# **Chapter 2 – Environment**

*in strategic environmental assessment report*

*(SEA 2007 report – US)*

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**Prepared**
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**by the Greenland Home Rule**
**SEA working group**

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# Chapter 2 Environment

## 1 Summary

### 1.1 Introduction

The chapter on the environment in the strategic environmental assessment describes seven central environmental themes: aquatic environment, water resources, waste, waste water, air emissions, noise and dust.

A number of the environmental impacts that will arise as a consequence of the aluminium project will basically be the same irrespective of where the aluminium smelter is located. For a number of the seven environmental themes it will therefore not be possible immediately to point to a single location that will be preferable rather than another, but combined with information on animal life and vegetation, natural areas protection or culture-historical values in an area, the review may contribute to identifying areas where the consequences vary.

In a review of the documents available no direct environmental impacts have been identified that would suggest that the project ought not to be implemented. However, a consequence of the establishment of an aluminium smelter is that Greenland's $CO_2$ emissions will be increased by 75 %. $CO_2$ emissions of this order conflict with applicable international obligations and with agreements concluded with Denmark, and it is as yet uncertain what the economic consequences of this will be.

Another purpose of this review is to throw light on topics that have not at present been illustrated sufficiently. Who will in the further course of events be responsible for being in charge of and financing the procurement of outstanding data is a matter to be decided in cooperation between Alcoa and the Greenland Home Rule.

The physical surroundings may be of decisive importance for the future effects of the facilities. An important purpose has therefore also been to create a basis for demonstrating how the establishment of the smelter, port facilities and roads, etc. will affect the natural surroundings before a decision is made concerning the final location.

A number of the environmental consequences of the project may be mitigated by demanding sound waste disposal, demanding limit values for the discharge of waste water and emissions and demanding that measures be taken that contribute to protecting animals and humans as much as possible during construction, establishment and operation. These demands are made in the environmental approvals of the individual parts of the activities on the basis of the current practice, experience and demands made on similar projects in Greenland, Iceland, Norway, Canada and the EU as well as the material presented by the clients in the EIA report.

In the description of the seven environmental themes, an evaluation and a description of the biological and health effects of the various environmental impacts as a result of the project during both the construction phase and the establishment phase have been provided only to a limited extent.
A brief summary of the conclusions regarding the seven environmental themes is provided below. This summary includes the most important consequences, duration, mitigation measures and proposed further investigations.

**1.2 Aquatic environment**
The initial considerations show that the onshore and offshore aquatic environment will be affected both in connection with the establishment and during the operation of the various facilities.

In particular it is important to keep in mind that the establishment of hydroelectric power stations results in secondary effects in the inner parts of the fjords because the water chemistry and the content of suspended matter are changed. In addition, it may be anticipated that the structure of the rivers will change as a result of changes to the flow whereby changes will occur in sedimentation.

It is recommended that plans should be made on nature's own terms already at this early stage so that the construction of port facilities and discharges of waste water are tailor-made so that the use of, for instance, heavy technology that can result in extensive disturbance of the sea bed can be avoided. By making environmentally acceptable plans at this early stage the environmental impacts can be reduced.

In consequence of this it is recommended that the facilities should be tailor-made for the individual locations and that scenarios should be prepared in connection with the EIA process that describe precisely the environmental impact and the impact on nature for the individual locations.

**1.3 Water resources**
Drinking water is a limited resource in many areas of the country because most towns are situated close to the coast on islands or peninsulas. Nevertheless

water is an important parameter for the realisation of the project. The effect of implementation of the project may be negative for the area where the smelter is established and considerable inroads will be made into the existing water resource.

It is possible to remove salt from sea water, but that process is cost intensive and difficult. This will be detrimental to the profitability of the project. In reality the need for fresh water from lakes or rivers is therefore constant and great. The only measure that can be taken to remedy this is to incorporate lakes at more distant locations as water resources. This will involve large costs in construction and operation, for instance costs of frost proofing of the raw water pipes.

In connection with the environmental impact studies the raw water resources must be assessed in detail with regard to special vulnerability, quality and final capacity. When those studies have been completed there will be a need for preparation of abstraction permits, approvals of protection zones and water supply works; see part 6 of the Environmental Regulation.

### 1.4 Waste

As far as waste is concerned more information is needed concerning waste quantities, composition, etc. as well as information concerning waste management plans. When this information is available it will be necessary to examine the environmental consequences this will have. Detailed plans should be prepared for the management of the various types of waste during the construction phase, the establishment phase and the operating phase. Furthermore, the plans must describe the types, quantities and composition of waste that can be expected to be produced during the individual phases. Finally, a time schedule is required which shows where, when and from where the individual types, quantities and composition of waste may be expected to be produced. This time schedule should be prepared so that it can be rendered visible when a waste system will need to be ready to manage the various quantities and types of waste.

It is very likely that the increased activity will lead to a need for an extension of the municipal waste systems. Therefore, this need must be assessed in more detail.

Generally an illustration is needed of the types, quantities and composition of waste and what plans have been envisaged for the management of the individual types and fractions of waste. In addition, an evaluation is needed of the environmental impacts that the management methods selected will bring about.

At present far too little is known about the quantities of waste from the individual activities, the composition of the waste and the choice of waste disposal methods, etc. Therefore it is not possible to indicate whether one location should be preferred to another.

On the basis of what is known it is not possible to assess the environmental consequences that will be brought about by the quantity of waste produced.

**1.5 Waste water**

In a possible later phase of the project it is quite clearly the discharge of waste water from the aluminium smelter to which the authorities should pay most attention since the largest impacts will come from that discharge.

In relation to waste water discharges there is generally a need for more information about the project as a whole, including the physical location of all facilities that are related to such discharges and the technical solutions and technologies intended to be employed before any specific statements can be made concerning the waste water problems in relation to a project of this order.

For instance, the same quantity of waste water will be discharged from the aluminium smelter irrespective of where it is located, but it may appear that some marine ecological environments will be more vulnerable to the addition of nutrients and xenobiotic substances than will others.

Therefore a thorough analysis of recipients ought to be performed before a final decision is reached on the location of the waste water outlets. Such an analysis can be made in connection with the EIA report and the base line surveys.

In addition it is found that an examination is needed concerning wastewater treatment technology in relation to the aluminium industry and its effect in Greenland and concerning limit values for this type of industry.

Finally, it must be borne in mind that in connection with the construction of, for instance, hydroelectric power stations and dams, tunnel excavations, etc. activities will be carried on at several locations. A characteristic of some of these locations will be that it will not immediately be possible to discharge waste water to the sea or to a fjord. Therefore it will be necessary to find another practical and environmentally sound way in which to manage the waste water.

**1.6 Air emissions during the operation of the smelter**

It is anticipated that during normal operations the smelter will at worst have an annual impact on the surroundings of approximately:

- 4,600 tons of $SO_2$ (sulphur dioxide)
- 110 tons of fluorides
- 180 kg of PAHs
- 90 tons of particulate matter (under 10 μm)
- 450,000 tons of $CO_2$
- 7.1 tons of PFC gases corresponding to 46,000 tons of $CO_2$ equivalents

In addition, an unknown quantity of the following airborne substances will be emitted: Nitrogen oxides, carbon monoxide and cyanide that may be toxic even in small doses.

By introducing wet flue gas cleaning and carbon anodes with a high sulphur content a large part of the sulphur dioxide will be discharged with the waste water whereby the air emissions will be reduced annually to approximately:

- 300 tons of $SO_2$ (sulphur dioxide)
- 95 tons of fluorides
- 160 kg of PAHs
- 75 tons of particulate matter (under 10 μm)
- $CO_2$ and PFC unchanged emission

It must be assumed that there will also to a certain extent be a discharge of other environmentally damaging substances in the form of heavy metals, arsenic, vanadium, etc. as well as xenobiotic organic compounds, including chlorine compounds that may accumulate in the arctic ecosystems. However, there is no information concerning such emissions in the material available for which reason a closer examination should be made.

On the basis of the information available the emission of fluorides is regarded as the most important of the air pollution impacts on the surroundings. The reason for this is the relatively large quantity as compared with the low tolerance value of the ecosystems in respect of fluoride.

Furthermore, it is believed that emission of airborne substances as a result of operating accidents, etc. may constitute a not inconsiderable source of increased impact on the environment.

It should be emphasised that the above-mentioned quantities of emission relate to the corresponding Icelandic smelter and that therefore they are not necessarily to be regarded as applicable to a coming aluminium smelter in Greenland.

In connection with environmental approval of the aluminium smelter demands must be made with regard to cleaning with the use of the best available technology.

### 1.7 Noise

In connection with the construction of a smelter and dams the surroundings may be exposed locally to noise of a temporary nature. Transmission lines, transformer stations, ports and production plant may involve permanent noise exposure.

Noise is one of the factors that form part of the overall impact on the natural surroundings and a specific evaluation must be undertaken for each of the coming locations in which the anticipated generation of noise and the vulnerability of the area are weighed.

Noise load from enterprises is regulated by conditions in the environmental approvals of the enterprises and normally the point of departure is the indicative limit values issued by the Danish Environmental Protection Agency.

### 1.8 Dust

The anticipated dust impact from construction activities and operation of the smelter and hydroelectric power stations is partly dust fall where small particulate matter settles on the vegetation, partly from fine and ultra-fine particulate matter from the exhaust of vehicles, ships, etc. and from the discharge from production plants. It is expected that dust fall will be of a local nature, primarily related to construction activities, roads and extraction of sand and gravel to be used as construction materials. The actual harmful effect must be evaluated in relation to the vulnerability of the individual areas as far as plants and animal life are concerned. It is expected that dust-emitting materials such as cement and aluminium oxide will be stored in closed systems, containers, or the like, and therefore the dust impact from these is expected to be primarily related to accidents in the event of damage to silos or pipe systems.

Discharge of particulate matter from the production plant is considered in the section on emissions.

The discharge of fine and ultra-fine particulate matter from ships, planes and the exhaust of vehicles is injurious to health, but it must be expected that it will be considerably less than for instance the impact from a road with normal traffic. Locally the discharge of particulate matter will be a new impact, however, since in most areas there has been no activity previously.

## 2 INTRODUCTION

The aluminium project consists of two sub-projects: The establishment of an aluminium smelter and the establishment of at least three hydroelectric power stations that are to provide the smelter with the necessary quantity of energy. Both of these sub-projects in turn consist of a number of minor projects and plants.

The construction of the aluminium smelter has the effect that simultaneously a concrete foundry, storage facilities for raw materials and secondary materials, storage facilities for the finished aluminium bars, port facilities and road facilities are to be established at the chosen location. Correspondingly the establishment of the hydroelectric power stations will involve the construction of roads, dams, turbines, inlet tunnels as well as trenches for the transmission line from the hydroelectric power station to the aluminium smelter. It is not clear how the establishment of the facilities will be implemented in practice, but it will probably be necessary to construct ports, site roads and work camps at a number of different locations.

As a result of the two sub-projects, the aluminium smelter and the hydroelectric power stations, a great need for labour will be created and according to the preliminary information[1] the expectations as regards the manning situation during the construction and establishment phase and the operating phase, respectively, are as follows:

| | Manning | Time of construction and establishment in years |
|---|---|---|
| Establishment of hydroelectric power stations | 2,000 | 4 – 5 years |
| Establishment of aluminium smelter together with roads, port, etc. | 1,500 – 2,000 | 2 – 2½ years |
| Operation of aluminium smelter | 600 – 700 | |
| Operation of hydroelectric power stations | 25 – 50 | |
| Indirect employees after commissioning of the aluminium smelter and the hydroelectric power stations | 1,000 | |

These figures will be important for giving an estimate of some of the environmental consequences of the many activities that we have endeavoured

[1] From the website of Greenland Development www.aluminium.gl

to describe in this chapter, for example household waste and sanitary waste water.

## 2.1 Contents of the chapter on the environment in the SEA

The environmental consequences of the establishment of an aluminium smelter with hydroelectric power stations are illustrated first with a summary of the general environmental impacts of the project. Section 3 describes the impacts for seven central environmental themes: Aquatic environment, water resources, waste, waste water, air emissions, noise and dust.

Section 4 describes the environmental issues that are related to the establishment and operation of the aluminium smelter. The section ends with a description of the need for additional information.

Section 5 contains a description of the environmental impacts resulting from the establishment and operation of the hydroelectric power facilities. For both the establishment and the operation, the environmental impacts are described on the basis of the seven environmental themes and the section ends with a description of the need for additional information.

Sections 6 to 9 contain a description of the environmental impacts from utility trenches, accommodation and office facilities, port facilities and roads during construction and during operation.

The need for base line investigations, monitoring and supervision is discussed in section 10.

Section 11 contains a preliminary risk assessment for the project while section 12 provides a brief description of the necessary environmental approvals and permits.

Section 13 contains a brief introduction to the applicable environmental legislation, including the regulatory measures that follow from the project.

Finally a description is given of the need for resources to perform the new tasks that follow from the project, including in particular the need for resources for the preparation of environmental approvals, supervision and ongoing revision of approvals.

## 2.2 Brief description of the background material

The material on which this chapter is based is in the first instance a number of articles on the environmental problems relating to the production of aluminium, including a presentation of the environmental problems and possible solutions relating to the project (2007) by Johansen, Asmund and Aastrup (National Environmental Research Institute, Arctic Environment (DMU, Arktisk Miljø)).

Bergsdal, Strømman and Hertwich (2004) present a general introduction to aluminium production, including applied technology and the environmental impacts in the form of emissions, waste, etc.

An assessment of the environmental impacts (EIA report) for Alcoa's newly established smelter in Fjardaal near Reydarfjördur, Iceland, has also been included as background material. The aluminium production was begun in 2007 and the smelter has a number of similarities with the smelter designed for this project, for instance capacity and technology.

The environmental impacts of the establishment and operation of a number of hydroelectric power stations are described on the basis of an environmental report for the hydroelectric power station in Qorlortorsuaq, a nature impact assessment of the hydroelectric power station that is currently being constructed at Tasersuaq in the municipality of Sisimiut and finally an EIA report for the Karahnjukar hydroelectric power station in Iceland.

Furthermore, the introductory cumulative survey for the area between Evighedsfjorden, Sønder Strømfjord and Sarfartoq Kuua has been employed. Each of the municipalities of Sisimiut, Maniitsoq and Nuuk has contributed with a report[2], in which each municipality describes three possible locations for the smelter. These reports have also been included as background material.

At an early stage in the SEA course of events, the National Environmental Research Institute (NERI) made a sketch which shows how the hydroelectric power stations could be placed based on utilisation of the lakes Tasersiaq (7e), Sdr. Isortup Isua (7d) and Imarsuup Isua (6g). In the section on nature the sketch has been reproduced as Fig. 1. This sketch has also been used in connection with the preparation of the chapter on the environment.

[2] The three reports are available on the website of Greenland Development, www.aluminium.gl

## 2.3 Description of the limitations of the material

The most important limitation of the material available is its general nature. It is still so early in the project that a number of central decisions concerning location and design have not been made. As far as the smelter is concerned that means that there is every probability that the plant to be established will resemble Alcoa's new smelter in Reydarfjördur, adjusted for the technological progress that will occur from now and until the plant is commissioned in 2014. But that leaves us with limited information about, for instance, emissions from the plant, quantities of waste and water consumption.

The background material to the hydroelectric power stations is also limited. At least three hydroelectric power stations are needed, but only one of five potential resources, Tasersiaq, has been selected to form part of the project with certainty. The lakes are very different and depending on which lakes are incorporated there are various needs for dams, canals and inlets from the lake to the hydroelectric power station itself.

Experience has already been gained of the establishment and operation of hydroelectric power stations in this country whereas the same does not apply to aluminium production. No EIA reports as such have been prepared, but there are limited environmental reports and nature impact assessments for the existing power stations. Neither the present hydroelectric power stations nor the power station that is being built at Taserssuaq can compare as far as capacity is concerned with the hydroelectric power stations that are to be established to produce power for the aluminium smelter.

## 2.4 The problems in relation to CO2

In spite of the use of hydroelectric energy, the aluminium smelter designed will discharge a relatively large quantity of carbon dioxide, $CO_2$, corresponding to around 1.2 tons per ton of aluminium produced. The carbon dioxide is released in connection with the electrolysis process since carbon is used as anode material.

With a production of 350,000 tons of aluminium annually that means a discharge of approximately 450,000 tons of $CO_2$. This should be seen in relation to Greenland's total discharge which was 650,000 tons of $CO_2$ annually in 1990, the reference year in relation to the Kyoto protocol. Thus the project will contribute with an increase of 70%.

The release of PFC gases from the aluminium smelter will further increase the emission of greenhouse gases by up to 46,000 tons of $CO_2$ equivalents annually.

The protocol of the climate convention concerning a reduction of the discharge of greenhouse gases, the Kyoto protocol, has been ratified by Denmark. Greenland has acceded to Denmark's ratification and has thus committed itself to work for a reduction in the discharge of, for instance, carbon dioxide.

In 2001 Greenland and Denmark concluded a framework agreement for the period 2008-2012, which is the commitment period of the Kyoto protocol. The framework agreement opens the way for a renegotiation with the following: *If before the expiry of the first commitment period of 2008-2012 activities are established in or around Greenland that contribute considerably to emissions, including the extraction of oil, gas and/or minerals and which thus make it difficult for Greenland to live up to a reduction commitment of 8 % this must be followed up by a separate negotiation".*

The aluminium smelter will be in operation only after the commitment period of the Kyoto protocol, and therefore the coming negotiations between Greenland and Denmark must be based on the agreements concluded concerning reduction targets after 2012.

However, there may be a need to renegotiate the framework agreement from 2001 as the activities that will be initiated before 2012 in connection with the aluminium project will no doubt lead to an increase in Greenland's energy consumption that is so large that it will be difficult to meet the reduction obligation of 8 %.

If Greenland does not succeed in obtaining an exemption from the Kyoto protocol through negotiation, a necessary alternative may be to purchase $CO_2$ emission allowances. The price of emission allowances will depend on market developments. With the anticipated discharge from the aluminium smelter the cost is assessed at present at approximately DKK 75 million annually.

# 3 GENERAL COMMENTS ON THE ENVIRONMENTAL IMPACTS OF THE PROJECT

## 3.1 Aquatic environment

The use of the concept aquatic environment in this section covers both the marine and the fresh water environment defined as the sea, lakes and rivers.

In connection with the establishment of given facilities (an aluminium smelter, port facilities, hydroelectric power facilities, etc.) there will be a need to assess the environmental impact on the aquatic environment in connection with the establishment and construction phase and the operating phase.

The degree of the physical and chemical impact will depend on the physical conditions prevailing at the location in question with regard to temperature, precipitation, ice formation, etc.

### *3.1.1 Fresh water environment*

#### *3.1.1.1 The fresh water environment – lakes with hydroelectric energy potential*

Generally, the lakes that are regarded as being likely to have hydroelectric energy potential are located close to the glacial cap.

In connection with the construction work relating to the construction of a dam the aquatic environment both in the lake itself and downstream will be affected. The reason for this is:

- that to begin with topsoil and peat deposits are to be removed so that stable foundation conditions can be secured
- that a rise in the water level in a given lake can give rise to anaerobic conditions since there may be a risk of putrefactive processes
- that the material dug up is suspended
- that the digging up of sediments can cause seepage of heavy metals and PAHs.

In connection with the selection of a site for a dam it must be kept in mind that the best environmental solution to reduce potential impacts and pollution is to adapt the development plans to the potential that exists for the area in question.

For an evaluation of this it is recommended that the local solutions should be based on background investigations for the areas in question. This should in particular be seen in the light of the fact that at present it is found that sufficient background information is not available to assess which environmental consequences will arise by, for instance, damming the lake Taserssuaq, which is approximately 70-80 km long and oligotrophic. This means, therefore, that it is extremely important that background investigations are prepared for every single location.

The background investigations are thus to constitute the basis for assessing the environmental impacts that can be expected to arise. That is to say that for each location the following should be considered:

- The characteristics of the catchment areas with regard to background rocks and loose materials since these affect the chemical composition of the water whether they are flooded or suspended on account of removal of material in the freshwater environment.

- To secure correct dimensioning of the facilities it is believed that there is a need to assess the risk of drainage of ice-dammed lakes (jôkul).

- It is believed that there is a need for a closer investigation of the influence of the rise in the water level of the lakes in relation to the thawing of the permafrost, thermokarst and landslides. This is due to the fact that the thermal capacity of the water will have the effect that the ice thaws whereby the flooded deposits "collapse". It is not known whether this settlement can cause landslides and therefore this must be investigated in more detail. It must also be expected that increased seepage of heavy metals from the active stratum above the permafrost will occur.

- Since it must be expected that a dam will cause accumulation of clay and silt at the bottom of the lake it will be necessary to assess whether this material needs to be dug or pumped up on an ongoing basis. Secondary problems related to the above will be:
  - where this bottom material is in that case to be deposited,
  - a risk of pollution caused by outflowing nutrients and heavy metals,
  - it is also believed that the use of motorised barges and the related process of using dumpers for handling the bottom materials will constitute an environmental risk to the aquatic environment.

- When the water level in the lakes is increased via dams and when the lakes are connected via tunnels and canals, the hydrology of the lakes with regard to runoff must be assessed so as to reduce the risk of adverse impacts on the environment and nature on account of full or partial drying up of streams.

To this should be added the formation of ochre as a result of periodical drainage of deposits that have not been removed.

- Hydro chemistry: It can be expected that the water in the lakes will have a low pH value, which can cause corrosion of metal and pipelines. Likewise problems in relation to the concrete should be investigated in detail to establish whether the concrete can have a negative effect on the water.

- Sedimentation: It is believed that in the lakes situated closest to the glacial cap and at the glaciers at Sukkertoppen suspended matter will have the highest settling rate. That means that estimates must be made in relation to the risk of wear of the turbines on account of suspended silt and clay.

  Another problem that has not been solved is that at present it is not known what effect the clay and the silt in the water will have in connection with the casting of concrete.

- Erosion of sediments in connection with a rise in the water level in the lake. An example of this is erosion caused by waves.

#### *3.1.1.2 Rivers*

When a given lake is dammed, the damming will have a secondary effect on the rivers downstream. It is believed that the largest effects will be:

- complete or periodical drying up of the river
- changes in flow whereby the course of the river and sedimentation will change, and
- changes to the chemical composition of the water and the content of suspended matter.

#### *3.1.1.3 Freshwater Environment – lakes for the smelter*

It must be considered what effects the establishment of an aluminium smelter will have on the aquatic environment in the coastal lakes.

In the event of establishment and operation of a smelter together with port facilities an assessment must be made as to whether sufficient supply capacity can be guaranteed and it must be ensured that the water is of the right quality. In relation to the inland lakes to be used for the generation of hydroelectric energy there are other matters for which allowance must be made in connection with their incorporation into the production of process water. For instance, the permafrost and suspended matter will not affect the water.

In this context it must be ensured that there is sufficient capacity to supply both process and drinking water. It must be expected that in the areas where it is believed that a risk of lack of water could arise, dams must be built to increase the water level.

In connection with the construction work involved in the construction of a dam the aquatic environment both in the lake itself and downstream will be affected. The reason for this is:

- that to begin with topsoil and peat deposits are to be removed so that stable foundation conditions can be secured
- to secure the water quality in connection with a rise in the water level all peat and topsoil must be removed to prevent anaerobic conditions
- that the material dug up is suspended
- that the digging up of sediments can cause seepage of heavy metals

In connection with the selection of a site for a dam it must be kept in mind that the best environmental solution to reduce potential impacts and pollution is to adapt the development plans to the possibilities available for the area in question.

For an evaluation of this, it is recommended that the local solutions should be based on background investigations for the areas in question. The background investigations must therefore constitute the basis for assessing the environmental impacts that can be expected to arise. That is to say that for each location the following should be considered:

- The characteristics of the catchment areas with regard to background rocks and loose material since they affect the chemical composition of the water whether they are flooded or suspended on account of removal of material.

- As it must be expected that a dam will cause accumulation of clay and silt at the bottom of the lake it must be assessed whether this material needs to be dug or pumped up on an ongoing basis. Secondary problems related to the above will be:
  - where this bottom material is in that case to be deposited.
  - a risk of pollution caused by outflowing nutrients and heavy metals
  - It is also believed that motorised barges and the related process of transport by dumpers for the handling of the bottom materials will constitute an environmental risk.

- When the water level in the lakes is increased via dams the hydrology of the lakes with regard to runoff must be assessed so as to minimise the risk of adverse impacts on the environment and nature on account of full or partial drying up of streams. To this should be added the formation of ochre as a result of periodical drainage of deposits that have not been removed.

- Hydro chemistry: It can be expected that the water in the lakes will have a low pH value, which can cause corrosion of metal and pipelines. Likewise problems in relation to concrete should be investigated in detail to establish whether the concrete can have a negative effect on the water.

Besides it can be recommended that planning should make allowance for exploitation of the potential of the location in question. Therefore it can be recommended that plans should be made on nature's own terms at this early stage so that the construction of dams is tailor-made for the individual lakes.

In summary, additional investigations are required to ensure that the ecological conditions will be disturbed as little as possible in connection with the construction activities and the subsequent operation.

As lakes will be close to the aluminium smelter from which fluorine, PAHs, etc. will be discharged, monitoring of such discharges is required.

### *3.1.2 Marine environment*

In connection with the establishment and operation of an aluminium smelter and a hydroelectric power station, it will be necessary to construct port facilities that will affect the marine environment. To this should be added increased marine traffic, discharge of waste water, etc. which will constitute an environmental risk.

#### *3.1.2.1 Marine pollution*

First it should be emphasised that a given polluted area is unique and that therefore tailor-made solutions must be developed for each port and fjord area. Therefore it should be remembered that no single standard solution exists that may be used in all ports and marine fjord areas in Greenland owing to the physical differences with regard to current, ice formation, etc.

Contamination of the sea floor is no problem as long as the pollutants do not get into contact with living organisms. Therefore, the best solution is to leave the contaminated area on the sea floor alone and cover the sea floor with clean sediments so that the pollutants do not spread to the water. But if local conditions do not allow this the polluted sediments must be dug up and dumped elsewhere. In that connection there will be a risk that the digging/pumping up and dumping will cause suspension and thus spreading of the sediments including the pollutants.

##### *3.1.2.2 Industrial development versus environmental requirements in connection with the construction of port facilities in areas with a high settling rate*

In connection with the selection of a site for an aluminium smelter, a port and a town extension, etc. attention should be paid to the fact that the best environmental solution to prevent environmental impacts/pollution is to adjust the development plans to the potential of the area in question. It is recommended that background investigations should be used as a basis for an evaluation of local solutions.

At locations where a quay is to be constructed it is important to consider the following:

- Nature of the sea bed (soft bed or bedrock),
- Sedimentation, including suspended matter
- Depth, including threshold conditions.
- Waves and erosion
- Current, including tide, coriolis force, thermal and halocline circulations
- Ice, including ice formation period, ice foot formations, ice packs

In that way it will be possible to ensure that the marine ecology will be affected as little as possible when it is exposed to a given discharge.

In addition, it can be recommended that the planning should be adapted so as to exploit the potential of the location in question. It is believed that digging, pumping and any covering required will constitute an environmental problem and these activities are also very cost intensive.

Therefore it can be recommended that plans should be made on nature's own terms at this early stage so that the construction of port facilities, discharges of waste water, etc. are tailor-made so as to avoid the use of heavy technology that can result in extensive disturbance of the sea bed. By planning the measures in a constructive manner already now the environmental impact can be reduced.

#### *3.1.2.3 Health consequences of the construction of port facilities / installation of a wastewater transfer system*

It must be expected that the construction of port facilities will result in pollution of the surrounding fjord areas by xenobiotic substances whereby the consumption of fish and clams may involve a health risk. That means that restrictions must be expected in the areas with regard to whaling, sealing and fishery.

For example it can be expected that the contents of, for instance, fluoride, sulphate, dry matter, TBT, PAHs, aluminium concentrate, cyanide, etc. in fish liver and clams will be increased. The xenobiotic substances will accumulate in the fish liver and it must be expected that the Danish Nutrition Council will advise children, pregnant women and women of childbearing age not to eat fish liver from these areas.

#### *3.1.2.4 Construction of quays*

It appears from a "Report on energy intensive industry in Greenland" (”Redegørelse om energiintensiv industri i Grønland") that the quay facilities in relation to the aluminium smelter at the three towns of Nuuk, Maniitsoq and Sisimiut are situated close to the coast and at the mouths of the fjords. In addition, it will be necessary to construct quay facilities at the bottom of the fjords. The reason for this is that in connection with the construction of dams, tunnels, etc. it will be necessary to construct quay facilities so that building materials, construction machinery, service facilities, etc. can be transported to the area.

### *3.1.3 Review of the marine environments*

Very simply it can be established that the marine environment will differ from location to location. However, a distinction can be made between an outer, central and inner fjord environment.

#### *3.1.3.1 The inner fjord environment*

The inner fjord environment at the bottom of Godthåbsfjorden (Ilulialik), Søndre Isortoq, Evighedsfjorden and Søndre Strømfjord (Sarfartoq) is characterised by being very shallow and having a high settling rate.

It can be expected that there will be large areas with bedrock overlaid by a sandy bed. The thickness of the sand strata is unknown and so is the settling rate. The sand surfaces will be influenced by the tide and therefore they will presumably be dry at low water. Much relief in the sand bed areas cannot be expected. At places where the sand is transported over a slope (where a delta is developed) to deeper waters, a flat of accumulated sand will often form. Locally, flooded shore formations such as tongues of land and tombolos can form long elevations on the sand bed and where transported sand converges, very large sand banks can form.

That means that if a port is to be constructed in these areas, a deepening of the areas will be needed for which reason dumping of the bottom material elsewhere will be required on an ongoing basis.

Because matter that is washed out from the river settles it can be expected that organic matter will accumulate via the waste water. In addition, xenobiotic substances may also accumulate in the sediments. During winter ice will form in the areas.

#### 3.1.3.2 The central fjord environment

This fjord environment will be located just outside the delta areas. The area will not be influenced by the tide, which means that the water depth is shallow at low water. At places without bedrock, fine grained matter will settle.

That means that if a port is constructed in these areas it may at times become necessary to deepen such areas, which means that the bottom material must be dumped elsewhere.

Since the bottom material is more fine-grained here than in the inner fjord environment it must be expected that there is a risk of accumulation of xenobiotic substances and organic matter.

During the winter period ice will form in the area, which may obstruct marine traffic.

#### 3.1.3.3 The outer fjord environment

Generally the outer fjord environment will be characterised by a greater water depth and there will be no ice formation during the winter period. It is anticipated that the sea floor will mainly consist of bedrock and there may be reefs.

Likewise it may be expected that the water exchange will be large and that there is a thermocline relatively close to the coast owing to density differences in the bodies of water. Any waste water discharges must be planned accordingly.

#### 3.1.3.4 Location of quays and preparedness

Prior to the location of a quay a detailed hydrographic survey will be required with regard to water depths in the area. The water depths must correspond with the sizes of the ships and the facilities must also be adapted to the expected number of ships calling at the quay.

It will also be necessary to make specific arrangements with the Greenland Command and Fire Brigade with regard to preparedness in relation to the sea environment since more marine traffic must be expected in the areas, by way of both larger ships and increased carriage of hazardous substances.

#### 3.1.3.5 Sources of contamination and impact on the marine ecology

Environmental impacts may originate from point sources such as:

- Waste water discharge containing fluoride, $SO_4$, PAHs, etc.
- Discharge of hot water.
- Surface runoff of water from the catchment area that may have been contaminated by xenobiotic substances from the quay areas.
- Temporary stocks of material
- Suspended matter in connection with the construction works, etc.
- Release of, for instance, phosphorus from the fjord bed in connection with deepening, which may be an important source of benthic and pelagic primary production during periods with a low external nutrient load.
- TBT contamination originating from the bottom paint of ships.
- Spillage of hydrocarbons, for instance in connection with filling of fuel tanks

It is believed that the secondary effects can lead to changes in the diversity of species and therefore reference is made to chapter 1.

### 3.1.4 The aquatic environment - summary

These initial considerations show that the onshore and offshore aquatic environment will be affected both in connection with the establishment and during operation of the various facilities.

In particular it is important to keep in mind that the establishment of hydroelectric power stations will have secondary effects in the inner parts of the fjords because of changes in the water chemistry and the content of suspended matter. In addition, it can be expected that the structure of the rivers will change as a result of the changes in the flow whereby changes will occur in the sedimentation.

It is recommended that plans should be made on nature's own terms at this early stage so that the construction of port facilities and discharges of waste water are tailor-made so as to avoid the use of, for instance, heavy technology that can result in extensive disturbance of the sea bed. By making environmentally acceptable plans already now the environmental impacts can be reduced.

In consequence of this it is recommended that the facilities should be tailor-made for the individual locations and that scenarios should be prepared in connection with the EIA process that describe precisely the impacts on the environment and nature for the individual locations.

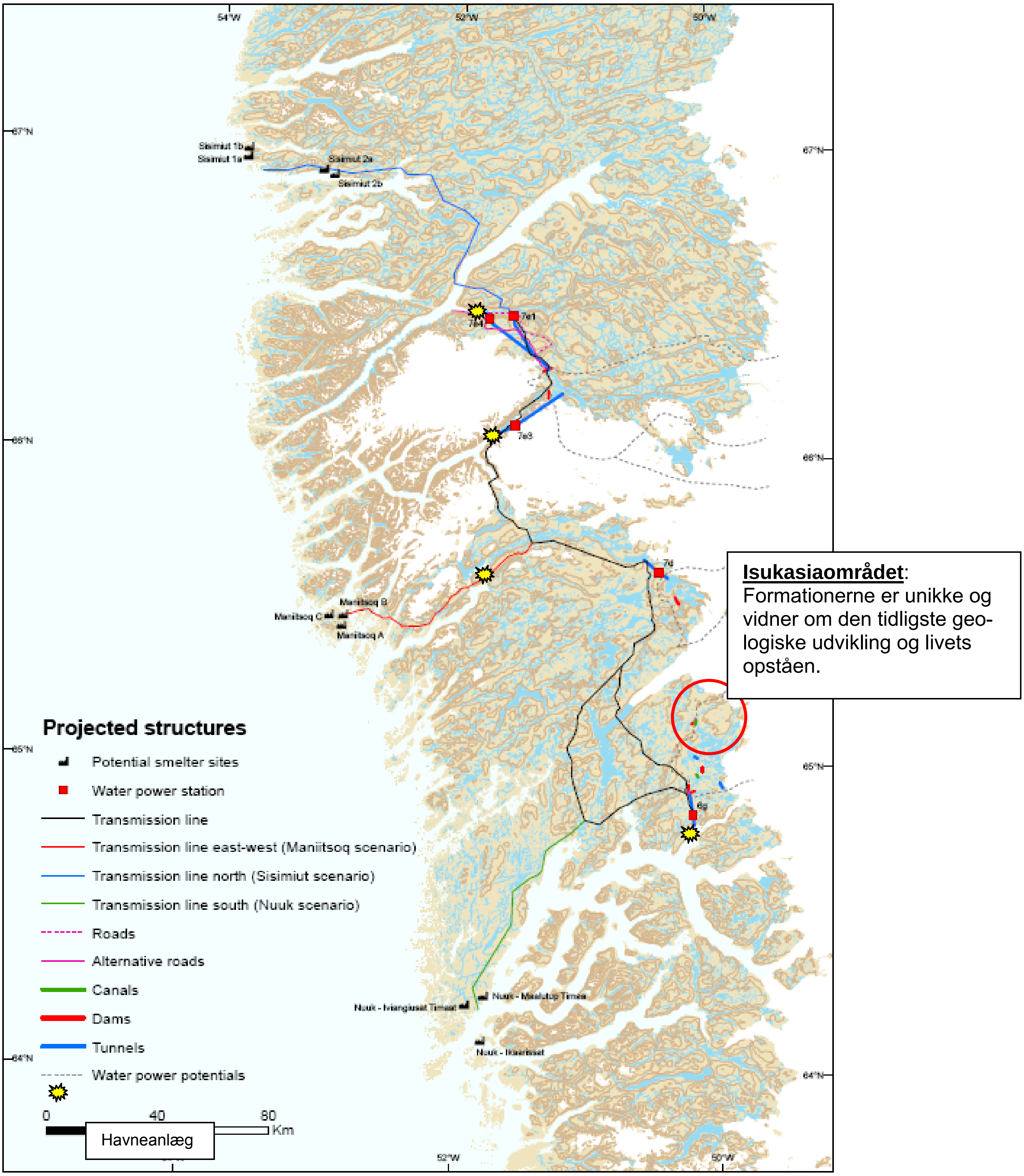



Fig. no. 2.1 Survey of potential sites for port facilities

## 3.2 Water resources

In connection with the establishment, construction and operation of large facilities it will be necessary to secure large quantities of water to be used as drinking and process water.

From a health point of view, the drinking water must at all times observe the applicable requirements. The Greenland authorities are the supervisory body in relation to drinking water.

On the other hand, it must be up to the client to ensure that the raw water that is to be used as process water is of the right quality and that the client performs internal production control. The quantities of water abstracted are subject to supervision, however.

### *3.2.1 Drinking water*

Fresh potable water will be needed for the many workers at the building sites.

It is anticipated that the establishment of the aluminium smelter will take two years and during this period an estimated 1,500 – 2,000 workers will need access to drinking water. It is estimated that the establishment of the hydroelectric power stations will require around 2,500 workers for a period of 4-5 years. It has not been indicated whether these figures are average figures so that the drinking water requirement will at times be greater.

The need for fresh potable water can on the basis of the above be estimated at 320,000 $m^3$ of fresh water annually[3] distributed over several locations for drinking water alone. In connection with the establishment of the aluminium smelter alone an average need for potable water of just over 90,000 $m^3$/year[4] will arise for a period of two years and if a site is selected for the smelter near a town this increased consumption is to be seen in combination with the town's present consumption as well as the water resources available.

### *3.2.2 Process water*

Process water will be needed for example for the production of concrete and for the cooling of aluminium in the aluminium smelter. To this should be added that it is expected that sea water will be used for the flue gas plant.

[3] (250 l x 3500 x 365 days) corresponds to a water requirement of 319,375 $m^3$ /year.
[4] (250 l x 1000 x 365 days) corresponds to a water requirement of 91,250 $m^3$ /year.

At present no data are available that can be used as a basis for assessing the quantity of fresh water required for the establishment of the aluminium smelter and the construction of the port, dams, etc.

On the basis of this it is necessary, with the present project, to divide the water resources into the following:

1. Process water expected to be used for the aluminium smelter.
2. Process water for concreting of dams.
3. Drinking water for the aluminium smelter during the construction and operating phase.
4. Drinking water for the production of hydroelectric energy and for the construction of the port during the construction and operating phase.
5. Drinking water for a town extension.

*Re 1: Process water for the aluminium smelter*

*Fresh water*

Process water means water that is to be used in the manufacturing process at the aluminium smelter. In connection with the production of aluminium fresh water must be added as process water and according to the information available 2.95 $m^3$ of fresh water is used for each 1,000 kg of aluminium produced by the smelter.

With a planned capacity of 340,000 tons of aluminium annually the overall process water requirement needed to operate the aluminium smelter has been assessed at just over 1 million $m^3$ /year. An application for permission to abstract this quantity of water is to be made.

It does not appear from the material available which quality requirements the industry will make on the raw water. It can be expected that the raw water will be acidic as a result of the acidic background rocks at Nuuk and Sisimiut. This means that any water treatment required to adjust, for instance, the pH value must be ensured by means of the internal production control at the aluminium smelter.

*Salt water*

No information is available about the flue gas cleaning method Alcoa will be using. If Alcoa chooses for instance a wet scrubber for the flue gas cleaning it is assumed that abstraction of large quantities of sea water will be required.

Furthermore, no information is available as to whether Alcoa plans to use salt water for the cooling of molten aluminium during casting.

*Re 2:* *<u>Process water for concreting of dams and aluminium smelter</u>*
Process water means water that is to be used for the production of concrete. Since no information is available on the planned location of the dams or on the size of the dams it is not possible at present to prepare an estimate of the anticipated water quantities required for the production of concrete. Usually 150 – 175 litres of water will be needed for the production of 1m$^3$ of concrete.

An application for an abstraction permit is to be made.

It is not known whether simple water treatment of the raw water is required as a result of the water being acidic owing to acidic background rocks.

During the flood period much surface water is washed into the lakes. This will affect the raw water that will as a result of this have a different chemical composition during the spring. It will also contain clay and silt that may be rich in silicate. At present the assessment of the Greenland Ministry of Nature and the Environment is that an evaluation should be made of the suitability of the raw water in relation to concreting. The Greenland Ministry of Nature and the Environment is not in possession of information about the silicates in the water, which means that there is a risk that the water has corrosive properties. Consequently it may be necessary to add xenobiotic substances that will have a negative impact on the aquatic environment.

This means that the client and the client's contractor must evaluate this and arrange for any water treatment required via their own production control.

Finally, it should be pointed out that there are lakes in the area at Kangerlussuaq that have a high salinity and therefore it will not be possible to use the water from these lakes for production purposes.

*Re 3:* *<u>Drinking water for the aluminium smelter during the construction and operating phases</u>*
In connection with the establishment and operation of an aluminium smelter, the need for fresh potable water will increase during the period when it is anticipated that the aluminium smelter will be constructed.

In connection with the construction of the aluminium smelter, it must be ensured that drinking water can be supplied for temporary site sheds. It is anticipated that between 1,500 and 2,000 persons will be involved in the construction of the aluminium smelter but at present no information is available about the number of persons who will be required in the event of any peak periods during the construction and establishment phase.

In addition it should be noted that Nukissiorfiit will not necessarily be able to supply drinking water to the plant. This is because Nukissiorfiit´s water supply system is based on the existing capacity in the local area. This means that clarification will be needed with Nukissiorfiit to possibly increase the water production.

In connection with the description of the environmental consequences of Alcoa’s aluminium smelter in Reydarfjördur, Iceland, the fresh water requirement is stated at 250 litres per person/day (Alcoa 2006:14).

Approval from the Greenland Ministry of Nature and the Environment (DMN) is required for the establishment of new water supply systems or for an extension of the existing systems. To obtain permission to abstract water an abstraction permit must also be applied for from the Greenland Ministry of Nature and the Environment. In addition protection zones must to be established around drinking water lakes in which the activities are regulated by section 30 of the Environmental Regulation.

*Re 4: Drinking water for the production of hydroelectric energy and for the construction of a port during the construction and operating phases.*
Both for the establishment and for operation of hydroelectric power stations there will be an increased need for fresh potable water.

In connection with the construction of facilities for the production of hydroelectric energy it must be ensured that drinking water can be supplied to temporary site sheds. At present no information is available about the number of persons required in the event of any peak periods during the establishment and construction phase.

In these areas it will be necessary to establish new facilities that must be adapted to the quality of the raw water. At the same time sufficient capacity must be ensured for the period when the largest number of workers will be using the site sheds. Subsequently the production must be adapted to the actual requirements.

In connection with the description of the environmental consequences of Alcoa’s aluminium smelter in Reydarfjördur, Iceland, the fresh water requirement is stated at 250 litres per person/day. (Alcoa 2006:14).

Approval from the Greenland Ministry of Nature and the Environment is required for the establishment of water supply systems. To obtain permission to abstract water an abstraction permit must also be applied for from the Greenland Ministry of Nature and the Environment. In addition protection zones must to be established around drinking water lakes in which the activities are regulated by section 30 of the Environmental Regulation.

*Re 5: Drinking water for a town extension.*
During the operating phase there will be an increase in population in the area where the smelter is constructed. Therefore, it may become necessary for Nukissiorfiit to adapt and increase the water supply to make allowance for the actual situation.

Approval from the Greenland Ministry of Nature and the Environment (DMN) is required for the establishment of new water supply systems or for an extension of the existing systems. To obtain permission to abstract water an abstraction permit must also be applied for from the Greenland Ministry of Nature and the Environment. In addition protection zones must to be established around drinking water lakes in which the activities are regulated by section 30 of the Environmental Regulation.

### 3.2.3 Water quality

In general it can be expected that the raw water in the area will be slightly acidic as a result of the background rocks that consist mainly of granite, etc. It can also be expected that during the flood in the spring the raw water will be of inferior quality with high colour and permangenate figures and a high concentration of iron, manganese and possibly also aluminium. The reason for this is that clay and topsoil are washed into the lakes.

In general it can be expected that the inland lakes at the glacial cap can be characterised as oligotrophic (low in nutrients). To prevent anaerobic (low oxygen) conditions in connection with a rise in the water level in the lakes that are to be used for the production of hydroelectric energy, additional assessments are required since the rise in the water level may affect the composition of the fauna.

At the same time it will be necessary to assess the risk involved in removal of peat and silt in connection with the construction works. This is because peat contains the mineral Vivianite ($Fe_2(PO_4)_2$-8 $H_2O$). When the mineral is oxidised, the nutrient phosphorus is released. This can cause eutrophication, which may constitute a risk for the environment and which may affect the composition of the fauna in the proximity of the construction works and downstream.

Another undesirable property of peat is that it contains heavy metals in the form of, for instance, aluminium and mercury which may also be washed out. In addition there may be a risk that heavy metals from removed material in the form of clay and silt are washed out. Therefore a background investigation is needed so that a risk assessment can be prepared. In addition to containing heavy metals peat often contains PAHs although only in small concentrations.

In connection with the rise and fall of the water level there will be a risk that ochre will be washed into the bodies of water because of temporary drainage.

When the water level rises, the thermal capacity of the water will result in lowering of the permafrost level, which may result in heavy metals being washed into the lakes.

### *3.2.4 Hydrology and capacity*

The lakes and rivers that are considered as providers of drinking water must be examined more closely with regard to runoff and capacity so that it can be ensured that there will be no periods during which they are drained.

### *3.2.5 Other matters*

It will be necessary to assess whether the lowering of the permafrost table can cause geotechnical instability in the deposits so that landslides occur which may result in a tsunami-like wave.

It is found that it will be necessary to prepare simple visualisation in GIS showing the extent of areas that will be flooded.

It cannot be expected that permission will be given during the construction period to abstract water from the lakes that are to be incorporated in the production of hydroelectric energy. This is because there may be a risk that the raw water will be polluted as a result of construction works. Another perspective is the establishment of a protection zone around the water resource catchment area to protect the raw water. This will mean that any activity that constitutes an environmental risk will not be permitted within this zone. This includes the execution of construction works.

### 3.2.6 Legislation

*Approval of the water treatment plant*

All kinds of water supply plants larger than 10 $m^3$/day[5] must be approved by the Greenland Ministry of Nature and the Environment and drinking water from the plant must always observe the applicable quality requirements. It is considered that extra large water supply plants will be required in connection with the construction of quay facilities, dams, tunnels, etc.

*Abstraction permit and capacity*

Incorporation of new water resources requires an abstraction permit from the Greenland Ministry of Nature and the Environment. As no exact information is available at present about the number of persons expected to be needed during the construction phase at the locations in question, sufficient water treatment capacity should be ensured. On that basis allowance should be made for 250 litres/day/person. At the same time it must be ensured that the large quantities of process water required do not result in lack of drinking water.

*Protection zone*

For all raw water lakes from which it is expected that water will be supplied, a protection zone must be established around the water resource catchment area. Inside this protection zone no activities are permitted that can cause contamination of the drinking water.

The protection zone includes the catchment area of the resource (the lake or river) and a surrounding safety zone of at least 30 metres. The width of the safety zone should be assessed for the entire area in relation to local conditions, however.

Within these protection zones the construction of buildings or institutions or the keeping of dogs or substances that may contaminate the water is not permitted under section 30 of the Environmental Regulation. Likewise activities of any kind, including motorised transport and recreational activities within the protection zones must be avoided in consideration of the protection of water quality. Therefore it will be an advantage if the drinking water resources are not located in the immediate vicinity of the plants or residential areas to which they are to supply water. In connection with the choice of raw water lakes the location of the available water resources in relation to areas where activities are taking place should therefore be considered.

[5] Corresponding to the consumption for around 40 persons

### *3.2.7 Water resources - summary*

Drinking water is a limited resource in many areas of the country because most towns are situated in coastal areas on islands or peninsulas. Nevertheless water is an important parameter for the realisation of the project. The effect of implementation of the project may be negative for the area where the aluminium smelter is established and heavy inroads will be made into the existing water resource.

It is possible to remove salt from sea water, but it is a process that is cost intensive and difficult, which will be detrimental to the profitability of the project. Therefore there is a constant and great need for fresh water from lakes or rivers. The only measure that can be taken to remedy this situation is to incorporate lakes at more distant locations as water resources. This will involve large costs of construction and operation, for instance costs of frost proofing of the raw water pipes.

In connection with the environmental impact studies the raw water resources must be assessed in detail specifically with regard to vulnerability, quality and final capacity. When such studies have been completed preparation of abstraction permits and approvals of protection zones and water supply works will be required; see part 6 of the Environmental Regulation.

## 3.3 Waste

In the Environmental Regulation, which is the main act concerning waste regulation in Greenland, the competence with regard to waste is vested in the local councils and the Greenland local authorities are the primary authorities when it comes to waste.

The local council lays down the specific rules concerning the removal of waste and oil and chemical waste within urban and district zones in waste regulations. The three towns - Sisimiut, Maniitsoq and Nuuk – have all established a receiving station for oil and chemical waste. All enterprises set up in these towns must make use of the receiving station. However, the Home Rule Government has authority to grant exemptions to enterprises from the obligation to deliver waste to the receiving station.

Waste processing plants are subject to Executive Order no. 11 of 20 August 2004 issued by the Greenland Home Rule concerning environmental approval of heavily polluting enterprises, etc. Such plants must receive an environmental approval from the Greenland Ministry of Nature and the Environment before they can be established and start operations.

If the aluminium smelter and the hydroelectric power stations are constructed outside urban and district zones it should be mentioned that at present no authority exists to prepare waste regulations for the open country. The coming executive order on waste will have the effect that the local authorities will be given authority to prepare waste regulations for the open country.

In addition to the categories of waste mentioned in section 4.2.3 from the smelting process as such, various categories of waste can be expected in relation to the establishment and operation of the aluminium smelter and the hydroelectric power stations, such as:

- Various kinds of construction waste
- Oil and chemical waste, hazardous waste
- Electronic scrap
- Household refuse and waste in the nature of household refuse
- Various office waste
- Scrap iron, etc.

The categories of waste mentioned here and in section 4.2.3 should not be regarded as an exhaustive list.

Generally the material collected illustrates only waste relating to the operation of the aluminium smelter whereas there are only few data on the quantities and composition of the waste that arises in connection with the establishment of both the hydroelectric power stations and the aluminium smelter.

### *3.3.1 Present capacity in Sisimiut, Maniitsoq and Nuuk*

Increased activity in connection with the construction and establishment phase for the aluminium smelter and hydroelectric power stations will for a number of years generate considerable quantities of waste of various kinds. The operation of the aluminium smelter will also generate considerable quantities of waste that must be handled. Therefore it is necessary already during the planning phase to include a strategy for sound waste management.

In addition to the quantity of waste that will be generated in connection with the establishment and operation of the hydroelectric power stations and the aluminium smelter as such, the increased activities will also lead to a general population increase in the towns, which will in turn produce a certain quantity of waste. However, it is as yet uncertain what the overall implication of the establishment of an aluminium smelter in Nuuk, Maniitsoq or Sisimiut will be for an increase in population in the towns in question, including in particular in the town near which the aluminium smelter is located. But, in connection with the creation of a basis for many new places of work, waste will be produced in quantities and fractions corresponding to the waste produced in a small or medium-sized town. This waste is partly the quantity of waste that is a consequence of the construction activities in connection with the establishment of a small or medium-sized town and the subsequent quantity of waste owing to the population increase. This requirement for increased waste management is also to be taken into consideration in connection with an extension of the municipal waste system. The local authorities must at an early stage start mapping and planning the need for development of the existing incineration plant and receiving stations for the management of this waste.

Depending on whether the aluminium smelter is located in Nuuk, Maniitsoq or Sisimiut there will be an increased need for more capacity to manage waste. With regard to the management of waste that can be incinerated it should be mentioned that the incineration plant in Nuuk is experiencing capacity problems at the moment. Therefore, Nuuk has already started considering the possibilities of establishing a new incineration plant. Maniitsoq has spare capacity but will hardly be able to handle the waste after a population increase. In Sisimiut the quantity of waste produced at present and the capacity of the plant balance but after a population increase a new solution is required. Therefore it may become necessary to establish a new incineration plant. Irrespective of the location selected there will be problems of disposing of waste, in particular household refuse and waste suitable for incineration, by means of the existing incineration plants already at the time when the aluminium smelter and the hydroelectric power stations are built. It is considered that in the event of a population increase in the towns, problems will not arise to the same extent with the capacity at the receiving stations, but the increased quantity of waste will require storage facilities and personnel to manage hazardous waste, electronic scrap and waste involving special problems of a similar nature before the waste is passed on to Mokana[6] in Denmark.

Generally it must be expected that the activities will result in more litter in the open country as the establishment of the aluminium smelter and the hydroelectric power stations and the related construction of new ports and roads will provide access to areas that have until now not been particularly

[6] I/S Mokana is a joint municipal partnership owned by the following local authorities: Brønderslev, Jammerbugt, Mariagerfjord, Randers, Rebild, Skive, Vesthimmerland, Aalborg. In addition an association and cooperation agreement has been concluded with the 18 local authorities in Greenland.

accessible. This can for instance result in a number of activities in the areas such as driving, hunting, walking and the building of cabins. Furthermore the construction itself will give rise to a certain interest in visiting the areas. Experience shows that such increased activity in a new area will result in bottles, packaging, remains from hunting activities and other items being left in nature. The environmental consequences of this are limited but such litter disfigures the landscape.

It is very likely that the increased activity will lead to a need for an extension of the municipal waste systems. Therefore, this need must be assessed in more detail.

### 3.3.2 *Need for additional information*

As far as waste is concerned more information is needed concerning waste quantities, composition, etc. as well as information concerning waste management plans. When such information is available an examination of the environmental consequences will be required. Detailed plans should be prepared for the management of the various types of waste during the construction phase, the establishment phase and the operating phase. Furthermore, the plans must describe the types, quantities and composition of waste that can be expected to be produced during the individual phases. Finally, a time schedule is required which shows where, when and from where the individual types, quantities and composition of waste may be expected to be produced so that the local authorities can recognise when a waste system must be ready to manage the various quantities and types of waste.

It is very likely that the increased activity will lead to a need for extension of the municipal waste systems. Therefore, this need must be assessed in more detail.

At present far too little is known about the quantities of waste from the individual activities, the composition of the waste and the choice of waste disposal methods, etc. Therefore it is not possible to indicate whether one location should be preferred to another.

On the basis of what is known it is not possible to assess the environmental consequences of the quantity of waste produced.

## 3.4 Waste water

This section describes the types, composition and quantities of waste water that must be anticipated in connection with the realisation of the aluminium project.

Furthermore, a description is provided of the environmental consequences of the discharge of waste water, including the importance to the recipient and the possibilities of remedial measures.

The section is concluded by a brief description of the current legislation on waste water and an account of the need for additional information.

### 3.4.1 Types, composition and quantities of waste water

#### 3.4.1.1 Sanitary waste water

The discharge of sanitary waste water will take place from all buildings constructed in connection with the construction and operation of a smelter and hydroelectric power stations.
In particular in connection with the establishment of the hydroelectric power stations there will be a need to set up more work camps at various locations, for instance in the areas where a tunnel is to be constructed, where a dam is to be built, where port facilities and roads are to be constructed, etc.

*Composition of the waste water*

Sanitary waste water will often be divided into "black waste water", which covers only waste water from toilets (faeces, urine, toilet rinsing water and paper), and "grey waste water", which covers waste water from bathing facilities, wash basins, cleaning and kitchens. In addition the term night soil is used which covers waste water from chemical toilets (faeces, urine and paper).

The pollutants in sanitary waste water are primarily biodegradable organic substances, nutrients (nitrogen, phosphorus and ammonia), micro-organisms (bacteria, viruses), old medicine, a number of metals (mercury, lead, cadmium, chromium, copper, nickel and zinc) as well as precipitable matter.

*Quantity of waste water*

In a calculation of the quantities of waste water from ordinary households the waste water will in theory be equated with the water consumed. Usually the consumption of water in Denmark is calculated at 150-200 litres per person per day (l/pd) and thus the quantity of waste water is of a corresponding magnitude. These figures are verified in the report ”Explanatory and pilot project concerning the handling of environmental problems as a result of waste water in Greenland towns – Phase 1: Mapping of the scope of the problem" ("Udrednings- og pilotprojekt vedr. håndtering af miljøproblemer som følge af spildevand i de grønlandske byer – Fase 1: Kortlægning af problemomfang") (2005), which investigates the water consumption in Greenland towns and districts. The following average figures appear from the report:

| | |
|---|---|
| Average water consumption in districts | 45 l/pd |
| Average water consumption in towns | 156 l/pd |
| Average water consumption in Nuuk | 190 l/pd |

The districts stand out significantly since the water consumption per person is considerably lower than in the towns.
There are also a number of indicative values for, for instance, waste water from institutions. For instance the theoretical water consumption at offices may be calculated at 40-60 litres per employee per day, at hotels at 200-300 litres per guest per day and at restaurants at 15-40 litres per guest per day. This may be relevant in relation to a potential future aluminium project where for instance the work camps may be in the nature of hotel-keeping and where the provision of meals will most likely be in canteens or the like.

For comparison the calculation of the water consumption was 250 litres per person per day in connection with the construction of Alcoa's aluminium smelter in Iceland (Source: EIA report for Reydarfjördur, Iceland, page 14).

#### ***3.4.1.2 Rain and melt water***

During periods of rain and thaw, surface water will naturally be discharged from the ground and from the surfaces of buildings such as roofs, roads, outdoor parking areas and storage areas, etc. This surface water may be contaminated by, for instance, oil, heavy metals and xenobiotic substances originating from atmospheric fallout and local contamination from activities (including spillage and traffic) on impermeable surfaces.

*Anticipated composition of rain and melt water*

Surface water typically has the following contamination parameters: suspended matter (various types of particulate matter mixed into water), nutrients (nitrogen phosphorus), organic matter, heavy metals (cadmium, chromium, copper, lead, zinc, mercury, nickel, silver), PAH[7], MTBE[8] and other organic xenobiotic substances, oil, chlorides and de-icers.

[7] Polycyclic Aromatic Hydrocarbons
[8] Methyl Tertiary Butyl Ether

During the operating period of the aluminium smelter there will also be a risk that the surface water may contain fluorides, cyanides, etc. as a result of air emissions and spillages on the ground. The fluorides come from the electrolysis process in particular.

*Quantities of rain and melt water*
It is possible to make a theoretical calculation of the probable quantities of surface water that will be led out into the nearby recipients. The theoretical calculation is based for instance on the precipitation in the area in question, the quality of the surfaces and the area of the surfaces.

#### *3.4.1.3 Waste water from construction works*
Waste water from construction works is typically water that is used in the work processes. The use of water for cooling in connection with drilling operations, the spraying with water to avoid dust generation from the various work processes and during dry periods, the use of water to clean construction equipment, machinery and vehicles and water spillage in connection with concrete production.

*Composition and quantity of waste water from construction works*
It must be expected that the waste water from construction works will contain some of the same substances as the surface water, but it has not been possible to find exact information on this. The same applies with regard to quantities.

#### *3.4.1.4 Other waste water*
During the operating phase small quantities of waste water may accumulate in connection with the washing of vehicles. It must be expected that the waste water will contain some of the same substances as does the surface water, as well as fatty substances.

#### *3.4.1.5 Process waste water from aluminium production*
*Waste water from flue gas cleaning*
In order to reduce the emissions from the smelting process a flue gas cleaning system has typically been installed. The background material on which this section is based describes two different methods of flue gas cleaning, a dry process (dry scrubber) and a wet process (wet scrubber). Fresh water or salt water may be used for the dry process. At Alcoa's aluminium smelter in Iceland a flue gas cleaning plant has been used that employs salt water.

When a wet process is employed waste water will be produced since during the cleaning the water absorbs a number of the pollutants in the flue gas.

*Composition and quantities*

In connection with the construction of the aluminium smelter in Iceland a quantity of waste water of 260,400 $m^3$/day from flue gas cleaning was anticipated with an annual aluminium production of 346,000 tons/year.

Correspondingly, an annual production of 350,000 tons/year is anticipated from a potential future smelter in Greenland. That means that in Greenland by and large the same quantity of waste water from flue gas cleaning can be expected as in Iceland.

Waste water from the flue gas cleaning typically has a temperature of 10–15 $^oC$ and contains sulphur dioxide ($SO_2$), fluorides (F), PAHs (PAH-16[9]) as well as suspended matter. The table below shows the annual discharge from the aluminium smelter in Iceland.

| | Quantity | | Concentration | |
|---|---|---|---|---|
| Quantity of waste water | 10,850 | $m^3$/hour | | |
| Sulphur dioxide ($SO_2$) | 840 | kg/hour | 77 | mg/l |
| Fluorides (F) | 2.25 | kg/hour | 1.51 | mg/l |
| PAH-16 | 1.8 | g/hour | 0.17 | µg/l |
| Benzo(a)pyrene (BaP) | 0.07 | g/hour | 0.006 | µg/l |
| Suspended matter | 3.71 | kg/hour | 0.64 | mg/l |

In addition heavy metals may be discharged; see section 4.2.5 concerning air emissions.

In addition there is a risk that the pH value of the water will be lowered when $SO_2$ reacts with water.

*Process waste water from the casting process (cooling water)*

In connection with the casting process fresh water is used for cooling the hot aluminium. Typically, this cooling water will be recirculated through a cooling tower and a water treatment plant to be discharged later to a recipient.

[9] PAH-16 refers to the sum of concentrations of benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, indeno(1,2,3-cd)pyrene, acenaphthene, acenaphthylene, anthracene, benzo(ghi)perylene, fluoranthene, fluorene, naphthalene, phenanthrene and pyrene.

*Composition and quantities*
Only very little information has been found concerning the pollutants that this cooling water contains in addition to suspended matter and residual oil products (total hydrocarbons). It does not appear which residual products, but PAHs could be a possibility. Correspondingly there is only little information concerning the quantities in question.

### 3.4.2 Components and impacts

Some of the substances discharged with the waste water can have a negative impact on the animal and plant life in and around the point of discharge. These substances can also have a negative impact on human health. In this section it has not been considered whether the various pollutants will constitute an actual problem to humans, animals and plants in connection with the construction, establishment and operation of an aluminium smelter, hydroelectric power plants and other related facilities.

#### 3.4.2.1 Surface water and sanitary waste water

*Suspended matter*
Particulate matter mixed into surface water may be deposited in streams and rivers and change the course of the river. This may have consequences for any fish stocks in the recipients in question.

*Nutrients*
Nitrogen, phosphorus and organic matter are nutrients that stimulate plant production in recipients with low water exchange (streams, lakes and fjords) and which may impair the oxygen conditions in the recipients to the detriment of, in particular, animal life (eutrophication).

Eutrophication as a result of the discharge of nutrients has until now not been regarded as a problem in Greenland as the discharge of waste water is most often to recipients with high water exchange. However, problems may arise locally with eutrophication.

*Bacteriological contamination*
Bacteria in the waste water are of interest only in the instances where foods are handled in the immediate vicinity of the waste water discharge (for instance flensing of seals and whales).

*Heavy metals*
Heavy metals are absorbed in organisms and are adsorbed to particle surfaces of especially organic matter. Generally they have a hampering effect on the

enzyme systems of the organisms and they can be acutely toxic and also damage organisms living in water, for instance fish, in the longer term. In addition, especially mercury, lead and cadmium can accumulate and become concentrated through the food chain. Since heavy metals easily bond with particulate matter they will settle and accumulate in the sediment and thereby in particular be a threat to animals living at the bottom.

*POPs*

What characterises POPs is that they are slowly degradable and have a residence time in the environment of decades. POPs accumulate in the fatty tissue of humans and animals.

*PAH*

PAH is one of the three main groups under the POPs. PAH is a group of substances that are not easily degradable and which are relatively toxic. Certain PAH compounds, including benz(a)pyrene are carcinogenic. PAH can arise for instance in connection with incomplete combustion of wood, oil, waste and from traffic.

*MTBE*

Methyl tertiary butyl ether (MTBE) is an additive that is in particular added to non-leaded petrol to increase the octane number. It gives a strong disagreeable taste to drinking water and is under suspicion of being carcinogenic. It is water soluble and thereby very mobile in the environment and it is decomposed only slowly.

#### *3.4.2.2 Process waste water*

*Sulphur dioxide ($SO_2$)*

Sulphur dioxide reacts with sea water forming sulphuric acid, which will lower the pH value of the water. The effect on marine plant and animal life is unknown. In connection with the construction of the smelter in Iceland a risk assessment[10] was made according to which marine plant and animal life will be able to tolerate a pH reduction of 0.5 – 1.0. Therefore the impact has been assessed as being insignificant but it is mentioned that there is a small risk that marine molluscs will be affected in the immediate proximity of the point of discharge.

*Fluorides (F)*

[10] Ecological risk assessment for use of wet scrubbers at Alcoa aluminium plant in Reydarfjördur, Fjardabyggd, Iceland

Fluoride occurs naturally in sea water and can also be found naturally in some drinking water resources. In high concentrations fluoride is harmful to humans and animals and can, for instance, cause damage to teeth and bone. WHO has fixed a limit value of 1.5 mg fluorine/l.

A study conducted in Canada[11] has shown that the discharge of fluorine from an aluminium factory affected the ascent of Pacific salmon to Columbia River. The fluorine discharged partly acted as a chemical barrier, partly exposed the salmon to damage so that the salmon which did after all pass the point of discharge to a great extent suffered excessive mortality. The study found a threshold value of around 0.2 mg fluorine/l. Below that concentration there was no impact.

*PAH*

As mentioned earlier process waste water from the operation of the aluminium smelter contains PAHs (PAH-16). The effects of PAHs were described in the previous section.

*Suspended matter*

It has not been possible to find detailed information about the chemical composition of suspended substances in the process waste water from the aluminium smelter. Therefore it is difficult to say anything about the negative impacts, for which reason supplementary information must be provided

### 3.4.3 Recipients

In connection with the discharge of waste water there are different types of recipients. These may be streams, lakes, fjords, coastal water bodies and possibly soil.

According to the environmental legislation in force in Greenland it is generally not permitted to discharge liquids and substances that may contaminate sea water or fresh water. Ordinary waste water from households and other waste water may to a small extent be discharged into fjords or the sea, but not into lakes or streams. Non-sanitary waste water (grey waste water) may upon consultation with the public health officer be discharged to the ground or to open ditches falling into a fjord or the sea.

11 Damkaer D.M. & Dey D.B 1989. Evidence for fluoride effects on salmon passage at John Day Dam, Columbia River, 1982-1986. N.-AM.-J.-FISH.-MANAGE. 1989. vol. 9, no. 2, pp. 154-162.

In Greenland the general practice is to ensure that the discharge of waste water is to a recipient with high water exchange so that it is guaranteed that the waste water is quickly dissolved and led away from the source. However, problems may be experienced locally with discharges of waste water to bays and inlets with low water exchange. The same may apply to threshold fjords.

The discharge of grey waste water to the ground is not an ideal solution since the discharge can involve a risk of transfer of diseases and bacteria. Furthermore discharge to the ground may have a negative impact on neighbouring properties downstream of the point of discharge and there may be problems with ice formations during the winter period. Discharge to the ground is therefore not a recommendable solution unless the problems that such a solution involves have been solved from the very start.

The problems relating to waste water are also discussed in section 3.1 concerning the consequences of the project for the aquatic environment.

### *3.4.4 Remedial measures*

*Possibilities of treatment*

One of the possibilities of mitigating the effects of the discharges of waste water is to arrange various treatment solutions in connection with both the construction and establishment phase and during the operating phase. In this context an efficient solution during the operating phase is particularly interesting.

In the event of establishment of a waste water treatment plant, design of the capacity of the plant so that it can treat waste water from both the smelter and the nearby town should be considered. Apart from an agreement with Alcoa, a condition for this is that a site is selected for the smelter near the town and that the town's waste water can be led to the site in an interconnected sewerage system.

*Use of waste heat*

Heat from the process waste water may potentially be exploited for the heating of buildings, de-icing of roads, etc.

The precondition for being able to exploit this waste heat in Greenland is that a site is selected for the smelter close to a town and that a district heating system is established. At the moment waste heat is generated already for instance from incineration plants but this heat is exploited only to a limited extent. A good solution with regard to exploitation depends on negotiations between Alcoa, the local authorities in question and Nukissiorfiit.

*Other technical solutions*
In addition, grease separators from large kitchens should be installed as well as oil separators from wash sites and similar places where oil spillage may occur.

### 3.4.5 Legislation

At present waste water issues in Greenland are regulated by:

- Greenland Parliament Regulation No. 12 of 22 December 1988 concerning Environmental Protection with later amendments.
- Executive Order No. 27 of 17 September 1993 issued by the Greenland Home Rule concerning chemical toilets and disposal of night soil and sanitary waste water.
- Executive Order No. 35 of 30 August 1994 issued by the Greenland Home Rule concerning limitation of contamination from enterprises, etc. which have not been granted a special environmental approval.
- Executive Order No. 11 of 20 August 2004 issued by the Greenland Home Rule concerning environmental approval of heavily polluting enterprises, etc.

This legislation does not fix limit values for industrial discharges into the aquatic environment, but when an environmental approval is granted, limit values are usually fixed. These limit values are fixed on the basis of limit values in other countries and a risk assessment which makes allowance for the specific conditions related to the concrete project.

For inland locations there will be no immediate possibility of discharging waste water either to the sea or to a fjord. This may constitute a problem in relation to the current environmental legislation as this legislation does not authorise discharge of waste water to fresh water recipients. Therefore it will be necessary to find another practical and environmentally sound way in which to manage the waste water.

*Evaluation of the Greenland legislation on waste water and sewerage*
A major part of the conclusion from an elucidation concerning waste water from 2005[12] was that a general improvement of the waste water conditions in Greenland will be possible only if parts of the regulatory basis are changed and/or clarified. As a follow-up on this the project ”Evaluation of Greenland's waste water and sewerage legislation” was initiated. It is expected that this project will be completed at the end of 2007. The purpose of the project is to suggest how the regulatory framework for the management of waste water issues can be strengthened. Therefore new legislation may be expected in this field within the foreseeable future.

#### *3.4.6 Need for additional information*
Generally, more information is needed about the project as a whole, including the physical location of all facilities that are related to the project and the technical solutions and technologies intended to be employed before any more specific statements can be made concerning the waste water problems in relation to a project of this order.

In addition, the Greenland Ministry of Nature and the Environment needs to be provided with expertise regarding process waste water from the aluminium industry.

Elucidation is needed of the effects in Greenland of discharge of waste water from the aluminium industry, waste water treatment technology that may be applied as well as limit values.

A thorough recipient analysis ought to be performed before a final decision is reached on the location of the waste water outlets. Such an analysis should be made in connection with the EIA report and the base line surveys.

An assessment ought to be made from a nature and health perspective of the negative impact on animal and plant life and human health as a result of the discharge of waste water both during the construction and establishment phase and during the operating phase.

### 3.5 Air emissions
The individual facilities involved in the present project will inevitably have a negative impact on the environment both during the construction phase and

[12] COWI for the Danish Environmental Protection Agency, 2005: Elucidation and pilot project concerning the handling of environmental problems as a result of waste water in Greenland towns – phase 1: mapping of the scope of the problems.

during the operating phase. However, at present only limited information is available in the project documents that can illustrate the scope of air emissions from the individual facilities (hydroelectric power stations, utility trenches, port facilities, etc.) apart from the aluminium smelter. Therefore this report will first and foremost attach importance to assessing air emissions in relation to the operation of the aluminium smelter.

An evaluation of the impact of air emissions on the surroundings involves the following parameters:

- information on the environmentally damaging impacts of the substances
- quantity and concentration of the substances discharged
- the fate of the substances in the surroundings after their discharge into the atmosphere, for instance dispersion, dispersion radius, transformation, absorption by plants and animals, etc.
- the vulnerability of the surroundings

If substances are emitted through one or more off-gas outlets (chimneys, ventilation systems, exhaust pipes, etc.), it will be possible to limit the contamination by fixing limit values (emission limits) that are based on the best available technology.

The negative impact on the surroundings locally and regionally can be assessed by comparing the actual concentrations of substances with internationally adopted limit values and background investigations made. Normally, different limit values will apply to different types of impact.

As an example it may be mentioned that in the EIA report for Reydarfjördur reference is made to two different limit values for fluoride: a limit value of 25 $\mu g/m^3$ for health impacts and a limit value of only 0.30 $\mu g/m^3$ for impacts on vegetation. The first value is a ”short-term value” that must be observed over a period of 24 hours and the other is a ”long-term value” that must be observed as an average for the period from 1 April to 1 October. The same applies to other substances and groups of substances. Reference is also made to the section on legislation and limit values.

For some substances it is not the concentration, but the overall quantity discharged that is of importance. This is the case for, for instance, greenhouse gases that have no local impact but only contribute to the content of greenhouse gases in the atmosphere globally.

### *3.5.1 Location of the aluminium smelter in relation to prevailing wind directions*

In connection with the selection of a location for the aluminium smelter the meteorological conditions in the local area should be included as an important parameter.

Prevailing wind directions and velocities combined with types of weather will determine how the air pollutants discharged will be dispersed in the atmosphere and which areas in the vicinity of the plant will be most exposed to impacts via the air.

The location of vulnerable ecosystems, freshwater environments, water abstraction areas, residential areas, etc. in relation to the prevailing wind directions should therefore form part of the considerations about the selection of a site for the facilities.

A qualitative evaluation of these matters should in the first instance be made on the basis of the knowledge of prevailing wind directions at the individual locations.

The location of the smelter in relation to the existing towns and districts combined with the prevailing wind directions is of course a matter that should form part of the final choice of location.

A discharge of pollutants can be transported 10 km in approximately 15 minutes, which corresponds to the location Nuuk A in the case of a northerly wind at a wind velocity of 10 metres per second in relation to Nuuk town.

These considerations should be concerned with an evaluation of the risk of accidents and the resulting consequences for the surroundings in addition to the question of controlled air emissions from the smelter. Reference is made to the section on risk of accidents; see section 11.

On the basis of the weather observations listed below from the weather stations in Sisimiut, Maniitsoq and Nuuk the following priorities can be established in consideration of the most frequent wind directions:

Sisimiut: Wind directions primarily East and West.
No (neither A nor B) preferred location in relation to the most frequent wind directions.

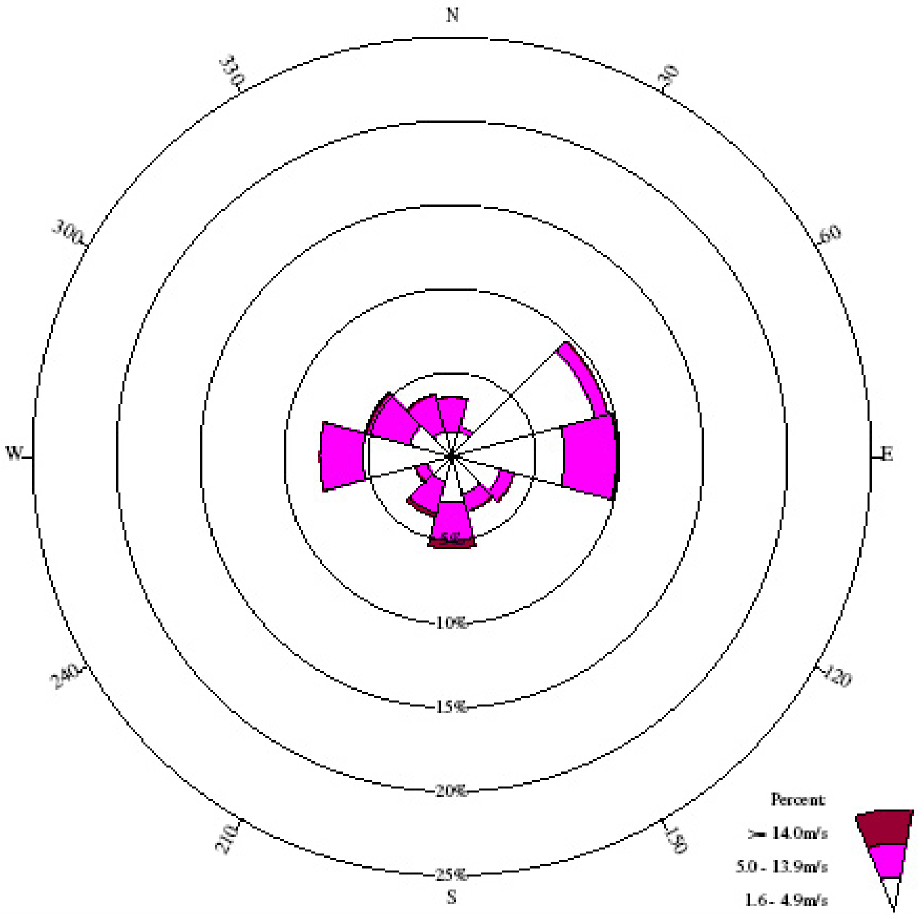
Maniitsoq: Wind directions mainly East and East-North East.
Locations A, B and C are all north of Maniitsoq town and therefore all favourable in relation to the most frequent wind directions.

Nuuk: Wind directions primarily North, North-North East and South.
Location B is most favourable (approximately 5% probability of a wind direction in the direction of Nuuk town).
Locations A and C are both unfavourable in relation to the most frequent wind directions.

Station 04230
SISIMIUT

01-08-1963 - 31-12-1999

Hele perioden




| | N | 30 | 60 | E | 120 | 150 | S | 210 | 240 | W | 300 | 330 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % | 3.5 | 1.8 | 9.7 | 9.9 | 3.8 | 3.4 | 5.5 | 3.7 | 2.2 | 7.9 | 5.3 | 3.9 | 60.7 |
| % 1.6-4.9m/s | 1.4 | 1.5 | 8.8 | 6.7 | 3.0 | 2.3 | 2.8 | 1.5 | 1.5 | 5.3 | 2.6 | 1.5 | 39.1 |
| % 5.0-13.9m/s | 2.1 | 0.3 | 0.8 | 3.1 | 0.8 | 1.0 | 2.3 | 2.0 | 0.7 | 2.6 | 2.7 | 2.3 | 20.6 |
| % >= 14.0m/s | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.1 | 0.4 | 0.2 | 0.0 | 0.0 | 0.1 | 0.1 | 1.0 |
| Mean wind speed | 5.6 | 3.5 | 3.1 | 4.4 | 3.7 | 4.5 | 6.5 | 6.8 | 4.4 | 4.2 | 5.5 | 5.9 | 4.7 |
| Max wind speed | 22.0 | 19.0 | 20.0 | 21.0 | 22.0 | 25.2 | 28.3 | 24.8 | 19.5 | 23.7 | 23.2 | 24.8 | 28.3 |

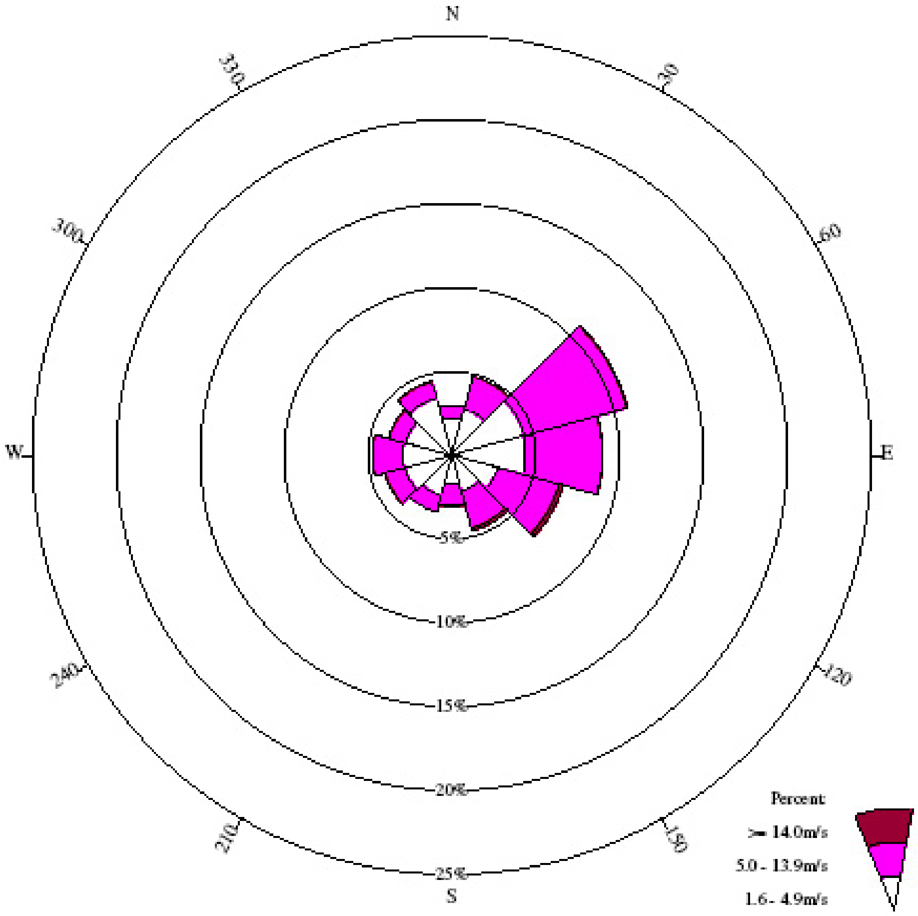
Number of observations = 118526
Source: DMI
Calm defined as wind speed <= 1.5m/s
Number of observations with calm/varying wind direction: 46572 = 39.3%
Observations with calm/varying wind direction are not used in the statistics

DMI

# Station 04240
# MANIITSOQ

01-01-1961 - 31-12-1978

Hele perioden




| | N | 30 | 60 | E | 120 | 150 | S | 210 | 240 | W | 300 | 330 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % | 2.9 | 4.9 | 10.8 | 9.0 | 6.8 | 4.7 | 3.1 | 3.5 | 4.1 | 4.7 | 3.9 | 4.5 | 63.0 |
| % 1.6-4.9m/s | 2.2 | 2.8 | 4.5 | 4.4 | 2.8 | 2.2 | 1.8 | 2.5 | 2.9 | 2.9 | 2.8 | 3.5 | 35.3 |
| % 5.0-13.9m/s | 0.7 | 2.0 | 6.3 | 4.6 | 3.8 | 2.3 | 1.2 | 1.0 | 1.2 | 1.8 | 1.0 | 1.0 | 27.0 |
| % >= 14.0m/s | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.7 |
| Mean wind speed | 3.9 | 4.7 | 5.6 | 5.2 | 6.2 | 6.1 | 5.3 | 4.1 | 4.3 | 4.5 | 4.1 | 3.9 | 5.0 |
| Max wind speed | 18.0 | 20.6 | 20.6 | 23.1 | 30.9 | 30.9 | 30.9 | 20.6 | 18.0 | 18.0 | 17.0 | 18.0 | 30.9 |

Number of observations = 52331

Source: DMI

Calm defined as wind speed <= 1.5m/s

Number of observations with calm/varying wind direction: 19364 = 37.0%

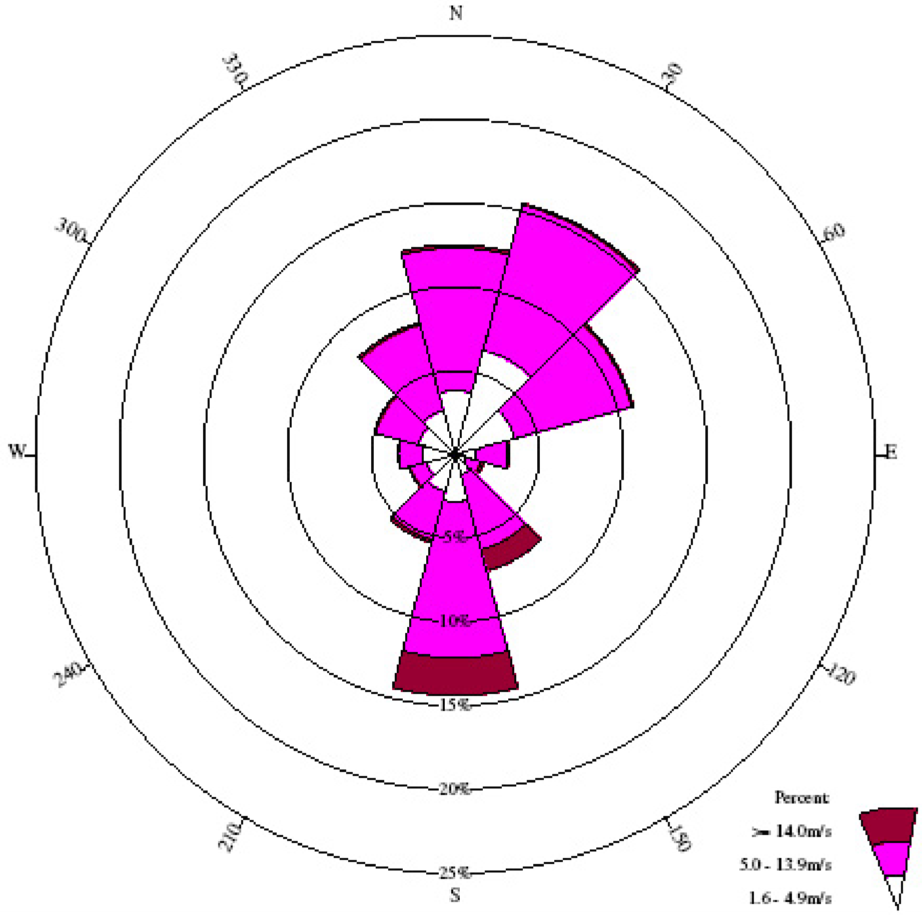
Observations with calm/varying wind direction are not used in the statistics

Station 04250

NUUK

01-09-1963 - 31-12-1999

Hele perioden




| | N | 30 | 60 | E | 120 | 150 | S | 210 | 240 | W | 300 | 330 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % | 12.5 | 15.5 | 11.0 | 3.2 | 1.7 | 7.2 | 14.4 | 5.4 | 2.8 | 3.4 | 5.0 | 8.1 | 90.2 |
| % 1.6-4.9m/s | 3.8 | 6.4 | 3.6 | 1.2 | 0.7 | 1.2 | 2.8 | 2.3 | 1.8 | 2.0 | 2.3 | 2.7 | 30.8 |
| % 5.0-13.9m/s | 8.5 | 9.0 | 7.2 | 1.9 | 0.9 | 4.6 | 9.3 | 3.0 | 1.0 | 1.4 | 2.6 | 5.3 | 54.8 |
| % >= 14.0m/s | 0.2 | 0.1 | 0.1 | 0.1 | 0.2 | 1.3 | 2.2 | 0.2 | 0.1 | 0.0 | 0.1 | 0.1 | 4.6 |
| Mean wind speed | 6.5 | 5.7 | 6.3 | 6.2 | 7.2 | 9.7 | 9.1 | 6.2 | 5.0 | 5.0 | 5.7 | 6.4 | 6.8 |
| Max wind speed | 23.1 | 26.0 | 25.7 | 25.7 | 30.4 | 36.0 | 36.0 | 29.9 | 27.0 | 21.9 | 28.3 | 26.0 | 36.0 |

Number of observations = 122333 Source: DMI

Calm defined as wind speed <= 1.5m/s

Number of observations with calm/varying wind direction: 11937 = 9.8%

Observations with calm/varying wind direction are not used in the statistics

### 3.5.2 Survey of air emissions in the case of use of oil products

As mentioned in the introduction there is only limited information in the project documents that can illustrate the order of air emissions from the establishment and operation of hydroelectric power stations, utility trenches, port facilities, etc.

The predominant contribution to the air pollution from many of these activities is from the use of construction machinery, drilling, production of concrete, blasting, stone crushing, construction work, production of electricity, transport by air, road and sea, storage of solid, liquid and gaseous substances as well as other activities that have not been specified.

It is estimated that total activities during the construction phase of the aluminium smelter and the hydroelectric power stations will result in a considerable consumption of energy and consequently also considerable emissions to the environment. It must be expected that the energy consumption will influence Greenland's $CO_2$ accounts noticeably during this period. Reference is made to the section concerning problems in relation to $CO_2$.

Below a list is provided of airborne emissions in operations where oil products are used as energy source:

| **Substance** | **Dispersion** | **Examples of harmful effects** | **Comments** |
|---|---|---|---|
| Sulphur dioxide ($SO_2$) | Locally and regionally | Acidification<br>Damage to vegetation<br>Damage to health | Approx. 2 g/l for diesel oil with a sulphur content of 0.1 % |
| Nitrogen oxides, $NO_x$ | Locally and regionally | Acidification<br>Photochemical smog<br>Eutrophication<br>Damage to health | The quantity depends on the use:<br>For diesel engines: 10-40 g/l |
| PAH compounds | Locally and regionally | Damage to vegetation<br>Damage to health | Are generated in connection with incomplete combustion of, for instance, diesel oil (soot particles) |
| Particulate matter | Locally and regionally | Damage to vegetation<br>Damage to health | Small particulate matter can be transported over |

| | | | |
|---|---|---|---|
| | | | long distances |
| Carbon monoxide | Locally | Acutely toxic for humans and animals | Transformed into $CO_2$ |
| Carbon dioxide $CO_2$ | Globally | Greenhouse gas | |
| Hydrocarbons (HC) | Locally and regionally | Impact on ecosystems<br>Damage to health<br>Photochemical smog | Evaporation from storage and handling of oil products. |

### *3.5.3 Need for additional information*

In this report the impact of air emissions on the environment as a result of the overall aluminium project are based mainly on information from the EIA report for Alcoa's facilities in Reydarfjördur, Fjärdabyggd, Iceland.

Below a summary is provided of information which is not available for an assessment of these impacts and related problems:

- No information is available that can illustrate whether the emission of heavy metals and other environmentally damaging substances can be of a magnitude that can affect the arctic environment. Mass balances for these substances may be relevant.
- Consequences of accidents as a result of unintended events (technical or human errors), description of the maximum conceivable accident. Experience from other industries shows that large discharges often occur in connection with accidents.
  For instance: What is the consequence of breakdown of an air pollution control system?
- Aluminium compounds exist in large quantities in the natural environment, but it is also well-known that under certain circumstances aluminium can be environmentally damaging and injurious to health. Information is lacking on the emission of aluminium compounds and consequent impacts on the environment.
- It has not been stated whether fluorine-carbon compounds are emitted other than the two PFC gasses that are mentioned ($CF_4$ and $C_2F_6$) and, if so, whether such compounds have any undesired impacts.
- It is not clear whether oil products heavier than gas oil are intended to be used.

- It has not been stated whether substances are emitted that can cause odour nuisances.
- It has not been stated to what extent the construction of hydroelectric power stations can lead to increased discharge of the greenhouse gas methane owing to decomposition of organic matter.
- A considerable consumption of energy must be expected during the establishment phase (4-5 years prior to the commissioning of the aluminium smelter). The scope of this does not appear from the project documents.
- No information is available concerning air emissions from blasting.

### 3.6 Noise

Noise is an environmental factor that has an impact on both animal life and human beings in the area that is exposed to noise. Noise is the designation for undesirable sound or sound that is perceived as uncomfortable and unpleasant.

According to WHO (the World Health Organization) noise exposure can be injurious to health for human beings and noise exposure at the workplace constitutes a serious problem in the working environment.

A large number of the activities and facilities that are related to the establishment and operation of an aluminium smelter in Greenland will place a noise load on the environment. At present there is no or only very limited information on the actual design and location of the individual facilities (hydroelectric power stations, utility trenches, port facilities, raw material extraction, roads, etc.). Below importance will be given to describing the noise sources that can be expected from the various activities and facilities, matters that affect the noise impact on the surroundings and potential remedial action and the basis for stipulating conditions in relation to noise.

On the basis of what is known it has not been possible to make a quantitative analysis of the noise generated by the coming activities. Therefore the section will primarily provide a qualitative description of the factors to which attention should be paid in connection with a decision as to whether a quantitative analysis of noise should be included in an EIA for the given activity/location.

A factor that should be included in the assessment of the noise impact from facilities and activities is that the majority of the sites to be selected will be found in areas in which there is no industrial or other human activity already. With the aluminium smelter and the related facilities a new noise impact on the areas will therefore be introduced.

Noise occurs in three main categories:

- as audible sound impact as such,
- as so-called infrasound, which is a very low-frequency sound (very deep tones),
- as vibrations.

### 3.6.1 Ordinary noise

Sound in the intermediate frequencies is perceived by human beings as being more disturbing than are higher and deeper sounds. In order for specifications of noise to reflect this, noise in noise measurements is expressed in the unit dB(A), which is a weighted expression of the intensity of sound that corresponds to the human perception of the sound as ”noise”.

### 3.6.2 Low-frequency noise and infrasound

Low-frequency noise is noise where a considerable part of the sound energy is in the frequency range below 160 Hz (deep tones). Low-frequency noise can come from many different sources, for instance, ventilation systems, combustion plants, transformer stations and traffic. The risk of a facility or activity producing low-frequency noise can be difficult to predict.

Infrasound is sound at a frequency below 20 Hz and therefore constitutes the deepest part of the low-frequency range. Infrasound is regarded as uncomfortable as soon as it is audible and the nuisance is increased more when the level increases than is the case for a more ordinary frequency composition[13]. As in the case of low-frequency sound it may be difficult to predict in advance whether a given activity will cause an infrasound impact on the surroundings.

### 3.6.3 Vibrations

Vibrations may originate from traffic, in particular where there are humps or irregularities in the road, from construction activities (vibration or piling and sheet pile driving), from large, low-speed diesel engines or from ships entering and departing from ports. Consequently there are several activities in connection with the aluminium project that can be expected to cause vibration and in an EIA study it must be remembered that areas that may be exposed to low-frequency noise and vibrations should be identified.

[13] Environmental review from the Danish Environmental Protection Agency no. 9/1997: Environmental low frequency noise, infrasound and vibration.

It appears from the environmental review[14] that the vibrations spread through the ground and the most high-frequency vibrations are dampened considerably. Only in exceptional cases have vibration nuisances been found in buildings further away than a few hundred metres from the vibration source, but most often the distance has been less than approximately 50 metres. It must therefore be expected that any vibration exposure will be of a relatively local nature.

### 3.6.4 *Factors influencing the noise exposure*

The noise exposure depends on a large number of factors some of which are specific for the given location, i.e. related to the topography of the area, the vegetation cover, etc., while others are dependent upon the design of the facilities and are thus independent of the location of the facilities.

The noise exposure is determined by for instance:

- Source strength: The strength at which the sound is emitted from the source.
- The frequency (tone) of the sound
- The nature of the noise: Constant noise such as the humming from a factory is not perceived in the same way as impulsive noise which occurs for instance in connection with blasting.
- Vibrations and infrasound.
- The duration of the noise and the time of day: (Long-term noise exposure is a greater nuisance than is noise of short duration, night noise is a greater nuisance than is day noise.

Matters that are specific for specific locations may influence the noise exposure and therefore they may be taken into account in a prioritisation of locations. They are:

- The distance from the noise source to a vulnerable area.
- Ground attenuation: The nature of the surface between the noise source and the area. An area covered by vegetation will attenuate the noise more than an area with bare, hard rock surfaces.
- The location of the source in relation to the surroundings: The topography affects the propagation of the noise since noise from sources in elevated and exposed locations will be propagated more than noise from sources located in, for instance, a hollow.
- Vulnerability of animals and plants.
- Distance to inhabited areas.
- The overall effect in the case of several sound sources.

[14] Ibid.

### *3.6.5 Indicative limit values*

Noise from enterprises in Greenland is regulated in the environmental approvals given to enterprises. The specification of conditions in relation to noise is based on the guidelines of the Danish Environmental Protection Agency [15] and recommended limit values for noise exposure.

For noise generated in connection with construction works the noise limits applicable according to Danish legislation are somewhat higher than the limits applicable during the operating phase. This is due to the fact that civil engineering work changes as the work progresses and therefore individual areas will be subject to exposure only for a limited period of time. Often, however, noise limits for the night will not be relaxed. Whether a corresponding differentiation is relevant in relation to the coming activities must depend on a specific evaluation of the conditions at the individual locations.

The Danish Environmental Protection Agency has prepared a number of indicative limit values for various types of areas after a weighing up of the noise to which human beings are exposed and economic considerations. In an EIA for an aluminium smelter and related facilities in Greenland it will also be relevant to include an assessment of the project in relation to the disturbance of animal life.

The table below shows the indicative values of the Danish Environmental Protection Agency for external noise from enterprises [16].

| | Monday - Friday 7 am – 6 pm, Saturday 7 am – 2 pm | Monday - Friday 6 pm – 10 pm, Saturday 2 pm – 10 pm, Sundays and holidays 7 am – 10 pm | All days 10 pm – 7 am |
|---|---|---|---|
| 1. Business and industrial areas | 70 dB(A) | 70 dB(A) | 70 dB(A) |
| 2. Business and industrial areas with a prohibition of enterprises that cause noise nuisances | 60 dB(A) | 60 dB(A) | 60 dB(A) |
| 3. Mixed residential and | 55 dB(A) | 45 dB(A) | 40 dB(A) |

[15] Environmental Guidelines no. 5/1993: Calculation of External Noise from Enterprises as well as Environmental Review from the Danish Environmental Protection Agency No. 9 / 1997: Environmental low frequency noise, infrasound and vibration.
[16] Environmental Guidelines no. 5/1993: Calculation of External Noise from Enterprises.

| | | | |
|---|---|---|---|
| business areas, town centre areas | | | |
| 4. Areas with blocks of flats | 50 dB(A) | 45 dB(A) | 40 dB(A) |
| 5. Residential areas with open-plan and low buildings | 45 dB(A) | 40 dB(A) | 35 dB(A) |
| 6. Summer house areas recreational areas open to the public | 40 dB(A) | 35 dB(A) | 35 dB(A) |

The limit values are stated as the A-weighted equivalent corrected noise level, *the noise exposure*. The equivalent noise level is the mean value of the noise over a long period of time (during the day 8 hours, in the evening 1 hour and at night 30 minutes). If the noise includes clearly audible tones or impulses 5 dB should be added to the equivalent noise level in order to determine the noise exposure.
The noise limits stipulated in a condition concerning noise must be observed at all points out of doors in the area in question and not only close to the buildings. For residential areas an indicative limit value exists for the maximum immediate level of noise at night, the maximum noise value. The limit value for the maximum level is 50 - 55 dB(A).

Special limit values apply to low frequency noise, infrasound and vibration based on assessments of the specific nuisances caused by these types of noise.

### *3.6.6 Remedial action*

Noise nuisances can be lessened by different types of remedial action. The most important measure that can be taken to reduce the nuisances is to locate facilities and activities that emit noise as far away as possible from areas that can experience a negative impact in consideration of the noise propagation factors that are mentioned above. Noise propagation can also be attenuated by establishing noise barriers or noise screens around facilities that emit noise. Finally, limit values and time limits for noise may be fixed in connection with environmental approval of facilities and plants, demands can be made on the use of low-noise equipment and demands can be made on, for instance, noise reducing road surfaces and screening.

Noise from helicopter flights in the areas in question can be regulated by adopting rules on flight corridors and demands can be made with regard to flying altitude and flying times over particularly sensitive areas.

At present the information concerning the anticipated noise emission from the coming facilities is so sparse that it is not possible to prioritise the locations on the basis of the load to which the surroundings will be exposed. In the section on nature the term "disturbance" is used in relation to an assessment of the vulnerability of individual animal populations. In this context noise will be one of several factors and an assessment must be made for the specific areas and activities as to whether the anticipated noise exposure can be of decisive importance for the location and whether detailed mapping should be made.

#### *3.6.7 Need for additional information*

Generally, information on the exact location and the noise emitted from the coming activities is not available. Whether it is relevant to map out the noise for the individual activities must be assessed in each case and will depend on, for instance, a specific evaluation of the sensitivity of the surroundings to noise.

## 3.7 Dust

A large number of the activities that are related to the establishment and operation of an aluminium smelter in Greenland will to a greater or lesser extent generate dust. At present there is no or only very limited information on the actual design and location of the individual facilities (hydroelectric power stations, utility trenches, port facilities, raw material extraction, roads, etc.). Below importance will therefore be attached to describing the factors that affect the generation of dust, what activities can be expected to result in the generation of dust and potential remedial action.

Dust generation is one of the factors that can have an impact on plant and animal life and human health. Therefore this section will primarily provide a qualitative description of the factors to which attention should be paid in connection with a decision as to whether a quantitative analysis of dust generation and dust nuisance should be included in an EIA for the given activity.

Discharges from the production plant as such are considered in the section on emissions – including the discharge of, for instance, dust containing fluorine.

### 3.7.1 Particulate pollutant emissions

Particulate matter emitted from ships, planes and the exhausts of vehicles consists of fine and ultra-fine particles that primarily originate from incomplete combustion of hydrocarbons in engines. Fine and ultra-fine particulate matter has a harmful effect on human health. Since the negative impact from activities related to the aluminium project will occur in areas that have not previously been exposed to traffic, etc. the project will result in a pronounced increase in the discharge of fine and ultra-fine particulate matter. At present no precise information is available on the anticipated traffic in connection with the project and therefore it is not possible to make a specific assessment of the impact from the increased traffic on the basis of what is known.

The total discharge must be expected to be considerably less than, for instance, the load from a road with normal traffic.

Locally in areas where there is heavy traffic and perhaps marine and helicopter traffic close to residential areas the negative impact of fine and ultra-fine particulate matter may constitute a health problem that ought to be mapped out. The effect on nature and marine areas is not known.

The discharge of fine particulate matter can be limited considerably by installation of particle filters and by demanding correct adjustment and maintenance of engines.

### 3.7.2 Dustfall

Dustfall is particulate matter from the atmosphere that falls on the surface of the ground or which reaches the ground in the form of precipitation – often designated sediment dust. Dustfall particulate matter is normally larger than 20-30 μm, and dustfall is measured as the average mass reaching a given area per time unit in $g/m^2/day$.

Dustfall influences the surroundings by covering the vegetation and any small animals in the vegetation in the area thus causing damage to these. When the dust settles on snow deposits the surface becomes darker, which results in increased smelting and therefore a shorter period of snow cover.

Large quantities of dust in the air can affect visibility and thereby cause a nuisance to vehicular traffic and aviation in the area.

In connection with the construction works it is anticipated that the dust impact will primarily be from relatively large particulate matter and the burden will therefore be relatively local in nature and be related to limited zones around the actual locations.

Coarse airborne particulate matter is typically formed by various mechanical processes, for instance whirling up of soil and road dust by the wind, tyre and road wear, turbulence caused by traffic, construction projects and industrial activities[17]. In connection with the aluminium project in particular blasting and crushing of broken rock to be used as building materials and stocks of dust emitting materials, such as cement, will be of importance. Furthermore, digging and transportation of gravel as well as loading and unloading of dusty materials can result in dust emission.

Raw material extraction and changed dynamics in the rivers (new areas with erosion/sediments) as a result of the hydroelectric power stations can contribute to creating new scars in the landscape, which can result in areas previously protected by vegetation being exposed to the wind. Therefore it is important that the top soil is removed and reused in connection with rehabilitation.

During the planning phase allowance should be made for timing and performance of these activities so that no scars are created in the landscape that may unintentionally initiate increased wind erosion. The planning should also include the preparation of rehabilitation plans and preventive measures.

The load from dustfall can be remedied or limited by the use of dust-laying agents or watering and by covering dust-emitting stocks and truck loads of dust-emitting materials or storing them in closed containers/buildings. In addition, road surface requirements and speed restriction can reduce the development of dust.

The Danish Environmental Protection Agency recommends a number of terms of operation that can limit the development of dust (Environmental Project 879 p 7):

- Requirements for equipment and machinery with a view to physical improvements, e.g. enclosure, wind shields, sprinkling, particle filters, ventilation including cleaning of the exhaust air in cyclones or bag filters, etc.
- Requirements for the performance of the work, e.g. continuous watering and possibly use of approved dust bonding agents, cleaning and maintenance of equipment, speed restriction, etc.

[17] Danish Environmental Protection Agency 2005: Environmental project 1021 - Air pollution with particles in Denmark.

- Requirements for instruction of employees.
- Requirements for inspection and monitoring

### 3.7.3 Need for additional information

The development of dust is generally considered to be a problem of a relatively local nature. Mapping as such of the dust impact on the individual locations should, where relevant, form part of an overall mapping of the loads to which the area is exposed.

# 4 ALUMINIUM SMELTER

## 4.1 The aluminium smelter during the construction and establishment phase

### *4.1.1 Aquatic environment – the aluminium smelter*

***Fresh water***

The lakes that are planned to be incorporated into the project can be characterised as coastal lakes. Their sizes will vary the largest lakes being situated around Sisimiut and on the Nordlandet at Nuuk.

On the other hand, there are problems on the islands where there are no lakes/large rivers near the areas selected for the smelter. Therefore it will be necessary to dam the existing lakes and rivers in the areas so that optimum water resources can be guaranteed. It is recommended that Alcoa keep this in mind as the establishment of very long water pipes that need to be frost proofed by means of heating cable will involve large construction and operating costs.

An alternative is to provide water from other areas via a submarine cable.

***Lakes***

Since the lakes on the Nordlandet and at Sisimiut will be close to the aluminium smelter, from which there may be a discharge of fluorine and PAHs, monitoring of the water in the surrounding lakes is required.

| Location | Comments |
|---|---|
| **Nuuk** | The present capacity does not allow establishment and operation of an aluminium smelter in relation to the present water resource catchment area. |
| Nuuk A (Maalutup Timaa, Akia) | It is not known which lake is planned to be used.<br>Hydrological surveys are required to find the most suitable lake. |
| Nuuk (Iviangiusat, Akia) | The same |
| Nuuk (Ikaarissat) | It will be necessary to incorporate new water resources and establish a submarine line to Ikaarissaat as Nuuk's water resources do not at present have the necessary capacity. |
| **Maniitsoq:** | The present capacity does not allow establishment and operation of an aluminium smelter in relation to the present water resource catchment area. |
| Maniitsoq A (North East) | It will be necessary to incorporate new water resources. Hydrological feasibility studies will be required to assess the capacity. Preparation of |

| Location | Comments |
|---|---|
| | prognoses in relation to climate changes will also be required with regard to quantities of precipitation. |
| Maniitsoq B (North West) | The same |
| Maniitsoq C (South-East) | The same |
| **Sisimiut** | Capacity is available to meet the need for water in connection with establishment of the aluminium smelter |
| Sisimiut A (Kangerluarsuk Tulleq) | Capacity is available to meet the need for the water in connection with establishment of the aluminium smelter. However, it will be necessary to conduct ordinary hydrological feasibility studies to find the most suitable lake. |
| Sisimiut B (Narsaq/ Utoqqaat) | The same |
| Sisimiut C (Itillinguaq) | The same |

***Rivers***

At the moment no information is available as to which rivers will be affected by an aluminium smelter for which reason reference is made to the general sections 3.1 and 3.2.

***Marine environment***

In connection with the establishment of the aluminium smelter the marine environment will be influenced only by the secondary effects (cumulative) in connection with the establishment of the aluminium smelter.

### *4.1.2 Water resources – the aluminium smelter*

The primary expertise on which this section is based is Asiaq's report from 2003 concerning Greenland's drinking water supply. In addition information is included from the proposals made by the local authorities in Sisimiut, Maniitsoq and Nuuk for the location of the aluminium smelter all of which were published in 2007.

It is anticipated that up to 1,500 – 2,000 persons will be involved in establishing the aluminium smelter, which means that the annual consumption of drinking water will be around 91,000 $m^3$.

It is not known how much water is to be used for the casting of concrete for the building project and therefore additional assessments in relation to this are required.

In the drinking water table shown below, which was prepared on the basis of Asiaq's report, the existing water resources in the three towns where an aluminium smelter may be located, have been calculated.

| **Location** | **Minimum capa-city of existing water resource $m^3$** | **Current annual water consump-tion $m^3$** | **Prognosis for annual additional water consumption for operations, etc. $m^3$** | **Comments** |
|---|---|---|---|---|
| **Nuuk** Volume available during summer: 624,000 $m^3$ | 2,200,000 | 1,433,000 | | At present there is capacity to establish an aluminium smelter in relation to the present water resource catchment area. |
| Nuuk A (Maalutup Timaa, Akia) | | | 91,000 | No immediate problems. However, it will be necessary to conduct hydrological studies to find the most suitable lake. |
| Nuuk B (Iviangiusat, Akia) | | | 91,000 | The same |
| Nuuk C (Ikaarissat) | | | 91,000 | It will be necessary to establish a drinking water pipe to the island from Nuuk. |
| **Maniitsoq:** Volume available during summer: 493,500 $m^3$ | 551,000 | 554,000 | | It is considered that the present capacity does not allow establishment of an aluminium smelter in relation to the present water resource catchment area. |
| Maniitsoq A (North East) | | | 91,000 | It will be necessary to incorporate new water resources/ extend existing resources. Hydrological feasibility studies will be required to assess the capacity. |
| Maniitsoq B (North West) | | | 91,000 | The same |
| Maniitsoq C | | | 91,000 | The same |

| Location | Minimum capa-city of existing water resource m³ | Current annual water consump-tion m³ | Prognosis for annual additional water consumption for operations, etc. m³ | Comments |
|---|---|---|---|---|
| (South-East) | | | | |
| **Sisimiut** Volume available during summer: 3,486,700 $m^3$ | 7,200,000 | 854,000 | | Capacity is available to meet the need for water in connection with establishment of an aluminium smelter |
| Sisimiut A (Kangerluarsuk Tulleq) | | | 91,000 | Capacity is available to meet the need for water in connection with establishment of an aluminium smelter. However, it will be necessary to conduct ordinary hydrological feasibility studies to find the most suitable lake. |
| Sisimiut B (Narsaq/ Utoqqaat) | | | 91,000 | The same |
| Sisimiut C (Itillinguaq) | | | 91,000 | The same |

In conclusion it is believed that for the locations on Akia and for all locations at Sisimiut the drinking water available will be sufficient for the establishment phase if the project is realised. However, it will be necessary to conduct ordinary hydrological studies and to make model calculations to find the most suitable lake.

*Process water*

As there are no estimates of the quantities of water needed for the concrete production, supplementary information in relation to this is required. It can be recommended that the client already now consider these problems.

### 4.1.3 Waste – the aluminium smelter

It is believed that the construction and establishment phase of the aluminium smelter will generate considerable quantities of construction waste that must be handled. In addition it must be expected that a relatively large quantity of the types of waste mentioned in section 3.3 such as oil and chemical waste, etc. will be generated. It must be presumed that temporary storage facilities will be required for the individual fractions of waste. If this is the case an assessment must be made of the environmental consequences of such storage facilities. At present sufficient information is not available concerning the quantities of waste and its composition. Therefore this must be illustrated in more detail.

### *4.1.4 Waste water – the aluminium smelter*

The types of waste water that will be relevant in connection with the construction and establishment of the aluminium smelter are:

- Sanitary waste water from the work camp related to the building site.
- Waste water from the construction work
- Rain and melt water drained off from the building site and related storage areas, construction sites, etc.

At present sufficient information about the practical implementation of the building and civil engineering project is not available. Therefore it is not possible to provide a qualified evaluation of the quantities of waste water and the consequent negative impact.

### *4.1.5 Air emissions – the aluminium smelter*

During the construction phase for the smelter extensive activities will take place in connection with levelling of the factory area, the construction of buildings, storage facilities, etc. On the basis of the information available, the air emissions resulting from these activities cannot be estimated.

With regard to air emissions as a result of energy consumed, reference is made to the general section about the environmental impacts of the project.

### *4.1.6 Noise – the aluminium smelter*

In connection with the construction and establishment of the aluminium smelter the following activities will cause noise exposure: blasting to clear the construction area, raw material extraction, crushing plant, transport of materials and personnel, concrete production, concreting and vibration, construction equipment.

#### 4.1.7 Dust – the aluminium smelter

In connection with the construction and establishment of the aluminium smelter the following activities will cause dust impacts: blasting, crushing, storage of dust-emitting materials (for instance cement for concrete production), the use of heavy equipment, raw material extraction, temporary waste landfills as well as transport of materials and personnel.

### 4.2 The aluminium smelter during the operating phase

#### 4.2.1 Aquatic environment – the aluminium smelter

During the operating phase it will be necessary to monitor the aquatic environment in the surrounding lakes and the river. Therefore a monitoring programme adapted to the individual location must be prepared.

#### 4.2.2 Water resources – the aluminium smelter

***Drinking water***

In connection with the operation of the aluminium smelter only 600 employees will be required. It is expected that the employees with their families will take up residence in the immediate vicinity of the aluminium smelter and therefore the need for potable water will be increased considerably at the location that is selected.

It is as yet uncertain how many people will take up residence in Nuuk, Maniitsoq or Sisimiut, if one of these places is selected for the smelter. The number of people taking up residence in the area will depend on the work situation in the area as well as the work situation in the rest of the country, but in a project outline prepared by the Department of Industry secondary employment of 1,000 persons is mentioned of which some jobs will be bound up with the location selected, for instance jobs at schools and in the healthcare sector. A total increase in the population of 2,000 persons over a certain period will hardly be unrealistic and therefore it is necessary to coordinate the supply security with regard to drinking water with Nukissiorfiit.

The average consumption of water is currently 130 litres per person per day. These figures cover large variations between towns and districts but it can be expected that the newcomers will resemble city dwellers as far as consumption is concerned. This means that the operation of the aluminium smelter will result in an increase in the population's consumption of drinking water by almost 120,000 $m^3$ /year [18].

It may be concluded that the establishment and operation of an aluminium smelter will increase the need for fresh water by an estimated 1,120,000 $m^3$ /year permanently.

The table below sets out a calculation of the existing drinking water resources in the three towns where an aluminium smelter could be placed in proportion to the probable water consumption for the smelter during the operating period:

| **Location** | **Minimum capacity of existing water resource $m^3$** | **Current annual water consump-tion $m^3$** | **Prognosis for annual additional water consumption for operations, etc. $m^3$** | **Comments** |
|---|---|---|---|---|
| **Nuuk** Volume available during summer: 624,000 $m^3$ | 2,200,000 | 1,433,000 | | The present capacity does not allow operation of an aluminium smelter in relation to the present water resource catchment area. |
| Nuuk A (Maalutup Timaa, Akia) | | | 1,120,000 | No immediate problems. However, it will be necessary to conduct hydrological studies to find the most suitable lake. |
| Nuuk B (Iviangiusat, Akia) | | | 1.120.000 | The same |
| Nuuk C (Ikaarissat) | | | 1,120,000 | It will be necessary to incorporate new water resources/increase the capacity as Nuuk's water resources do not at present have the necessary capacity. |
| **Maniitsoq** Volume available during summer: 493,500 $m^3$ | 551,000 | 554,000 | | The present capacity does not allow operation of an aluminium smelter in relation to the present water resource catchment area. |
| Maniitsoq A (North East) | | | 1,120,000 | It will be necessary to incorporate new water resources and increase the capacity. Hydrological feasibility studies will be required to assess the capacity. |

[18] An increase in the population of 2,000 persons with an average consumption of 130 l/p/d will give rise to a capacity requirement of 118,625 $m^3$ annually.

| Location | Minimum capacity of existing water resource $m^3$ | Current annual water consump-tion $m^3$ | Prognosis for annual additional water consumption for operations, etc. $m^3$ | Comments |
|---|---|---|---|---|
| | | | | Preparation of prognoses in relation to climate changes will also be required with regard to quantities of precipitation. |
| Maniitsoq B (North-West) | | | 1,120,000 | The same |
| Maniitsoq C (South-East) | | | 1,120,000 | The same |
| **Sisimiut** Volume available during summer: 3,486,700 $m^3$ | 7,200,000 | 854,000 | | Capacity is available to meet the need for water in connection with operation of an aluminium smelter |
| Sisimiut A (Kangerluarsuk Tulleq) | | | 1,120,000 | Capacity is available to meet the need for water in connection with operation of a smelter. However, it will be necessary to conduct ordinary hydrological feasibility studies to find the most suitable lake. |
| Sisimiut B (Narsaq/ Utoqqaat) | | | 1,120,000 | The same |
| Sisimiut C (Itillinguaq) | | | 1,120,000 | The same |

In conclusion it is believed that for the locations on Akia (Nuuk A and Nuuk B) and for all locations at Sisimiut the water available will be sufficient to meet the need for drinking and process water if the project is realised. However, it will be necessary to conduct ordinary hydrological studies and to make model calculations to find the most suitable lake.

***Water resources for Nuuk***

If it is decided to place the smelter at Ikaarissat (Nuuk C) the present capacity is not sufficient to meet the need for water to operate an aluminium smelter. It will be necessary to conduct hydrological studies of new, potential water resources.

The local authorities in Nuuk state that if the supply capacity is extended to the maximum it will be possible to increase the annual supply of fresh water by up to 2,100,000 $m^3$ /year with minimum capacity, i.e. for years with long winter periods and a small quantity of precipitation.

In the event of a potential additional increase in the drinking water supply the mountain area south of Kangerluarsunnguaq must be included. In order to ensure stable water supply, hydrological studies are needed to evaluate the capacity.

***Water resources for Sisimiut***

Capacity is available to meet the need for water in connection with operation of a smelter. However, it will be necessary to conduct ordinary hydrological studies to find the most suitable lake.

***Water resources for Maniitsoq***

For the three locations at Maniitsoq (Maniitsoq A, B and C) the immediate assessment is that they do not have the required capacity to meet the need for water. Maniitsoq's annual water consumption is 182,500 $m^3$ and if the prognosis for water consumption after the realisation of the project is added to this figure, the overall quantity of water needed is just over 1,300,000 $m^3$ /year.

The minimum capacity for Lake 2 and water reservoir Lake 1 is 551,000 $m^3$ /year to which should be added a potential catchment area, 2 A, which has a minimum capacity of 68,000 $m^3$ /year, which together gives a resource of 619,000 $m^3$ /year. The available volume for Lake 1 and Lake 2 is 493,500 $m^3$ and during the winter period only 383,000 $m^3$, with an ice thickness of 1 m. It is not known what the increase in volume would be if catchment area 2A were incorporated for which reason specific hydrological surveys are required.

Based on a minimum capacity without catchment area 2A, it is estimated that there will be a shortage of water of 380,000 $m^3$ annually. If the figures are based on the minimum capacity alone, there will be a shortage of water of approximately 690,000 $m^3$ /year.

The Municipality of Maniitsoq (2007: page 7) states itself that further to the north on the island there are lakes that can supply water to the plant. The Greenland Ministry of Nature and the Environment finds that it will be necessary to conduct a hydrological study in order to estimate the capacity on the island of Maniitsoq.

There is a discrepancy between the information held by the Ministry of Nature and the Environment and the information presented by the Municipality of Maniitsoq in its proposal for realisation of the project on the island of Maniitsoq.

Seen in the light of the fact that the supply of fresh water is important for the realisation of the project it is recommended that the Municipality of Maniitsoq, possibly in cooperation with Nukissiorfiit, investigate the possibilities of mapping the potential water resources at Maniitsoq.

### 4.2.3 *Waste – the aluminium smelter*

In connection with electrolysis and the casting of aluminium into bars (ingots) a number of waste products will be generated. In an article Bergsdal, Strømman and Hertwich calculate the average quantity of waste from the overall aluminium production in Norway during the period 1960 – 2000 as reproduced in the table below[19]:

Average quantities of waste in kg/tons of finished aluminium

| **By-product for reuse externally** | **Electrolysis** | **Ingot** |
|---|---|---|
| Dross | | 13 |
| Filter Dust | | 0.57 |
| Other by-products | 5.1 | |
| Refractory Material | 0.5 | 0.5 |
| Scrap | | 2.2 |
| SPL Carbon fuel/reuse | 9.9 | |
| SPL Refr. bricks/reuse | 5.5 | |
| Steel | 6.9 | |

[19] Bergsdal, Strømman and Hertwich 2004: The aluminium industry – environment, technology and production, page 19.

| **Solid waste** | **Electrolysis** | **Ingot** |
|---|---|---|
| Carbon waste | 4.6 | |
| Dross (landfill) | | 7.7 |
| Filter dust (landfill) | | 0.4 |
| Other Landfill Wastes | 7.3 | 1.3 |
| Refractory waste (landfill) | 1.2 | 0.7 |
| Scrubber sludges | 13.7 | |
| Spend pot lining (SPL) (landfill) | 17.3 | |
| Waste alumnia | 4.7 | |

The figures shown above do not reflect use of the best available technology, but are average figures of the overall Norwegian production based on the use of both Söderberg technology and Pre-bake technology. Nor do the figures describe the technological development that is decisive for a reduction of the quantity of waste. However, it has not been possible during this process to provide more recent data.

The average figures listed above have been used in the table below to make an estimate of the quantity of waste from production of 350,000 tons of aluminium. Consequently, the table is not to be seen as a precise picture of the quantities of waste that would be generated by a coming aluminium smelter in Greenland, but has been included to illustrate the order of the quantity of waste that can be expected. In the event of establishment of the aluminium smelters in Greenland it must be presumed that the most recent technology will be employed. Therefore it must be expected that the quantities of waste from a Greenland aluminium smelter will be reduced and that a larger quantity of waste will be reused.

Average waste in tons per year with a production of 350,000 tons of aluminium per year

| **By-product for reuse externally** | **Electrolysis** | **Ingot** |
|---|---|---|
| Dross | | 4,450 |
| Filter Dust | | 199.5 |
| Other by-products | 1,785 | |
| Refractory Material | 175 | 175 |
| Scrap | | 770 |
| SPL Carbon fuel/reuse | 3,465 | |

| | | |
|---|---|---|
| SPL Refr. bricks/reuse | 1,925 | |
| Steel | 2,415 | |

| **Solid waste** | **Electrolysis** | **Ingot** |
|---|---|---|
| Carbon waste | 1,610 | |
| Dross (landfill) | | 2,695 |
| Filter dust (landfill) | | 140 |
| Other Landfill Wastes | 2,555 | 455 |
| Refractory waste (landfill) | 420 | 245 |
| Scrubber sludges | 4,795 | |
| Spend pot lining (SPL) (landfill) | 6,055 | |
| Waste alumnia | 1,645 | |

Carbon waste consists of coke, aluminium and alumina residue. In the production also dross and filter dust will be generated. If a wet scrubber is installed (flue gas cleaning) the operation of the scrubber will generate sludge.

After 6 – 7 years of operation the cathode (spend pot lining (SPL)) is to be replaced. In addition to residue from the electrolysis the used cathode contains an unknown quantity of cyanide.

Parts of the waste generated can be reused. It is considered, however, that some of this waste is of a quantity and nature that makes it unfit for the existing municipal waste system. Therefore it must be expected that this part of the waste must be exported as Greenland has not set up any reprocessing industry as such.

#### *4.2.4 Waste water – the aluminium smelter*

The types of waste water that will be relevant in connection with the operation of the aluminium smelter are:

- Sanitary waste water from administration buildings, canteens, personnel facilities, etc.
- Rain and melt water drained from outdoor areas (parking areas, storage areas, etc.).
- Waste water from outdoor washing of various vehicles, etc.
- Process waste water from the production.
    - Waste water from flue gas cleaning
    - Waste water from the casting process (cooling water)

At present sufficient information about the practical implementation of the project is not available. Therefore it is not possible to provide a qualified evaluation of the quantities of waste water and the consequent negative impact.

#### *4.2.5 Air emissions – the aluminium smelter*

It is assumed that the carbon anodes used in the smelter are manufactured outside Greenland and transported to Greenland.

Below comments are made on the airborne emissions that are of material importance in connection with the normal operation of the aluminium smelter and which are regarded as potentially harmful to the environment or injurious to health. The list is not necessarily exhaustive as there may be substances or emission sources that have not been included on the list. The information concerning the magnitude of the emissions is from the EIA report from Alcoa's smelter in Reydarfjördur, Iceland.

The most important sources of air pollution are the following emissions:

- emissions from the foundry.
- emissions from the electrolysis process.
- ventilation of electrolysis halls.
- emissions from stocks of solid, liquid and gaseous products.
- emissions from loading and unloading of ships and any other handling of materials.
- emissions from stocks of waste.
- other emissions.

In the survey provided below the pollution components are described individually.

*Sulphur dioxide ($SO_2$)*

Sulphur dioxide originates from the anode coals and is emitted with the exhaust air from the electrolysis vessels. The air from these vessels is led through a chimney after first having been cleaned in a dry flue gas filter.

Sulphur dioxide will be deposited in the immediate surroundings but may also be transported over distances of several hundred kilometres from the point of discharge. $SO_2$ will be deposited on snow, soil, vegetation and in fresh water where it has an acidic effect. Since the entire area between Nuuk and Sisimiut is deficient in lime the area is vulnerable to acidification.
Detrimental impacts on fresh water environments and effects on vegetation are well-known effects of $SO_2$ acidification. Examples of acidification of fresh water

environments on a large scale are known for instance from Norway, Sweden and Canada where large areas are under the influence of air pollution transported over long distances.

Lichens and mosses are particularly vulnerable to airborne $SO_2$.

The local effects can be limited by increasing the height of chimneys whereby the concentration at the surface of the ground is reduced. The highest concentrations of $SO_2$ at the surface of the ground will be found at some distance from the chimney, downstream in relation to the wind direction. These factors can be mapped by means of a meteorological dispersion calculation if observations of wind and weather conditions in the area are available

The emission of sulphur dioxide can be reduced by means of wet flue gas cleaning, based on sea water. In this way a large part of the $SO_2$ of the flue gas is transferred to the sea water (in the form of sulphate) and it is expected that this sulphate will subsequently be discharged to the sea.
The quantity of sulphur dioxide discharged from the plant will depend on the quality of the anode coal that is employed since the sulphur content may vary. Anodes containing 1.8 % or 3.0 % sulphur are used in the above-mentioned plant.

*Nitrogen oxides, $NO_x$*

Nitrogen oxides NOx, also called NOs (NO and $NO_2$) are discharged in connection with heating of atmospheric air to a high temperature, for instance in connection with the flaring of oil and gas. No information has been found in the material available concerning any formation of NOx in connection with the production process, but it must be expected that in certain sub-processes nitrogen oxides are formed to a greater or lesser extent.
NOx has the same effect as sulphur dioxide since it has both a local and a regional effect.

Nitrogen oxides have an acidifying effect on the surroundings, but can also have an effect on oligotrophic ecosystems as NOx is transformed into nitrate in the soil solution and acts as a plant nutrient. Species with high nutrient demand will thereby oust the more hardy plants.
Together with other airborne pollutants (e.g. hydrocarbons) NOx can contribute to photochemical air pollution.

*Fluorides (HF and fluoride compounds)*

Fluorides are discharged via the extraction air from the electrolysis vessels as fluorine compounds are released during the electrolysis. The fluorides exist in the form of gaseous hydrogen fluoride, HF (hydrofluoric acid) and as fluoride in the form of particulate matter (e.g. potassium fluoride). Furthermore fluoride-bearing dust can be emitted as a result of the handling and storage of raw materials (cryolite and aluminium fluoride) and waste products.

Fluorides and hydrogen fluoride have relatively low limit values owing to their known harmful effects on the surroundings.
Fluoride pollution is known, for instance, from the fertilizer industry. Increased fluorine content has been demonstrated in plants, animals and human beings in the area around a given fertilizer enterprise at distances of up to 10 km. The increased fluorine content could be demonstrated, for instance in bone and teeth in animals and humans, see chapter 3 on health.

The emission of fluorides can at worst affect fresh water environments in the local area and cause increased fluoride content in lakes and rivers. The fluoride content of the air is reduced during precipitation periods owing to wash-out, but during periods without rain or snow it must be expected that fluoride particles can be transported over long distances.

Installation of a wet flue gas cleaner, based on sea water, does not have any major effect on the emission of fluorides, but first and foremost the content of sulphur dioxide in the flue gas is reduced[20]

No information is available that can illustrate to what extent the diffuse (uncontrolled) emission from the handling and storage of raw materials etc. (e.g. aluminium fluoride) contributes to the airborne emission of fluoride compounds.

Fluorides are very mobile and can spread in the environment by many routes. Therefore, fluoride content is an important environmental parameter.

*Cyanides (HCN and cyanide compounds)*
Cyanides are to be found in the solid waste product from the aluminium smelter and possibly also in the waste water. It does not appear from the material available whether cyanide compounds in the extraction air from the smelter have been demonstrated. Where cyanide is present it will be in the form of gaseous hydrogen cyanide (hydrocyanic acid), HCN or in the form of particulate matter, for instance potassium cyanide.

[20] Earth Tech for Alcoa 2006: Assessment of air quality impacts of emissions from the Alcoa aluminium plant in Reydarfjördur, Iceland.

Cyanides are known for their acutely toxic effect on human beings and animals as the absorption of cyanide causes lack of oxygen.

Airborne cyanide compounds can be deposited in water and soil after which they will be biodegraded or be otherwise decomposed.
It is anticipated that cyanide compounds will be formed to a greater or lesser extent during the electrolysis process, but no information is available about the quantity and concentration in the extraction air and in waste.

Additional studies are required of both sources and effects of the discharge of cyanides.

*PAH (Polyaromatic hydrocarbons)*
PAH compounds, also called tar substances, are formed during the reaction in the electrolysis vessels and in connection with processes in the smelter during which oil products are combusted. The greater part of the PAHs is discharged via the room ventilation from the top of the electrolysis halls.
The PAH compounds consist of a number of polyaromatic hydrocarbons. The material available contains information about five-ten different substances present as gas or particulate matter in the air current discharged.
Some of the PAH compounds are potentially carcinogenic and even in small concentrations have a harmful effect on plants and animals. PAH compounds can be deposited direct on the surface of the vegetation or accumulate in the roots of plants.
The PAH compound benzo(a)-pyrene, which is known as the most harmful in this group of substances, is known to reduce the reproductive capacity in birds and mammals.

The airborne emission of PAH from the electrolysis process can be reduced considerably by employing dry and wet flue gas cleaning. In this way the PAH substances are discharged with the waste water.

The largest PAH particles will be deposited in the immediate environment around the smelter while airborne particles of a diameter of around 10 μm or less will be capable of being transported over distances of several hundred kilometres by the wind.

Studies of the harmful effects of the PAH compounds indicate that in general the effects are long-term effects and that there is no lower threshold value below which the effect ceases; see the impact of POPs on human beings and animals.

Therefore, fixed limit values for the discharge of PAH compounds must be perceived as an expression of the degree of cleaning that can be achieved by means of the best available technology at the time in question (the BAT principle).
In connection with the fixing of limit values attention should be paid to the fact that the arctic population is already contaminated by POPs and is therefore extra vulnerable to any additional negative impact.

*Particulate matter*
The off-gases emitted from the facilities of the smelter contain dust particles to a greater or lesser extent in addition to the content of fluorides and PAH particles already mentioned. In addition, diffuse sources contribute to the emission of dust particles.

It is in particular the part of the dust particles that can float in the air for a long time (suspended dust) which has a harmful effect on the environment and is injurious to health. Therefore the content of the particulate matter fraction with a diameter below 10 µm is often used as an expression of the harmful part of the dust particles. The parameter is designated PM10 (Particulate Matter < 10µm) and is often used in connection with the fixing of limit values.

The fine dust particles are removed slowly – or not at all – by the air and therefore may be transported over long distances by the wind. The very finest particulate matter is not eliminated in the upper respiratory passages of animals and human beings and can therefore have a negative impact on their health.

*Emission of other airborne substances*
In addition to the substances already mentioned which are described in the material available it must be expected that other smaller quantities of components will be present in the emission air and it cannot be excluded that these components will have an environmental impact. The substances in question are residue in the carbon anodes employed and other raw materials or substances that form during the process.
These substances are for instance:

- Heavy metals (lead, cadmium, mercury, chromium, nickel, etc.).
- Aluminium and aluminium compounds that may be potentially harmful to the environment.
- Other elements in the raw materials used (arsenic, vanadium, etc.).
- Chloride and organic chlorine compounds that may have formed during the production process.

- Other substances that may have formed during the production process and which may have a negative environmental impact.
- Vapours from stocks of oil and gas and other volatile products.

It is important to ensure that the aluminium smelter will not emit xenobiotic substances to the surroundings. The arctic environment is already exposed to, for instance, heavy metals that become concentrated through the food chains and therefore it should be investigated whether the emission from the smelter will contribute additionally to this pollution.

*Carbon dioxide and carbon monoxide,* $CO_2$ *and CO*
Carbon monoxide, CO, is emitted from the electrolysis vessels. Carbon monoxide is toxic and is therefore removed together with the extraction air. The carbon monoxide is transformed relatively quickly into carbon dioxide, $CO_2$, and the air will contain both CO and $CO_2$.when it is discharged through the chimney.

No information on the CO content in the air in the immediate vicinity of the smelter as a result of the discharge is available nor are there any calculations of the CO content.
In the atmosphere the carbon monoxide discharged is transformed gradually into $CO_2$.

Owing to its short residence time in the atmosphere CO has an effect only locally while $CO_2$ only has a global effect since it acts as a greenhouse gas. The problems in relation to the discharge of greenhouse gases from the aluminium smelter are described in section 2.4.

*PFC gases*
In connection with the reaction in the electrolysis vessels gases are formed that consist of fluorine and carbon, so-called PFC gases (PerFluoroCarbon gases). These gases are removed with the extraction air and discharged through the chimney.
The gases consist of the two components, $CF_4$ and $C_2F_6$, which both have the effect of strong greenhouse gases with an effect that is 6,500 and 9,200 times stronger than $CO_2$, respectively.
No information is available as to whether other PFC gases or possibly HFC gases (HydroFluoroCarbon gases) are formed in the process.

*Results from a meteorological dispersion calculation in the area around the aluminium smelter in Reydarfjördur, Fjärdabyggd, Iceland*

A number of meteorological dispersion calculations have been made for the above-mentioned plant with a view to assessing whether any of the substances discharged will be critical in the local area around the smelter, i.e. in the dilution zone within a distance of 3-4 km from the smelter.

Two scenarios have been assessed:
Scenario 1: exclusively dry flue gas cleaning and the anode carbon having a low sulphur content
Scenario 2: both dry and wet flue gas cleaning but the anode carbon having a high sulphur content

The critical parameters are assumed to be the sulphur dioxide concentration and the fluoride concentration in relation to effects on the vegetation.

The result was as follows:
For sulphur dioxide the limit values (the toxicity limit for the most sensitive species, i.e. lichens and mosses) are not exceeded in any of the scenarios.
For fluorides the limit values are exceeded in scenario 1 within an area of approximately 400,000 $m^2$ within the dilution zone, and in scenario 2 within an area of 1,000,000 – 5,000,000 $m^2$ .

The explanation as to why the dispersion is lower when wet flue gas cleaning is introduced is that the outlet conditions have changed owing to a lower flue gas temperature. Wet flue gas cleaning has little effect on fluorides, but a high effect on sulphur dioxide.

It is anticipated that the environmental authorities will get an opportunity to discuss this with Alcoa in connection with the preparation of environmental approvals.

*Survey of air emissions during the operation of the smelter*

The following survey shows the magnitude of the air emissions from the smelter where these are stated. The statements of quantities are from information concerning Alcoa's corresponding Icelandic plant with an annual production of 340,000 tons of aluminium:

| **Survey of air emission from the aluminium smelter[21]** | | | | | |
|---|---|---|---|---|---|
| **Substance** | **Quantity** kg/tons Al | tons/year | **Dispersion** | **Examples of harmful effects** | **Comments** |
| Sulphur dioxide $SO_2$ | 13.3 (0.88) | 4600 (300) | Locally and regionally | Acidification<br>Damage to vegetation<br>Damage to health | The figures in parenthesis are with wet flue gas cleaning |
| Nitrogen oxides $NO_x$ | | | Locally and regionally | Acidification<br>Photochemical smog<br>Damage to health<br>Eutrophication | Quantity not stated |
| Fluorides HF + fluoride compounds | 0.32 (0.27) | 110 (95) | Locally and regionally | Damage to vegetation<br>Absorption by plants (and animals)<br>Damage to health | Low threshold value for effects on vegetation. Will be absorbed in bone and teeth of animals |
| Cyanide HCN + cyanide compounds | | | Locally and regionally | Acutely toxic for humans and animals | Quantity not stated |
| PAH compounds | 0.00050 (0.00045) | 0.18 (0.16) | Locally and regionally | Damage to vegetation<br>Damage to health | The figures in parenthesis are with wet flue gas cleaning |
| Particulate matter | 0.260 (0.220) | 90 (75) | Locally and regionally | Damage to vegetation<br>Damage to health | The quantities given are for small particulate matter ($PM_{10}$) |
| Other airborne substances | | | | | These are for instance heavy metals, organic chlorine compounds which may accumulate in the Arctic environment |
| Carbon monoxide CO | | | Locally | Acute toxic for human beings and animals | Transformed into $CO_2$ |
| Carbon dioxide $CO_2$ | 1,300 | 450,000 | Globally | Greenhouse gas | Including the CO that has formed |
| PFC gases | 140 | 46,000 | Globally | Greenhouse gas | The quantity is stated in $CO_2$ equivalents |

The above data are from the EIA report for Alcoa's smelter in Reydarfjördur, Iceland. Therefore the data are not to be regarded as applicable to a coming smelter in Greenland and it is anticipated that demands will be made for a further reduction of air emissions as compared to the above.

[21] HRV Engineering for Alcoa 2006: Aluminium plant in Reydarfjördur Environmental Impact Statement.

### *4.2.6 Noise – the aluminium smelter*
In connection with the operation of the aluminium smelter the following will cause noise exposure: noise from the plant – machines, extraction systems, etc. as well as traffic to and from the plant.

### *4.2.7 Dust – the aluminium smelter*
In connection with the operation of the aluminium smelter the following will cause noise exposure: stocks of raw materials, etc., particles in flue gas (is discussed in the section on emissions) as well as transport.

# 5 HYDROELECTRIC ENERGY FACILITIES

## 5.1 Hydroelectric energy facilities in the construction and establishment phase

### *5.1.1 Aquatic environment – hydroelectric energy facilities*

According to research completed by GEUS[22], there are several lakes between Nuuk and Sisimiut of the potential size for hydroelectric power station use – see the simplified table below.

No scenarios have been prepared visually illustrating the extent of the nature and environmental impact of raising the water level of the lakes and / or connecting the lakes by means of tunnels and canals.

We recommend that visualisations be prepared using GIS to have a tool from which to assess the extent of the impact.

| Name | Type | Comments |
|---|---|---|
| Umiiviit | Mainland lake | Has not been included in the research of NERI |
| Tasserssiaq | Mainland lake | |
| Qapiarfiufiusaap Sermia | Coastal lake | Has not been included in the research of NERI |
| Søndre Isortup Isua | Mainland lake | |
| Tasersuup Isua | Mainland lake | |
| Imarsuup Isua | Mainland lake | Closer examination in relation to raw material exploration is required and the problem regarding Isukasia is also unique in relation to the emergence of life. |

For all lakes, an environmental risk will be related to the construction work as described in section 3.1.

*The Isukasia problem*

In connection with raising the water level in the Isukasia area, elaborate research is required regarding its influence on the locality. The reason for this is that the Isukasia is characterised by being a type locality for the world's oldest well-preserved sedimentary and igneous rocks. Locally, the rocks contain carbon particles whose isotope composition shows that the carbon is of organic origin and made of plankton organisms embedded in the clay sediment at the sea bed. These formations are unique and of great international research

[22] Geus, 1996: IS OG ENERGI special issue, no. 5 December 1996.

interest and bear witness of the earliest geological development and the beginning of life.

It is believed that it might become problematic if these sediments are flooded by a rise in the water level.

With its iron deposits, the area is also considered to be of interest with regard to raw materials. Coordination with The Bureau of Minerals and Petroleum regarding the area is therefore required.

*Rivers*
There is no information regarding which rivers will be affected by a hydroelectric power station. Therefore please refer to sections 3.1. and 3.2.

*Marine environment*
On the background of the material available, it is not possible to assess the extent of the impact on the marine environment of the establishment of a given hydroelectric power station.

### *5.1.2 Water resources – hydroelectric energy facilities*

On the face of it, we estimate that there are good chances of finding suitable drinking water lakes in the areas. However, we want to point out that the lakes to be included in the generation of hydroelectric energy cannot be approved directly for the water supply since we estimate that construction work will constitute a health risk to the drinking water.

We do not know how many people will be at each location in connection with the establishment of a dam, tunnel, etc. However, the Icelandic research shows that consumption must be expected to be around 250 l/day.

Furthermore, we do not know at present how much water is needed for the casting of concrete. Further assessments are therefore required. Using water from the lake to be dammed up is recommended.

### *5.1.3 Waste – hydroelectric energy facilities*

The construction and establishment phase of the hydroelectric energy facilities are estimated to generate considerable amounts of building waste that must be handled. Moreover, it must be expected that a large amount of categories of the waste mentioned under section 3.3. such as scrap iron, oil and chemical waste, etc. will be generated.

Unlike the aluminium smelter, establishment of the hydroelectric energy facilities will not be limited to a single location. This activity will, therefore, result in the generation of waste of the types mentioned above at a number of localities.

It must be expected that temporary storage facilities will be required for each waste fraction. Should this be the case, we need to evaluate which environmental consequences such storage facilities will have.

At present, we do not have sufficient information about waste volume and composition.

### 5.1.4 Waste water – hydroelectric energy facilities

The waste water types of interest in relation to the construction and establishment of the hydroelectric power stations are:

- Sanitary waste water from the work camps in connection with the building sites.
- Waste water from the building and construction work.
- Rain and melt water drained from the building sites and related storage areas, construction sites, etc.

At present, we do not have sufficient information about the practical completion of the building and construction project. Therefore, it is not possible to make an informed estimate of the waste water volumes and the impact resulting from them.

However, in connection with building the hydroelectric power stations and dams, tunnel excavations, etc., there will be activity in several different locations.

What is characteristic of a number of these locations is that there is no direct possibility of waste water discharge either to sea or fjord. Therefore, it will be necessary to find another practical and environmentally sound way in which to handle the waste water.

### 5.1.5 Air emissions – hydroelectric energy facilities

In the construction phase of the hydroelectric power stations, very extensive activities such as drilling, blasting, concreting, etc. will be completed. The resulting air emissions cannot be estimated from the current information.

With regard to air emissions from energy consumption, please refer to the general section on the environmental impact of the project, see section 3.5.

### 5.1.6 Noise – hydroelectric energy facilities

In connection with the construction and establishment of the hydroelectric power stations, the following activities will cause noise impact: Preliminary surveys (drilling, seismic surveys), helicopter transport, blasting (blasting of area for buildings, dam, tunnel, etc.), raw material extraction, concrete production, construction equipment, concreting as well as transport of materials and personnel.

### 5.1.7 Dust – hydroelectric energy facilities

In connection with the construction and establishment of the hydroelectric power stations, the following activities will cause dust impact: Blasting, raw material extraction, storage and handling of materials, construction equipment, transport of material and personnel as well as any stocks of dug up materials from the lake bed.

## 5.2 The hydroelectric energy facilities in the operating phase

### 5.2.1 Aquatic environment – hydroelectric energy facilities

Depending on which lakes one wants to use for hydroelectric energy, more elaborate research will be required describing the nature and environmental impact.

*Rivers*

There is no information regarding which rivers will be affected by a hydroelectric power station. Please refer to sections 3.1 and 3.2.

*Marine environment*

On the background of the material available, it is not possible to assess the extent of the impact on the marine environment of the establishment of a given hydroelectric power station.

In connection with operations, it will be necessary to develop an individual monitoring programme adjusted in relation to the surroundings.

### 5.2.2 Water resources – hydroelectric energy facilities

The water requirement for the operation of the hydroelectric power stations is estimated to be minimal. Each hydroelectric power station must be monitored and maintained on a regular basis by a couple of people and it is expected that accommodation for the personnel must be established in close proximity to each power station. There must be access to fresh potable water as well as water for toilets, washbasins, etc.

We estimate that it will be possible to find the necessary amount of water at each of the suggested localities.

### 5.2.3 Waste – hydroelectric energy facilities

During the actual operation of the hydroelectric power stations, the volume of waste is estimated to be limited compared with the construction and establishment phase. Furthermore, we estimate that waste from general maintenance will be generated.

### 5.2.4 Waste water – hydroelectric energy facilities

The types of waste water of interest in relation to operating the hydroelectric power stations are:

- Sanitary waste water from housing, administration offices, personnel facilities, etc.
- Rain and melt water drained from outdoor areas.
- Waste water from outdoor washing of various means of transport etc.

At present, we do not have sufficient information about the practical completion of the project. Therefore, it is not possible to make an informed estimate of the volumes of waste water and the impact resulting from them. However, the manpower at the hydroelectric power stations will be limited during the operating phase which means that the volumes of waste water will be limited. Moreover, the hydroelectric power stations will be placed at locations where there is no direct possibility of waste water discharge neither to sea nor fjord. Therefore, it will be necessary to find another practical and environmentally sound way in which to handle the waste water.

### 5.2.5 Air emissions – hydroelectric energy facilities

The operation of the hydroelectric power stations does not give rise to any large air emissions quantities.

There will be some energy consumption from oil products, e.g. by use of emergency generators.

With regard to air emissions from energy consumption, please refer to the general section on the environmental impact of the project, see section 3.5.

Due to a rise in water level in the fresh water areas affected above the hydroelectric power stations, increased methane formation may occur as the plant material from the flooded areas decays.

### *5.2.6 Noise – hydroelectric energy facilities*

In connection with the operation of the hydroelectric power stations, the following activities will cause noise impact: Transport at inspection, etc. as well as turbines.

### *5.2.7 Dust – hydroelectric energy facilities*

In connection with the operation of the hydroelectric power stations, any increased erosion of the shores and rivers with changed flow and any stocks of material dug up from the lake bed may cause dust impacts.

# 6 UTILITY TRENCHES

## 6.1 Utility trenches in the construction and establishment phase

### *6.1.1 Aquatic environment – utility trenches*

The construction of the utility trenches will result in the crossing of several rivers and perhaps lakes. There is no information about which rivers will be affected by the utility trenches. Please refer to sections 3.1 and 3.2.

### *6.1.2 Water resources – utility trenches*

In the construction phase, discharge of increased quantities of dissolved and suspended material may occur as well as clay and silt from digging and driving.

It cannot be expected that permission will be granted to establish a utility trench within the protection zone of a drinking water lake.

### *6.1.3 Waste – utility trenches*

The establishment of the utility trenches is estimated to result in different types of building waste. At present, we do not possess sufficient information about waste volume and composition. This should therefore be examined in more detail.

### *6.1.4 Waste water – utility trenches*

The waste water types of interest in relation to the construction and establishment of utility trenches from the hydroelectric power stations to the aluminium smelter are:

- Sanitary waste water from the work camps related to any building sites.
- Waste water from the building and construction work.
- Rain and melt water drained from any building sites and related storage areas, construction sites, etc.

At present, we do not have sufficient information about the practical completion of the building and construction project. Therefore, it is not possible to make an informed estimate of the volumes of waste water and the impact resulting from them.

In connection with the construction of the utility trenches, there will be activity over large areas. What is characteristic of a number of these areas is that there is no direct possibility of waste water discharge to sea or fjord. Therefore, it will be necessary to find another practical and environmentally sound way in which to handle the waste water.

#### *6.1.5 Air emissions – utility trenches*

The establishment of utility trenches will result in activity in the form of drilling, blasting, work involving construction equipment, transport, etc.

Air emissions from energy consumption are described in section 3.5.

#### *6.1.6 Noise – utility trenches*

In connection with the construction and establishment of the utility trenches, the following activities will cause noise impact: Reconnaissance (helicopter and vehicles), construction work, construction equipment, concreting, vibration as well as transport of material and personnel.

#### *6.1.7 Dust – utility trenches*

In connection with the construction and establishment of the utility trenches, the following activities will cause dust impact: construction work, transport of material and personnel as well as construction equipment.

### 6.2 Utility trenches in the operating phase

#### *6.2.1 Aquatic environment – utility trenches*

The positioning of high-voltage lines in open country may have an impact on the surface water (lakes and rivers). In particular, this applies to leaching of corrosive material from the plant. As the extent of the impact is unknown, we recommend that the problem be examined in more detail and that monitoring be carried out in this respect.

#### *6.2.2 Water resources – utility trenches*

The positioning of high-voltage line in open country may have an impact on the surface water and thus, the drinking water lakes. In particular, this applies to leaching of corrosive material from the plant. As the extent of the impact is unknown, we recommend that the problem be examined in more detail and that monitoring is carried out in this respect so as to ensure clean drinking water.

#### *6.2.3 Waste – utility trenches*

As soon as the utility trenches have been put into service, different types of building waste from general maintenance must be expected. At present, however, this is not expected to be of the same extent as at the actual establishment.

### *6.2.4 Waste water – utility trenches*

The only type of waste water that is of any relevance in relation to the utility trenches in an operating phase is corrosion, rain and melt water. The environmental impact in this respect must be expected to be of a limited extent.

### *6.2.5 Air emissions – utility trenches*

Due to the corona effect (sparking by high voltage), ozone ($0_3$) and nitrogen oxides ($NO_x$) will be formed in very small quantities in the high-voltage lines. The quantity will be so small that no environmental impact may be expected.

### *6.2.6 Noise – utility trenches*

In connection with the construction and establishment of the utility trenches, the following activities will cause noise impact: Corona noise from electric lines, noise from transformer stations as well transport in connection with inspections.

### *6.2.7 Dust – utility trenches*

No dust generation of significance is expected. Minor dust generation arising from driving or helicopters in connection with inspections along the utility trench, is not estimated to constitute a significant problem.

# 7 ACCOMMODATION & OFFICE FACILITIES

The accommodation covers temporary work camps to house a large number of building and construction workers during the construction of the hydroelectric power stations, the aluminium smelter and related plants as well as permanent housing for the employees of the aluminium smelter and the hydroelectric power stations, respectively, after these have been put into operation. If the aluminium smelter is positioned far from existing towns, it will also be necessary to establish housing for the people indirectly employed following the aluminium smelter, e.g. service jobs.

Likewise, the office facilities cover temporary offices for e.g. construction management during the construction of the hydroelectric power stations, the aluminium smelter and related plants as well as permanent service and administration facilities after the aluminium smelter has put into operation.

## 7.1 Accommodation & office facilities in the construction and establishment phase

### *7.1.1 Aquatic environment – accommodation & office facilities*

Please refer to the general section 3.1 as well as sections 4 and 5.

### *7.1.2 Water resources – accommodation & office facilities*

Please refer to the general section 3.1 as well as sections 4 and 5.

### *7.1.3 Waste – accommodation & office facilities*

The establishment of temporary accommodation and office facilities for approx. 1,500 men in connection with the establishment of the aluminium smelter will result in different types of building waste, oil and chemical waste, etc. The temporary personnel facilities will probably be established close to a town. The volume of waste produced may easily be transported to the local waste system. However, it is necessary to assess whether the local waste system has the necessary capacity to handle this volume of waste.

The 2,000 men involved in establishing the hydroelectric power stations must also have temporary accommodation and office facilities. Unlike the aluminium smelter, this will require personnel facilities at a large number of locations. In connection with setting up the personnel facilities, a certain volume of building waste will be generated at each location.

The aluminium smelter will result in the need for constructing and establishing permanent housing and office facilities corresponding to that of a small town.

Therefore, it must be expected that such establishment will generate considerable volumes of waste such as different types of building waste, oil and chemical waste, hazardous waste, etc.

#### *7.1.4 Waste water – accommodation & office facilities*

The waste water types of interest in relation to the construction and establishment of the accommodation and office facilities are:

- Sanitary waste water from the work camps related to the building sites.
- Waste water from the building and construction work.
- Rain and melt water drained from the building sites and related storage areas, construction sites, etc.

At present, we do not have sufficient information about the practical completion of the building and construction project. Therefore, it is not possible to make an informed estimate of the waste water volumes and the impact resulting from it.

#### *7.1.5 Air emissions – accommodation & office facilities*

The establishment of accommodation and office facilities includes blasting, drilling, construction equipment work, building work, etc.

Some energy consumption must be expected in the form of oil products. Emissions in that respect appear from the general section on the environmental impact of the project, section 3.5.

#### *7.1.6 Noise – accommodation & office facilities*

In connection with the establishment of accommodation and office facilities, the following activities will cause noise impact: Blasting, construction activities, construction equipment as well as transport of material and personnel.

#### *7.1.7 Dust – accommodation & office facilities*

In connection with the establishment of accommodation and office facilities, the following activities will cause dust impact: Blasting, construction activities, construction equipment as well as transport of material and personnel.

### 7.2 Accommodation and office facilities in the operating phase

#### *7.2.1 Aquatic environment – accommodation & office facilities*

Please refer to the general section 3.1 as well as sections 4.1.1 and 5.1.1.

#### *7.2.2 Water resources – accommodation & office facilities*

Please refer to the general section 3.1 as well as sections 4.1.2 and 5.1.2.

### 7.2.3 Waste – accommodation & office facilities

*Temporary accommodation and office facilities in the establishment phase of the aluminium smelter and the hydroelectric power stations.*

In connection with establishing a working town for approx. 1,500 men to live and work in the area for 2 to 3 years, a plan is required for the handling and disposal of the household refuse and the types of waste generated from ordinary office work. In connection with the selection of the location for the aluminium smelter, it is important to create a permanent road or ferry connection from the aluminium smelter to the neighbouring town. , It will be possible to transport the waste generated from the temporary accommodation and office facilities to the local waste system in an area close to a town. However, it is necessary to assess whether the local waste system has the necessary capacity to handle this volume of waste.

From their temporary accommodation and office facilities, the approx. 2,000 men involved in the establishment of the hydroelectric power stations will generate considerable volumes of household refuse at a number of small locations in the open country.

*Accommodation and office facilities in connection with operating the aluminium smelter and the hydroelectric power stations*

The permanent housing and office facilities to be established as a consequence of operating the aluminium smelter and related service facilities will result in considerable volumes of waste. At present, this is estimated to result in volumes, types and composition corresponding to a small or medium-sized town. Therefore, it must be ensured that the waste system of the town in question is able to handle the waste volume generated.

Once the hydroelectric energy facilities have been established, they will employ a total of approx. 25 to 50 employees. Therefore, different types of office waste and household refuse must be expected from the personnel in charge of the day-to-day operation of the plants.

### 7.2.4 Waste water – accommodation & office facilities

The waste water types of interest in relation to the operation of the accommodation and office facilities are:

- Sanitary waste water from general households, offices, canteens, etc.
- Waste water from outdoor activities such as the washing of cars.

- Rain and melt water.

At present, we do not have sufficient information about the practical completion of the project. Therefore, it is not possible to make an informed estimate of the waste water volumes and the impact resulting from it.

### *7.2.5 Air emissions – accommodation & office facilities*

Air emissions from operating accommodation and office facilities stem first and foremost from electricity consumption and heating for which it must be expected that oil products will be used.

With regard to air emissions in this respect, please refer to the general section on the environmental impact of the project, section 3.5.

### *7.2.6 Noise – accommodation & office facilities*

In connection with the operation of the accommodation and office facilities, no noise impact of significance is expected.

It must be expected that the housing established in connection with the construction and establishment phase will later be part of the permanent housing stock. When deciding on the location and lay-out of the accommodation, the expected noise impact in connection with both plants and operation should be taken into consideration.

### *7.2.7 Dust – accommodation & office facilities*

In connection with the operation of the accommodation and office facilities, no noise impact of significance is expected.

Similarly, it is expected that the housing established in connection with the construction and establishment phase will later be part of the permanent housing stock. When deciding on the location and lay-out of the accommodation, the expected dust impact in connection with both plants and operation should be taken into consideration.

# 8 PORT FACILITIES

## 8.1 Port facilities in the construction and establishment phase

### *8.1.1 Aquatic environment – port facilities*

*Marine environment – smelter and related port facilities*

In connection with establishing the aluminium smelter, port facilities must be established for storage of building materials, concrete silos, fuel tanks, asphalt, etc. The port environment will be affected by increased marine traffic, waste water discharge from site sheds, surface water, etc. resulting in a risk of environmental impact.

As there is no information available about the areas planned to be included in the port facilities, it has been difficult to obtain detailed information about the marine conditions. On the background of the material which the Greenland Ministry of Nature and the Environment has had access to, it is expected that the port facilities will be constructed in the outer fjord environment where sedimentation is poor and water exchange high.

The table below has been prepared on the background of “Redegørelse om energiintensiv industri i Grønland” and Google Earth:

| **Location** | **Sea bed conditions and depth** | **Type** | **Comments** |
|---|---|---|---|
| **Municipality of Nuuk*** | | | |
| Nuuk A (Maalutup Timaa, Akia) | Moderate water depth | Outer fjord environment | Possible wave impact by southerly winds |
| Nuuk B (Iviiangiusat, Akia) | Good navigation and lee conditions | Outer fjord environment Possible problems of pack ice between the islands | do. |
| Nuuk C (Ikaarissat) | Estimated good depth and lee conditions | Outer fjord environment | Good navigation. Detailed measuring is lacking. Risk of reefs according to Google Earth |
| **Municipality of Maniitsoq*** | | | |
| Maniisoq A (north-east) | Unknown | Outer fjord environment | Risk of reefs according to Google Earth |
| Maniisoq B (north-west) | do. | Outer fjord environment | do. |
| Maniisoq C | do. | Outer fjord | do. |

| Location | Sea bed conditions and depth | Type | Comments |
|---|---|---|---|
| (south-east) | | environment | |
| **Municipality of Sisimiut*** | | | |
| Sisimiut A (Kangerluarsuk Tulleq) | Unknown | Outer fjord environment | Risk of reefs according to Google Earth |
| Sisimiut B (Narsaq / Utoqqaat) | do. | Probably outer fjord environment | None |
| Sisimiut C (Itillinguaq) | do. | Inner to central fjord environment | Possibly characterised by a large sedimentation rate as a consequence of the Sarfartoq river. Possibly ice formation |

*Source: Redegørelse om energiintensiv Industri i Grønland

In general, additional information is required regarding depth, sedimentation conditions, ice formation, etc. with a view to being able to assess the vulnerability of the areas in question in connection with the construction of port facilities, increased marine traffic, waste water discharge, etc.

From an environmental point of view, we recommend that the location be chosen in relation to depth so as to minimize the need for initiating extensive deepening as much as possible.

*Marine environment – hydroelectric power station and related port facilities*
No information is available about the planned situation of the port facilities in connection with the establishment of the hydroelectric power stations. The only exception is at Sarfartoq at Kangerlussuaq.

In connection with establishing a hydroelectric power station, the establishment of port facilities will be required initially for storage of building materials, concrete silos, fuel tanks, asphalt, etc. The port environment will be affected by increased marine traffic, waste water discharge from site sheds, surface water, etc. resulting in a risk of environmental impact.

On the background of the material which the Greenland Ministry of Nature and the Environment has had access to, the port facilities are expected to be constructed at locations where the driving distance to the location of the hydroelectric power station is as short as possible, i.e. in the inner parts of the fjords. This is not estimated to be optimal due to the delta development in front of the river mouths. This means poor water depths and high sedimentation rates resulting in risk of accumulation of xenobiotic substances combined with sand and silt.

The table below has been prepared on the background of “Redegørelse om energiintensiv industri i Grønland” and Google Earth:

| **Location** | **Sea bed conditions and depth** | **Type** | **Comments** |
|---|---|---|---|
| **Municipality of Nuuk*** | | | |
| Ujaraqssuit pâvat | Shallow | Inner fjord environment | Ice formation - winter |
| Ilulialik | Shallow | Inner fjord environment | do. |
| Qugssuq | Unknown | Central | Longer work road, ice formation – winter |
| **Municipality of Maniitsoq*** | | | |
| Evighedsfjorden (The eternity fjord) | Probably shallow | Inner fjord environment | Sand bed, ice formation |
| Southern Isortoq | Probably shallow | Inner fjord environment | do. |
| **Municipality of Sisimiut*** | | | |
| Sarfartoq | Probably shallow | Inner to central fjord environment | Sand |

These initial considerations make the Greenland Ministry of Nature and the Environment recommend that a thorough preliminary survey be conducted with a view to finding the most suitable location for port facilities, i.e. high water depth and water exchange to prevent accumulation of xenobiotic substances, etc.

*Problems relating to Evighedsfjorden*

We estimate that it is not realistic to initiate the construction of roads, etc. in the valley which flows into the Eternity fjord. This is because at regular intervals, the glacier tongue melts back to be “re-built” by ice eruptions afterwards. Map material from 1992 shows for instance that a glacier tongue appears at the edge of the Eternity fjord which has today melted partly. This means that any foundation will quickly erode by later ice eruptions.

If the plan is to establish a tunnel with a related hydroelectric power station, the assessment is that detailed preliminary surveys are required with a view to assessing the suitability of the sediments and the area in this respect.

### *8.1.2 Water resources – port facilities*

Our immediate estimate is that there are good chances of finding suitable drinking water lakes in the areas. However, we want to point out that the rivers downstream of the lakes to be included in the generation of hydroelectric energy cannot be approved directly for the water supply as construction work may constitute a health risk to the drinking water.

We do not know how many people will be at each location in connection with the establishment of a dam, tunnel, etc. However, Icelandic research shows that consumption must be expected to be around 250 l/day.

Furthermore, at present we do not know how much water is needed for the casting of concrete. Further assessments are, therefore, required.

### *8.1.3 Waste – port facilities*

The construction and establishment phase of a number of port facilities will generate different types of building waste. At the same time, it must be expected that scrap iron, oil and chemical waste and other waste fractions will be generated (see section 3.3). At present, we do not have sufficient information about the volume of waste and its composition. This should, therefore, be examined in more detail.

### *8.1.4 Waste waster – port facilities*

The types of waste water of interest in relation to the construction of the port facilities are:

- Sanitary waste water from the work camps in connection with the building sites.
- Waste water from the building and construction work.
- Rain and melt water drained from the building sites and related storage areas, construction sites, etc.

At present, we do not have sufficient information about the practical completion of the building and construction project. Therefore, it is not possible to make an informed estimate of the waste water volumes and the impact resulting from it.

#### *8.1.5 Air emissions – port facilities*

The establishment of port facilities includes blasting, drilling, construction equipment work, concreting, etc.

Air emission from energy consumption as a consequence of these activities is described in the general section on the environmental impact of the project, section 3.5.

#### *8.1.6 Noise – port facilities*

In connection with establishing the port facilities, the following activities will cause noise impact: Blasting, breaking down sheet piling, crushing plant, filling and dumping broken rock, concreting, vibration, marine traffic, construction equipment as well as transport of material and personnel.

#### *8.1.7 Dust – port facilities*

In connection with establishing the port facilities, the following activities will cause dust impact: Blasting, crushing, storage of dusty materials (e.g. cement for the production of concrete), movement of heavy equipment, raw material extraction as well as temporary waste storage facilities.

### 8.2 Port facilities in the operating phase

#### *8.2.1 Aquatic environment – port facilities*

*Marine environment - smelter*

In connection with operating the aluminium smelter, there must be facilities for storage of aluminium oxide in silos, anodes, fuel, etc. The marine environment will be affected by increased marine traffic, waste water discharge from port facilities (e.g. office buildings, warehouses for aluminium, etc.), storage facilities for waste to be shipped and so on.

On the basis of the material which the Greenland Ministry of Nature and the Environment has had access to, it is expected that the port facilities will be constructed in the outer fjord environment where sedimentation is poor and water exchange high – please refer to the table in section 8.1.1 (Marine environment - smelter and related port facilities) in this connection.

In general, additional information is required regarding depth, sedimentation conditions, ice formation, etc. with a view to being able to assess the vulnerability of the areas in question in connection with the construction of port facilities, increased marine traffic, waste water discharge, etc.

From an environmental point of view, we recommend that the location be chosen in relation to depth so as to minimize the need for initiating extensive deepening as much as possible.

In the operating phase, a monitoring programme will need to be developed.

### *8.2.2 Water resources – port facilities*

The requirement for water for operating the port facilities is estimated to be minimal; similarly, it is estimated that it will be possible to find the necessary quantity of water at any of the locations suggested.

### *8.2.3 Waste – port facilities*

In the operating period, the port facilities will result in different types of waste from general maintenance, household refuse, etc. At present, it is difficult to say anything specific about the volumes and types of waste.

### *8.2.4 Waste waster – port facilities*

The types of waste water of interest in relation to the port facilities in an operating phase are:

- Sanitary waste water from any accommodation and administrative premises built in connection with the ports.
- Waste water from outdoor activities such as the washing of cars.
- Rain and melt water from surface water areas including storage areas, etc.

At present, we do not have sufficient information about the practical completion of the project. Therefore, it is not possible to make an informed estimate of the volumes of waste water and the impact resulting from it. In a further phase, focus should be on the surface water to be drained from the port established in connection with the aluminium plant as there may be an increased risk that the surface water is particularly contaminated here.

### *8.2.5 Air emissions – port facilities*

Among other things, air emissions from port facilities result from dust emission at unloading and loading of raw materials, intermediary products, finished products and waste. Information regarding handling of these products is insufficient to estimate the environmental impact in this respect.

With regard to air emissions from energy consumption when using oil products, please refer to section 3.5 regarding the environmental impact of the project.

### *8.2.6 Noise – port facilities*

In connection with operating the port facilities, the following activities will cause noise impact: Loading and unloading facilities, cranes and other material, marine traffic as well as transport by land.

### *8.2.7 Dust – port facilities*

In connection with operating the port facilities, the following activities will cause dust impact: Loading and unloading of finished products and raw materials as well as any storage  in the port itself.

# 9 ROAD CONSTRUCTION

## 9.1 Roads in the construction and establishment phase

### *9.1.1 Water environment – road construction*

The construction of roads will result in the crossing of several rivers and the establishment of bridges. There is no information about which rivers will be affected by the roads. Please refer to sections 3.1 and 3.2.

### *9.1.2 Water resources – road construction*

Permission to establish roads within the protection zone of a drinking water lake will not be granted.

It is unknown how many people will be part of the construction activities, but it is expected that the workers will live in the work camps established in connection with the other subprojects.

### *9.1.3 Waste – road construction*

The construction and establishment phase of a number of roads is estimated to generate different types of building waste. Moreover, it must be expected that some of the other categories of waste mentioned under section 3.3. such as scrap iron, oil and chemical waste, etc. will also be generated. At present, we do not have sufficient information about waste volume and composition. This should, therefore, be examined in more detail.

### *9.1.4 Waste water – road construction*

The types of waste water of importance in relation to the construction and establishment of the infrastructure necessary for the project in the form of roads are:

- Sanitary waste water from the work camps in connection with any building sites.
- Waste water from the building and construction work.
- Rain and melt water drained from any building sites and related storage areas, construction sites, etc.

At present, we do not have sufficient information about the practical completion of the building and construction project. Therefore, it is not possible to make an informed estimate of the waste water volumes and the impact resulting from it.

The work with establishing the necessary infrastructure will result in activities over large areas. What is characteristic of a number of these areas is that there is no direct possibility of waste water being discharged to sea or fjord.

Therefore, it will be necessary to find another practical and environmentally sound way in which to handle the waste water.

#### *9.1.5 Air emissions – road construction*

The establishment of roads will result in activities in the form of drilling, blasting, work involving construction equipment, transport, etc. as well as possibly asphalt work.

Air emissions from energy consumption when using oil products have been described in the general section on the environmental impact of the project. Any asphalt work may increase the emission of hydrocarbons and PAH compounds.

#### *9.1.6 Noise – road construction*

In connection with establishing the road construction, the following activities will cause noise impact: Construction work, construction equipment, transport of material and personnel as well as blasting.

#### *9.1.7 Dust – road construction*

In connection with establishing the road construction, the following activities will cause dust impact: Construction work, construction equipment, transport of material and personnel, possibly blasting as well as fine and ultra fine particles from exhaust.

### 9.2 Road construction in the operating phase

#### *9.2.1 Water environment – road construction*

In connection with the operation, a monitoring programme may need to be developed.

#### *9.2.2 Water resources – road construction*

No consumption.

#### *9.2.3 Waste – road construction*

During the operation period, the roads will result in different types of waste from general maintenance. At present, it is difficult to say anything about the volumes and types of waste.

#### *9.2.4 Waste water – road construction*

The only type of waste water that is of any relevance in relation to the roads in an operating phase is rain and melt water. The environmental impact in this respect may constitute a problem. As at present we do not have sufficient information about the practical completion of the project it is not possible to make an informed estimate of the waste water volumes and the impact resulting from it.

### 9.2.5 Air emissions – road construction

First and foremost, air emissions from road construction include emission of exhaust gas, please see section 3.5 on the environmental impact of the project.

Furthermore, air emission from lorry and tanker transports of volatile and dusty materials may occur.

### 9.2.6 Noise – road construction

In connection with establishing the road construction, the following activities will cause noise impact: transport of material and personnel as well as traffic in general.

### 9.2.7 Dust – road construction

In connection with establishing the road construction, the following activities will cause dust impact: whirled up dust, dust from tyres, road dust / wear as well as fine and ultra fine particles from exhaust.

## 10 RISK ASSESSMENT

In connection with the construction and operation of large industrial plants, there will be a risk of extensive accidents as a consequence of unintended events. Examples to be mentioned are:

- fire and explosion
- waste of oil or chemicals
- spill or emission of environmental and hazardous substances as a consequence of breakdowns, power failure, etc.
- natural disasters in the form of hurricanes, rock slides, floods and the like.

The consequences of major accidents in connection with the construction and operation of an aluminium smelter and hydroelectric power stations could be serious and must therefore be part of the assessment of the final location of these plants. In that connection, the directions of prevailing winds in relation to the neighbouring towns and villages as well as the position in relation to vulnerable recipients will be of essence to the selection of location.

Plans must be prepared to prevent and meet considerable accidents as well as plans to fight any accidents and evacuate in case of any accidents.

In its environmental approval, the environmental authority (DEN) will determine the terms of prevention of accidents on the background of an assessment of the risk that considerable accidents may have consequences for the environment and health outside the facility.

Information about the risks and consequences of considerable accidents in connection with establishing and operating the aluminium smelter and the hydroelectric power station is lacking.

## 11 NECESSARY APPROVALS

In Appendix 1, we have made a preliminary overview of the environmental approvals, exemptions, etc. necessary for the completion of the project. During a later stage, this overview may be used to build a full picture of how many approvals, etc. will need to be prepared for the entire project. A conservative estimate is around 500 for the entire project.

This figure covers both the permanent plant necessary to the aluminium smelter and the hydroelectric power stations in an operating phase, but also approval for a number of buildings and plants only existing during the building and construction phase, but which will require an environmental approval all the same. As an example of this, we can mention temporary rock crushing plants in connection with building the hydroelectric power stations and dams.

We suggest that the environmental approval process takes place as an ongoing process so as to start by prioritising environmental approvals of the activities most critical in relation to the initiation of the actual building and construction. Activities relating to establishing the hydroelectric power stations and dam constructions should, therefore, be approved to begin with, followed by the transmission net and finally, the actual smelter. During the entire process, it will be important with an ongoing dialogue between the environmental authorities and the clients.

# 12 LEGISLATION AND LIMIT VALUES

In this section, we will briefly describe the environmental legislation of importance to establishing an aluminium smelter and the hydroelectric power stations. Special emphasis has been placed upon describing the legislative measures which the Greenland Ministry of Nature and the Environment expects to take in the coming years as well as describing the current framework for environmental approvals of heavily polluting industries, including how terms about limit values for emissions, etc. are laid down today.

## 12.1 Environmental legislation

The Home Rule Parliament Regulation regarding the protection of the environment[23] is the parent act for the environmental protection area in Greenland. The purpose of the Regulation is to prevent and fight pollution of air, water, ice, mountains and earth to protect plant and animal life and ensure human conditions of life.

The Environmental Regulation was last amended at the parliamentary session in the autumn of 2007 when an amendment of the regulation in force was passed with the particular purpose of specifying the rules for waste handling and disposal. When a fact-finding mission regarding waste water has been completed, a more extensive task will be initiated revising the regulation as a whole.

To protect the marine environment in fjords and sea in the Greenlandic territorial sea, the rules in the Marine Environment Regulation[24] apply. In the Marine Environment Regulation, rules regarding the transport of oil, liquids and

[23] Home Rule Parliament Act no. 12 of 22 December 1988 on the protection of the environment as subsequently amended.
[24] Home Rule Parliament Act no. 4 of 3 November 1994 on the protection of the marine environment as subsequently amended.

solid substances of importance to the aluminium project are laid down. The regulation contains a ban on dumping substances and material into the Greenlandic territorial sea and a right to limit the discharge of waste and waste water from ships.

The Marine Environment Regulation is not about to be amended.

Following the parliamentary session in the autumn of 2007, the Greenland Ministry of Nature and the Environment will initiate a thorough revision of several executive orders authorised by the Environmental Regulation of importance to the aluminium project as a whole.

The Executive Order on Environmental Approval of heavily polluting industries[25] is to be amended as the order does not include either aluminium industry or hydroelectric power stations at present (please see 13.3 regarding legislation on environmental approvals).

Executive orders on the disposal of waste[26] are also to be amended. Following the passing of the proposed amendment of the Environmental Regulation at the parliamentary session of the autumn of 2007, a number of improvements in the area of waste have been authorised, including laying down the framework for the collection of waste fees and sorting at source. The amendment was not necessitated by the aluminium project, but will naturally apply to this as well.

Before the end of 2009, the Greenland Ministry of Nature and the Environment will prepare an executive order on the assessment of the environmental impact. According to both the Environmental Regulation and the Protection of Nature Act, there is now authority to lay down more specific rules that before establishing e.g. a hydroelectric power station and aluminium industry, an assessment of the environmental impact must be prepared describing the consequences of the project to the environment and nature in general. As a minimum, rules regarding the preparation of the assessment of the environmental impact will include the aluminium smelter, the hydroelectric power stations, the ports and the utility trenches.

Finally, the Greenland Ministry of Nature and the Environment will publish a guide to preparing green accounts in 2008. Following a voluntary accounting

[25] Home Rule Executive Order no. 11 of 20 August 2004 on environmental approval of heavily polluting industries, etc.
[26] Home Rule Executive Order no. 28 of 17 September 1993 on the disposal of waste as well as Home Rule Executive Order no. 29 of 17 September 1993 on oil and chemical waste.

period of 2 years, rules will be laid down regarding the preparation and publication of green accounts for a number of companies, institutions and authorities. Alcoa is expected to be affected by these rules.

### 12.2 Legislation on environmental approvals

The legislation on environmental approval of heavily polluting industries is subject to part 5 of the Environmental Regulation, but the more detailed rules may be found in the Home Rule Executive Order no. 11 of 20 August 2004.

Schedule 1 of the executive order contains a list of heavily polluting industries, plants and arrangements which are all liable to approval. According to the rules, these activities must be approved environmentally before they are constructed and put into operation.

The executive order in force for the time being does not include aluminium production and hydroelectric power stations and, simply for this reason, an amendment of the order must be made soon.

According to Schedule 2 of the executive order, when applying for an environmental approval of a facility, etc., the applicant must describe the production of the facility including consumption of raw material, energy, water and intermediary products as well as expected pollution and pollution limiting measures.

The applicant must account for the extent to which the facility is based on use of the best available technology including the possibilities of limiting consumption of energy, water and raw materials and the possibilities of reducing the volume of waste and improving water treatment.

Finally, the applicant must submit proposals for the terms of self-regulatory control for the operation of the facility, e.g. proposals for maintenance and control of a waste water treatment plant and proposals for ongoing monitoring of the environment near the facility.

According to the executive order in force for the time being, an environmental approval of an activity must be granted before the construction of a plant is initiated and before any operation is begun. On the other hand, it should however also be noted that an approval must be used within a specified deadline which must not exceed 2 years from the granting of the approval. The short time horizon is to ensure that the approvals for heavily polluting industries granted are in accordance with the current information about environmental impacts and the best available technology. In relation to the current project, the above makes it necessary to have an ongoing dialogue with Alcoa and the clients of the hydroelectric power stations.

The Greenland Ministry of Nature and the Environment will evaluate in more detail whether further specification and tightening of the executive order being in force is required. Specifically, it must be evaluated whether the right of the Home Rule to limit an approval should be specified, cf. sections 12 and 19 of the executive order in force for the time being.

### 12.3 Limit values

In the legislation in force for the time being, no limit values have been specified for the discharge of polluting substances from the industry. However, an approval scheme for heavily polluting industries does apply (see section 13.3).

According to the rules regarding environmental approvals, Alcoa must obtain an environmental approval from the Greenland Ministry of Nature and the Environment prior to setting up an aluminium smelter. In the environmental approval, a number of requirements regarding the discharge and other environmental conditions of the facility will be set out following a review of the specific project including the application of the facility and the assessment of the environmental impact.

The environmental approval will contain a number of requirements including requirements regarding:

- Observance of the limit values for the discharge to air, water and earth
- Disposal of waste
- Limitation of noise
- Arrangement and operation of the facility

When setting out requirements regarding the limitation of the discharge of polluting substances, the practice is to use Danish and internationally passed limit values as a basis while at the same time making allowance for the vulnerability of the neighbouring natural surroundings Moreover, the principle is applied that the discharge must be limited as much as at all possible by use of the best available technology.

## 13 RESOURCE REQUIREMENT

In this section, we will describe the requirement for resources to undertake the many new tasks resulting from the project including in particular the requirement for resources for preparing environmental approvals, inspections and ongoing revision of approvals.

As mentioned in section 11, a conservative estimate is that in total 500 approvals and the like will have to be prepared in connection with the project (see Appendix 1). These approvals must be prepared over a period of approx. 3 years from the first initial discussions until all necessary environmental approvals exist in final versions.
In Appendix 2, a preliminary schedule of partly the process of the assessment of the environmental impact partly the process of the environmental approval has been shown.

The time consumption for the preparation of all these approvals will vary a lot; some may be prepared in 1 to 2 days whereas others – in particular for the aluminium smelter – will require months and, thus, quite different amounts of work.

The calculation below provides an estimate of the time consumption and the resource consumption. In the calculation, we have calculated with an effective case handling period of 5 working days per approval.

| | |
|---|---|
| 500 approvals of 5 working days | 2,500 days |
| Average number of working days / year / employee (excl. holidays) | 225 days |
| Average number of working days / 3 years / employee (excl. holidays) | 675 days |
| **Number of employees necessary** | 3.7 ≈ **4 employees** |

At present, the environmental department has a standard staffing level of 7, which will be increased by one additional employee for the area of waste on 1 January 2008 as a consequence of the passing of the proposed amendment for the Environmental Regulation under EM2007 by the Home Rule Parliament.

With the current task portfolio of the environmental department, it is not considered possible to undertake the task of approving environmentally all the sub-activities of the aluminium project without further resources being allocated to the department. As stated in the calculation above, it is estimated that four employees will be necessary.

# 14 SOURCES

**Reports, etc.**

*Aluminium industry in general*


- Bergsdal, Strømman & Hertwich 2004: The aluminium industry – environment, technology and production, NTNU rapport 8/2004.
- International Aluminium Institute, September 2007: Life cycle assessment of aluminium: Inventory data for the primary aluminium industry – Year 2005 update.


*Aluminium smelters in Iceland and Norway*


- Christensen, Bjørn 2007: Regulering af Al bransjen i Norge, Statens Forurensningstilsyn, møde 15.03.2007.
- Sør-Norge Aluminium a/s 2006: Miljørapport 2006
- COWI 2004: Fjardaal smelter project – free field noise model.
- Earth Tech for Alcoa 2006: Assessment of air quality impacts of emissions from the Alcoa aluminium plant in Reydarfjördur, Iceland.
- Exponent for Alcoa Fjardaal 2006: Screening risk assessment for air emissions from the Alcoa Fjardaal aluminium smelter.
- HRV Engineering for Alcoa 2006: Aluminium plant in Reydarfjördur, Fjardabyggd, Environmental Impact Statement
- HRV Engineering for Alcoa 20xx: Air quality guidelines and limits applied in Iceland
- Earth Tech for Alcoa 2006: Assessment of air quality impacts of emissions from the Alcoa aluminium plant in Reydarfjördur, Iceland.
- HRV Group for Alcoa 2005: Reydarfjördur – dispersion of pollutants in the sea from a proposed aluminium smelter.
- Exponent for Alcoa Fjadaal: Ecological risk assessment for use of wet scrubbers at Alcoa aluminum plant in Reydarfjördur, Fjardabyggd, Iceland
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# 15 APPENDICES

Appendix 1: Preliminary overview of necessary environmental approvals, etc.
Appendix 2: Preliminary schedule of partly the process of assessment of the environmental impact and partly the process of the environmental approval