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THE ENVIRONMENTAL IMPACT OF DUMPING PITS FOR POTLININGS AND FILTERDUST FROM ISAL ALUMINIUM SMELTER AT STRAUMSVIK

A REVIEW OF RESEARCH CARRIED OUT ON THE BIOTIC DIVERSITY AND ACCUMULATION OF HEAVY METALS AND PAH IN ORGANISMS

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Contents

Abstract

The following chemicals can be found in pot-linings from aluminium smelters:
Metals: Hg, Pb, Cd, Cu, Zn and Ni
Inorganic compounds: F and CN
Organic compounds: PAH
Fertilizers: P and N compounds

Research on the diversity of the intertidal and sublittoral algae and invertebrates was carried out by Ingolfsson (1990) and Svavarsson (1990) and measurements on the accumulation of heavy metals and PAH (Polycyclic Aromatic Hydrocarbons) in blue mussels (*Mytulis edulis*) and the seaweed *Fucus disticus* by Audunsson et al. (1998). Audunsson et al. (1998) used Hvalfjordur as a control for natural concentrations of heavy metals and PAH.
The results from the biodiversity studies did not show any signifiacnt change in biodiversity in transects set out at various distances from dumping pits of different age. Increased concentrations of heavy metals were not found in the selected organisms, except for an increase in Cr close to the harbour, which can be related to ship traffic.
At Hvalfjordur, most of the PAH compounds were in such low concentrations (total 0.5-1 ng/g dry-weight for the seaweed, and wet-weight for the blue mussel), or they were not detected. At Straumsvik, the concentrations were much higher. For *F. disticus* 18 to 40 times higher and for blue mussels on the shore and in cages floating off the shore, the concentrations were 14 to 100 times higher. However, there was an inconsistency in the maximum concentrations of PAH. For blue mussels in cages they were close to the oldest dumping pits but for blue mussels on the seashore, collected a month earlier, highest concentrations were found close to the youngest dumping pit. This indicates that the PAH is windborne and concentrations can alter according to dominant wind direction. For *F. disticus* the highest concentrations were found close to the oldest dumping pits, even though the samples were taken at the same time as the blue mussels from the shore. It is estimated that the half time of PAH in organisms is 14 days.
It can be concluded that the environmental impact of the dumping pits is negiligible. No significant increased in concentration of heavy metals can be related to the dumping pits and the increased concentrations of PAH are presumably windborne from the smelter. The total PAH concentrations found in organisms are however, similar to background values used in Europe.

Introduction

Pot linings need to be renewed every 6-8 years. The aluminium smelter of the Icelandic Aluminium Co. Ltd. at Straumsvík has dumped the pot linings at three pits on the exposed seashores near the smelter at Straumsvík. The oldest dumping pit is near Kelatangi in the Straumsvík bay, the second is east of Einbúi and the third and the youngest is in Thordarvík presently in operation.
Pot linings are dumped behind a wall made of large rocks or boulders that prevent the sea waves from entering the pits. After use, the pits are closed with chalk rich sand, soil and grass. Seawater percolates through the protecting walls of the pits and washes out the chemical in the pot linings: The following chemicals can be found in pot-linings from aluminium smelters (Rygg and Green 1981, A/S Miljøplan 1988, Ólafsson 1996, Gudjón Jónsson pers. com):
Metals: Hg, Pb, Cd, Cu, Zn and Ni
Inorganic compounds: F and CN
Organic compounds: PAH
Fertilizers: P and N compounds.

Research on the diversity of the intertidal and sublittoral algae and invertebrates in the vicinity of the dumping pits was carried out by Ingolfsson (1990) and Svavarsson (1990). In accordance with. operating licence of the Icelandic Aluminium Co from 7 November 1995 (article 3.1) (Ministry for the Environment) it was decided to follow the previous research by measuring the accumulation of heavy metals and PAH (Poly Aromatic Hydrocarbons) in blue mussels (*Mytulis edulis*) and the seaweed *Fucus disticus* to assess the impact of the pot lining pits on the surrounding biota.

STRAUMSVÍK

Sigurdsson (1976) surveyed the groundwater flow in Straumsvik (Fig. 1). About 10 m3/s of groundwater flows underneath the lava fields south of Straumsvik in a north-west direction. Various polluting activities are in the catchment area, especially just south of the aluminium smelter. Amoung the activities are a closed steel smelter and an asphalt factory. It is assumed that the effluents from these activites enter the groundwater and are carried to Straumsvik. Therefore the sea shore ecosystems are also affected by other human activities than the aluminium smelter. Rubbish from households and industry is sorted east of the Aluminium smelter and rubbish pits from township Hafnarfjördur were operated in the catchment area of Straumsvik from 1968 to1990.
In the lava field just south of the smelter is a racing track and rubbish storing area. No infomation is available for polluting chemicals from the rubbish stored in the catchment area nor from the other activities.
Olafsson (1996) reviewed existing data from the Marine Research Institute on salinity and mixing of sea water off Straumsvik. He also measured nutrients in the sea in the vicinity of the pot lining pits at Einbúi and in Thórdarvik. The fresh water that emerges from underneath the lava fields floats on top of the sea water (less than 2 m thick layer) and mixes some distance from the shore. Accordingly, chemicals from the pot lining pits should be carried off by the fresh water and distributed in the sea

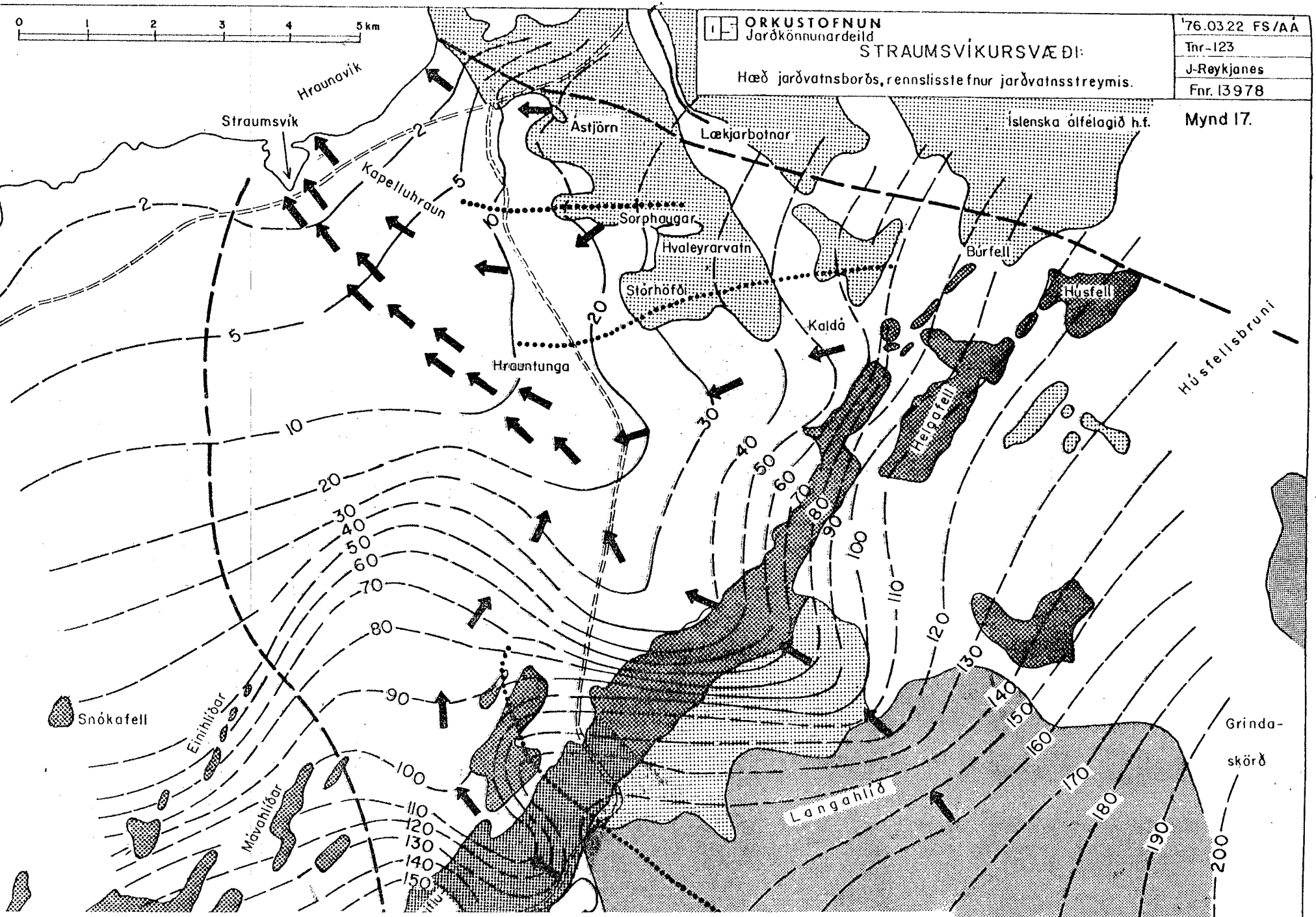

Fig. 1. Groundwater level and direction of groundwater flow in the Straumsvík catchment area (Sigurdsson 1976)

water some distance from the shore. The impact of the chemicals on the sea shore biota should therefore be minimal. However, nitrogen and phosphorus compounds are leaking from the pot lining pits, which could affect the algae growth in their vicinity.
Ingólfsson (1990) studied the species diversity of the intertidal biota adjacent to the pot lining pits and his results indicated that the pits had little or no effect on the biodiversity. However, the diversity declined eastward from the pits, but it was not possible to determine the causes. Svavarsson (1990) also concluded that the pits did not affect the species diversity sublittoral rocky bottom in and around Straumsvík. These results indicate that the chemicals from the pot lining pits mix with sea water. Simultaneously the fresh water layer mixes with the sea water. In a study on the distribution of heavy metals in the North-Atlantic (Johannesson et al. 1996) the quantity of copper, cadmium and zinc in blue mussels (*Mytilus edulis*) was not greater in Straumsvik than elsewhere in Iceland.

Procedure and methods

It was decided that Dr. Gudjón A. Audunsson at the Icelandic Fisheries Laboratories and Prof. Jón Ólafsson at the Marine Research Institute would plan a study programme in cooperation with Gudjón Jónsson at the Icelandic Aluminium Co. and Prof. Gísli Már Gíslason at the University of Iceland. The aim of the studies was to determine the accumulation of inorganic and organic trace in selected marine intertidal organisms in the vicinity of the aluminium smelter. The inorganic and organic pollution is released from the pot linings and from the emission of the smelter and taken up by the organisms. It was not possible to determine if the source of the pollution would be from the smelter or from other industrial activity in the catchment area of Straumsvík.
Transects on the sea shore were set out from pot lining pits at different ages (Fig. 2) to obtain information on accumulation of heavy metals and PAH (Poly Aromatic Hydrocarbons) in selected organisms.

Study programme

The research methods (Audunsson 1998) were limited to accumulation of chemicals in blue mussels (*M. edulis*) and the seaweed (brown alga) *Fucus disticus*. Blue mussels of different sizes were collected from Hvalfjördur in early May 1997 and kept in cages for 2 months before they were set out at Straumsvík. Blue mussels of similar size were set out in early July in cages at 7 sites on the shore and in the sea north of the smelter, at 1 m depth and at 5 m depth. Control cages were kept at Hvalfjördur. The cages were taken up in mid-September. *F. disticus* and blue mussels from three sites were collected from the intertidal zone near the pot lining pits (Fig. 2) and from Hvaleyri in Hvalfjördur for control. The study programme was based on the proposal made by Audunsson (1996), but determination of the possible pollution in the groundwater was not included. The heavy metals and PAH were measured from the shell and flesh of blue mussels and from *F. disticus*.

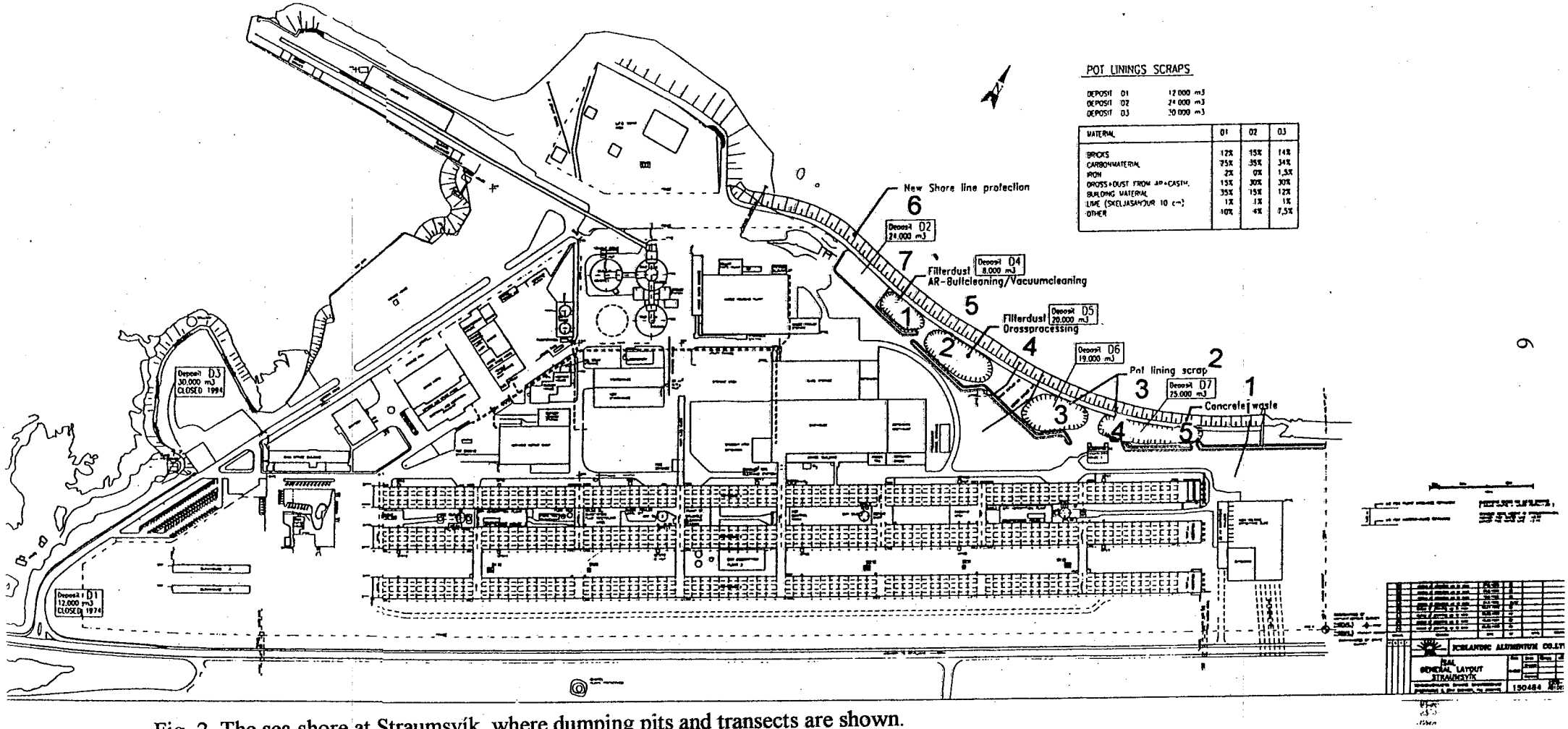

Fig. 2. The sea shore at Straumsvík, where dumping pits and transects are shown. Blue mussels were kept in cages off the shore (transects outside the protection walls of dumping pits) and seaweed and blue mussels wre collected in the intertidal zone (transects on the shore line). The oldest dumping pit is D3, then D2 and the youngest is D7.

Results and discussion

Audunsson (1998) submitted a report on the accumulation of heavy metals and PAH in blue mussels and kelp on the shore near the aluminium smelter in Straumsvík. His main results are summarized in this report, but for further information I refer to his report. Both at Straumsvík and in Hvalfjördur control site blue mussels grew well, but slightly faster at Straumsvík.

INORGANIC TRACE ELEMENTS

Heavy metals in cage blue mussels were found in similar quantity at Straumsvík as at the control site in Hvalfjördur, except for chromium (Cr), which was found in greater quantities at Straumsvík. The values were highest near the harbour. Presumably this is due to shipping traffic, but chromium is used to strengthen steel. Values are not available for other harbours in Iceland.

Mercury (Hg), cadmium (Cd) lead (Pb) and zinc (Zn) in blue mussels on the intertidal zone were similar at Straumsvík and at Hvaleyri in Hvalfjördur (control). Nickel (Ni) and copper (Cu) were found in highest concentrations close to the youngest pot lining pits and higher values were found than at the control site at Hvaleyri. Earlier studies on blue mussels from Hvaleyri have shown that concentrations of these heavy metals, especially nickel and chromium, increase with decreasing size of the blue mussels. Smaller blue mussels at site 3 probably explain the increased concentration of these heavy metals, because similar concentrations were measured in blue mussels at Hvaleyri.

Generally, similar concentrations of heavy metals were found in blue mussels on the shore and in the cages, with the exception of zinc, copper and cadmium. It is possible that lower salinity increases the uptake of the metals in the cages, but the metals are carried with the fresh water and distributed with vertical mixing. Since only a small growth was observed in blue mussels over the short period they were kept in cages at Straumsvík, there was no difference in the uptake in shells and flesh.

Concentration of fluorine (F) in *F. disticus* was not higher at Straumsvík than at Hvaleyri. Heavy metals as lead and mercury were not detectable by the chemical analyses. Zinc was found in higher concentrations in Straumsvík than at Hvaleyri, which could be due to the freshwater influence at Straumsvík or from pollution from the smelter. Copper was also found in higher concentrations at site 1 than at site 2 in Straumsvík, but lower in other samples, including samples from Hvaleyri. Apparently, the quantity of heavy metals in *F. disticus* in Struamsvik and Hvaleyri are within the natural concentrations.

PAH

PAH were found in much higher concentrations near the aluminium smelter than at the control site at Hvaleyri in Hvalfjördur. In Hvalfjördur only traces of two PAH (fenantrene and fluorantene) were found in *F. disticus.* The total concentrations for PAH *in F. disticus* at Straumsvík were 18 – 44 ng/g dw. Highest concentrations (total ca. 40 ng/g dw) were near the older dumping pits and lowest concentration was found near the youngest dumping pit (18 ng/g dw). Concentrations of PAH at Hvaleyri in Hvalfjördur was only detectable for 2 PAH (fenantrene and fluorantene, total 1.1 ng/g ww) in September, but 8 PAH were detected in July (8 ng/g). Blue mussels in the intertidal zone at Straumsvík near the dumping pits had the highest concentration near

the youngest pit (54 ng/g ww) and lowest (7 ng/g ww) near the oldest pit. Also, the concentration of PAH in the cage blue mussels was slightly higher than in blue mussels from the intertidal zone. Highest concentrations were found close to the oldest dumping pits and lowest near the youngest. Comparison between the cage blue mussels and shore blue mussels is difficult, since a month elapsed between the samplings. Samples from the intertidal zone were taken a month later than from the cages. PAH's half time is estimated 10-15 days (Audunsson pers. com.). Concentrations of PAH reflect the ambient concentrations for a few days prior to sampling. The difference in concentrations between the sampling periods indicates that the PAH compounds are windborne from the burning in the smelter and highest concentrations reflect dominating wind direction prior to sampling. This could also explain the difference in concentrations in the samples at the control site in Hvalfjördur at the beginning and at the end of the experiment period.

Conclusion

Apparently, none or small increase in heavy metals were found in organisms at Straumsvík compared with Hvalfjördur or in comparison with earlier studies on heavy metal all over Iceland (Jóhannesson et al 1995). Chromium was found in higher concentrations than at the control site, but usually chromium is found in higher concentrations in or close to harbours. No reference or background values are found for chromium, but values found at Straumsvík for other heavy metals were below standards for ecologically unacceptable values in fish flesh. Values for heavy metals in the vicinity of Straumsvík are similar as found in natural habitats. Higher concentrations are expected to be found near Iceland due to vertical mixing of deep water with upper layers of sea waters, which is more common around Iceland than elsewhere in the North Atlantic (Jóhannesson et al. 1995). Measurements of copper, zinc and cadmium in blue mussels in Straumsvík in 1990-1992 did not show any higher concentrations than elsewhere around Iceland (Jóhannesson et al. 1995). The values were expressed per dry-weight (dw) in earlier studies, but as per wet-weight (ww) in Audunssons (1998) studies, which makes comparison difficult. However, if dw is 10-25% of ww, the concentrations are similar now as found in earlier studies. Background values for PAH are low and almost undetectable in Iceland if the concentrations found in organisms at Hvaleyri at Hvalfjördur reflect correct values. The values found at Straumsvík were much higher. Almost all of the 23 PAH compounds were undetectable or at the limits of detectability in Hvalfjördur. At Straumsvík, the concentrations were much higher. Significant correlation between the concentrations of different compound indicates the same source of the compounds. Fluorantene, chrysene/triphenylene, benzo(b,j,k)fluorantene and benzo(e)pyrene were in similar and also in highest concentrations in blue mussel flesh in cages at Straumsvík and fluorantene in blue mussel flesh from the intertidal zone. Other PAH compounds were found in high concentrations in the seaweed *F. disticus* than in the blue mussels. Naphtalene, 1-methylnaphtalene and 2-methylnaphtalene were in highest concentrations. A difference was found in where, in relationship with the dumping pits, the highest concentrations of PAH were found in seaweed and blue mussels, both from cages and from the intertidal zone. PAH have a short half time (10-15 days) and the concentrations found in organisms reflect their occurrence shortly prior to the sampling. Presumably the PAH were airborne and their

concentrations indicate dominating wind direction shortly before samples were taken. If this is the case, the compounds are derived from the aluminium smelter emission. Total concentrations of PAH in blue mussels and other filter feeding molluscs and algae eating snails (e.g. *Littorina saxatilis*) were similar as values given as background values far away from sources of PAH (see Knutzen 1989 who reports the background values as 13-200 ng/g ww). The concentrations in the seaweed Fucus disticus at Straumsvík were lower than Knutzen and Sortland (1982) measured in the seaweeds Fucus vesiculosus, F. serratus and Ascophyllum nodosum from unpolluted or lightly polluted coastal areas of Norway. The concentrations of 20 PAH they measured, as "background values" were 300-2500 ng/g ww, or many times higher concentrations than were measured at Straumsvík. Later, Naes et al. (1995), pointed out the difficulties in measuring the PAH and they had their reservations regarding the values and suggested revaluation of the background values. For blue mussels (*M. edulis*) the total background concentrations were more likely 20 ng/g ww for carcinogenic (CPAH) and 1 ng/g ww for benz(a)pyrene. In uninhabited areas, free of car traffic, these values should be <10 ng/g ww for total PAH and possibly 0.1-0.2 ng/g ww for benz(a)pyrene. Background concentrations of these compounds could therefore be slightly lower than the concentrations of the same compounds found in blue mussels and seaweed at Straumsvík. This has also been found for airborne PAH, where the values at Straumsvík were lower than the background concentrations in Central Europe (Schunke and Thomas 1983).

No limits of concentrations of PAH in fish flesh have been set for human consumption in Iceland or the Nordic Countries. However, Unilever Ltd has guidelines for action for fish oils (Audunsson pers. com.) and they are 1 ppb for benz(a)pyrene and 7 ppb for total PAH. The concentrations found in blue mussels from the cages and the intertidal zone at Straumsvík were higher than these values, but not the concentrations found at the control site in Hvalfjördur. After the Braer oil spill at the Shetlands, concentration limits were set for PAH in blue mussels and fish in the area (Webser et al. 1997). Reference concentrations for PAH in blue mussels (*M. edulis*) are 13.7-66.1 ng/g ww (average 24 ng/g ww), but concentrations for PAH within the polluted area was at the average 221 ng/g ww and highest concentration was 316 ng/g ww. Advice was given not to consume fish from the polluted area. Concentrations of PAH at Straumsvík are close to the reference values.

The results from the studies made by Audunsson (1998), Ingólfsson (1990) and Svavarsson (1990) show that the effect of the dumping pits on the biota, both regarding species diversity and accumulation of heavy metals is small or not detectable. Airborne PAH are carried to the shore and the sea and accumulate in blue mussels and the seaweed F. disticus, and probably in other organisms. Accumulation of these compounds is similar or lower than in areas in Europe which are lightly affected by pollution or not at all. The effects of the dumping pits are therefore hardly detectable, but the accumulation of PAH in organisms at Straumsvík is presumably windborne.

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