Sustainable Urban Watermanagement based on the Concept of Industrial Ecology

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FOREWORD

Since the late 1960s the negative side effects of industrial and technological growth have produced the phenomenon that environmental problems today do not merely create local devastation but may cause global catastrophes. Evidently the damage of surroundings, physical sufferings, the discontent from experiences with conventional industrial and societal processes are signs. However, the real threat marks not only worsening environmental stress and the loss of life-quality, but the ability to destroy, if not the existence of life, at least the entire milieu for humanity.

Moreover have a number of human activities had negative impact on particular environments. Up to a certain level, nature is flexible enough to cope with damage, above this capacity irreparable changes occur: natural species decease, resources are depleted, biological processes are disrupted.

The traditional programmatic treatment for environmental problems with its "short-sighted philosophy" such as: avoiding pollution via building higher chimneys, carrying local waste to distant territories and escape from apparent environmental damages to recreation areas, contributed as well to the transition of ecological problems from a local to a regional and finally a global level.

The breadth of the ecological crisis inspires many theses, searching for an appropriate balance between the development of industrial cultures and the conditions of natural surroundings. Since the correlation of environmental issues is obvious, many of these concepts appreciate the global environment as interrelated areas. The present environmental situation is also perceived as extremely complex. Thus the problematique to gather relevant information on facts and effects of human activities towards nature is one of the most challenging for investigation.

The rate and scale of impacts on the environment demand systematised reflections on the structural relationships of heterogeneous sectors such as culture, technology and ecology. As the environmental crisis indicates, humans do not exist apart from their surroundings but interact with them through performances, routines and practices. Moreover, this interdependence implicates that humans value their milieu and have expectations towards the environment. Consequently, they should take an active part in creating desirable surroundings. Ecological improvements in society and industry require a better knowledge of corresponding activities between the sectors, in order to manage operations as responses to environmental requirements. These processes may entail fundamental social and economical restructuring and it will become necessary to revise goals and attitudes as well as procedures and techniques.

The intention of the following report on wastewater treatment in Trondheim community is to compare and relate political decision making, ecological necessities and technological activities to document their interdependence. It based on the second chapter of an interdisciplinary research, at the Norwegian University of Science and Technology titled:
"A Comparative analysis of functions based on the concept of industrial ecology."

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1 AN INTRODUCTION TO WASTEWATER TREATMENT ISSUES

1.1 Trondheimfjord

Norway's coast is unique with its various fjords forming not only fantastic scenery, but supplying humans with essential means for their well being. For that reason, settlings in Norway concentrate often nearby fjord areas. The "leftovers" of human activities in the form of sewerage, garbage, fishfeed, industrial waste etc., often end up in the fjords as well. At the same time fjords are important for leisure and recreation, and some of them well known as visiting places for tourists.

During the last years, some of the fjords have had to cope with more ecological hazards than they could sustain. Ecological hazard means: human caused pollution in the marine environment in the form of materials or energy, which damage living organisms in the fjord.

Since this became evident, the administration has increased its requirements for information on effects of contamination in maritime environments, in order to find appropriate solutions for fjord protection. Waste water management policies and practices thereby play a major role, for the environment as well as for economy and public health. Since many bodies are involved in this subject, the city of Trondheims´s efforts to expand and improve its wastewater treatment system over the last years, caused an intense controversy even if this issue claims to be act upon rather than something to dispute. A large and sometimes biting debate concerning the contamination of Trondheimfjord has finally centred on the question as to what degree the intended chemical upgrading of the existing wastewater plant in Høvringen benefits the ecological milieu and to what extent it is merely a result of environmental hysteria, the endconsequence being an increase in costs to customers.

Assessing the different positions from a holistic perspective requires an analysis of ubiquitous strategies for water- and wastewater treatment as well as their relation to the particular geographical, ecological and local circumstances of the area. Moreover it is necessary to investigate the different levels of political decisionmaking and transfer of international laws, to national, regional and communities bases.

The first section of this chapter will thus describe water- and wastewater policies comparatively, starting with the European situation, focusing then on national decisionmaking, and turning in the second section to policies and practices at Trondheim community level. Part three traces out the scientific debate between marine biologist and environmental engineers on wastewater issues and exposes their recommendations. The fourth section shows a methodological alternative to investigate such complex problems with the systems approach of industrial ecology. A comparison of intentions and results will be given in the summary of the fifth section.

Covering an area of 1579 km^2 (952 km^2 in Nord-Trøndelag and 627 km^2 in Sør-Trøndelag) the Trondheimfjord and the surrounding region of the Norwegian Sea facilitated 1995 an output of 254 Mio. NOK (abbr. Norwegian Crowns) from fishery products. The North Atlantic fishing banks off the coast provide Trondheim with a steady supply of catch. The geographical position of the region, north of the field of the algae and south of the coldbelt, grants also ideal conditions for fish farming; the world largest fish farm is located on the island Frøya at the mouth of Trondheimfjord. Trondheim has a central harbour for effective refining and distribution of fish. The transport company Nor-Cargo ships about 1000 tons of fish per year from Trondheim harbour all over Europe. The city is also a national centre for fish related research and aquaculture technique.[1]

As a recreation area Trondheimfjord offers a wide range of activities such as bathing, fishing, sailing and cruise travels. In 1996, 105 081 tourists visited Trondheim city, and many of those chosing the region because of the unspoiled nature of the fjord areas.

Humans have lived along the fjord for around 10.000 years. The population in the area has grown continuously from 2000 - 3000 in the 13th to 7478 people in the 18th century. From 1855 to 1961, the population has expanded rapidly from 16012 towards 143738 citizens. Subsequent urbanisation and industrialisation, associated with development of mining, agriculture, fisheries, energy, transportation, leisure activities and tourism, have created a classic complex of water management tasks such as water supply, pollution control, fisheries management, outdoor recreation demand etc.

1.2 Increasing demand for clean water

The ecological water cycle is constantly renewing the water supply. Enormous water masses[2] evaporate from the oceans and precipitate back to the solid earth as ice, snow or rain, Melting from mountains' ice and snow provide fresh water for rivers, streams and lakes.

Norway is certainly not in any danger running out of water, but the quality of fresh water could become a problem. If water resources are not treated more intelligently and efficiently it is also likely that consumers have to pay higher prices to receive desirable environmental benefits.

Water is clue for:

1. humans as uncontaminated drinking water and for sanitary reasons
2. agriculture for planting and breeding
3. bioregions to sustain ecosystems
4. industry for production purposes

1. Humans

Survival is dependent on water, which ranks second to oxygen as physical essence for life. The adult body consists of 55 to 75% water. Humans need lots of fresh water in supporting the absorption of food, regulating the body temperature, carrying nutrients and oxygen to cells, and removing toxins and other wastes. Moreover, it protects bodily cellular matter and organs, including the spinal cord, from shock and damage. Consequently, dehydration or contamined water increases the likelihood of diseases such as asthma, allergies, and headaches. Water can be polluted with contaminants with the likes of asbestos, lead, mercury, and organic chemicals.

The major factor influencing the quality of water is human population growth, and the connected urban and industrial development which are causing acute water and sanitation problems.

Nevertheless, industry could also play a vital role in tune with political decisionmaking and consumers by installing advanced water- and wastewater systems. This includes research and development of new technologies for the minimisation of wastewater and re-use of sludge and efficient infrastructural support for urban water management.

Significant progress has been made for instance in the area of water conservation. Most water is constantly being recycled by nature and up to a certain level technology can mimetise these processes, a method, which is in line with an industrial ecology axiom: technology may adhere to ecological activities.

2. Agriculture

Agriculture adds to water decay via the use of pesticides and fertilisers discharged into streams. It should be thus considered to be one central focal point for sustainable water strategies. Industry could contribute with improvements in environmental management, and irrigation technologies. Likewise, the introduction of fertiliser from transformed sludge is desirable.

3. Bioregions

The environment requires unpolluted water to maintain ecosystems and biodiversity. After e.g. rain falls, it can either soak into the soil and gradually metes out to plant roots or into aquifers or it can flow into surface water (lakes, streams, and rivers). In addition to the water cycle of rain, ice and snow evaporating and transpirating into the atmosphere, vegetation serves as a giant pump, returning water from the ground into the atmosphere

Water is exposed to a wide range of contaminants. The decline of species can be regarded as an indicator for the declining water quality. One of the best-documented consequences of human disturbances of an ecological cycle is the eutrophication, when high nitrogen loading causes a lack of oxygen in bottom waters. Eutrophication is linked to losses of the ecosystem diversity. In a sea floor community, it relates to seaweed, seagrasses, corals and planktonic organisms. In eutrophied waters an opportunity- or poison species may come to dominate the phytoplankton community. Increases in blooms of e.g. troublesome or toxic algae were observed in many estuaries and coastal seas. If water becomes unsafe for plants and animals, it might likely be unsafe for humans.

Formerly, industrial discharges were primary contamination sources. Today, however it is farms, urban and residential areas which are responsible for widespread pollution. Short-term economic gains have led to a dramatic ecological disaster - the relief costs far outweighing the benefits. Companies in the natural resource sectors of mining, forest products, paper, and oil and gas extraction need as do consumers, continued education in water practices.

4. Industry

The demand for water is growing quickly in industry in line with population- and production growth. Water consumption for industry means adopting procedures such as “Cleaner Production” and "Eco-Efficiency”. Both management approaches were developed by the World Business Council for Sustainable Development and promoted by the United Nation Environment Program's Cleaner Production as crucial elements for water issues. Cleaner production involves preventive and integrated environmental management strategies, implemented continuously in production processes and product life cycles to reduce risks. Eco-efficiency promotes that using fewer resources and producing less waste means making profits; the term "eco" relates to both economical and ecological benefits.

Eco-efficiency take place in areas such as:

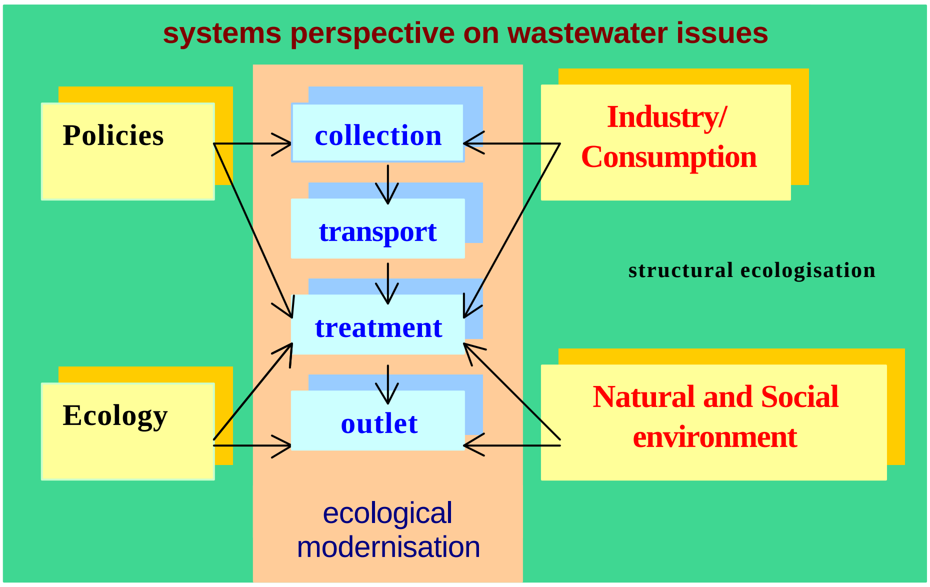
•Cleaner processes: modifying production processes and technologies so they generate less pollution and waste. This approach assumes that the product definition is fixed.

•Cleaner products: modifying the design and material composition of products so they generate less pollution and waste throughout their life cycle. This approach includes development of cleaner processes, but also allows for more fundamental changes in the product itself.

•Sustainable resource use: modifying the entire production system including relationships with suppliers and customers, so that fewer material and energy resources are consumed per unit of value produced[3].

1.3 Municipal waste-water treatment

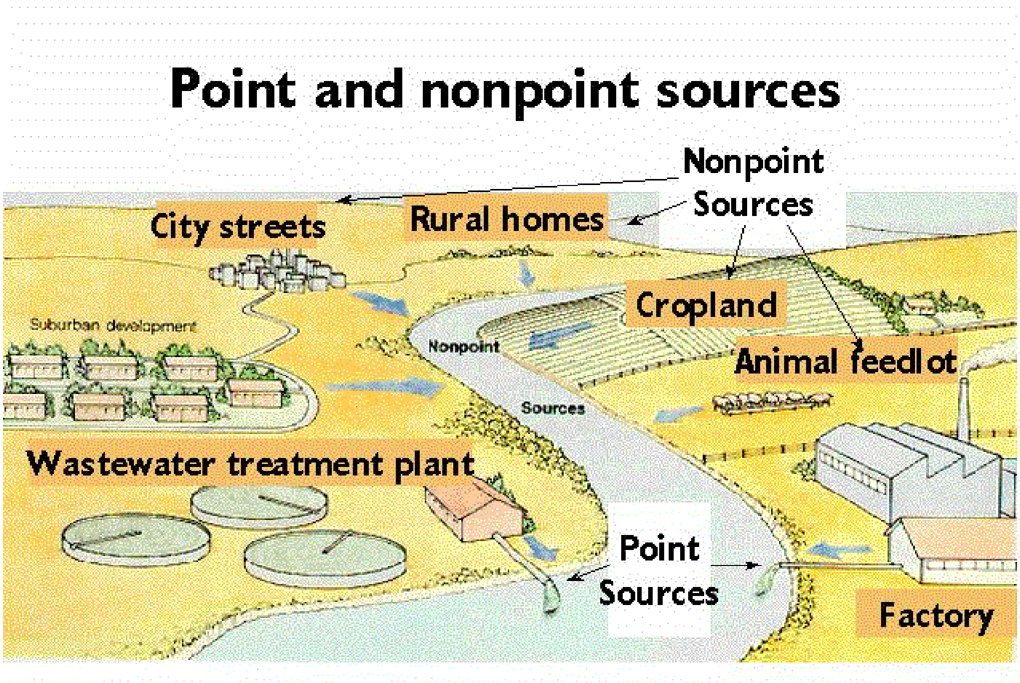
The system boundaries of a municipal wastewater system cover facilities and associated operations for collection, transport, storage, transmission, treatment, and distribution of sewerage. At the same time the wastewater system is embedded in a larger complex: Trondheim commune and Trondheimfjord. While the first system is connected with empirical and practical questions in the field of ecological modernisation, the latter asks for normative answers related to consciousness, responsibility and capacity for negotiations in the field of structural ecologisation.[4]



The primarily questions related to Trondheim wastewater system are:
• What are the types, amounts and effects of contamining substances?
• Where do they place in the system?
• What is the ecological response?

• What other problems occur, i.e. health hazards?
• What are the possibilities to prevent their flow into water or how to remove them?
• What supportive contribution can be expected from industry, consumers and administration?
The following targets were set for sustainable wastewater management:
• establish a healthy balance[5] of fresh water supply and pollution to preserve the natural function of assimilating contamination
• install with minimal cost effective water management
• grant water maintenance to the clientele in accordance with bioregional customs

Wastewater or sewerage can be categorised in three types: domestic sewerage, industrial sewerage, and storm sewerage. Domestic sewerage carries used water and sanitary sewerage from households. Industrial sewerage is used water from service-manufacturing- or chemical processes. Storm sewerage, or storm waters, is runoff from precipitation that is collected in a system of pipes or open channels.



point sources: specific, large, identifiable discharge outlets - wastewater treatment plants, industrial and factory drains

non-point sources: diffuse smaller various sources of drainage - agricultural fields, feedlots, street runoff, construction sites, and septic tank drainage.[6]

Domestic sewerage contains very little in quantity but a variety of dissolved and suspended materials. The main ingredients are organic but domestic sewerage can carry disease-causing microbes too. It is often the large volume of water, in which impurities are carried, that makes the disposal of domestic wastewater a difficult technical problem. Industrial wastewater usually contains chemical compounds, easily identifiable as outcomes of specific industrial processes. Storm sewerage includes organic materials, suspended and dissolved solids, and other substances washed away from the ground.

Main water hazards are:

• **BOD**: abbr. of Biological Oxygen Demand, materials that demand oxygen and therefore decrease the amount of oxygen in the water. High concentration of oxygen in water is an ecological quality factor. When sewerage is transmitted to a stream or a fjord, the decomposition of the organic materials starts. Microorganisms hereby use oxygen for their metabolistic processes. When the available oxygen level gets too low, trout and other aquatic species quickly disappear, a level of zero oxygen in the water finally causes an entirely toxic condition (sepsis). Usually industrial sewerage has higher BOD levels than domestic sewerage. The BOD of storm sewerage is of particular concern when it is mixed with domestic sewerage in combined sewer systems as for instance in Høvringen.

· **COD:** (chemical oxygen demand) refers to the amount of oxygen required to oxidise the organic compounds to carbon dioxide and water.

· **Suspended Solids**: solids in the water containing pollutants. Biosolids carry the same pathogenic organisms found in the domestic waste of the population and in food-related industries.

· **Nitrogen and Phosphorus**: nutrients causing growth of aquatic plants (excessively: eutrophication). e.g. of algae. Nitrogen and phosphorus are the most abundant major plant nutrients in biosolids.

Heavy Metals: Arsenic, lead, thallium, copper, nickel, chrome and mercury carried dissolved in drain or as parts of suspended solids (e.g. in sludge) can be toxic to the nervous system. Either acute or chronically poisoning, heavy metals may also cause cancer and genotype damages.

· **Pathogens**: specific causative agents (as a bacterium or virus) of disease, e.g. causing necrosis by secreting a toxin. The pathogens found in raw sewerage have included bacteria such as Salmonella, viruses such as Hepatitis A, and parasites such as tapeworms. Pathogens enter bodies in various ways via the skin, by water and food, or by being breathed into the lungs.

SPM: Suspended particulate matter as solid and liquid particles emitted from numerous natural and synthetic sources. SPM is a complex and variable mixture of different-sized particles with many chemical components. Larger particles may come from wind-blown and industrial dust, volcanic particles and plant pollen; finer particles tend to be formed by combustion and gas-particle conversions (mainly from SO2). The constituents can vary, although in urban areas they typically include carbon particles and polynuclear aromatic hydrocarbons (PAHs) produced by incomplete combustion.[7]

Wastewater is generally collected by a sewerage system. The task of water treatment is to remove microorganisms and disolved or suspended mineral-organic materials. In conventional wastewater treatment plants, physical, mechanical processes are often combined with chemical (e.g. clorination or coagulation) and biological treatment (e.g. oxidation). Frequently four levels of wastewater treatment can be applied: pre-, primary-, secondary-, and tertiary- (or advanced) treatment.

First screw pumps bring the influent wastewater up to an elevation such that gravity can be used to transport the water through the rest of the plant. The raw sewerage flows through bar screens where large material that could damage pumps, valves, etc is removed.

The sewerage is then pumped to the aerated grit chambers where dirt, sand, and other granular materials are removed, washed, and hauled to a sanitary landfill for disposal. To remove settable and floatable solids from the wastewater stream the flow of sewerage moves through long, narrow clarification tanks. At this stage, grease rises to the surface while heavier materials settle to the bottom of the tanks.

For secondary treatment e.g. Ferric Chloride and polymers are added to encourage coagulation. The solids are then scraped off the bottom and pumped to the digesters for treatment. At the bottom of the tank, a rotating scraper pushes the settled solids (sludge) down the slope into a pipe at the centre. The sludge goes to sludge handling. At the water surface, a rotating skimmer removes free oil, grease and other floating material. This material is pushed into a trough, collected, and removed.

Tertiary treatment or advanced treatment additionally uses aeration via trickling filters, rotating biological contractors (RBCs) or oxidation ponds, when it is necessary to remove extra suspended solids and to increase the biological oxygen reduced through the sludge. Disinfection of water through a selective destruction of disease causing organisms (pathogens) is possible with ultraviolet light, chlorine or ozone.

The quality of the water for the citizens is dependent upon the design of the wastewater facilities. The disposal of inadequately treated wastewater can seriously harm the surrounding bioregions and affect public health. Ideally, polluting contaminants should be prevented from entering the water. At the most, they can be allowed only in low concentrations. Naturally, there has to be more or less consensus on the identification and avoidance of hazards. Several governments' acts for water and wastewater management have been signed during the last decades, dealing with planning and implementation of programs for conservation, development and utilisation of water resources.

2 POLICIES AND PRINCIPLES

2.1 From international legislation to community regulations

2.1.1 Sustainable development

Agenda 21 as an international layout for actions concerning a global sustainable development emphasises environmental degradation and poverty as most important problems. It represents a common platform for development and co-operation, based on the principle that sustainability demands adequate environmental, social and economic development, and thus the participation of groups in different yet, corresponding areas is necessary. In the Report of the United Nations Conference on Environment and Development[8], chapter 21, the following sections relate to environmentally sound management of solid waste and sewerage related issues:

21.27. Even when wastes are minimised, some wastes will remain. Even after treatment, all discharges of wastes have some residual impact on the receiving environment. Consequently, there is scope for improving waste treatment and disposal practices such as, for example, *avoiding the discharge of sludge at the sea*.

21.29. Governments, according to their capacities and available resources and with the co-operation of the United Nations and other relevant organisations, as appropriate, should:

(c) By the year 1995, in industrialised countries, and by the year 2005, in developing countries, ensure that at least 50 per cent of all sewerage, wastewaters and solid wastes are treated or disposed of in conformity with national or international environmental and health quality guidelines;

(d) By the year 2025, dispose of all sewerage, wastewaters and solid wastes in conformity with national or international environmental quality guidelines.

2.1.2 The Esbjerg declaration

The First International Conference on the protection of the North Sea was held in Bremen 1984 with participation from Belgium, Denmark, France, Germany, the Netherlands, Norway, Sweden, United Kingdom and the European Commission. The aim was to provide a political impetus to intensify the work within relevant international bodies, and to ensure more efficient implementation of the existing international rules related to the marine environment in all North Sea States. The London Conference followed the Bremen Conference in 1987. At the London Conference, non-governmental organisations were for the first time permitted to attend parts of the conference. The Hague Conference followed the London Conference in 1990 where the Swiss Confederation for the first time attended. The Fourth Conference was held in Esbjerg in 1995. The ministers agreed that the next North Sea Conference would be held in Norway in the period 2000-2002.[9]

The North Sea Conferences are Ministerial Declarations and political commitments that play an important role in influencing legally binding environmental management decisions both nationally and within the framework of competent international bodies. They address a wide range of issues such as species and habitats protection, pollution by hazardous substances and nutrients, radioactive substances and pollution from ships and offshore installations.

Among wastewater priorities to be addressed are:

· **the protection of species and habitats**[10]

· **the prevention of pollution by hazardous substances:**

1.to pursue the development and use of clean technology for production processes;

2.to pursue the development and use of treatment technology;

3.to give priority to the development of environmentally sound products taking into account the whole life cycle of substances or products

4.to substitute the use of hazardous substances by less-hazardous substances or preferably non-hazardous substances where these alternatives are available

5.to employ usages and practices that avoid losses of hazardous substances to the environment.

· **further reduction of nutrient inputs:**

1.all North Sea states except the UK (which is not under an obligation to do so) have drawn up national action plans

2.all states, except France (which will achieve a 25% reduction) expect to reach reductions in phosphorus inputs of the order of 50% by 1995 into nationally defined problem areas

3.the 50% reduction target for nitrogen will not be achieved by 1995, with all contributing states concerned expecting to achieve between 20% and 30% reductions of nitrogen inputs into potential problem areas.

2.1.3 National assistance policy

On 1 January 1994 the European Community linked with five of the seven members of the European Free Trade Association (EFTA) to create the "European Economic Area" ("EEA").

All 7 EFTA members (Austria, Finland, Iceland, Liechtenstein, Norway, Sweden and Switzerland) signed the relevant agreement in 1992 at Oporto. As a system of co-operation, the EEA provides greater correspondence in different sectors than did previous free trade agreements. Key features of the agreement are:

- ensure free trade in industrial products and free movement of capital, services and persons by means of joint legislation
- provide common rules for state aid
- form the basis for Norway's co-operation in Western Europe in the fields of environmental protection, education, research, consumer issues and social issues

Much of the EEA legislation in the environmental sector is in the form of minimum requirements. Environmental policies' objectives for co-operation are:
- to preserve, protect and improve the quality of the environment;
- to contribute towards protecting human health; and
- to ensure a prudent and national utilisation of natural resources.
Member States are permitted to maintain and introduce more stringent protective measures, provided that they deal directly with environmental concerns and do not form an unjustifiable obstacle to the free movement of goods. This means, that it is the task of the individual countries to maintain or upgrade laws and standards.[11]. One objective of Norwegian national policy according to Report No. 19, Storting (1995-96) is to reduce the pollution of soil, air and water. For the latter, this applies to strategies such as:
1. Development of sustainable production systems and measures to preserve biological diversity. Efforts to improve the production base in primary industries are important (agriculture, forestry and fisheries).
2. Water supply, sewerage and waste management should be emphasised, also in urban areas. Management and direct technical measures may be appropriate.
3. Industrial pollution and the disposal of hazardous waste will be relevant in some cases. Co-operation with Norwegian industry and trade associations should be evaluated.

In 1987 the ministers of the environment from 9 North Sea states agreed to reduce nutrient inputs into areas where these might cause pollution, and to achieve a substantial reduction (50%) of phosphorus and nitrogen in these areas. Further discharges of selected persistent organic pollutants to the whole North Sea areas have to be reduced by 50-70% depending on the micropollutant question.[12] In 1992, Norway approved the OSPAR-convention[13] for preventing and eliminating pollution, and to protect the maritime area against the adverse effects of human activities. The Norwegian Pollution Control Authority (SFT) has given first priority to eliminate the effluents of 13 substances classified as micropollutants as quickly as possible.

The "precautionary principle", the “critical load- and the "polluter pays"-principle were main contents within the OSPAR declaration which, in accordance to the requests above, give guidelines for political decisionmaking on national and regional levels:

1. Precautionary principle: Give nature the benefit of the doubt. A discharge or emission should be regarded as harmful until proven harmless, exploitation of a limited resource should be regarded as unsustainable.

In a situation of high potential risk and lack of, or inadequate information, the concept of precaution requires that the onus of scientific proof be on those who intend to draw benefits from the resource and contend that there is no risk; i.e. reversal of the burden of proof.

2. Critical-load principle: The limit of pollution that the natural environment can withstand without becoming permanently damaged. The critical load should not be exceeded.

3. Polluter-pays principle: The natural environment is not free of charge. Industry must be stimulated to consider the environment.[14]

The Council of European Communities[15] publicised 1991 a directive on treatment plants, which states that: “The member states shall ensure that urban wastewater entering collecting systems shall before discharge be subject to secondary treatment or an equivalent treatment as follows:

- at latest by 31 December 2000 for all discharges from agglomerations of more than 15.000 p.e. (population equivalent)
- Beside exists several parameters for BOD, COD, phosphorous and nitrogen levels.
  BOD: 25-mg/l O_2 concentration, 70-90% minimum of reduction
  COD: 125-mg/l O_2 concentration, 75% reduction
  Suspended solids: 35-mg/l O_2 concentration, 90% reduction[16]

2.1.4 Local Agenda 21 and wastewater issues in Trondheim

The realisation of water management based on political decisions take place at regional and at local levels. In context with the directives from Agenda 21, the North Sea Declaration, and the European Community Council, the Norwegian Ministry for Environment Protection changes its policy from so called “end-of-pipe” to comprehensive solutions.

When national requirements are fulfilled, each community has the possibility to define particular standards of water quality for the local consumers.

Regarding predominantly the ECC directive, Article 4, the county government of Sør-Trondelag decided chemical upgrading for Høvringen to reach a reduction of 85% of the suspended solids in the sewerage. In a revised document, the word “chemical” is replaced by “advanced“. The status quo (1999) on which the county and the municipality of Trondheim agreed, is to implement advanced treatment in Høvringen until 2002.

But the argument on appropriate strategies continues. The intended enlargement of Høvrin-gen with chemical cleaning is rumoured to be more “political cleansing” than ecologically necessary. Hence, over the last years the debate on Trondheimfjord and wastewater management has become more and more a politicum. The former decision from the county government on chemical extension based on a recipient examination from the Oceanor Company from 1987-88. Some data in this report suggested reducing bacteria levels and sludge. Nevertheless, Oceanor pointed out too that chemical cleansing would not solve the problems best, but that improvements of point and non-point sources of sewerages and of the water system might be much more effective.

One main argument in the debate is that chemical upgrading for Høvringen is costly, especially concerning the running costs (capital costs app. 90 Mio. running costs ca. 22 Mio, sum 580 Mio. NOK) compared to e.g. mechanical improvements (capital costs 352, running costs 14, sum 460 Mio. NOK)

The investments would increase the charge for private customers for around 65%-70% from 1999-2002 (afterwards it shall remain steady). For the largest commercial consumers an increase of 60% means:

NTNU (University):	1.181.000	NOK
EC Dahl´s Brewery:	1.125.000	NOK
Nidar:	877.000	NOK
Farmers Selling.Com	369.000	NOK
Electricity Com.	290.000	NOK[17]

In relation to the argument that the fjord is ecologically endangered, experts pointed out that it can cope with the wastewater, released in the bottom area, because of its high stream flow. The main water masses in the fjord shift several times and the deep-water masses are at least substituted once a year. It is moreover not guaranteed that a new chemical cleaning plant would have great impact on the water quality of the fjord.

The Høvringen case shows that sufficient pre-cautionary strategies progressing ecological and cultural sustainability are most required. From an industrial ecology point of view preventive applications such as improvements of point and non-point sources are more convenient than end of pipe solutions (see Chapter II.4.) The dilemma of sustainable wastewater management is thus a very interesting one anyway with respect to the concept of industrial ecology. One the one hand there seems to be no ecological reason for chemical upgrading of the Høvringen treatment plant or any other improvements because the Trondheimfjord is able to cope the sewerage. On the other hand there are of course moral obligations, legal contracts and social concerns such as health, recreation and the wish to protect the natural environment.

2.2 From principles to applications: Høvringen

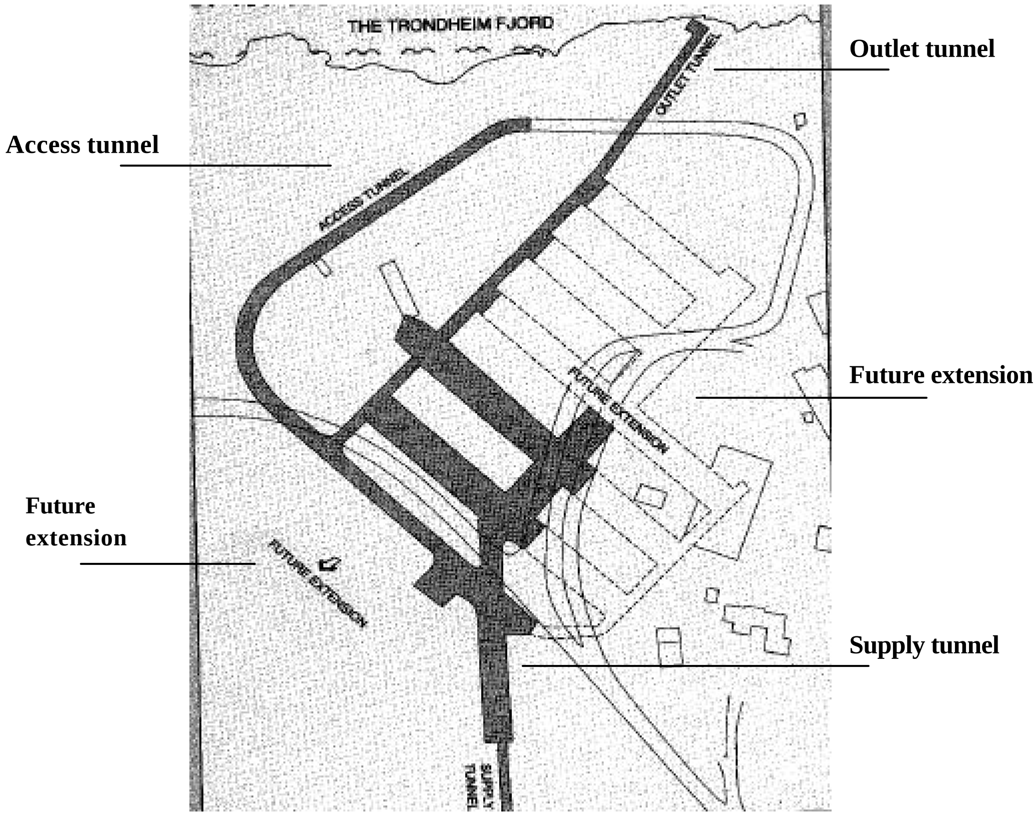
The underground sewerage treatment plant in Høvringen is situated about 2-km northwest of the city of Trondheim centre close to the fjord. The main interceptor Høvringen wastewater tunnel runs from south to north beside Nidelva, to take advantage of the continuous, gradual slopes of the river valleys. The landscape is hilly, so the sewers are laid with a rather steep inclination and the wastewater flows fast through them. This causes an enrichment of Oxygen to the wastewater by turbulences, resulting decreased amounts of easily biodegradable organic matter (organic acids) in dissolved form and increased amounts of heavily biodegradable organic matter as biomass.[18]

The main interceptor is connected with Høvringen plant at the coastline. It has a length of 6,8 km. Two types of sewer systems supply the main interceptor:

- Sanitary sewers, which carry raw sewage from homes and businesses to plant.
- Combined sewers, which carry a combination of raw sewage and stormwater runoff.

The sewer pipes are made of concrete. They are laid following street patterns, and access holes with metal covers are provided periodically for inspection and cleaning. Connected to the main interceptor are 83 subcatchments. The system consists of 50 overflow structures, 22 pumping stations and 11 direct connections to the main sewer.[19] It serves 136.000 p.e. The facility has been designed and constructed to be expanded in the future (intended was chemical cleansing). The first stage was completed in 1978 as a pre-treatment facility consisting of trash-racks, sand traps and fat skimmers (removed sand 700 m^3, 1989). Rotation filter screens with openings of 1-mm diameter were introduced in 1988. The cleaning amount is 1.0008 tons (1996) of sand and filter contents. The grit (removed 1200m^3, 1989[20]) is pressed and transported to containers and removed. The ventilation was improved. A recovery plant was established that converts warmth from the sewerage to the energy supply for the plant. The plant serves 90000 persons that is about 70% of Trondheims population, and slightly less than 80% of the plant capacity. Only one of the two main parallel caverns that was excavated in 1978 has so far been taken into use. Tunnels and caverns are basically unsupported. Rockbolts have been installed and shotcrete applied only where strictly needed. The major part of the shotcrete was applied only a couple of years ago, and steelfibre reinforcement was used. The marine outfall has a depth of 47m located 100m from the shore.[21] The wastewater of Høvringen has high hydraulic loads due to long periods of rain and snowmelt. The hydraulic load is 950 litre per second (max. 1900 litre). The current inflow to the plant in a representative year is within the limits of 50.000 and 100.000 m^3 /day for 80% of the time. The maximum daily inflow is close to 300.000 m^3/day.[22]

1986 the county governor advocated an extension of Høvringen considering a suspended solids reduction of 85%, the avoidance of sludge sedimentation, excessive plant growth in beach zones and improvements of the poor working conditions (air, temperature, humidity) within the plant. Trondheim commune appealed against this in 1989 to the Ministry of Environment, but the application was confirmed in 1990. 1996 the commune applied for a five years postponement for Høvringen, one year was accepted, and in 1997 the legislation given from EEA, the Ministry of Environment and the Norwegian Pollution Control Authority took place. 1998 another postponement for two years was made. Until today different cleaning strategies have been assessed, and a similar chemical process as in the Ladehammer plant is favoured. However chemical cleaning does not remove heavy metal contents, which is important for uncontaminated bathing places as well as for the use of sludge as fertiliser.[23] Therefore an additional pasteurisation of the sludge is necessary. Mechanical filtering which is less expensive and would remove 50% suspended solids is also taken into account.



Høvringen sewerage plant - Commissioned 1978

3 THE SCIENTIFIC DISCUSSION

3.1 Engineering schemes

Technologies to treat and manage wastewater depend on the characteristics of the sewage, the required environmental quality of discharges, the existing treatment facilities and on the implementation- and running costs. The volume of sewerage released in Trondheimfjord every day is approximately 100 000 m^3 with ca. 12-15 tons of sludge. It contains small quantities of hazardous substances in a matrix of non-hazardous matter. The following technological proceedings for wastewater treatment in Trondheim are currently relevant for the discussion. In order to give a survey on the likelihood of their successful implementation they will be evaluated within a simple effort-efficiency matrix.

Alternative 1: Mechanical purification of the sewerage

This physical process includes screening, grit removal, and sedimentation. The screens are cleaned mechanically, and the material (wood, stones etc.) is disposed. Grit causes excessive wear and tear on pumps and other plant equipment. Its particularly important for systems with combined sewers to remove grit carrying silt, sand, and gravel, from storm or snowmelt run off. Suspended solids that pass through screens and grit chambers are transported to sedimentation tanks. As the sewage flows through these primary clarifiers, the solids gradually sink to the bottom. The primary sludge is moved along the tank bottom by mechanical scrapers. The sludge is collected while mechanical surface-skimming devices remove grease and other floating materials.

Alternative 2: Chemical upgrading:

Chemical treatment of water involves clarification. Clarification in the first phase is done by sedimentation. Yet, some smaller and lighter particles do not settle at all. Because of this a chemical process known as coagulation is added. Chemicals (coagulants and polymers) bring those particles into larger, heavier masses of solids called floc. Coagulation includes rapid mixing and slow mixing. Rapid mixing disperse the coagulants evenly in the water completes the chemical reaction. After a small flash-mix provides about one minute of detention time, a longer period of gentle agitation is needed to support particle collisions and the growth of floc. This mixing, flocculation happens in a tank at least for a half-hour of detention time. After the flocculation, the water flows into the sedimentation tanks. In the

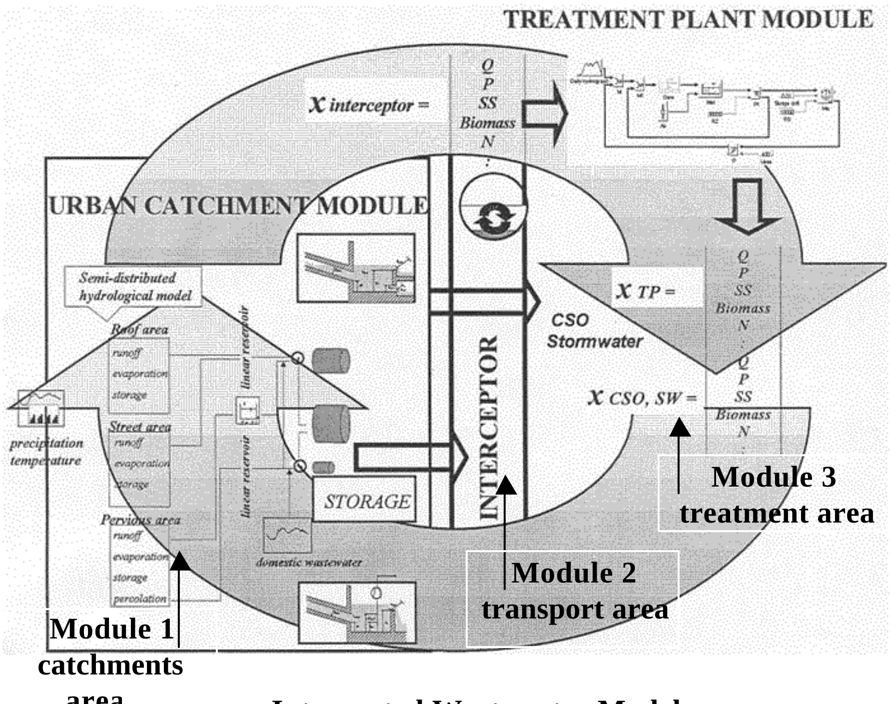
Ladehammer plant coagulation and sedimentation is combined in solids-contact tanks.

An alternative to conventional coagulation processes is a combination of biological and synthetic polymers for wastewater cleaning. This process had been applied intending the reduction of nitrogen in sewerage. Gels of polymer alginate are used to entrap cells. The alginate has a double function: to immobilise the cells with low loss of activity and cope with the high microbial and organic load of the sewerage.[24] Since the gel beads dissolve within few weeks the algiante is used as a server for a synthetical polymer, called PVA-SbQ. The goal of the process is to reach an acceptable nitrification activity at low temperatures by choosing a less temperature-dependent factor. The results showed a supportive strategy for self-purification of wastewater. During the gel entrapment it was possible to maintain 70% of the nitrification activity of active nitrifying sludge.[25]

Alternative 3: Improvements of the entire wastewater system:

A sustainable wastewater management concept was presented from SINTEF[26] environmental engineers in form of an integrated urban water model. The idea is to use existing technologies related to systematised wastewater treatment, where, via an appropriate design, functions of several modules are integrated and serve to support natural processes.

In the Trondheim wastewater system poor drainage, blockages and leaking pipes sometimes lead to sewage overflows into nearby streams. Sanitary sewage overflow happens when sewer pipes clog or pumping stations break down. Raw sewage overflows from leaking pipes e.g. into Nidelva river. Storms or snowmelt causes combined sewer overflows (CSO) when flow capacity of the pipes leading to a treatment plantis exceeded. They occur when a single collection pipe is used to convey both storm runoff and sanitary wastes. When heavy rains cause these combined sewers, completely untreated sewage is discharged directly into Nidelva River. One answer to this problem is the integrated waste treatment model[27]. The model bases on a simulation under a joint Matlab/Simulink platform. It considers typical Norwegian conditions such as high water quantities because of snowmelt and long periods of rainfall, weak and cold sewage, and mechanical/chemical treatment processes. The model has been implemented on Trondheim /Høvringen Wastewater system. The overarching goal was to reach a high degree of diffusion of contamination in reduced CSO quantity (water masses as run-off from storms etc.) and to prevent large volumes of sludge. Improving remedial measures of whole area in two phases should do this. Phase one is applied before the sewerage enters Høvringen plant and includes a set of restorative activities, among others the reparation of leakages and the replacement of over twenty year old, worn out pipes (preferably with pipes of advanced or more environmental sound material). Phase 2, which is ongoing, involves designing activities within the plant, to reduce the water masses and their heavy metal and bacteria content, and to decrease (but not to eliminate) phosphorous and nitrogen.



Intergrated Wastewater Model

The integrated model perceives the water supply in Trondheim as an open system, where different elements interact. The scheme marks three modules representing urban wastewater collecting (A), -transport (B) and -treatment (C). Each module incorporate sub-systems showing different parts of the waste waster system. The collecting module includes water balance, the sewer network, and overflow structures, pumping stations and storage. Its sub-system includes different types of runoff: from roofs, streets and parks. The simulation model can deal with several substances (measured were suspended solids, phosphorous, and chemical oxygen demand (COD) plus the wastewater flow and overflow discharge.

The most important remedial measure was:

The refinement of the separation of combined sewers and reduction of infiltration/inflow in the sub-catchments served by the old networks. Simulation showed a significant decrease of the hydraulic load of the plant. Activating the available storage in the main interceptor shall support this strategy.

Evaluation: Effort-efficiency analysis

CRITERIA	STRATEGIES 1 2 3
Economic investment	Low[28] Medium High
1. Length of the strategies pay-back	1—–2—-3—–4—–5—6—7—8-—9--10
2. Length of projects development time. The shorter the time the less likely objectives, users and personnel will chance	1—–2—-3—–4—–5—6—7—8-—9--10
Operational investment	highest benefit = lowest effort lowest benefit = highest effort
1. User acceptance. Support from public	1—–2—-3—–4—–5—6—7—8-—9--10
2. Changes to organisation politics and structure. Accordance to existing policies	1—–2—-3—–4—–5—6—7—8-—9--10
3. Changes to method of operation, practices and procedures	1—–2—-3—–4—–5—6—7—8-—9--10
Technical investment	
1. Skill and design facilities. Former experience	1—–2—-3—–4—–5—6—7—8-—9--10
2. Proven equipment, hard-and soft-ware	1—–2—-3—–4—–5—6—7—8-—9--10
3. Strategies complexity. Requirement of high or modest technical skills and specialisations	1—-2—-3--4—-4—-5—-6—-7—-8—-9—-10
Environmental benefit	
Ecological relevance	1—–2—-3—–4—–5—6—7—8-—9---10
Aesthetic relevance	1—–2—-3—–4—–5—6—7—8-—9---10
Social acceptance	1—–2—-3—–4—–5—6—7—8-—9---10

Remarks: Strategy 1 will improve the existing situation slightly through sedimentation with increased separation of particles. Economical and technological investments are comparatively low.

Strategy 2 is connected with larger technological efforts and is rather costly. The proposed amount for chemical upgrading in Høvringen has been estimated around 400 Mio. NOK for capital and 22 Mio. for operation costs. In addition are the costs for production and transport of around 2000 tons of chemicals and transportation for the sludge. On the other hand, coagulation grants high quality sludge. Costs could be offset by selling this as by-products (fertiliser, etc).

In general, strategy 3 reduce overflow discharge and pollution load to half the volume.[29] It is rather cost intensive. The supporting strategy is a cost effective means of reducing overflow operation before it reaches the treatment plant. The strategy requires attention to the increased opportunity of sedimentation occurring in huge storage tanks.

3.2 Fjord ecology

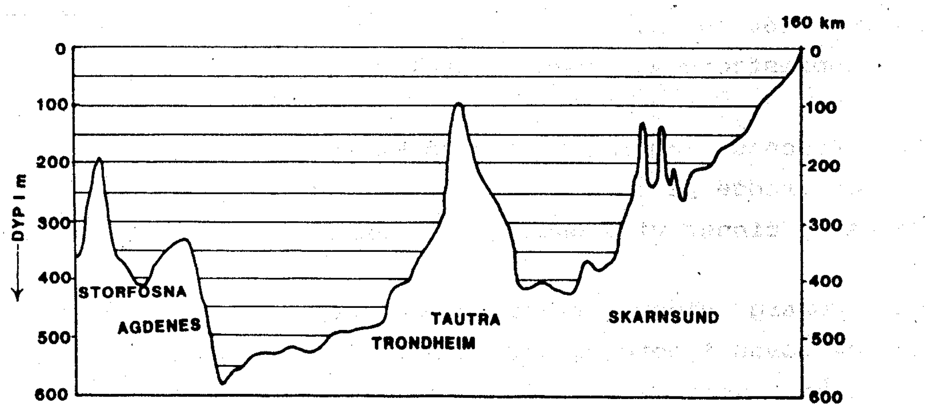
Decisions on wastewater management that contribute to an ecologically vital and diverse Trondheimfjord should at least consider some of the geographical, aquatic and biological particularities of this area. It is for instance important that not only BOD, nitrogen, phosphor, heavy metals and pathogens from households-, industry- and agriculture sewerage cause ecological problems, but one should not underestimate direct encroachments such as mechanical disturbances by ships (destruction of coral reefs), use of contaminating anti-fouling paint for ships, and fishing routines (increasing the rate of opportunity species, which are fast and high in quantity growing, and decreasing diversity, as existence of different species). Other critical factors are the disposal of solid wastes that conflict with sustainable water treatment and the problem of river pollution in Trondheim.

3.2.1 Physical features

The Trondheimfjord is a part of the Norwegian Sea, a zone of the North Atlantic Ocean, bordered northwest by the Greenland-, northeast by the Barents sea, east by Norway, south by the North Sea, Shetland and Faroe islands, and west by the Atlantic Ocean, Iceland and Jan Mayen. The Norwegian Sea reaches a maximum depth of about 3,970-m. A submarine ridge linking Greenland, Iceland, the Faroe Islands, and North Scotland separates the Norwegian Sea from the open Atlantic. Cut by the Arctic Circle, the sea is often associated with the Arctic Ocean to the north. The warm Norway Current flows, northeastward off the Norway coast and produces generally ice-free conditions. Colder currents mixing with this warm water create excellent fishing grounds, mainly for cod, herring, and whitefish.

The Norway Current, sometimes considered a continuation of the Gulf Stream (issuing from the Gulf of Mexico), enters the Norwegian Sea north of Scotland and flows northeastward along the coast of Norway before flowing into the Barents Sea. With subsurface temperatures ranging from 8^0 C in the south to about 4^0 C in the north, the current influences also the climate of Norway.[30]

The Trondheimfjord is a wide and open fjord with several deep thresholds, characterised oceanographically as an Inland Sea. The upper level (1-50m) carries deep brackish water. In the upper level streams water over the nearest surface. This flow is replaced with the flow from the next deeper level. The middle level (50-200m) holds water masses between brackish water and threshold level. The bottomwaters (200-600) watermasses under threshold level. The shift of deeper masses is mainly depended of the wind conditions. Enduring wind from north presses the coast water out and the Atlantic water up. When the coast water is over the threshold level it flows in the fjord and into deeper parts of the basin. Old groundwater is pressed up and replaced by freshwater. This happens mostly in the spring season[31].

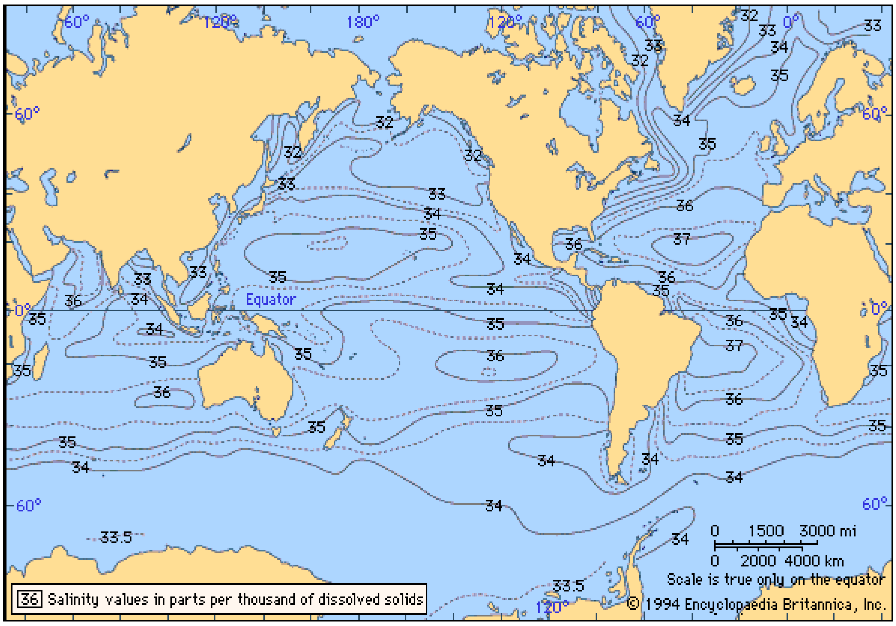


Longitudinal section of Trondheimfjord

3.2.2 The aquatic situation

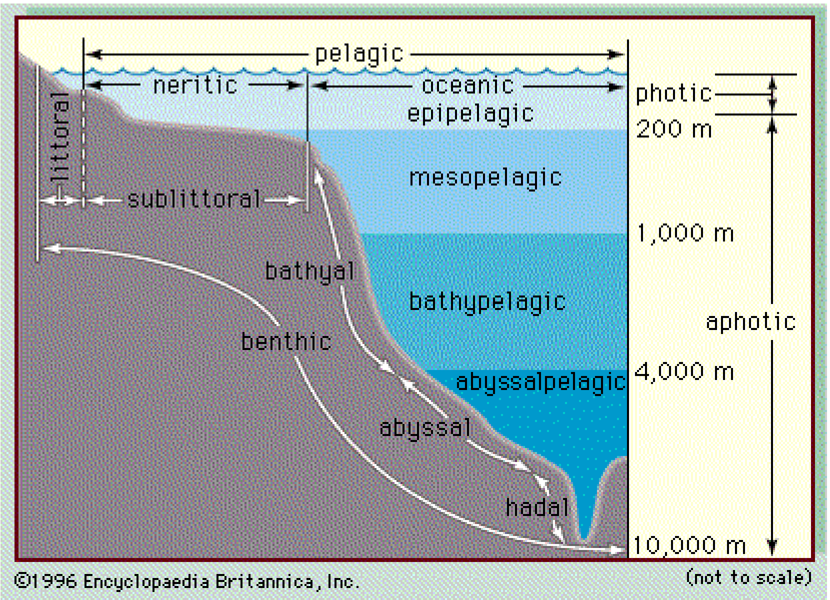
Seawater is pure water plus dissolved solids and gases. The dissolved solids come from 'weathering' processes of continental landmasses, rocks being dissolved by rainwater and flowing out to sea with the rivers. The gases come from the atmosphere. As water is a universal solvent, many different compounds are dissolved in it. One litre oceanic saltwater contains ∅ 35 mg of dissolved compounds, including inorganic salts, organic compounds from living organisms, and dissolved gasses. The solid substances are known as 'salts' and their total amount in the water is referred to by a term known as salinity. The amounts of dissolved salts in saline water range from fresh water with 1mg/l to ocean water with around 35mg/l. Oceanic salinities generally range from 34 to 37 mg/l. Variations from place to place are due to factors such as rainfall, formation of sea-ice evaporation, biological activity and radioactive decay. Fresh supplies of salts are now being added to the oceans from the rivers at roughly the same rate that various physical, chemical and biological processes are removing them. In contrast to the other salts, nitrates, phosphates, required for photosynthesis and silicium vary in concentration related to biological activity. .

Beside the salinity, temperature is another very important physical parameter in the marine environment. It limits the distribution and ranges of ocean life by affecting the density, salinity, and concentration of dissolved gasses in the oceans, as well as influencing the metabolic rates and reproductive cycles of marine organisms. Latitude, depth, and proximity to the shore affect the seasonal range of temperature in the ocean. Marine temperatures change gradually because of the heat capacity of water. In the abyssal zone, water temperatures are remarkably stable and remain virtually constant throughout the year. Similarly, in equatorial and polar marine regions, ocean temperatures change very little with season.[32]



3.2.3 The marine ecocycle

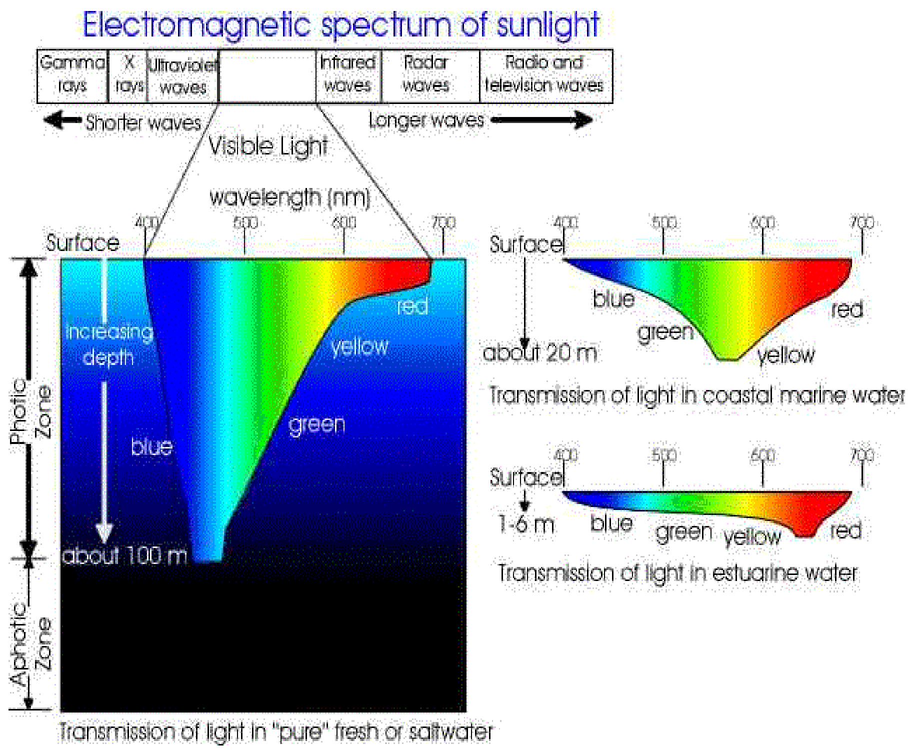
Oceans are the largest repositories of organisms on the planet, with representatives from about 40 phyla (major groups of animals); at least 15 of these groups are found only there. Life varies from large whales, fish, corals, shrimp, krill and seaweed, to the microscopic bacteria floating freely in the seas. The marine environment consists of different species and habitat depending on each other. The characteristics of specific bioregions create different habitats and influence what types of organisms will inhabit them. The availability of light in different seasons, the water depth, and topographic circumstances affect a marine ecosystem. The area of complete darkness is called the aphotic zone (see figure below). The more illuminated region above it the photic zone, within the euphotic and disphotic zones. The euphotic zone is the layer closer to the surface that receives enough light for photosynthesis to occur. Beneath lies the disphotic zone, which is illuminated but so poorly that rates of respiration exceed those of photosynthesis. The euphotic zone can extend to depths of 80 to 100 metres and the disphotic zone to depths of 80 to 700 metres.



Marine life forms can be classified broadly into two environments:
1. The water or pelagic environment upto 11,000 metres' in depth where animals and organisms such as plankton and nekton live. The numbers of individuals and species decrease with increasing depth. Pelagic life consists of three categories. The phytoplankton, which constitute the food base of all

marine animals, are microscopic organisms that inhabit only the sunlit uppermost oceanic layer, using sunlight to photosynthetically combine carbon dioxide and dissolved nutrient salts. Zooplanktons are the marine animals that rely mainly upon water motion for transport, although some forms such as jellyfish are feeble swimmers. Zooplankton subsists on phytoplankton and smaller zooplankton and is dominated in their numbers by small crustacean copepods and euphasiids. Nekton, the free swimmers, are dominated by the bony and cartilaginous fishes, molluscans, and decapods, with rarer mammals and reptiles.

2. The bottom or benthic environment with sediments (organic and inorganic compounds), bacteria, microalgae (e.g. diatoms), macroalgae (e.g. the kelp: Laminaria digitata), or sea grass (e.g. Zostera). Some organisms are benthic in one stage of life and pelagic in another. Producers that synthesise organic molecules exist in both environments.[33] The bottom area of the marine environment consists of sediment. These inhere organic and non-organic parts, rock and soil particles from land areas, remains of marine organisms, products of submarine volcanism, chemical precipitates from seawater, and materials from outer space (e.g., meteorites) that accumulate on the seafloor. Sediments are dissolved with help of oxygen by life forms of the benthos, whose left-over are consumed by plankton and algae (detritus chain) in the pelagic zone. To a certain depth algae take active part converting carbon dioxide into food using sunlight (photosynthesis) as the figure below shows[34].



Crucial for every ecological activity in marine systems is the aquatic production, categorised in primary and secondary production. During primary production living organisms create biomass, energy rich organic material from energy-poor materials in the environment via photosynthesis. Most primary producers require nitrogen and phosphorus, while the amount and quality of light influence the production. Producers (autotrophs) in the marine environment are pelagic phytoplankton and benthic microalgae and macroalgae. Most primary production is done by pelagic phytoplankton and by single-celled 0.5- to 10-micrometre phototrophs (bacteria and protists). Secondary production is the rate at which energy is converted by photosynthetic and chemosynthetic autotrophs (life forms which oxidise inorganic compounds to organic substances). The term "gross primary productivity" describes the total amount of productivity in a region or system, which is partly used to sustain the life of producers and partly to maintain the systems productivity. "Net productivity" is the amount of organic material, produced by living organisms and is available to support the consumers (herbivores and carnivores). It is usually measured within a particular area in units of energy, such as gram calories per square metre per year.

Food chains in marine environments are regulated by nutrient concentrations, which determine the development of phytoplankton. Phytoplankton supplies food for the primary consumers, such as protozoa and zooplankton, feed themselves for fish, squid, and marine mammals. As food passes along the food chain, only about 10% of the energy is transferred to the next level. For instance, 10% of the energy phytoplankton received from photosynthesis can be used by zooplankton at the next level, about 90% of the energy is lost. This means that there has to be a lot more organisms at the lower level than at the upper levels.

3.2.4 Marine environment of Trondheimfjord

The fjord is 130km long and has an average depth of 400m (max. 680m). The height of the waves is usually lower than 0,5m, but they can occasionally reach heights of about 4m. Its drainage area is about 20 000 km^2, causing marked seasonal variations in freshwater input. None of this water has a glacial origin and it is rich in humid matter. Water from the coast regions has a greater impact on the fjord than from rivers or streams.

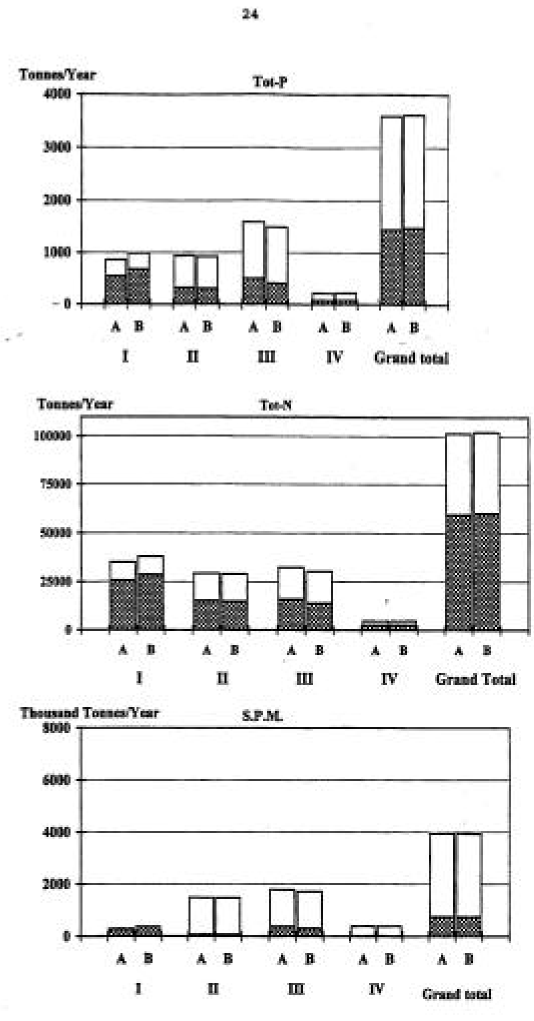
The tidal flow exchanges 2km^3 (2.000.000.000 m^3) water from the upper level of Trondheimfjord daily. The estuarine circulation (coastal water in which river water is mixed with seawater) replaces water masses in middle level with coastal water from the Baltic and later the Norwegian current

seasonally. The bottomwaters are replaced seasonally with water from the Atlantic.
Surface waters in the vicinity of the Trondheim Biological Station have a highly fluctuating salinity (10-33 mg/l) and temperature (2-20 ^{0}C). The fjord has been throughoutly studied since 1963 with respect to hydrography, currents, pollutants, ecology and plankton dynamics.

3.2.5 Pollution: reasons, factors and changes of ecological cycles

The limited water exchange in a fjord creates a particular sensibility for pollution. Fjordbassins seem to be collectors for waste from soil and water systems. Contamination usually settles in the sediments of the bottom area and is absorbed by organisms. Biosolids are dissolved from bacteria in the water or at the fjordbottom. The oxygen demand for this process increases with the growth of organic material. The lack of renewal of the bottom water, cause oxygen depletion, and the life at the bottom dies. Gases such as H_2S (hydrogensulficide) appear, which might enter the pelagic sphere and endanger species in this area.
Shipping, poorly treated sewerage and solid wastes cause marine pollution related to human activities. Less oxygen means increased hydrogensulficide levels, which hinder photosynthesis and poison species. Eutrophication increase the primary production and decrease secondary production i.e. more complex species. Eutrophication can also effect explosive toxic algae growth. Some years ago, masses of poisonous algae spread through the channels, which separate the coasts of Sweden, Norway, and Denmark. The slime affected 200 km of coastline, killed fish and other marine animals, and forced to close several bathing areas.
The danger of pathogens and heavy metal floating into the marine environment is their tendency to accumulate in higher organisms. Pollution increases its concentration when toxics pass up the food chain, making certain animals infertile and more vulnerable to disease.[35] Polluted sediments from industrial discharges or shipping activities are one main reason for toxification of fishes and shellfish. Contaminators are e.g. TBT, Tributyl tin, and TBTO, Tributyl tin oxide. Tributyl tin is one of the most toxic substances known. It is a biocide, used as an ingredient in ships' paint, against fouling and to prevent organisms from growing on ship hulls below the water line. TBT is relatively heavy to decompose. All organotin compounds accumulate in living organisms, especially in mussels and snails, which get highly contaminated. It has also been found that anti-fouling bottom paints are harmful to corals. Norway prohibited the use of TBT and TBTO in 1990 for boats under 25 m length. Today ships` paint with an electro conductive film to prevent growth and

protect the structures from corrosion is appl[illegible]ut this method is rather costly. Overfishing causes the loss of diversity via growth of opportunity species rates. Mechanical disturbances as the grounding of large sea-going vessels cause damages of coral reefs. Dredging is disposing of materials in the bay. Dredged disposal as mud, solid wastes, sewerage, garbage, sewerage sludge, munitions, chemical wastes, and biological materials may contain harmful metals and chemicals too. Dredging influences water conditions such as clarity, chemical content, nutrient balance dissolved oxygen, temperature, and salinity. Likely are also increased sedimentation and damages of coral reefs, when the suspended materials block the light.[36]



Nutrients and S.P.M. Total and river discharges 1997 (A) and Total normalized loads (B) from mainland Norway to convention waters and the four subregions:
I Skagerrak, II. The remaining North Sea, III. The Norwegian Sea, IV: The Barents Sea.

Whole columns	= Grand total
Light hatching	= Direct discharges ,
Dark hatching	= Main and tributary rivers

Reaction towards environmental pollution

EFFECTS	CATEGORIE S	ADAPTATION STRATEGIES
* increased mortality * less vitality of cells and larva	**Population**	* increased recruitment and rate of neophytes
* disturbance of physio-logical processes * reduced birth-rate * restrained growth * reduced energy re-serves * reduced fertility	**Organisms**	* avoidance behaviour * discharge of toxins * changes of energy distribution
* changes of cellmorphology * decreased cellsplit * abnormal growth	**Tissue**	* encapsulation * diverse growth of tissue
* destabilisation and bursting of lysozymes * damages of chromo-somes	**Organs**	* self consumption of lyso-zymes[37] * reproduction of endoplasmatic recticulum[38] * encapsulation of toxins * chromosome reparation
* gene mutation * structure changes * activities in enzymes	**Molecules**	* DNA reparation * detoxification * enzymatic and metabolistic re-sponses

Trondheimfjord contains huge watermasses. The main water accumulation does not indicate contamination. Even if a decrease of fish species has been observed through the last hundred years it is not proved which reason is due to that. In local milieus such as the river mouth and particular discharge areas pollution has been registrated, which shows:

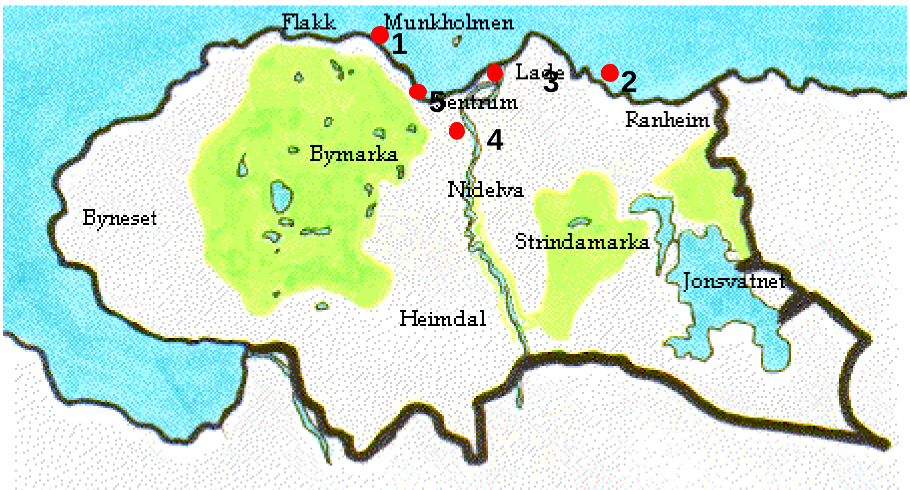
- sludge sedimentation and changes of the soft bottom fauna
- bacteria concentration at some of the bathing areas
- greening of beach zones

These problems are resulting from other sources than Høvringen emissions except the sludge sedimentation and the bottom fauna modifications nearby the plant.

Considering nutrient and bacteria input into open marine waters, one have to take also into account, that marine waters have, because of their high salinity, better conditions for sedimentation than lakes. Therefore, a significant part of pollutants, such as SPMs end up in fjord sediments. Moreover, stratification in fjords is in most cases strong, what cause that particulate pollutants in deep waters have less chance to be brought back to the euphotic zone.

3.2.6 Summary from marine experts

The community of Trondheim intends large-scale investments and attached running expenses considering the sewerage treatment at Høvringen plant. The question, however, remains open if these attempts will have essential meaning for pollution problems of Trondheims sewerage,



Places investigated[39]

1 Høvringen	4 Nidelva river
2 Ladebassin	5 Ilsvika
3 Nyhavna	

The Oceanographic Company of Norway (OCEANOR), specialised in environmental monitoring and information systems for oceans, coastal areas, rivers, lakes, groundwater and soil, points out[40] that their former evaluations (1987, 1988, 1991), which were used as source for decisionmaking, have to be reworked concerning a publication by the National Pollution Authority (SFT), released in 1997: “Classification of environmental quality in fjords and coastal waters. A guide.”

One intention was to assess the minimum cleansing required for Høvringen wastewater plant. Other point source polluters were not investigated. In relation to pollution a recipient rapport on four environmental occurrences in the near diffusion zone was published:

1. eutrophication effects
2. heavy metals in sediments
3. bottom fauna
4. bacteria pollution near particular bathing places

1. The flowing water masses of the fjord document no eutrophication effects. Increased algaegrowth was reported near some seaside areas, that might derive from upper level discharges and diffuse drainages. Oxygen decrease was measured in Nyhavna, caused possibly by emissions of organic substances from the Ladebasin and Nidelva River. There is little plausibility that further cleaning strategies in Høvringen will change this situation.

Quantifying organic loads in Trondheimfjord in relation to the BOD level of the major water masses counts indicator 10. Skoldaford in Rogaland, known as a very clean fjord, has 7,5 and the inner Oslofjord around 85 points in the BOD scale.[41] This is a clear indication that the fjords' capability is satisfactory to incorporate organic materials into the natural ecocycle.

2. Significant contamination from heavy metals (cadmium, zinc, lead, copper, silver, iron) was observed in sediments and in organisms (seaweed) nearby Ilsvika, caused by earlier discharge contamination from Killingdal excavation, which produced gravel from 1952 until 1986. Other places have modest contamination from mercury.

3. Near the Høvringen outlet moderate load was scaled with respect to the bottom fauna. It appeared in the form of increased individual numbers and the rise of so-called pollution species (in extreme leading to the shrinkage of complex species via development of opportunity families). A scaled change between 1974 (before Høvringen plant operated) and 1987 allows assuming that organic material from the plant settled in the bottom area. Usually sewerage treatment facilities increase the nutrient levels surrounding their outflow pipes and alter water temperatures, which supports algae blossom. How far later mechanical upgrading (remove large particles) and

the enduring service of the plant produced further changes is not determined today, because no new data is available.

5. Pollution via bacteria over the acceptable limit is presumably caused by discharges of sewerages to the surface water of the fjord. The Norwegian pollution authority has stated quality levels: “good - fairly good – not acceptable” for bathing areas. At least none of the areas in Trondheim belongs to the third category. After the discharge of the Ladebasin had been cleared, it is more likely that most of them belong to category one. On the other hand there is no reason to believe that upgrading of Høvringen plant will improve the situation anyway. Further improvement might be done instead with continued clearance of retaining point discharges and diffuse discharges to the surface layers of the fjord, the Nidelva River and the basins.

The Trondheimfjord is a recipient with great self-clearance capacity because of its big water volume and sufficient water mass shifts in relation to supplies from the surroundings. As a marine recipient it ranges thus under condition class 1 and 2 as a good or less vulnerable receiver.[42]

Concerning the Inner Trondheimfjord, Ilsvika, mentioned above, and Nyhavna are critical areas. Ilsvika because of the Killingdal excavations and Nyhavna because of a former gasworks. Høvringen release contains heavy metals, but with a level in the same range as cleared discharges in Oslo-Bærum-Asker areas.

Oceanor recommended as the most important initiative for Høvringen was to care as much as possible for a clearance of emissions before the sewerage reaches the plant. This concerns e.g. the identification of point sources and their avoidance from entering the main system. Clean sewerage means a minimum of heavy metals and other emissions to be dealt with in a responsible manner. For instance with an appropriate technological solution for discharging it into deep water, essentially to the bottom level. The discharge might contain nutrious salts, bacteria that would otherwise flow to surface waters, and particular matters that sink to the bottom and sediments. Organic particular matter and diffused emissions will of course settle at the bottom fauna, yet the oxygen use will be lower compared to “usual” load.

The removal of pollutants within Høvringen plant effects sludge with accumulated pollutants, which happens to be a detrimental result for an environmentally sound strategy. On the contrary, the discharge of sewerage into fjord regions under the threshold, in 50m depth, using diffusion systems, would grant that both ecological and esthetical requirements are satisfied. This method and the additional implementation of diffusion arrangements are inexpensive, but not preventive and do not take biomass as a product into account.

The importance of the Nidelva River has been discussed to little with respect to the fjord. River waters transport considerable amounts of matter to the fjord and thus sometimes contribute to its muddy consistency and displeasing colour. Perhaps this is a crucial factor influencing the public opinion that Trondheimfjord is polluted.

Summary:

Investments on environmental initiatives can create positive ecological effects. The fundament for decisionmaking in case of the Høvringen wastewater plant should be revisited and improved.

Oceanor suggests a focus on the following investigations and actions:

a) A new recipient investigation delivering the missing data
b) A sketch and classification of sources that pollute the sewerage and of other sources that contribute to the wastewater consistency.
c) Continued attention over these source points and their periodic control. This might include both, the Nidelva River and point sources.
d) A cost-benefit analysis of the contemporary proposed steps, which should include a compiled evaluation of environmental strategies from Trondheim commune with respect to discharges, sewerage, groundwater and the Trondheimfjord.

3.3 Political responses

In March 1999 the debate on upgrading of the Høvringen wastewater plant was transferred back from the community to the national level. Until May the majority of the parliament members were convinced that the chemical upgrading was not as urgent as for instance the improvement of the sewer network in Trondheim. A parliament member of the labour party pointed out that usually 99% of protests of local authorities against governmental orders concerning the environment relate to factually significant improvements, but Høvringen is an exception. Moreover it has been said that if nature protection shall be reasonable one should not spend money for unnecessary applications.[43]

The question is also one about the legal consequences, if a government mandate will be made to stop the process. The intended chemical upgrading of the plant based essentially on the European Communities Council directive, Article 4, 1991, 91/271/ECC, to reduce 85% of suspended solids until 2000. It has been implemented in Norway 1996. Since legal bindings between the EU and Norway exist, it might it be possible that the EU bring an action against Norway. More general, to what degree implicate environmental laws a range of autonomous decisionmaking in such cases?

In an official meeting the 4th May 1999 with representatives from the community the county administration, the Norwegian Pollution Control

Authority (SFT), OCEANOR, SINTEF, NTNU a new evaluation on the necessity of a chemical upgrading of Høvringen was required. The document was delivered from OCEANOR to SFT mid of May and sent to the Ministry of Environment as basis for the national decisionmaking.

At the meeting OCEANOR representatives already mentioned that the ecological situation of Trondheimfjord has improved. Nevertheless run-off in the beach zones still causes a high rate of bacteria and is thus dangerous for health. It has been said that this is, among other reasons, due to clumsy operation of the sewer network, which creates periodically worse circumstances, yet a profound investigation of reasons and effects has not taken place but is sorely needed.

The official recommendation from the Norwegian Pollution Control Authority[44] to the Ministry of Environment emphasises the following points:

- Høvringen sewerage influences the Trondheimfjord in local areas but the damage is comparatively little. The knowledge on this subject is, however, not sufficient.
- To fulfil the EU directive secondary treatment of Høvringen has to be introduced until the end of 2000. If the commune can document that the sewerage is not polluting the environment, the requirement of 85% can be lessen to 50% reduction of suspended solids and to 20% of the BOD within the primary treatment phase (Council directive: Article 6.2, application: Article 2.7.). Yet, filtering is not an application, which accomplish this claim completely.
- The financial difference between the primary and the secondary treatment are huge.

cleaning niveau	investments	running expenses	sum/yearly costs	claim
secondary treatment, 85%	390	22	58	**county governors permission**
secondary treatment, 80%	390	20	56	**EU-claim sec. treatment**
primary treatment, 50%	352	14	46	**EU-claim prim. treatment**
new filter facility ca. 15%	148	5	19	**insufficient**

The increase of water expenses for consumers 70%, 67% and 60% for the first, second and third alternative and 30% for the fourth. The building time will take 3,5 years for the three first strategies and 2 years for the last.

- Filtering and associated practices such as using diffusion systems and fat skimmers do not fulfil the requirements. SFT suggests therefore firstly to build the primary cleaning related to the EU claim. Secondly, either to undertake a new recipient evaluation and apply for a modification of the EU claim, in case the documentation shows definitely little pollution or the upgrading of Høvringen to secondary treatment.

4 HØVRINGEN: A SUMMARY

The final decision from the Ministry of Environment was a complete withdrawal of chemical upgrading at the 3rd of June 1999. It bases on the report of SFT mentioned above. The time frame for any accomplishment of the plant is now postponed until the 31st December 2002. A novel, detailed statement is however, required, which will be the foundation for further strategies choice for Høvringen.

Investigations and proposals concerning Høvringen focused mainly on the ecological situation of the Trondheimfjord, which is indeed not alarming today. But additionally to ecological and economical parameter are societal factors involved, which are necessarily to consider. Such were for instance the intentions of the county government to acts as a signal for other communes and introduce a minimum requirement for waste treatment in other sectors too.

Finally, all suggestions implicated an "end-of-pipe perception", where the fjord is regarded finally as the pipe to deal with the sewerage. Article 14.1. of the EU directive states, however, that sludge should not only be reduced but re-used "whenever appropriate".[45]

Attending a cyclic perception, industrial ecology will observe wastewater treatment in the next chapter from a systemic point of view, since we believe that human actions cause ecological reactions in the same system and the consequence is, at worst that polluters are polluted by their own pollution.

Universitetsavisa.17.6.1999, p.3:

NOTES

[1] source: http://www.trondheim.com/com/

[2] Continental precipitation provides 45,000 cubic kilometres of fresh water every year - enough to set entire Europe 2,3 meters under water.

[3] Source: http://www.indecol.ntnu.no/aboutie/emne1.htm

[4] see Keitsch,M.,1997, Towards an Interdisciplinary Research in Technologies and Humanities

on the Concept of Industrial Ecology

[5] Most water is constantly being recycled by nature and up to a certain level technology can mimetise these processes, a method, which is in line with an industrial ecology axiom: technology may adhere to ecological activities.

[6] source: http://bioag.byu.edu/aghort/282pres/Nonpoint/sld003.htm

[7] Source: http://www.geocities.com/RainForest/1161/index.htm.

[8] Rio de Janeiro, 3-14 June 1992

[9] Source: http://odin.dep.no/nsc/esbjerg/

[10] Regarding principles to protection of species and habitat:

A.collecting and evaluating relevant information, reviewing current measures and developing further initiatives, making maximum use of available information

B.developing criteria to identify ecologically important or key biodiversity indicator species and their habitats which are, or may become, threatened or vulnerable in the North Sea, including coastal and offshore areas

C.identifying and mapping the most threatened and/or ecologically important species and habitats in collaboration with the International Council for the Exploration of the Sea (ICES), European Environment Agency and/or other relevant organisations

D.defining ecological objectives for the protection of the identified marine species and habitats in order to sustain or restore them at a favourable conservation status

E.drawing up sets of measures that contribute substantially to the realisation of the ecological objectives, including consideration of suitable protection regimes

F.evaluating the use of protected areas in the North Sea basin as a means to protect threatened and vulnerable species, inter alia, based on the findings of the possible "undisturbed area" project

G.developing the existing monitoring programme and concomitant research to assess the progress with respect to realising the ecological objectives; and

H.periodically reviewing and reporting back on: the identification of species and habitats; the setting of ecological objectives; the monitoring programme; the implementation of any management regimes adopted.

[11] Source: http://www.odin.dep.no/ud/publ/ees/Index.html

[12] SFT, Report 750/98, Oslo and Paris Commissions (OSPAR), p. 4,22

[13] Declared in Paris 22 September 1992 regulating pollution of the North East Atlantic Ocean

[14] source: http://www.grida.no/soeno98/waste/ecopol.htm

[15] Council Directive 91/271/EEC

[16] ibd. Article 4, p. 401, 413

[17] Report from Trondheim Commune Meeting, 22.09.1998, Høvringen, Sak/nr. 98/427, p.2

[18] See: Ødegaard,H., Optimised particle separation in the primary step of wastewater treatment, in: Water science technology, Elsevier, Vol. 37, no. 10, pp 43-53, 1998, p.44

[19] Milina, J., Lei,J., Sægrov,S., et al., Maximisation of pollution load interception, May 1999, not published, p.7

[20] Data, Høvringen Kloakkanlegg, Trondheim Kommune, Teknisk Avd., 1990

[21] Source: Broch, E./Bjørgum,F.,Underground storage and treatment of wastewater and sewage in Trondheim, Municipality of Trondheim

[22] Milina, J., Lei,J., Sægrov,S., et al., Maximisation of pollution load interception, May 1999, not published, p.5

[23] Report from Trondheim Kommune Meeting, 22.09.1998, Høvringen, Sak/nr. 98/427, p.3

[24] See: C. Vogelsang, et.al., Functional stability of temperature-compensated nitrification in domestic wastewater obtained with PVA-SBQ/Alginate gel entrapment, in: Elsevier Science Ltd, UK, Wat.Res. Vol.31,No.7., pp. 1659-1664, p. 1659, 1996

[25] See conclusion, p.1663

[26] SINTEF (The Foundation of Scientific and Industrial Research at the Norwegian Institute of Technology) is Scandinavia's largest independent research organisation. The Institute for Civil and Environmental Engineering, Department Water and Wastewater investigates the treatment and transport of drinking water and waste-water, the treatment and recycling of sludge, water treatment and reuse in fish farms, the maintenance and modelling of water distribution networks and urban hydrology.

[27] see: J. Milina et. al.: Maximisation of pollution load interception, SINTEF conference paper for the EWPCA Syposium,4-6- May 1999, Munich

[28] The scale from 1-10 marks the efforts from lowest to highest

[29] See paper above, p.9

[30] Source: Britannica online: http://www.eb.com:180/bol/topic?eu=57718&sctn=1#s_top

[31] Table: OCEANOR Report: Trondheimsfjorden, 1987-88, Hovedrapport, p.14

[32] Source: Britannica online: http://www.eb.com:180/cgibin/g?DocF=macro/5004/74/12.html&keywords =saltwater%20contents&DBase=Articles&hits=10&pt=1&sort=relevance& config=config

[33] Source: Britannica online: http://www.eb.com:180/cgibin/g?DocF=macro/5000/74/91.html &keywords=Marine%20Ecosytem&DBase=Articles&hits=10&pt=1&sort=r elevance&config=config#5WZPM

[34] http://www.odysseyexpeditions.org/oceanography.htm

[35] See also table: Reaction towards environmental pollution, according to: Siebing,A., in: Bayne,B.L. et al., The effects of stress and pollution on marine animals, Praeger, New York 1985

[36] Table on pollution, SFT, Report 750/98, p. 24

[37] Lysozyme is an enzyme causing disintegration of bacteria.

[38] "The endoplasmic recticulum is a complex membranous system that forms intracellular compartments, acts as a transport system within the cell, and serves as a site for synthesising fats, oils, and proteins." Britannica online: http://www.eb.com:180/bol/topic?eu=108640&sctn=1#s_top

[39] Map: Oversiktskart over friluftsområder i Trondheim Kommune

[40] Tangen,K., Berge F.S., Nye spørsmålsstillinger i tilknyttning til rensetiltak ved Høvringen. Uofisielt notat. MEMO til Trondheim kommune V/ A.K. Slungård, 13.1.1999, p.1, the following recommendations build mainly on evaluations from OCEANOR.

[41] BOD scale from the article " Nødvendig opprydding av miljøhysteri, Strømgren,T., Universitetsavisa, 1,1999, p.14

[42] See SFT rapport: Klassifisering av miljøkvalitet i fjorder og kystfarvann, 1997

[43] Adresseavisen, 30.4.199, Sier nei til renseanlegget

[44] Recommendation to the Ministry of Environment, 21.5.199, Act nr: 99/611-MIF/KSK 631.22, 99/1472-7 HG 470

[45] ibd. p.406

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