EPA 1613*
Chlorinated organic substances [µg/kg DW]								
Pentachlorophenol	<20	<20	<20					ISO 17182:2014*

Hexachloro - 1,3-butadiene	<1	<1	<1					EPA 5021*

Location of sampling	Porto Montenegro, Tivat Bay	Porto Montenegro, Tivat Bay	Porto Montenegro, Tivat Bay	Porto Montenegro, Tivat Bay	Porto Montenegro, Tivat Bay	Porto Montenegro, Tivat Bay	Sediment Quality Guidelines (SQGs)				Method
Date of sampling	23.08.2023.	23.08.2023.	23.08.2023.	23.08.2023.	23.08.2023.	23.08.2023.	TEL	PEL	ER-L	ER-M	
Laboratory number	158/05/23	159/05/23	160/05/23	161/05/23	162/05/23	163/05/23					
Coordinates*											
Sampling depth [m]	10,3	11,8	6,0	8,8	11,6	14,5					
Parametar	Results of analysis	Results of analysis	Results of analysis	Results of analysis	Results of analysis	Results of analysis					
Trace elements [mg/kg DW]											
Mercury	8.1	11.54	13.25	95.5	55	8.1	0.13	0.7	0.15	0.71	AMA-112
Methyl mercury	-	-	-	0.0133	-	-					S-GC-36
Cadmium	0.125	0.19	0.31	0.37	0.58	0.092	0.68	4.21	1.2	9.6	IAEA-MEL-LPB
Lead	209	155	576	504	308	123	30.2	112	46.7	218	IAEA-MEL-LPB

Arsenic	50	53	57	201	148	33	7.24	41.6	8.2	70	IAEA-MEL-LPB
Copper	511	316	126	231	223	55	18.7	108	34	270	IAEA-MEL-LPB
Nickel	142	101	135	86	101	68	15.9	42.8	20.9	51.6	IAEA-MEL-LPB
Chromium	621	273	198	135	136	97	52.3	160	81	370	IAEA-MEL-LPB
Zinc	415	382	651	648	710	176	124	271	150	410	IAEA-MEL-LPB
Polycyclic Aromatic Hydrocarbons [µg/kg DW]											
Naphtalene	268	556	175	614	757	372	34.6	391	160	2100	EPA 8270D
2-methylnaphtalene	378	532	109	324	352	269	20.2	201			EPA 8270D
1-methylnaphtalene	285	307	64.3	211	197	160					EPA 8270D
Acenaphtylene	61.8	44.1	52.6	279	110	33.2	5.87	128			EPA 8270D
Acenaphtene	526	372	159	672	593	183	6.71	88.9	16	500	EPA 8270D
Fluorene	425	401	210	959	824	238	21.2	144	19	540	EPA 8270D
Phenanthrene	3252	3885	2144	8681	7904	2136	86.7	544	240	1500	EPA 8270D
Anthracene	511	771	497	2294	1964	518	46.9	245	85	1100	EPA 8270D

Fluoranthene	4903	5517	3968	14243	13222	3369	113	1494	600	5100	EPA 8270D
Pyrene	4285	4632	3354	12127	11728	2894	153	1398	665	2600	EPA 8270D
Benzo(a)anthracene	2352	2625	2124	7587	6952	1729	74.8	693	261	1600	EPA 8270D
Chrysene	2343	2612	2157	7308	6555	1655	108	846	384	2800	EPA 8270D
Benzo(b)fluoranthene	2581	2593	2413	7024	7014	1557					EPA 8270D
Benzo(k)fluoranthene	1231	1222	1125	3462	3420	748					EPA 8270D
Benzo(j) fluoranthene	956	975	874	2693	2507	599					EPA 8270D
Benzo(a)pyrene	2783	2884	2528	7781	8239	1791	88.8	763	430	1600	EPA 8270D
Indeno(1.2.3-cd)pyrene	1503	1483	1395	3946	3976	860					EPA 8270D
Dibenzo(a.h)anthracene	453	403	422	1218	1184	256	6.22	135	63.4	260	EPA 8270D
Benzo(g.h.i)perylene	1631	1700	1505	4236	4388	993					EPA 8270D
Sum Low molecular weight PAHs	5706	6868	3411	14033	12701	3910	312	1442	552	3160	EPA 8270D
Sum High molecular weight PAHs	25021	26646	21867	71627	69184	16452	655	6676	1700	9600	EPA 8270D
Total PAHs	30727	33514	25278	85660	81885	20362	1684	16770	4022	44792	EPA 8270D
Polychlorinated biphenyls [µg/kg DW]											

PCB 18	0.67	<0.1	1.25	5.11	4.46	0.34					EPA 8270D
PCB 31	1.10	0.94	1.50	2.59	2.32	0.64					EPA 8270D
PCB 28	1.20	1.00	1.52	2.25	2.33	0.62					EPA 8270D
PCB 52	12.8	10.3	27.8	134	80	5.45					EPA 8270D
PCB 44	2.74	2.4	3.21	7.94	7.82	1.06					EPA 8270D
PCB 101	27.4	32.1	153	407	561	20.1					EPA 8270D
PCB 149	62.5	57.5	317	695	1053	39.9					EPA 8270D
PCB 118	13.1	15.8	51.0	103	109	10.1					EPA 8270D
PCB 153	78.3	74.7	389	783	1019	56.8					EPA 8270D
PCB 138	54.2	52.3	262	493	740	40.6					EPA 8270D
PCB 180	66.8	56.3	283	526	768	38.6					EPA 8270D
PCB 194	9.15	9.05	39.40	81.82	142	6.51					EPA 8270D
Total PCB	982	916	2978	8513	4501	406	21.6	189	22.7	180	EPA 8080A
Organotin compounds [µg/kg DW]											
Monobuthyl-tin	2998	205	45	33	28	19					ISO 23161:2009
Dibuthyl- tin	3808	324	39	42	43	22					ISO 23161:2009

Tributhyl-tin	15941	692	65	123	135	57					ISO 23161:2009
Monooctyl-tin	4	<4	<4	<4	<4	<4					ISO 23161:2009
Tetrabuthyl-tin	96	10	<4	<4	<4	<4					ISO 23161:2009
Dioctyl-tin	<4	<4	<4	<4	<4	<4					ISO 23161:2009
Triphenyl-tin	118	23	<4	4	19	<4					ISO 23161:2009
Tricyclohexyl-tin	<4	<4	<4	<4	<4	<4					ISO 23161:2009
Organochlorine pesticides [µg/kg DW]											
Alpha endosulfan	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Beta endosulfan	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
α-HCH	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
β-HCH	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
δ-HCH	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
γ-HCH	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Dicofol	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Hexachlorbenzene	0.26	<0.1	<0.1	0.62	0.09	<0.1					EPA 8270 D
Chlordecone	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D

Aldrin	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Dieldrin	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Endrin	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Chlordane cis	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Chlordane trans	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Pentachlorobenzene	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Heptachlor	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Heptachlor epoxide	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
o,p DDE	0.25	<0.1	0.10	0.26	0.22	<0.1					EPA 8270 D
p,p DDE	<0.1	<0.1	0.90	10.64	1.70	0.50					EPA 8270 D
o,pDDD	1.09	0.92	1.80	<0.1	4.75	1.50					EPA 8270 D
p,p DDD	7.98	8.36	4.30	14.71	13.60	1.30					EPA 8270 D
o,p DDT	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
p,p DDT	<1	<1	<0.1	<1	<0.1	<0.1					EPA 8270 D
total DDT	9.32	9.28	7.10	25.61	20.27	3.30					EPA 8270 D
Mirex	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Polybrominated diphenyl ethers [µg/kg DW]											
BDE 28	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05					EPA 1614*
BDE 47	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05					EPA 1614*
BDE 99	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05					EPA 1614*

BDE 100	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05					EPA 1614*
BDE 153	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05					EPA 1614*
BDE 154	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05					EPA 1614*
BDE 183	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 1614*
Dioxins and Furans [µg/kg DW]											
2378-TCDF	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005					EPA 1613*
2378-TCDD	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005					EPA 1613*
12378-PeCDF	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
23478-PeCDF	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
12378-PeCDD	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
123478-HxCDF	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
123678-HxCDF	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
123478-HxCDD	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
123678-HxCDD	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
123789-HxCDD	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
123789-HxCDF	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
234678-HxCDF	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
1234678-HpCDF	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
1234678-HpCDD	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
1234789-HpCDF	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
OCDD	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05					EPA 1613*
OCDF	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05					EPA 1613*
Chlorinated organic substances [µg/kg DW]											
Pentachlorophenol	-	-	-	<20	<20	<20					ISO 17182:2014*

Hexachloro - 1,3-butadiene	<1	<1	<1	<1	<1	<1					EPA 5021*
Perfluorinated Compounds [µg/kg DW]											
Perfluorobutanoic acid (PFBA)	-	-	-	<0.50	-	-					S-PFCLMS02
Perfluoropentanoic acid (PFPeA)	-	-	-	<0.50	-	-					S-PFCLMS02
Perfluorohexanoic acid (PFHxA)	-	-	-	<0.50	-	-					S-PFCLMS02
Perfluoroheptanoic acid (PFHpA)	-	-	-	<0.50	-	-					S-PFCLMS02
Perfluorooctanoic acid (PFOA)	-	-	-	<0.50	-	-					S-PFCLMS02
Perfluorononanoic acid (PFNA)	-	-	-	<0.50	-	-					S-PFCLMS02
Perfluorodecanoic acid (PFDA)	-	-	-	<0.50	-	-					S-PFCLMS02
Perfluoroundecanoic acid (PFUnDA)	-	-	-	<0.50	-	-					S-PFCLMS02
Perfluorododecanoic acid (PFDoDA)	-	-	-	<0.50	-	-					S-PFCLMS02
Perfluorotridecanoic acid (PFTrDA)	-	-	-	<0.50	-	-					S-PFCLMS02

Perfluorotetradecanoic acid (PFTeDA)	-	-	-	<0.50	-	-					S-PFCLMS02
Perfluorobutane sulfonic acid (PFBS)	-	-	-	<0.50	-	-					S-PFCLMS02
Perfluorohexane sulfonic acid (PFHxS)	-	-	-	<0.50	-	-					S-PFCLMS02
Perfluoroheptane sulfonic acid (PFHpS)	-	-	-	<0.50	-	-					S-PFCLMS02
Perfluorooctane sulfonic acid (PFOS)	-	-	-	0.56	-	-					S-PFCLMS02
Perfluorodecane sulfonic acid (PFDS)	-	-	-	<0.50	-	-					S-PFCLMS02
6:2 Fluorotelomer sulfonic acid (6:2 FTS)	-	-	-	<0.50	-	-					S-PFCLMS02
8:2 Fluorotelomer sulfonic acid (8:2 FTS)	-	-	-	<0.50	-	-					S-PFCLMS02
Perfluorooctane sulfonamide (FOSA)	-	-	-	<0.50	-	-					S-PFCLMS02
N-Methyl perfluorooctane sulfonamide (MeFOSA)	-	-	-	<0.50	-	-					S-PFCLMS02

N-Ethyl perfluorooctane sulfonamide (EtFOSA)	-	-	-	<0.50	-	-					S-PFCLMS02
N-Methyl perfluorooctane sulfonamidoethanol (MeFOSE)	-	-	-	<0.50	-	-					S-PFCLMS02
N-Ethyl perfluorooctane sulfonamidoethanol (EtFOSE)	-	-	-	<0.50	-	-					S-PFCLMS02
Perfluoropentane sulfonic acid (PFPeS)	-	-	-	<0.50	-	-					S-PFCLMS02
Perfluorooctane sulfonamidoacetic acid (FOSAA)	-	-	-	<0.50	-	-					S-PFCLMS02
Perfluorooctadecanoic acid (PFOcDA)	-	-	-	<5.0	-	-					S-PFCLMS02
Perfluorononane sulfonic acid (PFNS)	-	-	-	<0.50	-	-					S-PFCLMS02
Perfluorohexadecanoic acid (PFHxDA)	-	-	-	<5.0	-	-					S-PFCLMS02
Perfluorododecane sulfonic acid (PFDoDS)	-	-	-	<0.50	-	-					S-PFCLMS02

Perfluoro-3,7-dimethyloctanoic acid (P37DMOA)	-	-	-	<0.50	-	-					S-PFCLMS02
N-Methyl perfluorooctane sulfonamidoacetic acid (MeFOSAA)	-	-	-	<0.50	-	-					S-PFCLMS02
N-Ethyl perfluorooctane sulfonamidoacetic acid (EtFOSAA)	-	-	-	<0.50	-	-					S-PFCLMS02
7H-perfluoroheptanoic acid (HPFHpA)	-	-	-	<0.50	-	-					S-PFCLMS02
4:2 Fluorotelomer sulfonic acid (4:2 FTS)	-	-	-	<0.50	-	-					S-PFCLMS02
10:2 Fluorotelomer sulfonic acid (10:2 FTS)	-	-	-	<0.50	-	-					S-PFCLMS02
Perfluoropropane sulfonic acid (PFPrS)	-	-	-	<2.50	-	-					S-PFCLMS02
2,3,3,3-tetrafluoro-2-(heptafluoropropoxy)propanoic acid (HFPO-DA)	-	-	-	<2.50	-	-					S-PFCLMS02
2H,2H,3H,3H-perfluoroundecanoic acid (H4PFUnDA)	-	-	-	<5.0	-	-					S-PFCLMS02

Perfluoroundecane sulfonic acid (PFUnDS)	-	-	-	<2.50	-	-					S-PFCLMS02
Perfluorotridecane sulfonic acid (PFTrDS)	-	-	-	<2.50	-	-					S-PFCLMS02
9-chlorohexadecafluoro-3-oxano nane-1-sulfonic acid (9Cl-PF3ONS)	-	-	-	<0.50	-	-					S-PFCLMS02
11-chloroeicosafluoro-3-oxaunde cane-1-sulfonic acid (11Cl-PF3OUdS)	-	-	-	<0.50	-	-					S-PFCLMS02
4,8-dioxa-3H-perfluorononanoic acid (DONA)	-	-	-	<0.50	-	-					S-PFCLMS02
Perfluoro-3-methoxypropanoic acid (PFMPA)	-	-	-	<2.50	-	-					S-PFCLMS02
Perfluoro-4-methoxybutanoic acid (PFMBA)	-	-	-	<2.50	-	-					S-PFCLMS02
Perfluoro(2-ethoxyethane)sulfonic acid (PFEESA)	-	-	-	<2.50	-	-					S-PFCLMS02
Perfluoro-4-ethylcyclohexanesulfonic acid (PFECHS)	-	-	-	<0.50	-	-					S-PFCLMS02

2H,2H,3H,3H-perfluorohexanoic acid (3:3 FTCA)	-	-	-	<2.50	-	-					S-PFCLMS02
2H,2H-perfluorooctanoic acid (6:2 FTCA)	-	-	-	<5.0	-	-					S-PFCLMS02
2H,2H,3H,3H-perfluorooctanoic acid (5:3 FTCA)	-	-	-	<5.0	-	-					S-PFCLMS02
2H-perfluoro-2-octenoic acid (6:2 FTUCA)	-	-	-	<5.0	-	-					S-PFCLMS02
2H-perfluoro-2-decenoic acid (8:2 FTUCA)	-	-	-	<0.50	-	-					S-PFCLMS02
2H,2H,3H,3H-perfluorodecanoic acid (7:3 FTCA)	-	-	-	<5.0	-	-					S-PFCLMS02
2H,2H-perfluorodecanoic acid (8:2 FTCA)	-	-	-	<5.0	-	-					S-PFCLMS02
Total Organic Carbon [%DW]	-	-	-	3.06	-	-					S-TOC1-CC
Granulometric analysis [%]											
(0.06-2.0)mm	-	-	-	53	-	-					
(0.002-0.06)mm	-	-	-	28	-	-					
<0.002 mm	-	-	-	19	-	-					

Location of sampling	Porto Montenegro, Tivat Bay	Porto Montenegro, Tivat Bay	Porto Montenegro, Tivat Bay	Porto Montenegro, Tivat Bay	Porto Montenegro, Tivat Bay	Porto Montenegro, Tivat Bay	Porto Montenegro, Tivat Bay	Sediment Quality Guidelines (SQGs)				Method
Date of sampling	23.08.2023.	23.08.2023.	23.08.2023.	23.08.2023.	23.08.2023.	23.08.2023.	23.08.2023.	TEL	PEL	ER-L	ER-M	
Laboratory number	164/05/23	165/05/23	166/05/23	167/05/23	168/05/23	169/05/23	170/05/23					
Coordinates*												
Sampling depth [m]	15,2	11,3	8,4	15	7,5	15	39					
Parametar	Results of analysis	Results of analysis	Results of analysis	Results of analysis	Results of analysis	Results of analysis	Results of analysis					
Trace elements [mg/kg DW]												
Mercury	10.5	17.1	5.2	3.51	2.52	4.1	0.406	0.13	0.7	0.15	0.71	AMA-112
Methyl mercury	-	0.00676	-	-	0.00141	-	0.00108					S-GC-36
Cadmium	0.09	0.17	0.19	0.093	0.15	0.071	0.14	0.68	4.21	1.2	9.6	IAEA-MEL-LPB
Lead	133	209	101	62	191	43	36	30.2	112	46.7	218	IAEA-MEL-LPB
Arsenic	35	57	59	25	30	27	13	7.24	41.6	8.2	70	IAEA-MEL-LPB

Copper	140	92	124	45	210	47	46	18.7	108	34	270	IAEA-MEL-LPB
Nickel	61	69	79	65	44	47	126	15.9	42.8	20.9	51.6	IAEA-MEL-LPB
Chromium	96	111	121	109	90	78	143	52.3	160	81	370	IAEA-MEL-LPB
Zinc	154	203	182	109	252	83	125	124	271	150	410	IAEA-MEL-LPB
Polycyclic Aromatic Hydrocarbons [µg/kg DW]												
Naphtalene	192	210	209	277	703	84.4	16.8	34.6	391	160	2100	EPA 8270D
2-methylnaphtalene	108	298	110	136	337	47.2	17.1	20.2	201			EPA 8270D
1-methylnaphtalene	50.1	98.3	75.0	70.4	135	27.5	11.7					EPA 8270D
Acenaphtylene	26.4	31.5	29.6	18.1	24.6	13.1	2.6	5.87	128			EPA 8270D
Acenaphtene	78	121	162	126	325	96	7.0	6.71	88.9	16	500	EPA 8270D
Fluorene	105	222	155	147	473	65.6	8.2	21.2	144	19	540	EPA 8270D
Phenanthrene	1093	1624	1658	1525	4156	762	59.5	86.7	544	240	1500	EPA 8270D
Anthracene	263	328	398	353	1007	171	10.6	46.9	245	85	1100	EPA 8270D

Fluoranthene	2091	2449	3339	2383	5363	1290	109.1	113	1494	600	5100	EPA 8270D
Pyrene	1826	2113	2801	1974	4445	1091	95.1	153	1398	665	2600	EPA 8270D
Benzo(a)anthracene	1141	1359	1833	1195	2551	667	64.2	74.8	693	261	1600	EPA 8270D
Chrysene	1116	1370	1747	1170	2459	657	63.1	108	846	384	2800	EPA 8270D
Benzo(b)fluoranthene	1236	1450	1786	1129	2193	670	78.7					EPA 8270D
Benzo(k)fluoranthene	596	679	836	536	1061	324	35.3					EPA 8270D
Benzo(j) fluoranthene	460	531	644	427	848	254	27.1					EPA 8270D
Benzo(a)pyrene	1396	1541	1948	1240	2545	750	71.7	88.8	763	430	1600	EPA 8270D
Indeno(1.2.3-cd)pyrene	720	823	1020	640	1203	374	46.9					EPA 8270D
Dibenzo(a.h)anthracene	210	236	304	191	363	113	12.6	6.22	135	63.4	260	EPA 8270D
Benzo(g.h.i)perylene	816	916	1092	714	1325	414	52.0					EPA 8270D
Sum Low molecular weight PAHs	1915	2932	2796	2653	7161	1267	133	312	1442	552	3160	EPA 8270D
Sum High molecular weight PAHs	11608	13465	17351	11597	24354	6604	656	655	6676	1700	9600	EPA 8270D
Total PAHs	13523	16398	20147	14250	31515	7870	789	1684	16770	4022	44792	EPA 8270D

Polychlorinated biphenyls [µg/kg DW]												
PCB 18	0.59	0.91	1.13	0.28	6.86	0.24	0.31					EPA 8270D
PCB 31	1.01	0.82	1.51	0.41	7.41	0.25	0.24					EPA 8270D
PCB 28	0.81	0.70	1.52	0.45	7.45	0.27	0.24					EPA 8270D
PCB 52	6.99	13.9	9.95	6.52	77.9	2.06	1.08					EPA 8270D
PCB 44	0.95	1.61	2.88	1.64	26.7	<0.1	<0.1					EPA 8270D
PCB 101	25.2	70.3	15.6	21.6	160	4.49	5.72					EPA 8270D
PCB 149	61.2	148	27.0	33.9	172	9.61	16.4					EPA 8270D
PCB 118	10.2	21.3	8.64	21.5	183	3.15	2.28					EPA 8270D
PCB 153	77.7	174	37.3	51.5	288	17.7	22.9					EPA 8270D
PCB 138	53.2	136	27.6	50.2	210	11.2	17.2					EPA 8270D
PCB 180	60.0	126	25.5	35.5	184	11.9	20.1					EPA 8270D
PCB 194	11.1	20.92	4.69	6.58	82.3	3.87	6.15					EPA 8270D
Total PCB	596	1426	313	438	4969	211	112	21.6	189	22.7	180	EPA 8080
Organotin compounds [µg/kg DW]												

Monobuthyl-tin	21	34	101	18	33	18	12					ISO 23161:2009
Dibuthyl- tin	18	40	152	28	43	8	9					ISO 23161:2009
Tributhyl-tin	40	98	334	70	84	33	26					ISO 23161:2009
Monooctyl-tin	<4	<4	<4	<4	<4	<4	<4					ISO 23161:2009
Tetrabuthyl-tin	<4	<4	<4	<4	<4	<4	<4					ISO 23161:2009
Dioctyl-tin	<4	<4	<4	<4	<4	<4	<4					ISO 23161:2009
Triphenyl-tin	<4	<4	<4	<4	<4	<4	<4					ISO 23161:2009
Tricyclohexyl-tin	<4	<4	<4	<4	<4	<4	<4					ISO 23161:2009
Organochlorine pesticides [µg/kg DW]												
Alpha endosulfan	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1					EPA 8270 D
Beta endosulfan	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1					EPA 8270 D
α-HCH	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1					EPA 8270 D
β-HCH	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1					EPA 8270 D

δ-HCH	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1					EPA 8270 D
γ-HCH	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1					EPA 8270 D
Dicofol	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1					EPA 8270 D
Hexachlorbenzene	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1					EPA 8270 D
Chlordecone	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1					EPA 8270 D
Aldrin	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1					EPA 8270 D
Dieldrin	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1					EPA 8270 D
Endrin	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1					EPA 8270 D
Chlordane cis	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1					EPA 8270 D
Chlordane trans	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1					EPA 8270 D
Pentachlorobenzene	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1					EPA 8270 D
Heptachlor	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1					EPA 8270 D
Heptachlor epoxide	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1					EPA 8270 D
o,p DDE	<0.1	<0.1	<0.1	<0.1	0.24	<0.1	<0.1					EPA 8270 D
p,p DDE	0.80	1.30	3.00	0.74	3.10	0.40	<0.1					EPA 8270 D
o,pDDD	0.28	0.94	0.56	0.26	3.90	0.10	<0.1					EPA 8270 D
p,p DDD	1.34	4.64	2.72	1.00	4.00	0.60	0.90					EPA 8270 D
o,p DDT	<0.1	<0.1	<0.1	2.20	3.90	<0.1	<0.1					EPA 8270 D

p,p DDT	<1	<1	10.00	14.00	32.40	<1	<1					EPA 8270 D
total DDT	2.42	6.88	16.28	18.20	47.54	1.10	0.90					EPA 8270 D
Mirex	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1					EPA 8270 D
Polybrominated diphenyl ethers [µg/kg DW]												
BDE 28	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05					EPA 1614*
BDE 47	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05					EPA 1614*
BDE 99	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05					EPA 1614*
BDE 100	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05					EPA 1614*
BDE 153	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05					EPA 1614*
BDE 154	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05					EPA 1614*
BDE 183	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 1614*
Dioxins and Furans [µg/kg DW]												
2378-TCDF	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005					EPA 1613*
2378-TCDD	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005					EPA 1613*
12378-PeCDF	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
23478-PeCDF	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
12378-PeCDD	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*

123478-HxCDF	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
123678-HxCDF	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
123478-HxCDD	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
123678-HxCDD	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
123789-HxCDD	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
123789-HxCDF	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
234678-HxCDF	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
1234678-HpCDF	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
1234678-HpCDD	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
1234789-HpCDF	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
OCDD	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05					EPA 1613*
OCDF	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05					EPA 1613*
Chlorinated organic substances [µg/kg DW]												
Pentachlorophenol	-	<20	-	-	<20	-	<20					ISO 17182:2014*
Hexachloro - 1,3-butadiene	<1	<1	<1	<1	<1	<1	<1					EPA 5021*

Perfluorinated Compounds [µg/kg DW]												
Perfluorobutanoic acid (PFBA)	-	<0.50	-	-	<0.50	-	<0.50					S-PFCLMS 02
Perfluoropentanoic acid (PFPeA)	-	<0.50	-	-	<0.50	-	<0.50					S-PFCLMS 02
Perfluorohexanoic acid (PFHxA)	-	<0.50	-	-	<0.50	-	<0.50					S-PFCLMS 02
Perfluoroheptanoic acid (PFHpA)	-	<0.50	-	-	<0.50	-	<0.50					S-PFCLMS 02
Perfluorooctanoic acid (PFOA)	-	<0.50	-	-	<0.50	-	<0.50					S-PFCLMS 02
Perfluorononanoic acid (PFNA)	-	<0.50	-	-	<0.50	-	<0.50					S-PFCLMS 02
Perfluorodecanoic acid (PFDA)	-	<0.50	-	-	<0.50	-	<0.50					S-PFCLMS 02
Perfluoroundecanoic acid (PFUnDA)	-	<0.50	-	-	<0.50	-	<0.50					S-PFCLMS 02
Perfluorododecanoic acid (PFDoDA)	-	<0.50	-	-	<0.50	-	<0.50					S-PFCLMS 02
Perfluorotridecanoic acid (PFTrDA)	-	<0.50	-	-	<0.50	-	<0.50					S-PFCLMS 02

Perfluorotetradecanoic acid (PFTeDA)	-	<0.50	-	-	<0.50	-	<0.50					S-PFCLMS02
Perfluorobutane sulfonic acid (PFBS)	-	<0.50	-	-	<0.50	-	<0.50					S-PFCLMS02
Perfluorohexane sulfonic acid (PFHxS)	-	<0.50	-	-	<0.50	-	<0.50					S-PFCLMS02
Perfluoroheptane sulfonic acid (PFHpS)	-	<0.50	-	-	<0.50	-	<0.50					S-PFCLMS02
Perfluorooctane sulfonic acid (PFOS)	-	<0.50	-	-	<0.50	-	<0.50					S-PFCLMS02
Perfluorodecane sulfonic acid (PFDS)	-	<0.50	-	-	<0.50	-	<0.50					S-PFCLMS02
6:2 Fluorotelomer sulfonic acid (6:2 FTS)	-	<0.50	-	-	<0.50	-	<0.50					S-PFCLMS02
8:2 Fluorotelomer sulfonic acid (8:2 FTS)	-	<0.50	-	-	<0.50	-	<0.50					S-PFCLMS02
Perfluorooctane sulfonamide (FOSA)	-	<0.50	-	-	<0.50	-	<0.50					S-PFCLMS02

N-Methyl perfluorooctane sulfonamide (MeFOSA)	-	<0.50	-	-	<0.50	-	<0.50					S-PFCLMS 02
N-Ethyl perfluorooctane sulfonamide (EtFOSA)	-	<0.50	-	-	<0.50	-	<0.50					S-PFCLMS 02
N-Methyl perfluorooctane sulfonamidoethanol (MeFOSE)	-	<0.50	-	-	<0.50	-	<0.50					S-PFCLMS 02
N-Ethyl perfluorooctane sulfonamidoethanol (EtFOSE)	-	<0.50	-	-	<0.50	-	<0.50					S-PFCLMS 02
Perfluoropentane sulfonic acid (PFPeS)	-	<0.50	-	-	<0.50	-	<0.50					S-PFCLMS 02
Perfluorooctane sulfonamidoacetic acid (FOSAA)	-	<0.50	-	-	<0.50	-	<0.50					S-PFCLMS 02
Perfluorooctadecanoic acid (PFOcDA)	-	<5.0	-	-	<5.0	-	<5.0					S-PFCLMS 02
Perfluorononane sulfonic acid (PFNS)	-	<0.50	-	-	<0.50	-	<0.50					S-PFCLMS 02

Perfluorohexadecanoic acid (PFHxDA)	-	<5.0	-	-	<5.0	-	<5.0					S-PFCLMS 02
Perfluorododecane sulfonic acid (PFDoDS)	-	<0.50	-	-	<0.50	-	<0.50					S-PFCLMS 02
Perfluoro-3,7-dimethyloctanoic acid (P37DMOA)	-	<0.50	-	-	<0.50	-	<0.50					S-PFCLMS 02
N-Methyl perfluorooctane sulfonamidoacetic acid (MeFOSAA)	-	<0.50	-	-	<0.50	-	<0.50					S-PFCLMS 02
N-Ethyl perfluorooctane sulfonamidoacetic acid (EtFOSAA)	-	<0.50	-	-	<0.50	-	<0.50					S-PFCLMS 02
7H-perfluoroheptanoic acid (HPFHpA)	-	<0.50	-	-	<0.50	-	<0.50					S-PFCLMS 02
4:2 Fluorotelomer sulfonic acid (4:2 FTS)	-	<0.50	-	-	<0.50	-	<0.50					S-PFCLMS 02
10:2 Fluorotelomer sulfonic acid (10:2 FTS)	-	<0.50	-	-	<0.50	-	<0.50					S-PFCLMS 02
Perfluoropropane sulfonic acid (PFPrS)	-	<2.50	-	-	<2.50	-	<2.50					S-PFCLMS 02

2,3,3,3-tetrafluoro-2-(heptafluoropropoxy)propanoic acid (HFPO-DA)	-	<2.50	-	-	<2.50	-	<2.50					S-PFCLMS 02
2H,2H,3H,3H-perfluoroundecanoic acid (H4PFUnDA)	-	<5.0	-	-	<5.0	-	<5.0					S-PFCLMS 02
Perfluoroundecane sulfonic acid (PFUnDS)	-	<2.50	-	-	<2.50	-	<2.50					S-PFCLMS 02
Perfluorotridecane sulfonic acid (PFTrDS)	-	<2.50	-	-	<2.50	-	<2.50					S-PFCLMS 02
9-chlorohexadecafluoro-3-oxano nane-1-sulfonic acid (9Cl-PF3ONS)	-	<0.50	-	-	<0.50	-	<0.50					S-PFCLMS 02
11-chloroeicosafluoro-3-oxaunde cane-1-sulfonic acid (11Cl-PF3OUdS)	-	<0.50	-	-	<0.50	-	<0.50					S-PFCLMS 02
4,8-dioxa-3H-perfluorononanoic acid (DONA)	-	<0.50	-	-	<0.50	-	<0.50					S-PFCLMS 02
Perfluoro-3-methoxypropanoic acid (PFMPA)	-	<2.50	-	-	<2.50	-	<2.50					S-PFCLMS 02

Perfluoro-4-methoxybutanoic acid (PFMBA)	-	<2.50	-	-	<2.50	-	<2.50					S-PFCLMS02
Perfluoro(2-ethoxyethane)sulfonic acid (PFEESA)	-	<2.50	-	-	<2.50	-	<2.50					S-PFCLMS02
Perfluoro-4-ethylcyclohexanesulfonic acid (PFECHS)	-	<0.50	-	-	<0.50	-	<0.50					S-PFCLMS02
2H,2H,3H,3H-perfluorohexanoic acid (3:3 FTCA)	-	<2.50	-	-	<2.50	-	<2.50					S-PFCLMS02
2H,2H-perfluorooctanoic acid (6:2 FTCA)	-	<5.0	-	-	<5.0	-	<5.0					S-PFCLMS02
2H,2H,3H,3H-perfluorooctanoic acid (5:3 FTCA)	-	<5.0	-	-	<5.0	-	<5.0					S-PFCLMS02
2H-perfluoro-2-octenoic acid (6:2 FTUCA)	-	<5.0	-	-	<5.0	-	<5.0					S-PFCLMS02
2H-perfluoro-2-decenoic acid (8:2 FTUCA)	-	<0.50	-	-	<0.50	-	<0.50					S-PFCLMS02
2H,2H,3H,3H-perfluorodecanoic acid (7:3 FTCA)	-	<5.0	-	-	<5.0	-	<5.0					S-PFCLMS02
2H,2H-perfluorodecanoic acid (8:2 FTCA)	-	<5.0	-	-	<5.0	-	<5.0					S-PFCLMS02

Total Organic Carbon [%DW]	-	-	-	-	3.24	-	1.22					S-TOC1-CC
Granulometric analysis [%]												
(0.06-2.0)mm	36	-	-	56	-	-	-					
(0.002-0.06)mm	39	-	-	28	-	-	-					
<0.002 mm	25	-	-	16	-	-	-					

Location of sampling	Port of Risan	Port of Risan	Port of Risan	Port of Risan	Port of Risan	Port of Risan	Port of Risan	Sediment Quality Guidelines (SQGs)				Method
Date of sampling	24.08.2023.	24.08.2023.	24.08.2023.	24.08.2023.	24.08.2023.	24.08.2023.	24.08.2023.	TEL	PEL	ER-L	ER-M	
Laboratory number	171/05/23	172/05/23	173/05/23	174/05/23	175/05/23	176/05/23	177/05/23					
Coordinates*												
Sampling depth [m]	5,2	8,7	6,7	7,9	5,7	13	16					
Parametar	Results of analysis	Results of analysis	Results of analysis	Results of analysis	Results of analysis	Results of analysis	Results of analysis					
Trace elements [mg/kg DW]												
Mercury	0.37	0.57	0.34	0.44	0.51	0.31	0.27	0.13	0.7	0.15	0.71	AMA-112
Methyl mercury	0.000982	-	-	0.00136	-	-	-					S-GC-36
Cadmium	0.15	0.13	0.12	0.15	0.13	0.16	0.11	0.68	4.21	1.2	9.6	IAEA-MEL-LPB
Lead	26	32	25	25	19	31	25	30.2	112	46.7	218	IAEA-MEL-LPB
Arsenic	10.3	10.1	9.4	10.7	10.9	13	10	7.24	41.6	8.2	70	IAEA-MEL-LPB
Copper	24	27	21	20	23	29	22	18.7	108	34	270	IAEA-MEL-LPB

Nickel	23	49	37	42	42	64	53	15.9	42.8	20.9	51.6	IAEA-MEL-LPB
Chromium	56	92	131	71	144	141	93	52.3	160	81	370	IAEA-MEL-LPB
Zinc	56	70	54	57	49	78	65	124	271	150	410	IAEA-MEL-LPB
Polycyclic Aromatic Hydrocarbons [µg/kg DW]												
Naphtalene	71.0	24.2	82.1	18.3	4.5	53.8	46.2	34.6	391	160	2100	EPA 8270D
2-methylnaphtalene	49.9	13.9	14.4	13.4	8.7	11.5	21.6	20.2	201			EPA 8270D
1-methylnaphtalene	35.2	8.7	8.9	9.0	5.4	5.8	12.5					EPA 8270D
Acenaphtylene	17.2	9.4	9.9	10.1	3.9	6.1	2.4	5.87	128			EPA 8270D
Acenaphtene	110	21.9	23.2	14.6	5.0	10.7	10.0	6.71	88.9	16	500	EPA 8270D
Fluorene	147	26.1	28.3	21.5	6.9	13.9	18.6	21.2	144	19	540	EPA 8270D
Phenanthrene	1306	332	318	230	74.8	149	129	86.7	544	240	1500	EPA 8270D

Anthracene	331	80.5	66.0	62.5	17.0	33.6	29.5	46.9	245	85	1100	EPA 8270D
Fluoranthene	2182	666	545	456	157	272	178	113	1494	600	5100	EPA 8270D
Pyrene	1859	612	498	428	150	241	140	153	1398	665	2600	EPA 8270D
Benzo(a)anthracene	1191	366	285	249	84.8	148	99.1	74.8	693	261	1600	EPA 8270D
Chrysene	1098	337	269	226	78.9	138	91.0	108	846	384	2800	EPA 8270D
Benzo(b)fluoranthene	1020	326	252	229	82.9	133	91.0					EPA 8270D
Benzo(k)fluoranthene	505	164	125	113	39.5	64.3	42.9					EPA 8270D
Benzo(j) fluoranthene	401	129	99.9	88.8	30.9	48.9	32.1					EPA 8270D
Benzo(a)pyrene	1177	386	309	269	93.3	146	94.4	88.8	763	430	1600	EPA 8270D
Indeno(1.2.3-cd)pyrene	542	176	143	124	45.3	73.8	48.6					EPA 8270D
Dibenzo(a.h)anthracene	166	49.7	41.6	37.1	12.5	20.3	14.4	6.22	135	63.4	260	EPA 8270D
Benzo(g.h.i)perylene	575	194	160	135	51.8	80.2	52.4					EPA 8270D
Sum Low molecular weight PAHs	2067	517	551	379	126	285	270	312	1442	552	3160	EPA 8270D
Sum High molecular weight PAHs	10717	3407	2726	2354	827	1366	884	655	6676	1700	9600	EPA 8270D

Total PAHs	12784	3924	3277	2733	953	1650	1154	1684	16770	4022	44792	EPA 8270D
Polychlorinated biphenyls [µg/kg DW]												
PCB 18	0.21	0.16	0.10	<0.1	0.10	0.15	<0.1					EPA 8270D
PCB 31	0.61	0.14	0.12	0.12	0.13	0.27	0.17					EPA 8270D
PCB 28	0.62	0.14	0.13	0.15	0.15	0.25	0.18					EPA 8270D
PCB 52	2.87	0.52	0.15	0.44	0.29	0.41	0.36					EPA 8270D
PCB 44	0.57	<0.1	<0.1	<0.1	0.03	<0.1	<0.1					EPA 8270D
PCB 101	4.68	0.82	0.40	0.81	0.25	0.41	0.58					EPA 8270D
PCB 149	6.69	1.31	0.55	1.35	0.52	0.60	0.69					EPA 8270D
PCB 118	3.75	0.47	0.23	0.44	0.30	0.48	0.44					EPA 8270D
PCB 153	8.56	2.20	0.98	2.06	0.92	1.30	1.16					EPA 8270D
PCB 138	6.58	1.32	0.52	1.35	0.53	0.74	0.49					EPA 8270D
PCB 180	6.48	1.04	0.42	1.21	0.31	0.66	0.42					EPA 8270D
PCB 194	1.27	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270D
Total PCB	42.9	8.5	4.0	8.1	14.2	5.4	4.7	21.6	189	22.7	180	EPA 8080
Organotin compounds [µg/kg DW]												
Monobuthyl-tin	8	-	-	4	-	-	-					ISO 23161:2009
Dibuthyl- tin	13	-	-	<4	-	-	-					ISO 23161:2009

Tributhyl-tin	18	-	-	8	-	-	-					ISO 23161:2009
Monooctyl-tin	<4	-	-	<4	-	-	-					ISO 23161:2009
Tetrabuthyl-tin	<4	-	-	<4	-	-	-					ISO 23161:2009
Dioctyl-tin	<4	-	-	<4	-	-	-					ISO 23161:2009
Triphenyl-tin	4	-	-	<4	-	-	-					ISO 23161:2009
Tricyclohexyl-tin	<4	-	-	<4	-	-	-					ISO 23161:2009
Organochlorine pesticides [µg/kg DW]												
Alpha endosulfan	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Beta endosulfan	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
α-HCH	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
β-HCH	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
δ-HCH	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
γ-HCH	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Dicofol	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Hexachlorbenzene	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Chlordecone	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Aldrin	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D

Dieldrin	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Endrin	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Chlordane cis	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Chlordane trans	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Pentachlorobenzene	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Heptachlor	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Heptachlor epoxide	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
o,p DDE	0.18	0.10	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
p,p DDE	3.45	1.77	0.50	0.5	0.76	0.61	0.43					EPA 8270 D
o,pDDD	<0.1	<0.1	<0.1	1.5	0.23	<0.1	<0.1					EPA 8270 D
p,p DDD	6.85	4.74	0.48	1.2	2.79	2.1	0.18					EPA 8270 D
o,p DDT	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
p,p DDT	<1	<1	6.00	1.54	<1	3.7	9.00					EPA 8270 D
total DDT	10.48	6.61	6.98	4.74	3.78	6.41	9.61					EPA 8270 D
Mirex	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 8270 D
Polybrominated diphenyl ethers [µg/kg DW]												
BDE 28	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05					EPA 1614*
BDE 47	<0.05	0.114	<0.05	<0.05	<0.05	<0.05	<0.05					EPA 1614*
BDE 99	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05					EPA 1614*

BDE 100	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05					EPA 1614*
BDE 153	<0.05	<0.05	<0.05	0.05	<0.05	<0.05	<0.05					EPA 1614*
BDE 154	<0.05	<0.05	<0.05	0.06	<0.05	<0.05	<0.05					EPA 1614*
BDE 183	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					EPA 1614*
Dioxins and Furans [µg/kg DW]												
2378-TCDF	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005					EPA 1613*
2378-TCDD	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005					EPA 1613*
12378-PeCDF	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
23478-PeCDF	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
12378-PeCDD	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
123478-HxCDF	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
123678-HxCDF	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
123478-HxCDD	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
123678-HxCDD	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
123789-HxCDD	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
123789-HxCDF	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
234678-HxCDF	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
1234678-HpCDF	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
1234678-HpCDD	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*
1234789-HpCDF	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025					EPA 1613*

OCDD	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05					EPA 1613*
OCDF	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05					EPA 1613*
Chlorinated organic substances [µg/kg DW]												
Pentachlorophenol	<20		<20	<20		<20						ISO 17182:2014*
Hexachloro - 1,3-butadiene	<1	<1	<1	<1	<1	<1	<1					EPA 5021*
Perfluorinated Compounds [µg/kg DW]												
Perfluorobutanoic acid (PFBA)	<0.50	-	-	<0.50	-	-	-					S-PFCLMS02
Perfluoropentanoic acid (PFPeA)	<0.50	-	-	<0.50	-	-	-					S-PFCLMS02
Perfluorohexanoic acid (PFHxA)	<0.50	-	-	<0.50	-	-	-					S-PFCLMS02
Perfluoroheptanoic acid (PFHpA)	<0.50	-	-	<0.50	-	-	-					S-PFCLMS02
Perfluorooctanoic acid (PFOA)	<0.50	-	-	<0.50	-	-	-					S-PFCLMS02
Perfluorononanoic acid (PFNA)	<0.50	-	-	<0.50	-	-	-					S-PFCLMS02
Perfluorodecanoic acid (PFDA)	<0.50	-	-	<0.50	-	-	-					S-PFCLMS02
Perfluoroundecanoic acid (PFUnDA)	<0.50	-	-	<0.50	-	-	-					S-PFCLMS02

Perfluorododecanoic acid (PFDoDA)	<0.50	-	-	<0.50	-	-	-					S-PFCLMS02
Perfluorotridecanoic acid (PFTrDA)	<0.50	-	-	<0.50	-	-	-					S-PFCLMS02
Perfluorotetradecanoic acid (PFTeDA)	<0.50	-	-	<0.50	-	-	-					S-PFCLMS02
Perfluorobutane sulfonic acid (PFBS)	<0.50	-	-	<0.50	-	-	-					S-PFCLMS02
Perfluorohexane sulfonic acid (PFHxS)	<0.50	-	-	<0.50	-	-	-					S-PFCLMS02
Perfluoroheptane sulfonic acid (PFHpS)	<0.50	-	-	<0.50	-	-	-					S-PFCLMS02
Perfluorooctane sulfonic acid (PFOS)	<0.50	-	-	<0.50	-	-	-					S-PFCLMS02
Perfluorodecane sulfonic acid (PFDS)	<0.50	-	-	<0.50	-	-	-					S-PFCLMS02
6:2 Fluorotelomer sulfonic acid (6:2 FTS)	<0.50	-	-	<0.50	-	-	-					S-PFCLMS02
8:2 Fluorotelomer sulfonic acid (8:2 FTS)	<0.50	-	-	<0.50	-	-	-					S-PFCLMS02
Perfluorooctane sulfonamide (FOSA)	<0.50	-	-	<0.50	-	-	-					S-PFCLMS02
N-Methyl perfluorooctane sulfonamide (MeFOSA)	<0.50	-	-	<0.50	-	-	-					S-PFCLMS02
N-Ethyl perfluorooctane sulfonamide (EtFOSA)	<0.50	-	-	<0.50	-	-	-					S-PFCLMS02

N-Methyl perfluorooctane sulfonamidoethanol (MeFOSE)	<0.50	-	-	<0.50	-	-	-					S-PFCLMS02
N-Ethyl perfluorooctane sulfonamidoethanol (EtFOSE)	<0.50	-	-	<0.50	-	-	-					S-PFCLMS02
Perfluoropentane sulfonic acid (PFPeS)	<0.50	-	-	<0.50	-	-	-					S-PFCLMS02
Perfluorooctane sulfonamidoacetic acid (FOSAA)	<0.50	-	-	<0.50	-	-	-					S-PFCLMS02
Perfluorooctadecanoic acid (PFOcDA)	<5.0	-	-	<5.0	-	-	-					S-PFCLMS02
Perfluorononane sulfonic acid (PFNS)	<0.50	-	-	<0.50	-	-	-					S-PFCLMS02
Perfluorohexadecanoic acid (PFHxDA)	<5.0	-	-	<5.0	-	-	-					S-PFCLMS02
Perfluorododecane sulfonic acid (PFDoDS)	<0.50	-	-	<0.50	-	-	-					S-PFCLMS02
Perfluoro-3,7-dimethyloctanoic acid (P37DMOA)	<0.50	-	-	<0.50	-	-	-					S-PFCLMS02
N-Methyl perfluorooctane sulfonamidoacetic acid (MeFOSAA)	<0.50	-	-	<0.50	-	-	-					S-PFCLMS02
N-Ethyl perfluorooctane sulfonamidoacetic acid (EtFOSAA)	<0.50	-	-	<0.50	-	-	-					S-PFCLMS02
7H-perfluoroheptanoic acid (HPFHpA)	<0.50	-	-	<0.50	-	-	-					S-PFCLMS02

4:2 Fluorotelomer sulfonic acid (4:2 FTS)	<0.50	-	-	<0.50	-	-	-					S-PFCLMS02
10:2 Fluorotelomer sulfonic acid (10:2 FTS)	<0.50	-	-	<0.50	-	-	-					S-PFCLMS02
Perfluoropropane sulfonic acid (PFPrS)	<2.50	-	-	<2.50	-	-	-					S-PFCLMS02
2,3,3,3-tetrafluoro-2-(heptafluoropropoxy)propanoic acid (HFPO-DA)	<2.50	-	-	<2.50	-	-	-					S-PFCLMS02
2H,2H,3H,3H-perfluoroundecanoic acid (H4PFUnDA)	<5.0	-	-	<5.0	-	-	-					S-PFCLMS02
Perfluoroundecane sulfonic acid (PFUnDS)	<2.50	-	-	<2.50	-	-	-					S-PFCLMS02
Perfluorotridecane sulfonic acid (PFTrDS)	<2.50	-	-	<2.50	-	-	-					S-PFCLMS02
9-chlorohexadecafluoro-3-oxano nane-1-sulfonic acid (9Cl-PF3ONS)	<0.50	-	-	<0.50	-	-	-					S-PFCLMS02
11-chloroeicosafluoro-3-oxaunde cane-1-sulfonic acid (11Cl-PF3OUdS)	<0.50	-	-	<0.50	-	-	-					S-PFCLMS02
4,8-dioxa-3H-perfluorononanoic acid (DONA)	<0.50	-	-	<0.50	-	-	-					S-PFCLMS02
Perfluoro-3-methoxypropanoic acid (PFMPA)	<2.50	-	-	<2.50	-	-	-					S-PFCLMS02
Perfluoro-4-methoxybutanoic acid (PFMBA)	<2.50	-	-	<2.50	-	-	-					S-PFCLMS02

Perfluoro(2-ethoxyethane)sulfonic acid (PFEESA)	<2.50	-	-	<2.50	-	-	-					S-PFCLMS02
Perfluoro-4-ethylcyclohexanesulfonic acid (PFECHS)	<0.50	-	-	<0.50	-	-	-					S-PFCLMS02
2H,2H,3H,3H-perfluorohexanoic acid (3:3 FTCA)	<2.50	-	-	<2.50	-	-	-					S-PFCLMS02
2H,2H-perfluorooctanoic acid (6:2 FTCA)	<5.0	-	-	<5.0	-	-	-					S-PFCLMS02
2H,2H,3H,3H-perfluorooctanoic acid (5:3 FTCA)	<5.0	-	-	<5.0	-	-	-					S-PFCLMS02
2H-perfluoro-2-octenoic acid (6:2 FTUCA)	<5.0	-	-	<5.0	-	-	-					S-PFCLMS02
2H-perfluoro-2-decenoic acid (8:2 FTUCA)	<0.50	-	-	<0.50	-	-	-					S-PFCLMS02
2H,2H,3H,3H-perfluorodecanoic acid (7:3 FTCA)	<5.0	-	-	<5.0	-	-	-					S-PFCLMS02
2H,2H-perfluorodecanoic acid (8:2 FTCA)	<5.0	-	-	<5.0	-	-	-					S-PFCLMS02
Total Organic Carbon [%DW]	-	-	-	1.17	-	-	-					S-TOC1-CC
Granulometric analysis [%]												
(0.06-2.0)mm	65	-	44	44	-	-	-					
(0.002-0.06)mm	28	-	44	41	-	-	-					
<0.002 mm	7	-	12	15	-	-	-					