Water pollution in lakes in The Netherlands and Romania

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University of Groningen

Science Shop for Biology
Report 53

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A comparative (desk) study on water pollution in the Zuidlaardermeer, Lake Agrement and Lake Ciric, with specific attention given to eutrophication

Cuza University of Iasi

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Preface

This report is the result of a (desk) research-project in which Romanian and Dutch biology students co-operated. The subject of the project is water pollution in lakes.

This International Project on Water Pollution is part of the Dutch MATRA project "Science Shops in Romanian Moldavia" number RO/97/04. The Dutch Ministry of Foreign Affairs supports MATRA projects. The main goal is to enhance democratically orientated social changes in Central and Eastern Europe. The acronym MATRA stands for "MAatschappelijke TRAnsformatie" (Social Transformation) for Eastern European Countries. The project "Science Shops in Romanian Moldavia" started in September 1998 as a co-operation between the University of Groningen and the Universities of Iasi, Bacau and Galati. The aim of this project is to establish Science Shops in Romanian Moldavia, which will function as a link between university (science) and society. A Science Shop is a unit within a university, with the objective to transfer scientific information to organisations, known as Non Governmental Organisations (NGO's). As these bodies rarely have the means to do research, they need access to the scientific knowledge available at the universities. In Romanian Moldavia, four Science Shops (or Intermediu) have now been established. One at the University of Bacau (Faculty of Biology), one at the Technical University of Iasi, one at Cuza University (Faculty of Biology) in Iasi, and most recently one at the Technical University of Galati. These science shops are focused on environmental and nature-protection issues. Their target-groups are therefore public organisations concerned with the same kind of problems.

One of the objectives of the co-operation between Groningen and Romania is to set up international exchange-projects for students. This Water Pollution Project, the first one of that nature, started in September 1999. In September four Romanian biology students (Loredana Plesu and Hermes Clipa from Cuza University in Iasi; Carmen Pogar and Razvan Socea from the University of Bacau) came to the Netherlands and spent a month on research, together with two Dutch students. Also, two co-ordinators of the Intermediu Bacau (Laura Gorea and Christina Georgeta Ichimas) came for a study tour of two and a half weeks.

In October the two Dutch biology students (Marieke Harteveld and Lysbeth Feddema from the University of Groningen) travelled to Romania, to the universities of Iasi and Bacau, and continued their research there. After this period of exchange, both Romanian and Dutch students wrote comparative reports.

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GENERAL INTRODUCTION

TO

WATERPOLLUTION

1 Water pollution in a global perspective

A definition of water pollution is not easily formulated. A satisfactory operational definition might be that water pollution is anything, whether physical or chemical, that affects the natural condition or the intended use of the water (Wilber, 1971):

In general, pollutants can be released into the environment as gases, dissolved substances or as particles. Ultimately pollutants reach the aquatic environment through different media, including the atmosphere and the soil.
Pollution may result from point sources or diffuse sources. There is no clear distinction between the two, because a diffuse source on a regional or even local scale may result from a large number of individual point sources. An important difference between a point and a diffuse source is that a point source may be collected, treated or controlled. Domestic wastewater, industrial wastes and sewage are considered as point sources. Non-point sources are urban and rural runoff (Chapman, 1996).

The sources of pollution can be classified in the following categories (Wilber 1971):

- Organic pollutants contributed by domestic sewage and industrial wastes of plant and animal origin which remove oxygen form the water through decomposition;
- Infectious agents contributed by domestic sewage and by certain kinds of industrial wastes which may transmit disease;
- Plant nutrients which promote nuisance-growth of aquatic plant life such as algae and water weeds;
- Synthetic organic chemicals such as detergents and pesticides resulting from new chemical technology which are toxic to aquatic life and potentially toxic to humans;
- Inorganic chemical and mineral substances resulting from mining, manufacturing processes, oil plant operations, and agricultural practices which interfere with natural stream purification, destroy fish and aquatic life, cause excessive hardness of water supplies, produce corrosive effects, and in general, add to the cost of water treatment;
- Sediments which fill streams, channels, harbours, and reservoirs, cause erosion of hydro-electric power and pumping equipment, affect the fish and shellfish population by blanketing fish nests, spawn, and food supplies, and increase the cost of water treatment;
- Temperature increases, which result from the use of water for cooling in electric power plants and industry, and from storage of water in reservoirs, and which have harmful effects on fish and aquatic life, and reducing the capacity of the water to decompose wastes.

It will be clear that the tolerance for a specific form of pollution depends on the ultimate use of the water.

1.1 Pollution of lakes

Lakes are prime areas for human settlement, because of the availability of water for drinking, industrial cooling, hydropower generation, commercial fishery and recreational use. In addition, the water is used for agricultural irrigation and for waste disposal. Good water quality in lakes is essential for maintaining recreation and fisheries and for the provision of municipal drinking water. These uses are clearly in conflict with the degradation of water induced by agricultural use and by industrial and municipal waste disposal practices. The management of lake water quality is usually directed to the resolution of these conflicts of interest. Nowhere in the world has lake management been totally successful. However, progress has been made especially with discharges of waste at point sources (Chapman, 1996).

1.1.1 Eutrophication

Eutrophication of lakes and reservoirs ranks as one of the most pervasive water quality problems around the world and can have significant negative ecological, health, social and economic impact on man's use of a primary and finite resource (Rast *et al.*, 1989). Eutrophication is the term used to describe the biological effects of an increase in concentration of plant nutrients – usually nitrogen (N) and phosphorus (P), but sometimes others such as silicon (Si), potassium (K), calcium (Ca), iron (Fe) or magnesium (Mg) – on aquatic ecosystems. Eutrophication is considered to be a problem of the middle and late stages of the 20th century. In this context, it is normally the man-induced eutrophication that is referred to; a consequence of the (redundant) urban, industrial and agricultural use of plant nutrients and their subsequent appearance in the aquatic systems (Harper, 1992).

The German botanist Weber was the first person to use the adjective eutrophic, to describe the nutritive conditions which determine the plant community in the initial stages of the development of raised peat bogs. Weber described in 1907 the nutritive stages, which subsequently control the vegetation changes, as leading from eutrophic to mesotrophic and then to oligotrophic (low level of nutrients). These three terms were used twelve years later by the Swedish botanist Naumann, to describe types of freshwater lakes containing high, moderate or low concentrations of phosphorus, nitrogen and calcium (Naumann, 1919).

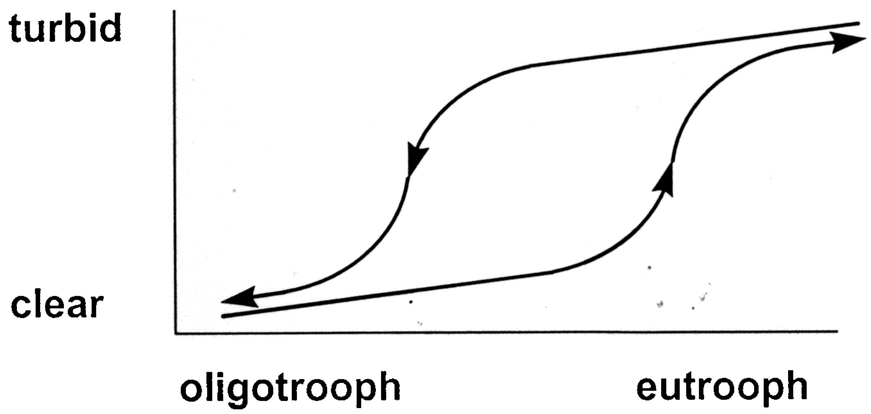

Figure 1 *Nutrient enrichment and reduction (copy overhead sheet Torenbeek, 1999)*

The availability of nutrients is one of the most important factors affecting species and quantity of plant material growing in lakes. These parameters in turn determine the oxygen eutrophication can be divided into those which are a direct result of raised nutrient influx - such as the stimulation of algal growth - and those which are an indirect effect - such as changes in the fish population as a result of reduced oxygen concentrations. The direct effects occur when organisms, usually planktonic algae, are released from nutrient-restrained growth. Also, bacterial production increases as a result of a raised level of nutrients (which bacteria may absorb directly in competition with algae) and of other detritus. Respiration of the bacterial biomass in the hypolimnial water column and sediment is the single most important consumer of oxygen. The hypolimnial water column is the lower layer of the water column. The upper layer is called epilimnion (Harper, 1992).

1.1.2 Assessment, monitoring and management

Effective eutrophication monitoring and management requires in the first place recognition of the problem, as well as sufficient support to formulate and implement a corrective policy (Rast *et al.*,1989). Assessment and monitoring is necessary to verify whether the quality of water is suitable for it's intended use. Water quality assessment is the entire process of evaluating the physical, chemical and biological characteristics of the water. Water quality monitoring is the repeated collection of the relevant information. Monitoring, survey and surveillance are all based on data collection (Chapman, 1996).

If the management goal is to alleviate the negative impact of eutrophication, the most effective approach usually is to treat the most readily controllable cause of the problem: the input of excessive quantities of phosphorus and/or nitrogen from the drainage basin to the water body. The control programme should be directed toward the major sources of these nutrients. These sources primarily are human and animal wastes (including municipal wastewater effluents and drainage from large animal feedlots). Non-point sources, especially runoff from urban and agricultural lands also offer important control targets. Treatment to reduce the level of the nutrients in these wastewaters is quite expensive. Some corrective measures can be applied directly in a lake to provide temporary relief from eutrophication while a long-term control strategy is being formulated or implemented. Examples are the dredging of bottom sediments, increasing the water circulation rate and bio- manipulation (Rast *et al.*, 1989).

The effectiveness of restoration management can be seriously hampered by the absence of an administrative and legal framework (together with an institutional and financial commitment) at local, regional and national levels (Chapman, 1996). It is difficult to provide general guidelines regarding the role of the government in environmental protection efforts. It is important to realise that a range of different forms of government, as well as economic conditions, exist around the world. Not all concerns about water pollution will receive the same degree of attention in all countries, as a result of differing priorities and national perspectives. Eutrophication management programmes are usually developed and implemented by a governmental entity. Consequently, all governmental agencies involved should be consulted. To obtain an understanding of the eutrophication process, a multidisciplinary approach is highly desirable. Co-operation between governmental units, rather than confrontation, will focus more energy and resources on solutions to environmental problems (Rast *et al.*, 1989).

This study

This study

Water pollution in lakes is a well-known phenomenon in the Netherlands as well as in Romania. In the Netherlands, research was done on the Zuidlaardermeer: a natural lake which main problem is eutrophication. In Romania, research was done on Lake Agrement and Lake Ciric. Both lakes are artificial lakes and have problems with different forms of pollution.

After this general introduction on water pollution, the report is divided in three sections. In the first part, the water pollution in the Zuidlaardermeer will be described, the second part is concerned with the water pollution in the lakes Agrement and Ciric. The following issues will be addressed: the status of pollution in the three lakes, the approach to solving the problems, the parties concerned and the relevant legislation. The studies are independent and in each a set of conclusions and recommendations will be given. In the third and last part, the results will be discussed, analysed and compared.

Figure 2 *Map of Europe (bron: http://www.ling.gu.se/sprakfrageladan/English/europe.html)*

2 Introduction

Before 1950 the water in shallow mesotrophic lakes and ponds in the Netherlands used to be clear. The system had a buffer, stabilising the ecosystem. Water plants and the associating fish species played a key role in it. The following processes and interactions are important in the maintenance of such a situation:

- Submerged and shore vegetation directly limit the growth of algae in the competition for nutrients,
- Some water plants excrete substances that inhibit the growth of algae,
- Shore plants function as a shelter for juvenile pike. The pike is also depending on this vegetation for reproduction,
- Pike and other predators mainly eat planktivorous fish like bream. A good pike stock restricts the number of planktivorous fish, leading to the increase of the number of water fleas,
- Water fleas feed on algae. Lakes with a high number of fleas contain hardly any algae,
- When water plants cover a large part of the lake-bottom, less silt will enter into the water column. Bream avoid areas covered with plants.

In the past, the professional bream fishery has probably contributed to a stable bream population.

All the processes listed above sustain a clear and stable fresh water system (Hosper, 1992).

The water quality of the Dutch lakes has changed greatly in the second part of the 20th century, due to the increased industrial activities, the growth of the population and the intensified agriculture. These developments were responsible for the use of phosphorus detergents, artificial fertiliser en pesticides, leading to the appearance of undesired substances in the surface water, especially phosphates and nitrates. This process, eutrophication, has resulted in turbid water with massive algal growth and not much else (Huis in't Veld *et al.*, 1998).

Unfortunately, not only the clear water system of the past but also the actual, turbid system is stable. Some of the mechanisms (Hosper, 1992):

- Planktivorous fish like bream are abundant in a turbid system. Bream eat water fleas, so algae can grow undisturbed,
- Algal bloom leads to a high oxygen demand (by decomposition of sinking algae) and a high pH (by net consumption of CO_2). Both factors, a low redox potential and a high pH, enhance P release from the sediments,
- The adult bream grub on the bottom for food, the water gets turbid and plant growth is hampered,
- Few water plants mean a lack of habitat for pike. Pike is absent in a turbid system,
- Waves easily agitate the silt on the bottom bringing it in suspension because water plants do not retain it.

These interactions maintain a stable turbid system.

Also, the Zuidlaardermeer changed during the second part of the 20th century from a stable clear system into a stable turbid one. In the beginning of 1900, the Zuidlaardermeer looked totally different from what it does now. The water was clear and water plants like Chara sp. (*Chara fragilis*) and Potamogaton spp. flourished. A population of pike (*Esox lucius*) kept the fish stock in balance. This ideal situation changed when the concentration of phosphates increased. Due to the subsequent growth of algae, the colour of the water changed into green which prevented sunlight to reach the bottom of the lake. Because of the turbidity, many water plants disappeared and the habitat of the pike was destroyed. Bream (*Abramis brama*), no longer threatened by pike, became predominant (Zuidlaardermeerproject, 1995).

The Zuidlaardermeer still is an area with high natural values and good opportunities for recreation. However, eutrophication is a serious problem in this lake. Recently a lot of work has been done to reduce the supply of nutrients, but the result is not satisfactory. Also the fish stock needs to be controlled. To accelerate the process from a turbid to a clear system, ecological restoration programmes are being applied (Zuiveringsschap Drente, 1998).

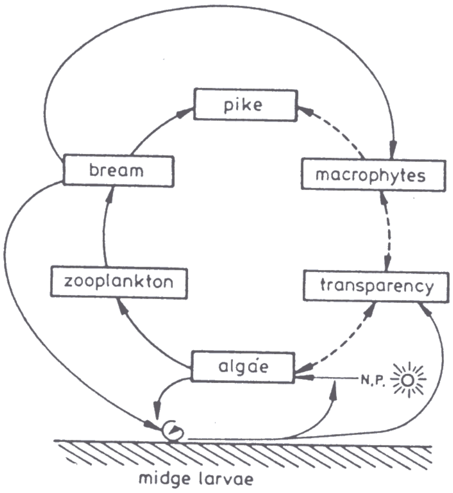

Figure 3 *Interactions between fish, plankton and plants in shallow lakes (Harper, 1992)*

Main question

What is the state of the water quality in the Zuidlaardermeer and which measures have been taken to reduce the water pollution?

Secondary questions:

- *What are the sources of pollution?*
- *What are the norms and standards to determine water quality?*
- *Which restoration methods are being used?*
- *Which are the parties concerned and what are their interests?*
- *Which legislation is applicable on Lake Zuidlaardermeer?*

3 Zuidlaardermeer

3.1 Topography

The Zuidlaardermeer is a natural lake situated between the towns of Hoogezand-Sappemeer, Haren and Zuidlaren. It is located on the border of the provinces of Drenthe and Groningen in the catchment area of a glacial sand ridge called the Hondsrug (see also figure 4). The lake covers an area of about 650 hectares and has an average depth of 1 metre. Because of sedimentation the area is getting smaller (Zweep, 1976). The Zuidlaardermeer is part of the hydrological system of the Hunze-valley. The Hunze is a small brook transporting rainwater to the lake throughout the year. The winter-flow of this river is 22 m^3/sec, the minimal supply in summer is merely one percent of this, approximately 0.25 m^3/sec. The water from the Hunze passes through a canal, the Drentse Diep, before entering the lake (Zweep, 1976).

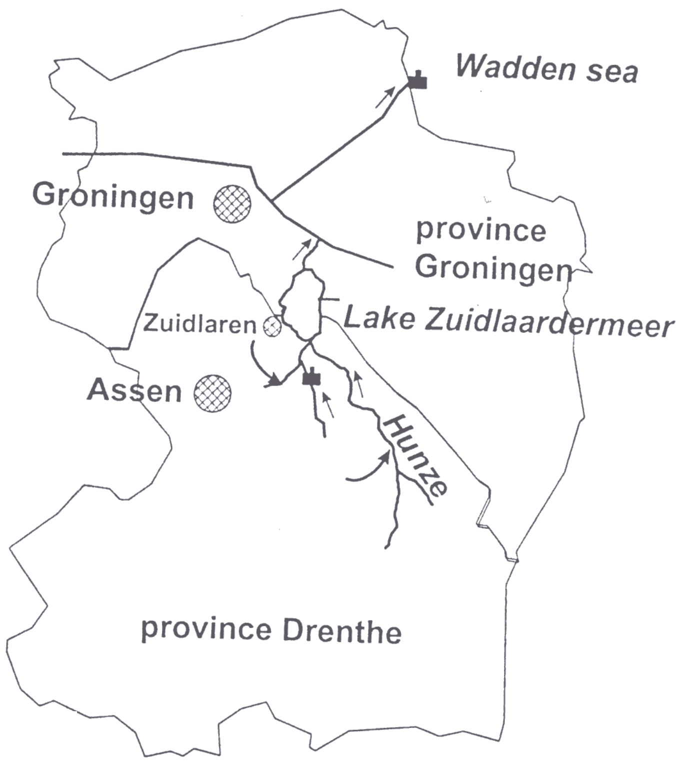

Figure 4 *Sketch showing location of the Zuidlaardermeer (copy overhead sheet Torenbeek, 1999)*

The bottom of the lake consists of a thick layer of sand with a twenty centimetre thick layer of silt on top (Huis in't Veld *et al.*, 1998). Especially in the south-western part of the lake, mud is deposited. For that reason dredging is done there once a year (Zweep, 1976).

3.2 Function

The Zuidlaardermeer area can be divided into three zones: recreation areas, areas with important natural values (peat lands and swamps) and nature development areas. There are plans to connect the areas with high natural values where recreation is not allowed. In the nature development areas, nature and recreation can be combined. In the recreational areas, the development of recreation will have priority. The main recreational activities are boating, fishing and swimming. On the lakeshore there are two campsites, three marinas, five restaurants and a sailing school (Oranjewoud, 1997).

The lake and its surroundings are important for migrating, breeding and wintering birds. Some of the bird species are included in the red list of birds according the international criteria of the IUCN (International Union for the Conservation of Nature and Natural recourses) (Osieck, 1986). The Lake Zuidlaardermeer meets the Ramsar criteria and has recently been assigned a Wetland of International Importance, especially as a Waterfowl Habitat. At the same time the lake is registered as an EC (European Community) Special Bird Protection Area. In de explanation the Minister of Agriculture, Nature Management & Fishery writes: “This Special Protection Area (SPA) is located in de provinces of Groningen and Drenthe and belongs to the municipalities of Hoogezand-Sappemeer, Haren and Tynaarlo. The surface of the area is ca 2.100 ha. The area is of great importance as breeding, foraging, wintering and resting area for migrating birds. The area has been registered as an SPA and a wetland because of the international importance for the little swan (*Cygnus bewichii*), the bean goose (*Anser fabalis*) and the white fronted goose (*Anser albifrons)*” (Staatscourant, 2000). The wet pastures are important for breeding and moulting *Limosa limosa* (Grimmett & Jones, 1989).

As a part of the Hunze-valley, Lake Zuidlaardermeer is an important element of the Dutch Ecological Network, according to the Nature Policy Plan. The National Ecological Network consists of core areas (larger than 500 hectares), nature development areas and ecological corridors (NBP, 1990).

4 Water pollution

The region surrounding the Zuidlaardermeer is an agricultural area, having to cope with a surplus of water in winter and a shortage in summer. In winter, the lake functions as a basin for drainage water and in summer the lake is used to maintain a stable groundwater level for the agricultural crops. Water is taken from the Zuidlaardermeer for agricultural and industrial use. By pumping water from the lake into the Eemskanaal via Wolfsbarge, water is drawn from the IJsselmeer to the Zuidlaardermeer (Zweep, 1976). This water originates from the polluted river Rhine, and is very rich in nutrients, especially phosphate and nitrate. For that reason this foreign IJsselmeer-water is not allowed to enter the lake anymore. It now flows directly into the agricultural areas (pers. comm. Torenbeek, 1999). Some of the nutrient-rich water, however still enters the lake because of imperfect isolation (pers. comm. Veenstra, 1999). A desirable solution would be to retain the entire surplus in winter in the area surrounding the lake, so that foreign water is not needed in summer, allowing the region to be autonomous (Wieringa, 1998).

The excessive amount of phosphates and nitrates is the main cause of the eutrophication process in the Zuidlaardermeer (see also figure 1). The intake of foreign IJsselmeer-water in summer is one source, a second source is the effluent water from a sewage system. In the sewage treatment plants at Zuidlaren and Gieten an effort is being made to eliminate nitrate and phosphate from the effluent water, but the result is insufficient yet. This may be because of an incomplete elimination of nitrate and phosphate, but is more probably due to other causes. The intake of water from the IJsselmeer in summer is held to be the main cause of the eutrophication in Lake Zuidlaardermeer by most specialists.

One of the effects of eutrophication is that blue-green algae (cyanobacteria) replace green algae and produce floating scum. Blue-green algae become dominant in the phytoplankton for two reasons. These algae are not much eaten by zooplankton or by fish, which prefer other algae, and they are more efficient than green algae at absorbing carbon dioxide and phosphate in low concentrations (Krebs, 1988).
In August 1999, the Zuidlaardermeer didn’t meet the quality standards for swimming water, because of the increase of blue-green algae. Most of the swimming waters in Drenthe do not meet the criteria for clearness (Zuiveringsschap Drenthe, 1998).

For decades there has been no submerged vegetation in the lake because of eutrophication. Shore vegetation like *Phragmites communis* (reed) and *Scirpus lacustris* (rush), so important for fish, declined. The fish stock is dominated by prey-fish like bream and there are hardly any predators like pike (Huis in ‘t Veld *et al*., 1998) (see also figure 3).

4.1 Restoration Programmes

The aim is to restore the lake into the old situation: clear water, rich in water plants and shore-vegetation, and a great variety of fish.
The ecological quality can be measured by several parameters. In the following table, the current values and the targets of the various parameters are listed.

Parameter	Target value	Present value
Total phosphate (mg P/l)	0.1	0.3
Total nitrogen (mg N/l)	1	1.3 – 1.5
Transparency (cm)	Bottom	25 – 40
Predator fish: prey fish	1 : 2	1 : 48
Area emerged vegetation	10 %	0.7 %
Area submerged vegetation	30 - 40 %	0 %
Number of algae species	High	Very low
Number of algae individuals (/ml)	< 10.000	> 40.000
Number of zoo-plankton (/ml)	High	App. Zero

Table 1 *Target and current values of various parameters in Lake Zuidlaardermeer (Huis in't Veld et al., 1998)*

4.2 Ecological Restoration (ABM)

The first step on the way to clear the water is to stop the influx of nutrient-rich water. For that reason, purification plants treat the wastewater before it enters the lake, and the nutrient rich water from the IJsselmeer is not taken into the lake anymore. However, it would take too long to wait for a spontaneous recovery of the lake. The two water quality managers involved (Zuiveringsschap Drenthe and Dienst Zuiveringsbeheer Provincie Groningen) want to accelerate the process by *Active Biological Management* (ABM). Active Biological Management, bio-manipulation, is an intervention in the ecological system to steer certain processes in the desired direction. In most cases, the aim is an improvement in water quality by a reduction of the algae-biomass, an increase in the number of algae-eating water fleas (*Daphnia*) and recovery of the submerged vegetation (Zuiveringsschap Drenthe, 1995).

ABM is being applied increasingly in Dutch water management to restore lakes and ponds. In the Netherlands, where this management-system has been known for more than 10 years, a recurrent ABM-technique is reducing the bream population by fishing (= reduction fishery). This approach is based upon the idea that an overpopulation of bream is detrimental to the clearness of the water (Meijer & De Boois, 1998).
One campaign of reduction fishery on a specific fish species in turbid lakes can already lead to durable recovery. These kind of drastic measures in an ecosystem can induce several processes, which eventually result into clear water, an increased number of water plants and a diverse fish stock. Both clear and turbid lakes are mostly in a stable situation, due to existing mechanisms in an ecosystem, which maintain a steady state. A drastic campaign of reduction

fishery can trigger the change from a stable turbid situation to a stable clear situation (Hosper *et al.*, 1992) (see also chapter 2).

The transition from a turbid to a clear situation follows a specific path. At first a decreasing influx of nitrates and phosphates will not have any effect on algae-growth. The existing fish population will keep the system in a turbid state. Only when nitrate and phosphate reach extremely low levels, the algae-growth is limited. At this point water plants will appear again and the system will change from a turbid into a clear one. The whole process will take a long time (Hosper *et al.*, 1992).

Considering that it is not easy to influence the various mechanisms in a relatively big lake, a phased approach was used. Characteristics of this approach are (Huis in 't Veld *et al.*, 1998):

- The restoration starts in a pilot area before applying it full scale,
- Time should not be the determining factor. Particularly the development of flood-marshes is a long process,
- Ecological restoration can only be achieved by an integral approach. All the different functions of and interests in the lake should be surveyed. In this integral approach the working group "Restoration and Development of Lake Zuidlaardermeer" plays an important role.

A phased approach allows the monitoring of the various processes in detail. The result of each phase is the determinant for the next one. The aim is the recovery of the whole lake at the end of the last phase (Huis in 't Veld *et al.*, 1998):

Phase 1: 1993 - 1994

In 1993 experiments have been done in two compartments of 25 by 25 m. In one compartment the fish stock was reduced and in the other one the fish population was maintained representative of the one in the lake. In the "reduced compartment" the water became clear and some water plants returned. In the control-compartment, the water remained turbid and no water plants returned. Based on this positive result, it was decided to continue the experiment on a larger scale. In 1994 the possibilities for the development of flood-marshes have been examined. Experiments to develop the shore vegetation for the benefit of fish have been done. The conclusion was that the best option would be a system to control the water level resembling natural circumstances. A second option would be the construction of artificial flood marshes.

Phase 2: 1995 - 2000

In phase two, a compartment of 75 ha was built at the east shore of the lake. Collection of data in this compartment was focused on reduction fishery. The second phase had two aims: (1) the gathering of information on the reactions in the lake on a larger scale, (2) the creation of a base for water plants. Water plants could spread into the whole lake from this base (the compartment) in phase 3.

In 1995-1996 research has been done on the migration of fish in the Drentse Diep. If in phase 3 ABM will be applied to the whole lake, a fish barrier in the Drentse Diep will be needed. This measure would mean going against the general policy of removing obstacles for migration. Research shows that the Drentse Diep is an important migration route for several fish species. Pike directly migrates to the lake for reproduction. This should be taken into account with the design of a barrier for fish. In the preparation of phase 3 the possibility of improving the shore vegetation has been investigated. The shore of the compartment is a suitable place for an artificial flood-marsh.

The developments in 1996 and 1997 were as follows. In the compartment, some important positive changes took place. The water became clearer and the development of submerged water plants started. At first the plants developed better in 1997 than in 1996, but in the course of 1997 the plants died prematurely. This is probably connected with the appearance of the blue-green algae *Aphonizomenon sp.* in the compartment. The future will have to demonstrate if this situation is a permanent one.
The reduction of the fish stock on a large scale turned out to be a good measure to clear the water. This conclusion provides a good basis for ABM in the whole lake in the year 2000.

Phase 3: 2000 - ?
The effects of phase 2 on the lake form the base for the decision whether or not to continue with phase 3 and to extend ABM to the whole lake. Of course, administrative aspects will play an important role in the eventual decision. It is very important that the started trend continue. The amelioration of the shore vegetation is necessary for the benefit of the fish. This can be done by either bringing up the water level to the required (semi) natural situation, or by the construction of artificial flood marshes (Huis in ‘t Veld *et al*., 1998).

4.3 Project “Water over Wolfsbarge”

“Water over Wolfsbarge” is a project of the Stichting Groninger Landschap (an NGO). The aim of this project is to realise dynamic flood marshes in the basin of the Hunze. That implies the introduction of a more natural water management system in the eastern part of Lake Zuidlaardermeer near the village of Wolfsbarge. The hope is to realise the project within two or three years (Jassies, 1997). With these experimental semi-natural flood marshes, essential habitats for water-bound organisms can be made. In the new floodplains fish can reproduce and travel upstream and down in the Hunze River. Such a system has a lot to offer to waterfowl (Wieringa, 1998). The present water management system is far from natural. In the area, the ground level is sinking due to natural-gas-extraction. As the sinking is not even, but concentrically and pocket-wise around the wells, water management calls for small entities - polders - isolated from each other by locks and gates. This reduces the natural water dynamics.

It is relatively easy to inundate the area surrounding Lake Zuidlaardermeer, by reducing the drainage of the polders. In such a situation, the depressions of Wolfsbarge will inundate. This is the core of a second project, a pilot-project, called “Swamp Development & Ecological Restoration of the Zuidlaardermeer” which will take place in a restricted area in the southern part of Wolfsbarge. In this area ditches will be made to create an open connection with Lake Zuidlaardermeer (SGL, 1997). The area will be connected to a special part of the Zuidlaardermeer, a compartment, which is isolated from the rest of the lake by a dam. In this part of the lake the Water Board of Drenthe is trying to improve the fish stock by an ecological restoration program (see also 4.2).

“Water over Wolfsbarge” is a project on a much lager scale, aiming to improve water quality and restore dynamics in a different way as compared to the pilot-project. Ideally, Wolfsbarge should become an important spawning ground for pike and other organisms dependent upon clear fresh water. In spring, when the flood marshes dry up, the area is very attractive to breeding wetland birds foraging for invertebrates and fish. The water level will be very low in summer and at it’s maximum in winter. The project is an experiment in wetland recovery. By monitoring the process from the beginning, the Water over Wolfsbarge project becomes a pilot project. By feeding-back the results of the monitoring, the course of the project can be adjusted at any time. These results can be used at the same time to inform the public about the progress (SGL, 1997).

In brief, the aim of the projects mentioned above is (SGL, 1997):

- to enhance the seasonal water-dynamics,
- to restore the connection between the polder and the lake,
- to provide suitable spawning ground for pike in the flood marshes,
- to supply and circulate sufficient clear water

In the framework of a large-scale restructuration project of the eastern part of Groningen-province and of de Veenkoloniën (peat-extraction area of the 19th century) on the border of Groningen and Drenthe, the areas under discussion will be re-allotted. In this programme, the whole area of Wolfsbarge will be allocated to the Groninger Landschap (SGL, 1997).

5 Parties concerned

There are different organisations having an interest in the Zuidlaardermeer. On the one hand there are groups mainly interested in the recreational possibilities of the lake and on the other hand there are those interested in the natural element. Efforts have been made to work out a compromise between the different groups.

Stichting Groninger Landschap
One of the parties concerned is the foundation Stichting Het Groninger Landschap. The aim of this nature conservation organisation is the protection, restoration and development of nature and landscape in the province of Groningen. Water as “leading principle” for a healthy ecological network is the most important issue today. The organisation owns and manages nature reserves and areas in the province of Groningen with the help of volunteers. About 2% of the inhabitants of Groningen are “protectors” of the foundation (SGL, 1999). One of the nature reserves concerned is the area surrounding Lake Zuidlaardermeer, at least large tracts of it. Groninger Landschap is the initiator of the Project Water over Wolfsbarge and has the opinion that the public should be allowed to enjoy nature as long as natural values are not disturbed (see also 4.3) (SGL, 1997).

Vogelbescherming Nederland (Bird Protection Organisation)
The Dutch Bird Protection Organisation has established in 1899 and is one of the members of BirdLife International. BirdLife International (formerly the International Council for Bird Preservation) was established for the protection of birds and their habitats and has been collecting information on the status in Europe which led to the publication of Important Bird Areas in Europe (Grimmet & Jones, 1989). This publication consists of an inventory of 2400 key sites for rare and threatened European bird species and sites with important concentrations of species. Lake Zuidlaardermeer is one of those areas (Grimmett & Jones, 1989; Bennett, 1994).
World-wide, this international organisation has partners in 66 countries and co-operates with another 56 countries. In Europe 32 partners are members. BirdLife Partners make strategic conservation programmes, which form the basis of their activities. The choice of the Dutch Bird Protection Organisation is to focus on the protection of Red List bird species and their habitats. That gives this organisation a role to play around the Zuidlaardermeer (Vogelbescherming Nederland, 1999).

There has been a lot of protest against the nomination of Lake Zuidlaardermeer as a Special Bird Protection Area, causing the final decision to be postponed until March 24, 2000 (Staatscourant, 2000). The municipalities, entrepreneurs and recreational organisations fear that their interests will no longer be recognised under the bird-protection laws. The Bird Protection Organisation naturally supports the nomination of the lake as a protected area for birds. The appointed areas will not be closed to the public, the current activities can still take place (pers. comm. Van Dijk, 1999). Any new plan has to be screened to be sure that natural values will not be affected. If current use proves to have a negative effect on the birds, the parties involved have to find another solution (NvhN, 1999; Provincie Groningen, 2000).

The water quality managers
The lake is located in two provinces. For those reason a water board from one province and a provincial authority from the other are together responsible for the quality of the surface water in the Zuidlaardermeer: Zuiveringsschap Drenthe and Zuiveringsbeheer Provincie Groningen. Of these two, the water board of Drenthe plays the most important part. Since January 1, 2000, the provinces no longer have a special task in water quality management. The water boards in the Netherlands are now “all-in water boards”, meaning that they are responsible for the management of water quantity as well as water quality (pers. comm. Toorenbeek, 1999). Some measures have already been taken to improve the water quality in the Zuidlaardermeer. One of those measures was to stop the intake of polluted water from the IJsselmeer in summer. A second measure was to limit the influx of nutrients from wastewater by building two sewage treatment plants, one in Gieten and the other one in Zuidlaren. The third measure is ecological restoration, using Active Biological Management (see also 4.2 and 4.3) (pers. comm. Toorenbeek, 1999).

Municipalities
The Zuidlaardermeer municipalities Hoogezand-Sappemeer, Haren and Tynaarlo are also important parties. In the context of the National Nature Policy Plan (NBP, 1990) certain important parts of the area have been appointed nature reserves (pers. comm.Veenstra, 1999) With this in mind the local governments studied the integration of recreation and nature. Initially there were two opposing opinions, one from nature development (Stichting Groninger Landschap and Bird Protection Organisation) and one from the economic perspective (municipalities and recreational organisations). Both visions were eventually combined into an Integrated Development Plan for the Zuidlaardermeer-area. Because of the fact that the lake and its shores are part of a plan to restore the hydrological system of the whole Hunze valley, the local plans should fit in with this master plan. The plan is to connect the areas with high natural values and allow no recreational use. In the nature development areas, nature and recreation can be combined. In the recreational areas, recreation will have priority.
Apart from this integrated development plan, the municipality of Hoogezand-Sappemeer also made plans for a dredging project. A thick layer of mud on the bottom of the lake is hampering recreation and contributes to the turbidity of the water. The plan is to dredge a trough in the southern part of the lake. The upper current in the lake is directed to the north, so the under-current is going southward. With the under current, the mud will be transported to the south and into the trough (Oranjewoud, 1997; pers. comm. Veenstra, 1999).

Recreational organisations
Lake Zuidlaardermeer is a very attractive area for recreational activities as boating, fishing and swimming. The main problem for boating is mud deposition on the bottom. The depth of the lake varies between 80 and 150 cm and it has decreased with 5 cm in the past year. In this perspective, recreation will be very much helped by a dredging project. The problem of eutrophication is not very urgent for recreation; serious negative effects of it have not been experienced yet. In summer, the public was advised not to swim because of the possible effects of the blue-green algae in the water. These algae can cause skin-irritation.
Recreational organisations fear that too many water plants in the lake will cause trouble for boats and there is no enthusiasm for ABM’s favouring water plants. There is also resistance against the appointment of the Zuidlaardermeer as a Special Bird Protection Area. It is feared

that recreation's interests will not be taken into account any more and that there will be too many restrictions. On the other hand, recreants also come to the lake to enjoy the natural surroundings. A compromise should be possible between nature and recreation (Oranjewoud, 1997; pers. comm. Nachbar, 1999).

6 Legislation and policy

6.1 National law

In the Netherlands there are tree different levels of government: *state, province* and *municipality.* At state level, laws and national policy for physical planning, water management, nature and environment are being prepared. The provinces make, within the framework of the national policy, strategic plans for their domains. Municipalities implement the provincial policy in their own plans. Water boards are responsible for the water management. The management of the nature reserves is taken up by different organisations, governmental as well as non-governmental. (SGL, 1997).

Pollution of Surface Waters Act, 1970 (Wet Verontreiniging Oppervlaktewater)
In 1970 the Dutch Pollution of Surface Waters Act became effective. This act banned the discharge of polluting or hazardous substances onto surface waters without a permit. This act also allocates tasks to the various authorities. In principle, the provinces are responsible for water quality management. Most provinces, though, have transferred this water quality management to the water boards (Maasdam, 1998). The managers of the water quality of Lake Zuidlaardermeer are Zuiveringsschap Drenthe and the Dienst Zuiveringsbeheer of the province (Huis in' t Veld *et al.*, 1998).

Nature Policy Plan, 1990 (Natuurbeleidsplan)
The Nature Policy Plan (NBP) presents the Dutch government's strategy to reverse the reduction and deterioration of natural ecosystems. The key element in this plan is the maintenance of national biodiversity. In order to achieve this goal, it is necessary to connect areas that are important for the conservation of nature in a coherent and robust ecological network. The development of this National Ecological Network (EHS) will take 20 to 30 years. The ecological network consists of core areas, nature development areas, and ecological corridors. It also contains ecosystems that are important from an (inter) national point of view (NBP, 1990; Nowicki *et al.*, 1996).
Provinces have to include the goals of the EHS in their physical plans, the water management plans and their environmental policy plans. If necessary, land will be acquired by private nature-organisations. These will be responsible for the maintenance of the areas, which is subsidised by the government. Zuidlaardermeer and its surroundings are part of the Hunze valley, which is a core area of the EHS (SGL, 1997).

In the Provincial Physical Plan of Drenthe the aim is to develop the Hunze Valley as a nature reserve combined with the collection of drinking water. In this plan Zuidlaardermeer will have an important function for recreation as well as for nature. The Hunze valley is one of the areas in Drenthe having priority for the improvement of the quality of the environment (POP, 1997).

Fourth Policy Document on Water Management, 1999 (Vierde Nota Waterhuishouding)
Water management plays an important role in the protection and development of natural values. In the past, the water quality was determined by physical and chemical parameters,

based on human use. Presently there is an ecological approach to water quality, which means that ecological indicators are used and ecological standards are being set. The water boards now also have the responsibility for the quality of the aquatic ecosystem. To fulfil this task there are laws and regulations applicable to water management. (De Valk, 1997).
The provincial water management of Drenthe used the quality criteria according the Third Policy Document on Water Management from 1989 (Zuiveringsschap Drenthe, 1998).
The government's latest intentions with regards to regional waters are written in the Fourth Policy Document on Water Management (Waterkader, 1999). The goals are: to restore natural water systems, to slow down the subsidence of the soil due to gas extraction and to adjust the ground water level according to ecological and agricultural needs. Many different measures have been taken towards these goals. For example the plans of provinces, municipalities and water boards should be integrated and the regional approach stimulated. Physical Planning will be based more on ecological and hydrological aspects. The Fourth Water Management Plan contains a long list of criteria, values and minimum requirements for surface water (see also appendix 1).

6.2 International law

The international laws overrule national ones, in case of incompatibility. Important though they are, obligations under international conventions and international co-operative programmes do not have the same force as EC legislation, which is legally binding for the 12 Member States (Bennett, 1991). The following international legislation is relevant to the protection of important bird areas in Europe.

Convention on Wetlands of International Importance Especially as Waterfowl Habitat
This Convention, known as the Ramsar Convention, came into force in December 1975 and was the first treaty exclusively concerned with the conservation of the habitat. The main undertakings accepted by the Contracting Parties are (Grimmet & Jones, 1989)
to:

> designate suitable wetlands within (their) territory for inclusion in a List of Wetlands of International Importance (article 2,1)

and to:

> formulate and implement their planning so as to promote the conservation of the wetlands included in the List, and as far as possible, the wise use of wetlands in their territory (article 3,1)

and to:

> promote the conservation of wetlands and waterfowl by establishing nature reserves on wetlands whether they are included in the list or not, and provide adequately for their warding (article 4,1).

The Convention of Ramsar is the most widely applicable set of directives in terms of geographical coverage, with 24 Contracting Parties in 1988 in Europe, and it has had a positive impact on wetland conservation in many European states. The "wise use" concept, which applies to all wetlands whether or not included in the List, is receiving increasing attention Grimmet & Jones, 1989; Bennet, 1991).

Directive and Resolution of the Council of the European Community on the Conservation of Wild Birds (EC Birds Directive)

The principal EC rule requiring Member States to protect habitats is the EC Birds Directive. Member States are obliged to " preserve, maintain or re-establish a sufficient diversity and area of habitats" for all wild birds. More specifically, they must protect sufficient habitats to ensure the survival of all species on the list of endangered and threatened species and all migratory species. The sites most suitable for this purpose must be classified as Special Protection Areas (SPAs). This designation carries considerable weight. The European Commission is responsible for its enforcement, and can take a case to the European Court of Justice if a Member State is considered to have violated the terms of the Directive (Grimmet & Jones, 1989). The Court of Justice ruled that Member States have no general powers to modify or reduce SPAs once they had been declared and can do so only on exceptional grounds.

However, the implementation of this Directive is seriously behind schedule; most Member States have been slow to designate the necessary SPAs (Bennett, 1991). Also the Netherlands was late with designation. Recently, on the 24^{th} of March 2000, the Dutch government classified the Lake Zuidlaardermeer as a Special Protection Area (Staatscourant, 2000).

7 Recapitulation, conclusions and recommendations

7.1 Recapitulation and conclusions

- The Zuidlaardermeer is a natural lake, partly surrounded by wet pasture and peat lands. The wet pastures are important for red list birds, breeding and moulting, especially for *Limosa limosa*. The lake has recently been appointed an EC Special Bird Protection Area and a Wetland of International Importance according the Convention of Ramsar. The lake is regarded as an SPA because of the national importance as breeding, foraging and wintering area for wildfowl including *Cygnus colombianus*, *Anser fabalis* and *Anser albifrons.* The nature reserve and its surroundings are very attractive for recreation, notably for water-sports. As part of the Hunze valley, the Zuidlaardermeer is assigned a core area of the Dutch National Ecological Network.

- The Zuidlaardermeer, located on the border of the provinces of Groningen and Drenthe is polluted with phosphates and nitrates. The concentration of phosphate is 3 times higher than it should be and the concentration of nitrate is about 1.5 times the norm. There is very little transparency in the water, one can see about 25 - 48 cm. The fish stock is unbalanced with a strong dominance of bream: the ratio pike/ bream is 1/ 48. Hardly any emerged and submerged water plants grow in the lake. Zooplankton is totally absent. The lake is typically eutrophic. In summer (1999, 2000) the public was advised not to swim because of the possible effects of the bloom of blue-green algae.

- The main source of pollution was the intake of foreign water in summer for the surrounding agricultural areas. This water is very rich in nutrients as it originates from the River Rhine and gains more pollution on the way. Since a couple of years the foreign water is not let into the lake anymore. A second source was, and still is, the effluent from municipal sewage plants. Two sewage treatment plants eliminate nitrates and phosphates before the effluent reaches the Hunze River and the Zuidlaardermeer. The third source is the influx from agricultural activities (drainage and dairy farming).

- Many different parties have interests in the Zuidlaardermeer. On the one hand there are the nature and landscape conservation organisations like Stichting Groninger Landschap, the Vogelbescherming (Bird Protection Organisation) and the water quality managers. On the other hand there are the recreational organisations and the municipalities. The interests of these organisations are different. Efforts have been made to reach a compromise within the restrictions of international and national rules and laws.

- The intention of the two water quality managers is to accelerate the development from a turbid to a clear water system by ecological restoration. Active Biological Management (ABM) is an intervening technique of the ecological system to steer certain processes in the desired direction. The ABM- technique of reduction fishery has been applied to a compartment of 75 ha of the Zuidlaardermeer. Since 1994 the ABM project has made some progress. Unfortunately, the results were not entirely positive in 1999, there was a strong development of blue-green algae in the experimental compartment. It will depend on the final results of this year, whether or not the ABM project will be continued.

- The Stichting Groninger Landschap owns large tracts of land surrounding the lake and is the initiator of the Project Water over Wolfsbarge. The goal of this project is the development of artificial marshes along the lake. Flood-marshes with periodical inundation are very attractive for birds and the swamps may have a great contribution to the chemical and biological restoration of these lakes.

- Apart from national laws, international laws, acts and directives apply to the Zuidlaardermeer. The Dutch Pollution of Surface Water Act prohibits the discharge of polluting substances without a permit. The Fourth Note on Water Management contains minimum quality standards for surface water and describes the tasks of the Dutch water boards. In the Nature Policy Plan Zuidlaardermeer is assigned part of the National Ecological Network as such and should have special protection. The Dutch government registered the lake as an EC Special Bird Protected Area and as a Wetland of International Importance according to the Convention of Ramsar.

- Despite the national and international laws, all the measures taken and some projects under way to improve the water quality, the situation has not improved significantly. The Zuidlaardermeer is still a turbid lake where hardly any water plants can grow, where bream is dominant and algae are abundant in summer. To bring back the oligotrophic stituation will take years, or rather decennia.

7.2 Recommendations

It is recommended that:

- the Active Biological Management be continued in the compartment and, with positive results, be applied to the whole lake,

- Stichting Groninger Landschap continue the Wolfsbarge Project and try to buy more land surrounding the lake,

- no foreign water be let into the lake again,

- a compromise be hammered out between the parties concerned and their interests,

- biological agriculture be practised in the adjacent agricultural area in consultation with the landowners.

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List of persons interviewed

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Drs. Herman Wanningen	Zuiveringsschap Drenthe
De heer A. Veenstra	Gemeente Hoogezand-Sappemeer

LAKE AGREMENT

LAKE CIRIC

ROMANIA

8 Introduction Lake Agrement

8.1 Topography

Lake Agrement (Agrement is the Romanian word for recreation) is a part of the Bistrita river system, situated to the northeast of Bacau City in Romanian Moldavia. The river system consists of nine artificial accumulation lakes and Lake Agrement is one of these nine. The main tributary of the lake is Barnat brook, which enters at the north-shore. Barnat brook is the confluence of three smaller rivers or brooks: Trebes, Limpedea and Negel. These brooks pass through several villages upstream before flowing together, e.g. Margineni village upstream on the Trebes, Lilieci village on the Limpedea and Magura village on the upper course of the Nigel.

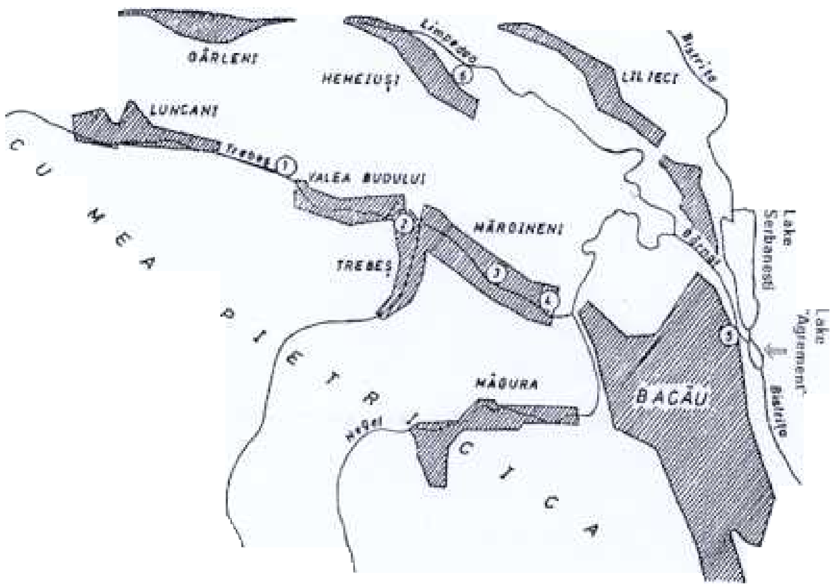

Figure 5 *Sketch showing location of Lake Agrement and five sampling areas*

The lake has a surface of 185 ha and a capacity of about 993.000 m^3. An island is situated in the southern part of the lake. This island, used for recreation, is managed by the Bacau Mayorality (City Hall). The Bacau branch of the water authority Apele Romane Company controls the water quality of the lake, together with EPA (Environmental Protection Agency) and the Department of Public Health.

Lake Agrement has different functions, especially for recreation. However, water pollution is a serious problem.

8.2 Function

One of the functions of the lake is to protect Bacau against flooding, especially in wintertime. Another function is to provide water for a few industrial companies. The water is also used as a coolant. The companies are allowed to use the water under the condition that the water level does not change.

Recreation is the main function of the lake. In the past, it was used for swimming. Unfortunately this is no more possible, because of polluted water and consequent health risks. Boating and fishing is still being done on the lake.

Every 5-6 years, the whole lake is emptied when the water is used to clean the filters of the power plant, which is situated on the shore (pers. comm. Gorea & Ichimas, 1999).

8.3 Ecosystem

The ecosystem of the lake is not in balance. The high concentration of nutrients causes eutrophication and stimulates the growth increases of algae and micro-organisms. The water is turbid and the deposit of organic material on the bottom of the lake makes it soft and muddy. The slippery mud at the bottom combined with the turbidity of the water makes the lake an unsuitable habitat for water plants. Predator fish need water plants as a cover while hunting. Young predator fish need the plants as a shelter. The present situation is favourable for prey fish, but there are still predators like *Perca fluviatilis* (perch), *Carasius carasius* (carp), *Alburnus alburnus* (bleak) and *Cyprinus carpio* (carp) present in Lake Agrement (see also figure 2 and appendix 4)

The vegetation in Lake Agrement consists of emerged flora such as reed *Phragmites communis,* which covers the banks, and submerged flora, such as *Chara*, *Cladopora*, *Potmogeton*, *Elodea* and *Spirogyra*.

The predominant species of aquatic birds are: *Anas platyrhynches* (duck), *Larus spp.* (gulls), *Aythya fuligula* (diver duck), *Fulica atra* (coot). Bird species, characteristic for grasslands and forests, are found on the Island: *Turdus merula* (blackbird), *Dendrocopus spp.*(woodpecker), *Streptopelia turtur* (turtle-dove), *Cuculus canorus, Asio otus* (long-eared owl) (pers. comm. Battes, Gorea & Ichimas, 1999).

Main question

What is the state of the water quality in Lake Agrement and which measures have been taken to reduce the water pollution?

Secondary questions

- *What are the norms and standards to determine water quality?*
- *What are the sources of pollution?*
- *Which restoration methods are being used?*
- *Which are the parties concerned and what are their interests?*
- *Which legislation is applicable on Lake Agrement?*

9 Water pollution

9.1 Organic pollution

Biology students (Carmen Pogar and Dalia Maciuca) from Bacau University took water samples from the brooks Trebes (which flows into the Barnat) and Barnat (wich flows into the lake) and Lake Agrement. They investigated the presence of micro-organisms (the total number of germs, coliform bacteria, faecal coli, streptococci) and bio-chemical pollutants (nutrients and the major ions). For a complete assessment of the water quality of Lake Agrement they used the official reports from EPA and Apele Romane Company. Professor Mazareanu and Intermediu co-ordinator Laura Gorea supervised the students. The results are presented in the tables 2 and 3.

Trebes and Barnat
To be able to compare the results, samples were taken at five different locations (see figure 5 and table 2) and in three different months: March 1999, July 1999 and October 1999.
The first location is at Valea Budului, in the mountain zone just before the brook Trebes enters the village and where the water is relatively clean. The other locations reflect the influence of human activities (faecal and industrial contamination).

No.		**TNG** cells/ml	**TC** cells/l	**FC** cells/l	**FS** Cells/l	**Sampling data**
	STAS-standard		10.000	1.000	200	
1	Trebes Mountain zone Valea Budului	-- -- --	1.100 6.000 3.100	4.500 7.800 2.300	1.000 400 200	March ’99 July ’99 October ’99
2	Trebes Margineni	100.000 90.000 100.000	22.000 95.000 36.000	19.000 49.000 11.000	2.400 18.000 8.600	March ’99 July ’99 October ’99
3	Trebes Industrial zone	90.000 69.000 100.000	43.000 160.000 54.000	25.000 54.000 7.000	14.000 35.000 4.900	March ’99 July ’99 October ’99
4	Barnat before entering the lake	40.000 90.000 7 8.000	54.000 92.999 18.000	21.000 72.000 34.000	20.000 69.000 15.000	March ’99 July ’99 October ’99
5	Lake Agrement	7.800 10.000 5.400	54.000 160.000 18.000	20.000 45.000 40.000	14.400 160.000 32.000	March ’99 July ’99 October ’99

Table 2 *Water quality of the brooks Trebes and Barnat and of Lake Agrement (organic pollution) at five different locations and in three different seasons*

Legenda TNG = total number of germs/ml, TC = total number of coliforms/l , FC = total faecal coliforms/l, FS = total number of faecal streptococci

The results were compared with standards from STAS 3001-1983 (Romanian legislation), National Standard Analyses for Surface Water (see appendix 2).
Table 2 shows the number of germs present. In the mountain zone the water quality of the Trebes is rather clean compared to the other four locations. The TC is at the first location within the STAS-standard of 10.000 but is increasing when the water passes the villages and the industrial zone. In the industrial zone and in Lake Agrement the values of TC reach 160.000 cells/l. After passing the villages Valea Budului and Margineni, there is a tendency of increasing numbers of TC, FC and FS in the water, except in October.
The number of germs increases in spring, reach the maximum in summer and decrease in autumn and reach the minimum in winter. Exceptions are possible under two specific circumstances: in case of incidental and uncontrollable pollution and in spring when the snow is melting.

The water of the lake belongs to Categorie II from sapro-biological point of view.
In Central Europe a practical system for water quality assessment is used which is unknown in Western Europe: the Saprobic system. It is based on the observation that downstream of a major source of organic pollution a change in biota occurs. As self-purification takes place, further changes in ecosystems can be observed, principally in the components of the biotic communities. This system deals with biological communities (ecological approach) and not purely with indicator species. Since the taxonomy of aquatic organisms in Central Europe is well developed, it is possible to use the species level in the Saprobic system developed in that region. The Saprobic system is based on four zones of gradual self-purification: the polysaprobic zone, the α-mesosaprobic zone, the β-mesosaprobic zone and the oligosaprobic zone. These zones are characterised by indicator species, certain chemical conditions and the general nature of the bottom of the water body and of the water itself (Chapman, 1996).
According to this Saprobic system the EPA and Apele Romane Company classify the water quality of Lake Agrement as β-mesosaprobic (moderate pollution). The surface waters are characterised by a rich submerged vegetation, abundant macrozobenthos (particularly Mollusca, Insecta, Hirudinae, Entomostraca) and coarse fish (Cyprinidae) (see for indicators also appendix 5).

Lake Agrement
The locations of sampling in and near Lake Agrement were (figure 6 and table 3):
1) Northern part of the lake
2) Central part of the lake near the jetty
3) Southern part of the lake

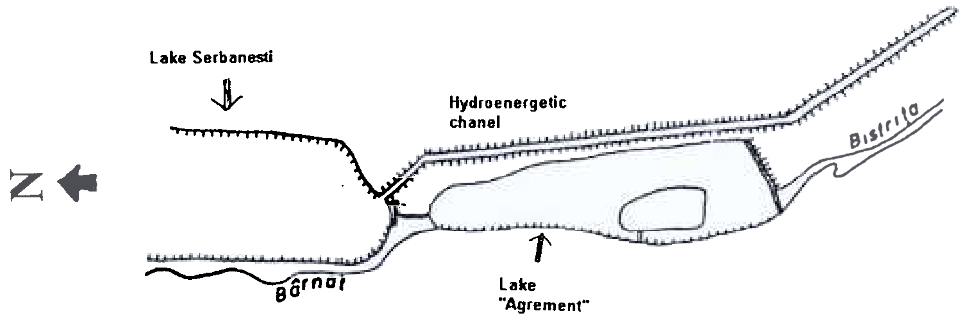

Figure 6 *Sketch showing the location of Lake Agrement with recreation island and jetty*

The results were compared with the standards for the quality of surface water, which is used for swimming and recreation from STAS 4706-1988 (Romanian legislation). Table 3 shows that the TC is on all locations within the STAS-standard in March and October and not in July. The FC is on all locations in each sample higher than the STAS-standard, in the centre of the lake in July almost 8 times as high.
The water of Lake Agrement is also polluted with faecal streptococci (FS), the values are throughout the year much higher than the standard. Even 800 times as high in July, in the centre of the lake around the jetty. The water of Lake Agrement belongs to Categorie III according Romanian legislation (see appendix 3) and is not suitable for swimming and recreation.

No.		**TNG** cells/ml	**TC** Cells/l	**FC** cells/l	**FS** cells/l	**Sampling Data**
	STAS-standard		100.000	10.000	200	
1.	Lake Agrement North	90.000 69.000 100.000	54.000 160.000 18.000	20.000 47.000 70.000	20.000 69.000 40.000	March ’99 July ’99 October ’99
2.	Lake Agrement Central (jetty)	40.000 90.000 78.000	21.000 160.000 11.000	32.000 78.000 72.000	14.000 160.000 32.000	March ’99 July ’99 October ’99
3.	Lake Agrement South	78.000 10.000 5.400	14.000 136.000 12.000	30.000 30.000 60.000	21.000 60.000 20.000	March ’99 July ’99 October ’99

Table 3 *Water quality of Lake Agrement (organic pollution) at three different locations and in three different seasons*

Legenda TNG = total number of germs/ml, TC = total number of coliforms/l, FC = total faecal coliforms/l,
FS = total number of faecal streptococci/l

The cause of the high level of coliforms and streptococci in the brooks and the lake is a lack of sanitary systems in the villages upstream. The high contribution of faecal germs (TC, FC, FS) in the centre of the lake, around the recreation island, is the result of recreational activities. The number of germs is maximal in summer (July) and minimal in winter (February), with average values in spring (March) and autumn (October).

Escherischia coli and streptocci can usually be used as indicators of the presence of human faecal matter and other pathogens possibly associated with it. The presence of human faecal matter in water bodies presents significant health risks when the water is used for drinking, personal hygiene, contact recreation or food processing (Chapman, 1996).

9.2 Chemical pollution

Chemistry students of the University of Bacau took water samples from Lake Agrement and examined the presence of nutrients (PO_4^{3-}, $NO2^-$, NO^{3-}, NH^{4+}) and major ions (Cl^-, K^+, Na^+). They also used the official reports of EPA and Apele Romane Company, because the laboratories of the university did not have the facilities and equipment to do all the analyses. The results are shown in table 4.

Samples	**1**	**2**	**3**	**4**	**5**	**6**	**STAS standard**
Conductivity m/s	4,45	1,03	0,74	0,75	0,76	1,99	
PH	7,7	8	8,5	7,5	7,5	8	6,5-8,5
PO_4^{3-} mg/l	2,1	1,3	1,2	0,95	0,9	1,7	3 mg/l
CCO-Mn mg/l	375	150	146	200	210	210	25 mg/l
Suspension mg/l	21	13	9	6	7	15	50 mg/l
NO^{3-} mg/l	7	11	15	10	12	10	30 mg/l
NH^{4+} mg/l	0,23	0,18	0,46	0,4	0,5	0,25	10 mg/l
Cl^- mg/l	5,6	0,52	0,16	0,28	0,23	0,83	300 mg/l
K+ mg/l	5	3	2,5	2,5	3	5	5 mg/l
Na^+ mg/l	120	90	75	80	80	80	90 mg/l

Table 4 *Water quality of Lake Agrement (chemical pollution) (Sources: EPA and Apele Romane Company). Samples have been taken in Mai 1999.*

Legenda CCO-Mn= chemical oxygen consumption

Table 4 shows that the concentrations of nitrate (NO^{3-}) in Lake Agrement range from 7 to 15 mg/l and are below the standard of 30 mg/l. The concentration of phosphate ($PO4^{3-}$) range from 0.9 to 2.1 and the standard value is 3 mg/l. The values of the chemical oxygen consumption (CCO-Mn) are too high compared with the STAS-standard of 25 mg/l.
The number of bacteria in Lake Agrement and in the tributaries should be decreased drastically according to the STAS-standards (see also the tables 2 and 3 and appendix 2). Together with the decrease in the number of bacteria, the O_2 demand by bacteria will also decrease, so that the dissolved oxygen will increase.
EPA and Apele Romane Company classify the quality of the water as mesotrophic. Mesotrophic lakes are less well defined than either oligotrophic or eutrophic lakes and are generally thought to be lakes in transition between the two conditions (Chapman, 1996).

9.3 Causes of pollution

Causes of pollution in Lake Agrement are the lack of the domestic sewage systems in the rural areas, the rural garbage problem and industrial activities in the Margineni zone. The lack of domestic sewage systems and municipal sewage treatment plants in the rural areas, is the cause of the large number of micro-organisms in Lake Agrement. In the villages there is no central system for the collection, transport and storage of household waste. Garbage is simply dumped on the bank of the brooks. The result is that the water flowing from these brooks into the lake transports a large amount of garbage from a number of villages.

On the Recreation Island there are not enough caretakers to ensure the enforcement of legislation pertaining to barbecuing and littering on the Island. These factors are the result of a lack of environmental awareness.

The lake functions as a catchment basin for the erosion materials, which are deposited on the bottom, resulting in an increased sediment accretion. To counteract this process, the materials have to be extracted from the lake. The polluted silt will then pose a major problem because there is no ready solution for its disposal.

9.4 Restoration programmes

Approach to the restoration of Lake Agrement

The water in the lake is used every 2-5 years to clean the filters of the power plant on the shore of the lake. On these occasions the whole lake is emptied. This would be a good opportunity to remove the deposited silt from the bottom of the lake. When the lake is empty, the silt can easily be removed. It will be more difficult to find a storage place for the silt, or a recycling method. Maybe it can be used as an agricultural fertiliser. If the silt would be polluted, some kind of purification will be necessary before storing or recycling it (pers. comm. Gorea & Ichimas, 1999)

To break the vicious circle leading to eutrophication in the lake, Active Biological Management can be used. With ABM the mesotrophic state of the lake can be changed into an oligotrophic state. Active Biological Management is the planned intervention in the ecological cycle of a water system. The purpose of this intervention is to steer certain processes in the desired direction. In most cases, an improvement in water quality, a reduction of algae, an increase in the number of algae-eating water fleas (*Daphnia*), and the recovery of submerged vegetation is desired (Hosper *et al.*, 1992).

Constructed wetlands or helophyte filters are also means to reduce the nutrient concentration in the lake. The constructed wetlands absorb the nutrients, and convert it into a biomass of reed (*Phragmites australis*). After a growing season the reed has to be cut and taken away to remove the nutrients from the system (Duel & Te Boekhorst, 1990).

Solution of the garbage problem

In table 5 some plans from the EPA are described in the Local Environmental Action Plan. This local plan is in fact a district plan. Only two of these plans have been implemented, although the dates suggest that almost all targets should have been reached by now. Storage of garbage and public education about the collection of segregated household waste, have been worked on. When the public is convinced that the environment is worth protecting, it will act in favour of the environment.

In table 5 some solutions for the garbage problem are given.

Plans/targets	Implementation	Responsible organisations
Collection		
a. Establishment of dumps for household waste	1988	
b. Identification of a good collection-system for household waste in rural areas	1998	City Halls
c. Identification of a new system for collection of urban household waste	1999	Local councils
d. Identification of two pilot-areas for the collection of segregated household waste from Bacau city	1999	City Halls
		City Halls
Transport		
a. Procurement of new vehicle for gathering the urban household waste	2002	Waste collection Company
b. Establishment of a new tax-system for the collection of garbage. This new tax-system must be a compromise between the interest of the urban people and that of the collecting companies	1999	Municipalities
Storage		
a) Controlled storage and improvement of the dump-sites	1998	Municipalities
b) Survey of all possible areas for the establishment of an ecological dump.	1998	Local and district Councils
c) Establishment of rural ecological garbage dumps	1998	District council
d) Separation of waste storage into organic and non-organic fractions	1998	Industrial Companies
e) Establishment of ecological garbage storage facility. Recycling of organic garbage e.g. for use as fertiliser.	1999	
f) Setting-up a monitoring system to detect seepage from organic waste dumps	2000	
Stimulation of competition between household collection companies, especially in rural areas	2000	Municipalities
Inform and educate the public on the collection of segregated household waste from both financial and aesthetical point a of view	1999	Municipalities Local councils EPA, mass media

Table 5 *Local Environmental Action Plan from the Environmental Protection Agency (EPA) for household waste and the responsible organisations (LEAP, 1997)*

10 Parties concerned

The following information has been obtained by interviewing the institutions involved.
The responsible organisations mentioned in table 5 (chapter 9) are not listed below because of lack of time. The opinion of the citizens who use the lake for recreation is not known either.

Environmental Protection Agency (EPA)
EPA is the environmental institution in Bacau and directly subordinated to the Ministry of Waters, Forestry and Environmental Protection (MWFEP). EPA is financed by the Romanian government (Ministry of WFEP) and received this year (2000) 0,04% of the GNP (Gross National Product). The institution has to control and monitor the water (drinking and surface water), the air and the soil in the district of Bacau and is in charge of observing and implementing the Romanian Environmental Legislation. It has laboratories to do chemical and biological analyses on water, air and soil samples. A special car is used for field sampling and exploration of new problem areas. Inspections are carried out once a year. Another task of the EPA is to inform and educate the public on ecological legislation and rules. To reach this goal EPA work together with NGO's and schools. At this moment there is hardly any co-operation with the municipal council.

The EPA considers the chemical factories together with the garbage problem as the two main sources of pollution. According to EPA, a solution for the garbage problem at Lake Agrement can only be found in enforcing rules. The mentality of the public is difficult to change. The environmental agency has no specific budget for this, money has to be allotted by the local councils of Bacau and the villages. Communication between Apele Romane Company and EPA is not always efficient. The main reason is the state of transition of the Romanian society. A good co-operation is necessary to improve the water quality of Lake Agrement (pers. comm. Axinte, 1999).

The Department of Public Health, together with EPA, City Hall and the police are responsible for issuing permits to new and present factories and private business. These permits are sometimes given too easily and certain institutions do not take full account of the consequences for the environment (pers. comm. Axinte, 1999).

EPA has connections to environmental agencies in the Netherlands and does implement a few projects with Dutch support. The establishment of the Local Environment Action Plan (LEAP) is a project in co-operation with IWACO (pers. comm. Axinte, 1999).

Water quality and quantity manager
The Apele Romana Company manages the water of Lake Agrement. The main task of this water agency is the administration of water quality and quantity. Lake Agrement can be considered to be unpolluted (pers. comm. Andro, biologist at Apele Romane Bacau, 1999). In spring and autumn there are diffuse sources of pollution. Silting up is a problem in the lake. Eutrophication is not a big problem at Lake Agrement and last year the concentration of organic matters decreased. The water agency points out that in political issues the economical interests are usually more important than the quality of the water (pers. comm. Apele Romane Bacau 1999).

Ornithological Society
The ornithological society organises youth camps. This is a good way of educating young people on environmental issues. They undertake special projects like collecting litter around the lake. The bad water quality of Lake Agrement affects the aquatic birds. On the southern part of the Recreation Island, where a lot of garbage is dumped, many dead birds are found. The Ornithological Society has no idea how big the problem really is. Research is needed to find out how the garbage and bad water quality affect the aquatic birds. The lack of respect for the environment is a major problem in Bacau city (pers. comm. Feneru, 1999).

Organisation of Fishery and Hunting
The organisation of Fishery and Hunting only hunts sick or old animals as well as the surplus individuals of populations. They hunt in order to keep the ecological cycle in balance. The sedimentation of erosion material from the mountains in Lake Agrement is the main problem of the lake. Politically, the household waste is not the main problem, but the chemical factories. They need a permit from the Department of Public Health and from the EPA. If factories are polluting the environment the permit can be withdrawn and the factory has to shut down. A filter for garbage coming from Barnat Brook would be a good solution for the waste problem. The lake is only polluted at special areas, e.g. where the velocity of the water current is low. These are also the places where the eroded material is deposited. In these regions of the lake helophyte filters can be used to clear the lake from nutrients (pers.comm. Rang, 1999).

11 Legislation

Water Law 1996
The Apele Romane Company (branch of Bacau) manages all lakes, ponds and rivers in the district of Bacau. The water board is responsible for water quantity as well as for water quality.

The tasks of the water board are (Water Law Nr. 107/1996 and Government Decision Nr. 30/1997):
a) Qualitative and quantitative management of surface and phreatic water. Protection of the water against pollution and depletion.
b) To control the consumption of water by institutions, households and factories. To control the pumping and distribution of water to the consumers.
c) Participation in activities concerning the conservation and protection of aquatic ecosystems, including their flora and fauna.
d) Participation in international meetings on water and water management.
e) Analyses of water to determine the values of physico-chemical, hydrobiological and bacteriological parameters.

Public health laws in Romania (Law nr. 204/1998 and order nr. 140/1997)
Hygienic laws concerning the gathering, the neutralisation and the removal of the solid residues
- The domestic residues must be gathered in special containers provided by the Municipality. It is very important that these containers have a suitable volume and be provided in sufficient number. The distance between two containers must be optimal. The containers should be emptied periodically, once every two days (April-October) and once every three days in winter (October-April). Organic residues (e.g. animal cadavers) must be gathered and treated in special installations. These installations may not pollute the environment.
- Individual systems concerning the disposal of domestic residues are only permitted in rural regions, provided that insects and rodents will be controlled. The dump for the domestic residues must be in a suitable place, where the local sources of water will not be polluted by seepage from the dump. The dump must be situated away from residential areas, to avoid an unpleasant smell in those areas.
- Water from natural zones (sea, rivers and lakes) can be used for swimming provided that the microbiological parameters are:

coli total:	< 10.000 cells/100 ml
coliform factor:	< 1.000 cells/100 ml
streptococcus factor:	< 20 cells/100 ml

- Swimming pool-owners must see to it that the parameters listed above are respected. The water quality of the swimming pool should be checked at regular intervals.

12 Recapitulation, conclusions and recommendations

12.1 Recapitulation and conclusions

- Lake Agrement is one of the nine accumulation lakes in the district of Bacau. The lake has a surface of 185 ha and a volume of about 993.000 m³. The Barnat Brook forms the main water supply.

- Lake Agrement has three functions:
  1) the lake protects Bacau against flooding in wintertime when there is a surplus of water,
  2) industrial companies use lake water as a coolant,
  3) inhabitants from Bacau use the lake for recreation.

- This research shows that the concentrations of nitrate and phosphate in Lake Agrement are below the standard values. The values of the chemical oxygen consumption (CCO-Mn) are too high compared with the STAS-standard. The ecosystem in the lake is not in balance and prey fish is dominant. Algal bloom is a well-known phenomenon. The state of the water quality of the lake is considered as mesotrophic and β-mesosaprobic according the Saprobic system. The velocity of the water through the lake is quite low, permitting the deposit of minerals and organic particles.

- The causes of water pollution are 1) the effluent of domestic and industrial wastewater, 2) the absence of sewage systems in the rural areas and of 3) sewage treatments plants, 4) the influx of rural garbage due to the lack of collection systems

- As Barnat brook is the main tributary of Lake Agrement, it is also the main source of pollution. Garbage, wastewater dumped in the brooks upstream will be transported to Lake Agrement, polluting it with organic materials, nutrients and pathogenic micro-organisms.

- The lake is polluted with micro-organisms which are indicators of the presence of human faecal matter: coliforms and streptococci. The results of research show that the number of these bacteria is above the STAS-standards for surface and swimming water throughout the year. The presence of human faecal matter in water bodies presents significant health risks when the water is used for drinking. The water is declared unsuitable for swimming and other (contact) recreation.

- The parties concerned do not have the same opinion about the gravity and the sources of pollution and do not agree about the solutions. According to the Organisation of Fishery and Hunting, the garbage is not the main problem. This organisation considers the chemical factories together with the silting up of Lake Agrement as the main problem. The Ornithological Society and the Intermediu of the University of Bacau have the opinion that the lack of environmental consciousness in Romania is the main problem. The Apele Romana Company points out that in political issues the economical interests are more important than the quality of water. The EPA, Environmental Protection Agency, has the opinion that the (new) permits for the factories are given too easily. Many institutions are not directly interested in respecting the environmental standards.

- The EPA (Environmental Protection Agency) and Apele Romane are responsible for the water quality and quantity. To control and solve the water pollution, they should have a clear understanding of the sources and consequences of the pollutants for human health and the ecosystem of the lake. Presently, progress in restoring water quality is not reported. Problems and obstacles encountered are unknown. Methodology is not discussed, there are no means to find out whether the water quality is monitored and, if so, by using which regime of sampling, interpretation and feed-back. One can only guess at the availability laboratory equipment, data processing capacity and financial support.

- The plans from the EPA to solve the garbage problem are described in the Local Environmental Action Plan, together with the responsible organisations. Of all the plans only two have started to be implemented: environmental education and storage of organic waste. Environmental education for the villagers is important but the actual problem is more at governmental and institutional level than at the level of individuals. It is not clear why the implementation is way off schedule and which problems are met.

12.2 Recommendations

It is recommended that:

- The need for (better) domestic sewage systems in the villages upstream be surveyed.
- The need of sewage treatment systems be assessed.
- A central dump for household waste in rural areas be set up (task of the local authorities).
- A central dump place for household garbage be established in the villages (task of the local authorities).
- Research be done on the extend of industrial pollution.
- More environmental education for the public at large.
- More resources for law-enforcement be made available.
- A filter for garbage coming from Barnat Brook be installed.
- Constructed wetlands or helophyte filters be used to reduce the nutrient concentration in the lake.
- Active Biological Management be used to improve the ecological cycle in the lake. With ABM the mesotrophic state of the lake can be changed into an oligotrophic one.
- Differences between parties involved be set aside and that a better co-operation be stimulated leading to agreement on the main issues and a collective approach to solve the problems.
- Bio filters be installed at drains from the toilets on the island.

13 Introduction Lake Ciric

13.1 Topography

The Ciric valley is one of the effluent valleys on the left bank of the river Bahlui. This river originates from the hills that dominate the Jija area. After a course of twenty kilometres from the hills the river enters Iasi. Ciric River supplies the valley with water. Ciric valley and Lake Ciric belong to the geographical unit of the Jija-Bahlui depression. The soil of this area consists of silty and sandy clays. On these clays, towards the upper part of the valley, there is some fluvial Carpatian gravel with sand and humus on top. Ciric valley is situated on a plateau, which is a little inclined to the South in the direction N/W-S/E. Because of the geological structure the infiltration water from the terrace flows into the valley. This water is used as a water source for the city of Iasi. Together with rain and melt water this can cause landslides. Lakes contain sediments due to deposition of transported materials. The old lake of Dorobanto, situated upstream of Ciric, and Lake Aroneau have accumulated sediments in the same way. Lake Ciric consists of three different lakes.

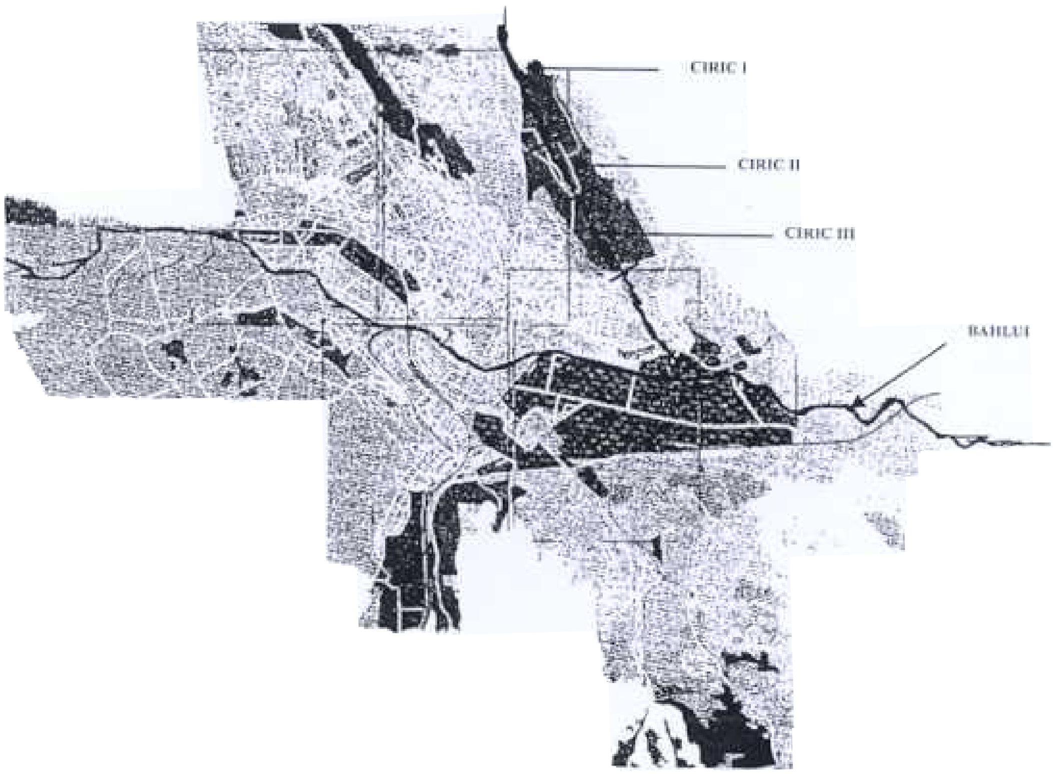

Figure 7 *Sketch showing location of Ciric I, II, III*

13.2 Function

Looking at the three lakes Ciric, Ciric I is almost entirely filled up with sediment. Ciric II and III (big Ciric and Venetia) are used as fishing and recreation areas for the citizens of Iasi. Ciric II and I are originally natural ponds, but after a long process of sedimentation en deposition, barrages have been made which created artificial lakes. The main purpose is to protect Iasi against flooding.

The largest lake, Ciric II, has an area of 30 hectares and an average depth of 2 meter. Downstream is Ciric III with an area of 7 hectares and an average depth of 1.5 meter. These reservoirs are also used for recreational purposes and have become favourite places. In the seventies, a lot of recreational facilities were build around the lake. These facilities were mostly used as a privilege for large companies. The buildings did not have proper sewage systems installed. Instead, for lack of money, an intermediate solution was implemented. Every company was obliged to make a small basin for the storage of their wastewater. When the basins were full the wastewater had to be taken to a treatment plant. As this involves money, the excess water was sometimes discharged into the woods (pers. comm. Apele Romana Iasi, 1999). The basins were meant as a temporary solution, but they are still in use. The basins often overflow, so the wastewater is still coming into the lake (pers. comm. Environmental Agency Iasi, 1999). The wastewater contains a lot of nutrients, which cause eutrophication.

Although the lakes are important for the city of Iasi, there has never been any research on their biological characteristics. There is only some information about the chemical composition. Ciric can be put in the bicarbonate class or in the mixed class, because of its dominant ions, Na^+ and Mg^{2+}. The colour of the water in Lake Ciric is generally yellowish-green. Because of eutrophication this is turning to blue-green. Lake Ciric has little transparency, because the water contains many particles, as is demonstrated by the sedimentation. The residence time of the lake is long, because the lake is rainwater fed. This also plays a role in the eutrophication process.

Main question

What is the status of water quality in Lake Ciric and which strategy can be used to reduce the pollution?

Secondary questions

What are the sources of pollution?
What are the standards to determine water quality?
Which restoration methods are being used?

14 Water pollution

One of the first things noticed by an interested visitor is the abundant littering in Lake Ciric. There are no waste bins, so all packaging materials end up in the lake.
But that is not the worst problem. The water quality does not meet the standards for swimming water and swimming is not allowed anymore. There are still possibilities for boating. The water in Lake Ciric is contaminated with germs causing diseases of the skin and of the digestive tract. Even the organisms responsible for meningitis have been found in the water (pers. comm. Environmental Agency Iasi, 1999).
The water quality in summer and winter varies in the lake because of the big difference in temperature (pers. comm. Environmental Agency Iasi, 1999). Water temperature influences the rate of physiological processes of organisms, such as the microbial respiration, which is responsible for much of the self-purification that occurs in the water. High temperatures support faster growth rates and enable some biota to attain significant populations (Chapman, 1996).

14.1 Norms and standards

The aim for Lake Ciric is to have clear water, where it is safe to swim. Preferably rich in water plants and with a balanced fish stock. For this the biological and chemical parameters should meet the STAS-standards for category I for surface water.

Indicator	**Quality category**		
	I	**II**	**III**
Total N (mg/l)	1		
Total P (mg/l)	0,1		
Dissolved O_2 (mg/l)	6	5	4
CBO_5 (mg/l)	5	7	12
CCO-Mn	10	15	25
Total coliform/l	10.000	No norms	

Table 6 *Norms for several indicators for surface water (STAS, 1998)*

Legenda CBO5 = Biochemical oxygen consumption, CCO-Mn = chemical oxygen consumption

	Oligotrooph	**Mesotrooph**	**Eutrooph**
Degree of oxygen saturation (%)	min. 70	40 – 70	max. 40
Total N (mg/l)	max. 0,311	max. 1	min. 1,5
Total P (mg/l)	max. 0,03	max. 0,1	min. 0,15

Table 7 *Indicators for the eutrophication process (STAS, 1998)*

14.2 Bio-chemical and chemical pollution

Values 1996	**CBO_5** Biochemical Oxygen Consumption (mg/l)	**CCO-Mn** Chemical Oxygen Consumption (mg/l)	**Total N** (mg/l)	**Total P** (mg/l)
Ciric I	9.65	14.40	7.31	0.126/3.65
Ciric II	9.30	17.92	7.20	0.116/3.18
Ciric III	20.0	21.12	7.15	0.085/3.85

Table 8 *Chemical values from Lake Ciric, August 1996 (Apele Romana Iasi, 1999)*

Values 1998	**CBO_5** Biochemical Oxygen Consumption (mg/l)	**CCO-Mn** Chemical Oxygen Consumption (mg/l)	**Total N** (mg/l)	**Total P** (mg/l)
Ciric I in	28.0	46.4	0.758	0.019
Ciric I out	42.0	91.2	1.177	0.084
Ciric II in	26.0	44.8	1.028	0.169
Ciric II out	21.0	40.0	0.902	0.005
Ciric III in	19.0	40.0	0.867	0.215
Ciric III out	14.0	28.8	1.036	0.117

Table 9 *Chemical values from Lake Ciric, May 1998 (Apele Romana Iasi, 1999)*

Values 1996	**Fytoplankton** (nr/l)	**Zooplankton** (nr/l)	**Total germs** (nr/l)	**Total coliform** (nr/l)
Ciric I	15.000.000	295	3.500.000	3.000.000
Ciric II	2.900.000	175	3.200.000	7.900.000
Ciric III	2.100.000	70	600.000	7.400.000

Table 10 *Values of biological indicators from Lake Ciric, August 1996 (Apele Romana Iasi, 1999)*

Lake Ciric is strongly eutrophicated, especially at the end of the summer, when the values of total N and total P are very high. The chemical and the biochemical oxygen consumption are high and this hampers the growth of water plants. The chemical and biological parameters of 1996 and 1998 show important differences in value. This could be caused at least partly by the fact that the measurements in 1996 have been taken at the end of the summer and in 1998 in spring. At the end of the summer most indicators do not meet the standards for Category 1 Waters, some even exceed the values for Category 2 and 3. Water that is in Category 1 is of a relatively good quality.

Values 1998	**Fytoplankton** (cells/l)	**Zooplankton** (cells/l)	**Total germs** (cells/l)	**Total coliform** (cells/l)
Ciric I in	9.429.000	41	2.000	6.000
Ciric I out	10.328.000	44	3.000	2.900
Ciric II in	8.112.000	33	5.000	1.300
Ciric II out	4.757.000	34	8.000	2.400
Ciric III in	2.950.000	35	6.000	5.000
Ciric III out	5.560	17	12.000	65.000

Table 11 *Values of the biological indicators from Lake Ciric May 1998 (Apele Romane Iasi, 1999)*

The total numbers of coliform bacteria is with 65.000 at the location Ciric III too high compared with the STAS-standard of 10.000 cells/l (see also appendix 2).

14.3 Causes of pollution

The main cause for the eutrophication is the domestic sewage from the recreation facilities around the lake. The basins, which were meant to be a temporary solution for the storage of wastewater, are now leaking and overflowing into the lake. The Ciric river also contributes to the bad water quality because there are many sources of pollution along the river, domestic as well as agricultural (pers. comm. Constantinescu, 1999).

Figure 8 *Sketch showing location of Ciric I, II, III and sources of pollution*

The river transports a lot of eroded material to be deposited in the lake. Deforestation increases the local wash-off (erosion) and therefore the sedimentation. Finally, recreation is also causing water pollution. Because of a lack of garbage containers, most of the plastics and tins are thrown into the lake. Furthermore, there are people who use the lake as a car-wash place (pers. comm. Constantinescu, 1999).

14.4 Restoration programmes

Finding a good solution for the sewage water of the recreation facilities around the lake is very important. This will eliminate the main cause of eutrophication in the lake. The plan is to make it mandatory to install small treatment-plants for the companies owning the recreation facilities. It would also be possible for a number of companies to build a plant together. However, it would be too expensive to construct a large sewage system transporting all the water to the city's treatment plant. In the near future it will be possible to give large fines to people who do not respect the rules concerning water-pollution. Companies not having a treatment plant can be charged with 70.000.000 Lei. Biological treatment plants are the least expensive (pers. comm. Constantinescu, 1999)

Two years ago the water board of Iasi took some measures to improve the water quality. Ciric III was emptied in order to remove the sediments and disinfect the bottom with calcium oxide. This action slows down the deposition process of the lake and the pH is increasing because of the calcium oxide, creating an environment not suitable for pathogenic bacteria. Last summer the water board reduced the number of mosquito larvae by applying special chemicals. After this, pesticides were added to the water to fight adult mosquitoes. The project successfully prevented the spreading of meningitis. The chemicals were not harmful to the ecosystem of the lake (pers. comm. Apele Romane Iasi, 1999).

Apart from these practical actions, it remains very important to educate people and make them aware of the causes of environmental problems.

The retention time shortening could decrease the eutrophication. Upstream there is sufficient water to refresh the water of Ciric III (pers. comm. Constantinescu, 1999). The use of constructed wetlands for wastewater treatment can help decrease the eutrophication. Furthermore, it is important that Ciric valley be replanted with trees. This will decrease the runoff and therefore the sedimentation.

15 Conclusions and recommendations

- Lake Ciric consists of three different lakes. Ciric I is almost entirely filled up with sediments. Ciric II and III (big Ciric and Venetia) were originally natural lakes. After a long process of sedimentation barrages were build, which created artificial lakes. They are used for recreation.

- In Lake Ciric four different phenomena are causing the problems: eutrophication, contamination with germs, sedimentation and litter from Apart of these problems there is also a problem with littering because of recreational activities.

- The values of total P, total N, CBO_5 and CCO-Mn exceed the STAS-standards. Especially in summer, the values are very high. The lake is polluted with micro-organisms which are indicators of the presence of human faecal matter: coliforms and streptococci. The number of these bacteria is above the STAS-standards for surface and swimming water throughout the year. The presence of human faecal matter in water bodies presents significant health risks when the water is used for drinking. The water is declared unsuitable for swimming and other (contact) recreation.

- The major cause for the high level of nutrients is the malfunctioning of the sewage systems of the recreational buildings around the lake, the effluents flow into the lake. The deforestation in the area causes an increase in the local runoff. These particles in the run-off are the cause of the process of sediment accretion in the lake. The residence time of the lake is long.

- The Water Board took some measures to solve the problems. Two years ago Lake Ciric III was emptied, the sediments were removed and the bottom disinfected with calcium oxide to create an environment not suitable for pathogenic bacteria. Last year the water board applied pesticides to reduce the number of mosquito larvae and adults. This measure prevented the spreading of meningitis.

- However, the first things that should be done is the realisation of wastewater treatment plants and the reforestation of the area. Constructed wetlands or helophyte filters could be used to reduce the concentration of nutrients in the lake.

- Litter bans should be placed near the lakes. Environmental education for the public at large is necessary.

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COMPARISON

AND

DISCUSSION

17 Comparison and discussion

Even though the problem of water pollution in lakes is a well-known phenomenon in both Romania and the Netherlands, it is difficult to compare the pollution in the two countries. The Zuidlaardermeer is a natural lake situated in the north of the Netherlands. Lake Agrement is one of nine artificial accumulation lakes in the district of Baca in Romanian Moldavia. Lake Ciric consists of three lakes. Ciric I is almost entirely filled up with sediments. Ciric II and III were originally natural lakes, which have been changed into artificial ones, near the city of Iasi in the north of Romanian Moldavia. All the lakes are used for recreation. The Zuidlaardermeer is also a nature reserve. Lake Agrement is used for industrial activities and as a cooling reservoir. Pollution is what the three lakes have in common.

The main problems in the Zuidlaardermeer are eutrophication and sedimentation. The main source of pollution was the intake, in summer, of polluted and nutrient rich water from the IJsselmeer for the benefit of the surrounding agricultural areas. Since a couple of years this foreign water is not let into the lake anymore. A second source is the effluent from municipal sewage plants. Two sewage treatment plants have been built to eliminate nitrates and phosphates before the effluent reaches the Zuidlaardermeer. The third source is the influx from agricultural activities (drainage and dairy farming). The water quality managers are trying to accelerate the development to a clear water system by ecological restoration, i.e. by reduction fishery. The nature conservation organisation initiates a project to develop artificial marshes along the lake.

The problems in Lake Agrement are the effluents of domestic and industrial wastewater, the absence of sewage treatments plants and of collection systems for the rural garbage and the process of sedimentation. The water quality is classified as mesotrophic and β-mesosaprobic. In the district of Bacau the Environmental Protection Agency (EPA) identified several projects to solve the problems with garbage in the LEAP (Local Environmental Action Plan). The LEAP is a practical guide for local and regional use on how to handle environmental issues. Of all projects, only two have started. It appears that even civil servants and employees of environmental agencies have never read it. A programme such as the LEAP cannot function without an administrative and legal framework at local, regional and national levels. Governmental departments and other responsible organisations (EPA, Apele Romana Company, Department of Public Health and NGO's) should communicate and co-operate more efficiently and more frequently.

In Lake Ciric eutrophication, effluents of sewage and sedimentation are the main issues. The deforestation in the area surrounding Lake Ciric causes an increase in the local washout of soil particles. To solve this problem the Ciric valley should be replanted. The effluent of the malfunctioning sewage systems of the recreation facilities causes a very high number of germs, mainly coliform and streptococci. To construct a large sewage system is too expensive, but plans have been made to install small treatment plants. The problems with litter could be solved by placing litter bans around the Ciric lakes.

Some of the following data will show the degree of pollution in the three lakes much better.
In the Zuidlaardermeer the concentrations of total N are 1.3 – 5.3 mg/l and of total P 0.3 mg/l.
In Lake Ciric the concentration of total N is 3.7 mg/l and of total P is 7.2 mg/l (values 1996).

The norm is the same for both lakes: 1 mg/l N and 0.1 mg/l P. The chemical oxygen consumption is very high in lakes Agrement and Ciric. This indicates a high level of organic pollution. According the STAS-standards (standard for surface water quality), the water in both lakes Agrement and Ciric is of very bad quality, categorie III.
In the present situation the number of algae species is low in the Zuidlaardermeer. The number of algae cells is high and reaches more than 40.000 cells/ml. In the summer, blue-green algal bloom and the water classified as not safe for swimming. In Lake Ciric the same number of algae cells are counted per ml. Unfortunately, the diversity of algal species in Lake Ciric has not been assessed. A high number of algae cells in combination with a limited number of species is characteristic for eutrophicated lakes. Algae prevent light reaching submerged water plants.
The total number of coliform bacteria (TC) in Lake Ciric I is 30.000, in Ciric II 7.900.000 and in Ciric III: 7.400.000 cells/l (samples 1998). In Lake Agrement south, TC is 140.000 cells/l, Lake Agrement north: 36.000 and river Barnat: 160.000 cells/l (samples 1999). The number or faecal coliform (FC) in Lake Ciric south is 62.000, Agrement north: 540.000 and river Barnat: 160.000 cells/l. The STAS-standard for the TC is 10.000 cells/l. Both lakes exceed this standard enormously. The presence of these high numbers of faecal bacteria presents significant health risks when the water is used for drinking, personal hygiene or contact recreation.
In the Zuidlaardermeer the fish stock is out of balance, the pike to bream ratio is 1:48. The aim is to reach a 1:2 distribution. The reduction fishery (Active Biological Management) practised in the compartment of the Zuidlaardermeer, should result in a balanced fish stock. In Lake Agrement the same situation is found. Prey fish are dominant, but fortunately there are a few predator fish species left in Lake Agrement.
In the Zuidlaardermeer the area of emerged and submerged vegetation is much smaller (0.7% and 0%) than the targets (10% and 30-40%). The creation of flood-marshes will, in combination with the extension of the area with reed vegetation, function as a helophyte filter. Helophyte filters could also be useful in the two Romanian lakes to serve the same purposes. At the same time a helophyte filter project could be used as a demonstration project for the public. Environmental education for the public at large is necessary and should have more attention and support in Romania.

The Zuidlaardermeer is a nature reserve and has been appointed an EC Special Bird Protection Area and a Wetland of International Importance according the Convention of Ramsar recently. The Ramsar-convention is not applicable to the Romanian lakes, but they are valuable as (water) bird areas. The situation in the Zuidlaardermeer proves that a combination of nature conservation and recreation is possible. Co-operation and communication between all parties concerned was crucial to this integrated approach. In the Netherlands it is a government policy to develop a National Ecological Network. The Zuidlaardermeer and surroundings are part of this network. The provinces have to make sure that their physical plans are not in conflict with the National Ecological Network.

This international project demonstrates the differences between the two countries worked in. Where this is very easy in the Netherlands, it is quite difficult to collect information in Romania. The information from Romanian organisations and institutions is often contradictory and incomplete. Libraries do not have large collections to facilitate verification and completion. The difference in approach to problems was notable. Not all concerns about environmental pollution will receive the same degree of attention everywhere in the world as a result of different priorities and national perspectives. The fact that Romania is a country in transition from a communist system to a democratic one and is not being spared, either economically or socially, complicates the researcher's life even more.

Glossary of terms

Agricultural runoff. The water, and the materials carried by the water, flowing from agricultural lands to water bodies, following rainfall or snowmelt events.

Algae. Small, often microscopic, aquatic plants in a water body; they exist either as phytoplankton (free-floating cells) or as periphyton (filamentous algae attached to rocks or other underwater structures)

Algal bloom. The nuisance or excessive growth of phytoplankton in a lake or reservoir, which interferes with the aesthetic quality and/or human, uses of the water resource; often denoted by a "pea-

Aquatic ecosystem. The sum of the living (biological) and non-living (chemical and physical) components of an aquatic system, such as a lake or reservoir, which interact to give the system its specific characteristics.

Biomanipulation. The use of native or artificially-introduces biological organisms to treat eutrophication, as contrasted with the use of chemicals or other non-natural control measures.

Bottom waters. The water layer at the bottom of al lake or reservoir; usually refers to the water in the hypolimnion.

Discharge. A term used to denote the volume of stream flow or effluents.

Domestic effluents. Discharges or releases of liquid wastes from sewage materials form municipal wastewater treatment plants to surface waters (lakes); usually contain high concentrations of biologically-available phosphorus and nitrogen, thereby constituting a primary point source of these aquatic plant nutrients.

Effluents. The liquid wastes from municipal sewage, industrial and septic sources which are released to surface waters.

Eutrophic. From the Greek ("well-nourished"), the most productive trophic state of a water body; characterised by high nutrient loads, high photosynthetic activity and low water transparency.

Eutrophication. The natural ageing process of a lake, whereby it slowly becomes filled with sediments from its drainage basin, usually on a geologic time scale, eventually becoming a marsh system and, ultimately a terrestrial system; when the process is accelerated by human-induced nutrient inputs, it is termed "cultural eutrophication".

Food chains. The feeding relationship described by lower trophic level organisms sequentially serving as food source for higher trophic level organisms.

Ground water. Water which flows beneath the soil surface.

Growth-limiting nutrient. The nutrient (usually phosphorus or nitrogen) which primarily controls or limits the maximum level of algal biomass in a lake or reservoir.

Inflow. The waters entering a lake or reservoir, usually from tributaries.

Littoral zone. The water in a lake that is closest to the shore, in contrast to the deeper waters in the centre of the lake.

Mesotrophic. An intermediate trophic state describing the transitional condition between high productivity (eutrophic) and low productivity (oligotrophic) water bodies.

Natural lakes. Naturally formed water bodies, in contrast to man-made impoundments (reservoirs).

Nitrogen. The sum of all organic and inorganic forms of nitrogen, a primary aquatic plant nutrient (sometimes called total nitrogen).

Non-point sources. Aquatic plant nutrient sources in a drainage basin which are diffuse (non-pipeline) in nature, and usually difficult to identify or quantify (in contrast to point sources); examples include runoff from urban and agricultural lands following storm events.

Nutrients. Usually refers to phosphorus and nitrogen, the primary phytoplankton and aquatic plant nutrients in lakes and reservoirs.

Oligotrophic. From the Greek ("poorly-nourished"), the least productive state of water body; usually characterised by low nutrient loads, low photosynthetic activity, and high water transparency.

Phosphorus. The sum of all organic and inorganic forms of phosphorus, a primary aquatic plant nutrient (sometimes called total phosphorus).

Phytoplankton. Microscopic algae and microbes that float freely in lakes and reservoirs.

Primary production. The production of new organic matter from inorganic materials by photosynthetic organisms using sunlight energy.

Recreational fishery. Fish caught as a recreational or sporting pursuit, in contrast to fish caught and sold as a commercial venture.

Reservoir. A man-made lake usually constructed by the placement of a dam across a river channel; in contrast to natural lakes, reservoirs exist because they were constructed for a specific purpose or water use.

Sediments. The bottom material in a lake or reservoir deposited its formation; usually consists of the remains of aquatic organisms, precipitated minerals and erosion washed into water body.

Substrate. A general term used to denote the food source for microbes.

Surface overflow. The outflow or discharge of waters from the surface layer (epilimnion) of a water body, in contrast to the bottom layer (hypolimnion).

Topography. The general configuration (usually surface contours) of a land or lake bottom surface area.

Urban runoff. The water, and the nutrients and other materials carried by the water, flowing from urban areas to water bodies, usually following rainfall or snowmelt events.

Wastewater. The discharge or releases of liquid wastes from sewage materials form municipal wastewater treatment plants to surface waters.

Water column. The vertical distribution of water from the surface to the bottom of a lake or reservoir.

Water quality. A description of the general chemical conditions existing in a water body during a specific time interval.

Water transparency. The clarity or transparency of lake and reservoir waters; often measured with the Secchi disk.

Zooplankton. Microscopic animals which float freely in the water column, usually feeding on bacteria, phytoplankton (algae) and/or detritus; serve as food for higher level organisms, including fish.

(Source: Rast, Holland & Ryding, 1989)

Appendix 1

Norms and standards of surface water quality in The Netherlands (Waterkader, 1998)

Nutrients & Parameters for eutrophication	National aim value	Minimal demand
Total phosphate (mg p/l)	0,05 (summer value)	0,15 (summer value)
Total nitrate (mg N/l)	1 (summer value)	2,2 (summer value)
Ammonia (mg N/l)	-	0,02
Chlorophyll-α (μg/l)	-	100

Salts	National aim value	Minimal demand
Chloride (mg Cl/l)	-	200
Fluoride (mg F/l)	-	1,5
Bromide (mg Br/l)	-	8
Sulphate (mg SO_4/l)	-	100

General parameters	National aim value	Minimal demand
Colour, smell, foam, waste, turbidity	Not visible polluted or not smelling	Not visible polluted or not smelling
Temperature (°C)	-	25
Oxygen (mg/l)	-	5
PH	-	6,5 - 9
Clarity (meter)	-	0,4

Bacteriological parameters		
Thermo-tolerance Coli	-	20
Entero-viruses /phages	-	Absent in 10 L

National norms and standards of surface water quality in the Netherlands (Source: Waterkader, 1998)

Appendix 2

Parameter	Norm	Analyses
Cd^{2+} mg/l, max	0,005	STAS 7852 – 80
CN^{-} mg/l, max	0,01	STAS 7685 - 79
Ph	6,5 – 8,5	STAS 6325 - 75
Anionic detergentia mg/l	0,5	STAS 7576 - 66
Hg^{2+} mg/l, max	0,005	STAS 8045 - 79
O_2 mg/l, max	6	STAS 6536 - 62
CBO_5	5	STAS 6560 - 82
Transparancy, m	2	
TC, MPN/l, max	10.000	STAS 3001 - 83
FC, MPN/l, max	1.000	STAS 3001 - 83
FS, MPN/l, max	200	STAS 3001 - 83

The norms of different parameters according to STAS (National Standard Analyses for Surface Water)
MPN = Most Probable Number

Appendix 3

Indicators for swimming and recreation in Romania

Standard norms for quality of surface water which is used for swimming according to STAS 4706/1988 (Romanian legislation).
Total coliform < 10.000 germs/100 ml water
Faecal coliform <1.000 germs/100 ml water
Faecal streptococcus < 20 germs/100ml water

For swimming water exist three categories, according STAS 4706/1988 (Romanian legislation):
The I Category- water good for swimming - when 50% from samples made in one month (not less than 10 samples) FC is less than 100 germs/ 100 ml water.
The II Category- water acceptable for swimming-when 90% from samples in one month (not less than 10 samples) FC is between 100 - 1000 germs/100ml water.
The III Category - water which is not recommended for swimming and recreation and represent an risk for human health, if in 10 over 10% of samples taken in 1 month FC are more than 1000 germs/100ml water.

Appendix 4

Biodiversity Lake Agrement

The following phytoplankton species are present:
- diatoms
- cyanophiceae
- chlorophyta

The following zoobentos (Tubificidae, worms) species are present**:**
- *Limnodrilus hoffmeisteri*
- *Tubifex tubifex*
- *Bracyura sowerbi*

Chironomidae (larves of insects)
- *Procladius choreus*
- *Polypedilum nubeculosum*
- *Chironomus plumosus*

The fish population consists of:
- *Perca fluviatilis* (perch) - predator
- *Gobio gobio sp.* (gobies)
- *Carasius carasius* (carp) - predator
- *Albumoides bipuntcatus* (bleak)
- *Alburnus alburnus* (bleak) - predator
- *Scardinius eryopthalmus* (rudd)
- *Cyprinus carpio* (carp) - predator
- *Abramis brama* (bream)
- *Acerina cernuus* (ruff)

The predominant species of aquatic birds are:
Anas plathyrhynchos, Larus ridibunda, Larus argintata, Aythya fuligula, Fulica atra;

Bird species, characteristic for grasslands and forests, are found on the Island:
Turdus merula, Dendrocopus major, Dendrocopus medius, Garrulus glandarius, Streptopelia turtur, Streptopelia decaocto, Cuculus canorus, Sturnus vulgaris, Pica pica, Asio otus.

Appendix 5

Indicator species of the b-mesosaprobic zone

Cianoficee - *Microcystis, Gloeotrhia, Oscillatoria, Nostoc, Aphanizomenon*
Diatomee - *Melosira, Diatoma, Fragilaria, Synedra, Pinnularia, Surirella, Synedra uvella*
Rizopoda - *Amoeba proteus*
Flagelata - *Uroglena volvox*
Ciliata - *Parameccium bursaria, Didinum nasutum, Coleps hirtus, Voticella campanula;*
Rotifera - *Brachionus urceus, Monostyle lunaris*
Worms - *Stylaria lacustris, Dendrocoellum lacteum*
Mollusca - *Ancylus fluviatilis, Pisidium cinereum;*
Insects - *Cloeon dipterum, Hydropsyche lepida*.

The periphyton is represented by*: Navicula rhynchocephala, Synedra acus, Ulotrix zonata.*

Appendix 6

Helophyte filters or constructed wetlands for waste water treatment

Natural wetlands have been used for wastewater treatments for centuries. In many cases, the reasoning behind this use was disposal, rather than treatment. Uncontrolled discharge of wastewater led in many cases to an irreversible degradation of many wetland areas. However there has been an explosive growth of knowledge about and a radical change in attitude towards wetlands during the last few decades.
Natural wetlands are still used for wastewater treatment, but the use of constructed wetlands is becoming more popular and effective. Constructed wetland treatment systems have been designed and constructed to utilise the natural processes involving wetland vegetation, soils and their associated microbial assemblages to assist in treating wastewater. They are designed to take advantage of many of the same processes that occur in natural wetlands, but do so within a more controlled environment.
Some of these systems have been designed and operated with the sole purpose of treating wastewater, while others have been implemented with multiple-use objectives in mind, such as using treated wastewater effluent as a water source, for the creation and restoration of wetland habitat, for wildlife and for environmental enhancement.
Wetland systems reduce many contaminants including organics, suspended particles, nitrogen, phosphorous, trace metals and pathogens. This reduction is accomplished by diverse treatment mechanisms.

Numerous studies have proven that the major removal mechanism of nitrogen in most constructed wetlands is microbial nitrification and denitrification. Nitrification is usually defined as the biological oxidation of ammonium to nitrate with nitrite as an intermediate in the reaction sequence. Nitrification is a chemo-autotrophic process. The nitrifying bacteria derive energy from the oxidation of ammonia and/or nitrite and carbon dioxide is used as carbon source for synthesis of new cells. Oxidation of ammonium to nitrate is a two step process.

(1) $NH_4^+ + 1.5\ O_2 \Rightarrow NO_2^- + 2\ H^+ + H_2O$
(2) $NO_2^- + 0.5\ O_2 \Rightarrow NO_3^-$

$$NH_4^+ + 2\ O_2 \Rightarrow NO_3^- + 2\ H^+ + H_2O$$

The first anoxic oxidation process to occur after oxygen depletion is the reduction of nitrate to molecular nitrogen or nitrogen gases. This process is called denitrification. More and more evidence is being provided that nitrate reduction can occur in the presence of oxygen. Hence in waterlogged soils nitrate reduction may also start before the oxygen is depleted. Denitrification is illustrated by the following equation.

$$6\ (CH_2O) + 4\ NO_3^- \Rightarrow 6\ CO_2 + 2\ N_2 + 6\ H_2O$$

Nitrification and denitrification are known to occur simultaneously in flooded soils where both aerobic and anaerobic zones exist. This would be the case in a flooded soil or water bottom containing an aerobic surface layer over an anaerobic layer or in the aerobic rizosphere microsites in otherwise anaerobic soil. Its net productivity and the concentration of nutrients in the plant tissue limit the potential rate of nutrient uptake by plant. Nutrient storage is similarly dependent on the ultimate potential for biomass accumulation, the maximum standing crop. The uptake capacity of emergent macrophytes, and thus the amount that can be removed if the biomass is harvested, is roughly in the range 1000-2500 kg N ha-1 yr-1. If the wetland is not harvested, the vast majority of the nutrients that have been incorporated into the plant tissue will be returned to the water by decomposition processes.

Phosphorous is typically present in wastewater as orthophosphate, dehydrated orthophosphate and organic phosphorus. Phosphorus removal in wetland treatment systems occurs from adsorption, plant adsorption, complexation and precipitation. Most wetland studies have shown that sediment accumulation is the major long-term phosphorous sink. Plants adsorb phosphorous trough their roots and transport it to the growing tissues. The uptake capacity of macrophytes is lower compared to nitrogen, as phosphorus concentrations in plant tissues are much lower than that of nitrogen. In order to remove phosphorous from the wetlands it is necessary to harvest macrophyte biomass. After the plants decay, similar to nitrogen, phosphorus is released back to the system. *Phragmites australis* (common reed) is the most commonly used macrophite in the European constructed wetlands.

The macrophites in constructed treatment wetlands may also have functions that are not directly related to the water treatment processes. In large systems, the wetland vegetation may support a diverse wildlife, including birds, reptiles, etc. This may be of importance, as natural wetlands and thereby the wetland habitat has been destroyed at a high rate in many places (Vymazal *et al*., 1998)